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모바일 애드혹 무선 네트워크에서 멀티 홉 협력 전송 프로토콜

A Multi-hop Cooperative Transmission Protocol in Mobile Ad-hoc Wireless Networks

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요 약 본 논문에서는 레일리 페이딩 채널의 멀티 홉 협력 전송 프로토콜을 제안한다. 제안된 프로토콜에서, 멀티 홉 협력 전송은 시스템 성능의 향상을 위해 사용되었다. 중계라는 특성으로 인해, 전송받는 노드와 다음의 노드뿐만 아니라, 목적지와 그 사이의 전송 받는 모든 노드들이 제한되어 있지 않다. 제안된 프로토콜은 선택된 릴레이나 몇몇의 중간 노드로부터 건너 뛰어 전송되는 멀티 홉 직접 전송 프로토콜에 비해 평균 전송 전력을 절약할 수 있다. 제안하는 기법은 모바일 ad-hoc 무선 네트워크에서 시행 및 평가되어진다.

Abstract In this paper, we propose a multi-hop cooperative transmission protocol over Rayleigh fading channels. In the proposed protocol, the multi-hop cooperative transmission is used to improve the system performance. Due to broadcast nature, we do not limit the receiving node to be only the next node, but the destination and all the nodes between the transmitting node and the destination. The proposed protocol can hence save the average transmit power, compared with multi-hop direct transmission protocol due to the skipped transmissions from some intermediate nodes or chosen relays. The proposed scheme is implemented and evaluated in mobile ad-hoc wireless networks.

Key Words : Cooperative Transmission, Outage Probability, Mobility, Mobile Ad-hoc Wireless Networks.

Ⅰ. Introduction

Recently, multi-hop cooperative transmission has gained a great interest in research community. Currently various cooperative transmission protocols have been studied in several literatures [1-2]. In these protocols, each node on the route can receive the signals from the previous transmitting nodes, processes the received signals and forwards the processed signal without using combining techniques. In [3-4], the relay terminals are equipped with maximal combining technique (MRC) to enhance the outage performance. However, the authors in [1-4] only considered the static networks in which nodes are assumed to be stationary. In [5], a multi-hop cooperative transmission scheme proposed and implemented in mobile ad-hoc networks.

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However, in this protocol, the cooperative transmission is realized at each hop, which can reduce the channel utilization efficiency.

In this paper, we propose a multi-hop cooperative transmission protocol in mobile ad-hoc network. In proposed scheme, named MCT, a route is established by network layer and the relays are selected at each hop along this route. At physical layer, due to broadcast nature, we let the destination have the permission to receive the packet from the source or the nodes being on the established route (hereafter called intermediate nodes) or the selected relays at each hop. If the destination receives successfully, the transmission of the new packet will start. Otherwise, the successfully intermediate node that is nearest to the destination will be considered as a source again and will repeat the procedure as the previous source does. In the proposed protocol, we use mobility prediction technique to construct a stable route and select stable relays at each hop. We then evaluate the performances of the MCT protocol in terms of packet delivery ratio (PDR) and end-to-end delay.

The rest of the paper is organized as follows. The system model is described in Section II. The simulation results are presented in Section III. Finally, the paper is concluded in Section IV.

II. System Model

2.1 The construction of a stable route using the mobility prediction technique

In this paper, the most stable route among all available routes is selected by using the mobility prediction technique [6]. With this method, two nodes, inside the transmission range (Z) of each other, can know the mobility information and the position information of each other. Therefore, we can determine the duration of time these two nodes will remain connected. Assume that at time t, node i is a neighbor of node j and vice versa. Let denote (x_i, y_i) as the

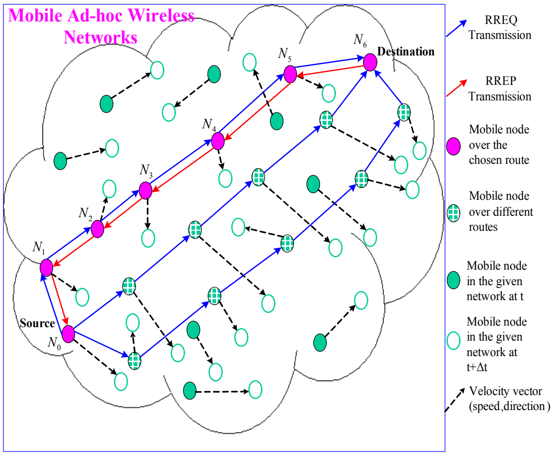

그림 1. 이동성 감지 기술을 사용한 경로의 설정
Fig. 1. Establishment of a route using the mobility prediction technique.

coordinate of node i and (x_j, y_j) as that of node j. If v_i and v_j are the velocities, and α_i and α_j are the directions of nodes i and j, respectively, then the amount of time that they would stay connected is predicted by [6]:

$$T_{i,j} = \frac{-(ab+cd)+\sqrt{(a^2+c^2)Z^2-(ad-bc)^2}}{a^2+c^2} \quad (1)$$

where $a = v_i \cos\alpha_i - v_j \cos\alpha_j$, $b = x_i - x_j$, $c = v_i \sin\alpha_i - v_j \sin\alpha_j$ and $d = y_i - y_j$.

The operation of the route establishment can be performed as follows:

Step 1: As reactive routing protocols such as Ad hoc on-demand Distance Vector (AODV)[7], the source generates RREQ packet and this packet is forwarded to destination or nodes which know the route for destination. In this paper, RREQ packet contains the mobility information and the position information of node which sends it.

Step 2: After receiving the RREQ packet from neighbor i, mobile node j calculates the amount of the connection time: $T_{i,j}$, according to (1). In our proposal, each node just broadcasts the RREQ packet when it receives the first RREQ packet from its neighbor. If it receives the RREQ packet again, it just updates the information from this packet. Next, assume that node k receives RREQ packet from node j at the first time; similarly, node k calculates the connected time $T_{j,k}$, and compares this value with the received value $T_{i,j}$. Then, the minimum value between $T_{j,k}$ and $T_{i,j}$ will be attached in the RREQ packet broadcasted by this node. Sequentially, the RREQ packet is forwarded to the destination by the different routes and the destination can calculate the lifetime of these routes. For example, consider a route that consists of nodes N_0, N_1, N_2, N_3, N_4, N_5 and N_6, where N_0 is source node and N_6 is destination node, as shown in Fig. 1. The lifetime of this route is given by

$$LT_{N_0-N_6} = \min\left(T_{N_i,N_{i+1}}\right) \qquad (2)$$

where i=0,1,2,3,4,5.

Step 3: When the destination receives RREQ, it only chooses the route with the maximum lifetime and replies to the source by sending a Route Reply packet (RREP) along this path. The RREP packet also includes the mobility information and the position information of node which sends it. When the source receives RREP from the destination, a route is established and the source can send the data packets to the destination.

2.2 The relay selection strategy using the mobility prediction technique

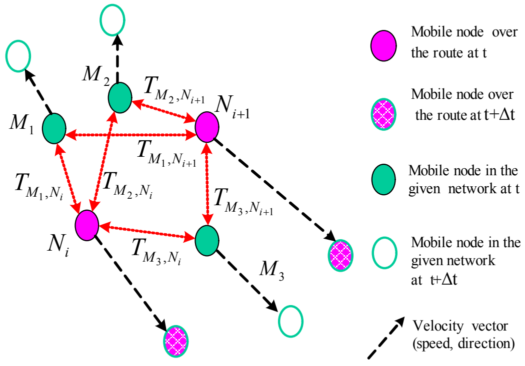

그림 2. 이동성 감지 개념을 사용한 중계기 선택
Fig. 2. Relay selection using the mobility prediction concept.

Applying the mobility prediction scheme as mentioned above, we propose a relay selection method as follows. First, we assume that the route including intermediate nodes N_1, N_2, N_3, N_4, and N_5 is chosen (see Fig. 1). Now, we consider hop i+1 between nodes N_i and N_{i+1} as presented in Fig. 2. Denote A (i.e., $A=\{M_1, M_2, M_3\}$ as the set of nodes that are in radio range of both nodes N_i and N_{i+1}. By the operation of route construction, each node belonging to the set D can receive RREQ packet from node N_i and RREP packet from node N_{i+1}. Therefore, each node $M_j(j=1,2,3)$ can calculate the connection time T_{M_j,N_i} and $T_{M_j,N_{i+1}}$ and sends these values to node N_i. Node N_i will then choose the stable relays by following strategy:

$$M_j:\ \min\left(T_{M_j,N_i}, T_{M_j,N_{i+1}}\right) \geq T \qquad (3)$$

Equation (3) implies that relay M_j staying in the radio range of nodes N_i and N_{i+1} with the amount of time that is larger than a certain threshold T will be chosen as relays for cooperation. In this paper, we set T to equal the lifetime of the established route. Furthermore, to reduce the control overhead and complexity, the chosen relays should be used during the lifetime of the route. When the route is broken, the source finds a new route to the destination and relays at each hop of this route are re-selected as the strategy above.

When a route is established and the relays are chosen at each hop, the source can send the packet to the destination by using the following transmission strategy.

2.3 Cooperative Transmission at Physical Layer

At first time slot, the source cooperates with the chosen relays at the first hop to transmit the source packet to the destination and intermediate nodes.

Generally, whenever the destination decodes incorrectly, a NACK message is sent to request a re-transmission. Then, the intermediate node that successfully decodes the packet and is nearest to the destination is considered as the source again and it cooperates with the chosen relays at that hop to transmit the source packet. The transmission is terminated when the destination receives successfully or, there is no more intermediate node that can decode successfully. In addition, in the MCT protocol, it should be noted that the size of NACK message is negligible relative to the size of the packet and hence the total time delay of finding an intermediate node for the re-transmission is also negligible, in comparison with the average delay of a packet transmitted from a transmitter to a receiver.

We assume that the channels between two nodes are subjected to flat Rayleigh fading plus AWGN. It is assumed that K transmitters, $S=\{T_1, T_2, \ldots, T_K\}$, cooperate to transmit the same packet to a receiver R. The mutual information between the transmitters and the receiver R is give as

$$I_{S-R} = \frac{1}{K} log_2\left(1 + \sum_{t=1}^{K} \frac{P}{P_0} |h_{T_t,R}|^2\right) \quad (4)$$

where P is the average transmit power, P_0 is variance of Gaussian noise, $h_{T_t,R}$ is Rayleigh fading coefficient between nodes T_t and R. In (4), the factor $1/K$ implies that the cooperative transmission is realized by K time slots. In this paper, we assume that the receiver R can decode the packet from K transmitters successfully if $I_{S-R} \geq R_{th}$ where R_{th} is target rate of the system. If $I_{S-R} < R_{th}$, it is assumed that the receiver R cannot receive the packet correctly.

Ⅳ. Simulation Results

In mobile ad-hoc wireless networks, the proposed protocol is implemented by the Optimized Network Engineering Tool (OPNET). We model a network consisting of 50 nodes that are placed randomly within a square area of 1 km x 1 km. Each node is assumed to be aware of its position exactly. The mobile nodes are also assumed to have constant radio range of Z= 250m. Furthermore, we use the random mobility scenario, in which speed and direction of each mobile node are uniformly distributed with speed range $[0, V_{max}]$ km/h and direction range $[0, 2\pi]$, respectively. During the simulation, each node moves around the network area, and when a mobile reaches to the boundary of the given network, the node reenters into network.

In the following simulations, we set the target rate of the system R_{th} to 1.5 packet/sec/Hz, the path loss exponent β to 3, the simulation time to 100 seconds, the rate of sending packets to 5 packets/sec. In addition, we assume that in interval of 5 seconds, the speech and velocity of each mobile node is constant, 5 seconds for reconstructing a new route from a source to a destination and the maximum number of chosen relays at each hop (V) is 2.

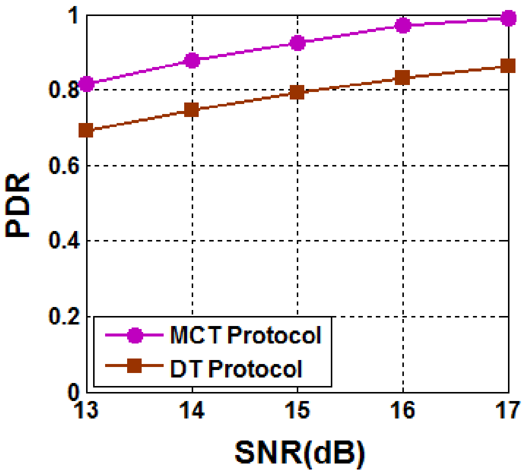

그림 3. $V_{max}=20$ km/h 일 때, 패킷 전송율.
Fig. 3. Packet delivery ratio when $V_{max}=20$ km/h.

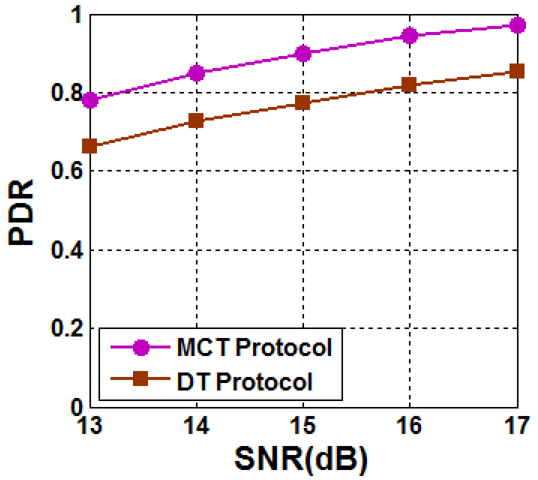

그림 4. $V_{max}=40$ km/h 일 때, 패킷 전송율.
Fig. 4. Packet delivery ratio when $V_{max}=40$ km/h.

Figures 3-4 show the packet delivery ratio (PDR) as a function of transmit signal-to-noise ratio ($SNR = P/P_0$) in dB when the value of V_{max} is fixed. PDR is the ratio of the number of packets received at the destination to the number of packets transmitted at the source. In these figures, for all presented values of velocities, the PDR of the proposed protocol is larger than that of the DT protocol. It is due to the fact that the proposed scheme uses cooperative diversity transmission which enhances the reliability of the data transmission.

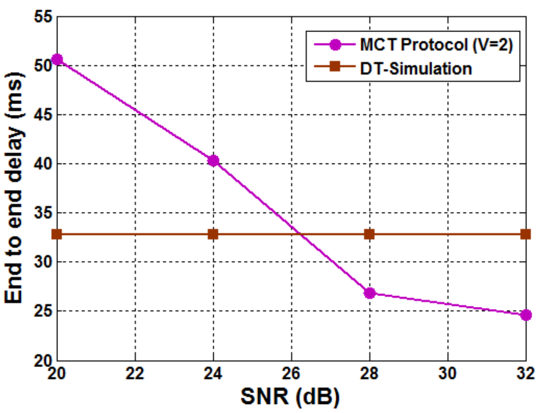

그림 5. 제안된 기법과 DT 프로토콜의 단-대-단 중계
Fig. 5. End-to-end delay of the proposed scheme and the DT protocol.

In Fig. 5, we present the average end-to-end delay time as a function of the transmit SNR in dB. It is noted that in this simulation, the end-to-end delay does not depend on the velocity of mobile node. It can be observed that the end-to-end delay of the proposed protocol decreases with increasing SNR, while the multi-hop direct transmission protocol (MDT) protocol keeps the constant one.

Ⅴ. Conclusion

In this paper, we proposed the multi-hop cooperative transmission protocol (MCT) over Rayleigh fading channels. The proposed scheme can increase the PDR when compared to the MDT protocol. Furthermore, relying on broadcast nature, the MCT protocol can decrease the average number of transmissions so reducing power consumption and end-to-end delay which are important criteria in multi-hop transmission. Furthermore, we considered a realistic approach that based on mobile nodes in mobile ad-hoc wireless network.

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