Distributed Relay Selection Algorithm for Cooperative Communication

Thant Zin Oo *, Choong Seon Hong **
Department of Computer Engineering, Kyung Hee University.
* tzoo@networking.khu.ac.kr, ** cshong@khu.ac.kr

Abstract

This paper presents a distributed relay selection algorithm for cooperative communication. The algorithm separates the decision making into two simple steps, decision making for employing cooperative communication and decision making for relay selection.

Key Words: Relay Selection, Cooperative Communication

1. Introduction

Cooperative communication has been proposed as a new relaying scheme to solve many existing problems in wireless networks. It was first introduced to overcome fading in physical layer where a source transmits cooperatively with a relay [1]. Cooperative communication was then used in MAC layer to increase aggregate throughput of a network [2].

Selecting the best relay requires much overhead and the marginal gain obtained in using cooperative communication is reduced. Sometimes during operation, relay selection protocols cannot choose a relay in spite of the running overhead of the algorithm and the source has to revert back to direct communication. In this paper, we propose a distributed relay selection algorithm to jointly optimize the relay selection phase and data transmission phase of cooperative communication to reduce delay time incurred by overhead and to ensure a relay will be selected if the selection protocol is used.

2. Relay Selection Algorithm

In our proposed relay selection algorithm, the destination decides whether to use cooperative communication or transmit directly. This is done in first *RTS-CTS* handshake control messages by adding one decision bit in *CTS*. If the destination decides to employ cooperative scheme, the relay selection phase begins with potential relays $n = |\{N_s\} \cap \{N_d\}|$ transmitting Relay Contention Messages (*RCMs*) where $\{N_s\}$ and $\{N_d\}$ stand for neighboring nodes of source and destination respectively.

After the relay selection phase, the source sends out Relay Selection Message (*RSM*) which includes the chosen relay's address followed by a Short Inter-frame Space (*SIFS*) before data transmission. This message informs the destination and potential relays about the chosen relay, together with a field for data transmission rate from source to relay. The other potential relays which are not selected will go to sleep for data transmission phase. The chosen relay then receives the data and transmit Destination Forward Message (*DFM*) containing data rate from relay to destination which serves as an acknowledgement to source and confirmation to the destination. Then the data transmission follows and after the data exchange, the destination replies with *ACK*.

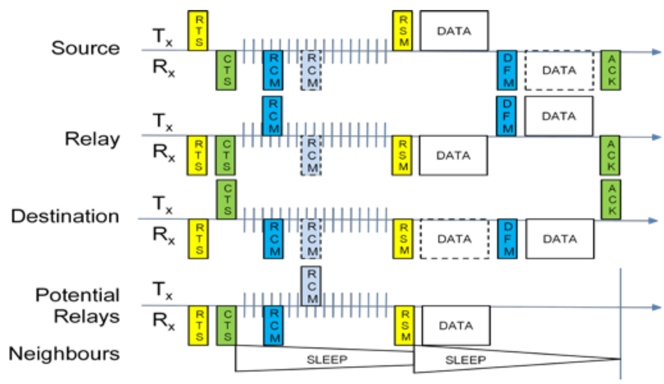

Figure 1. MAC layer message exchange of proposal

3. Distributed Decision Making

In our proposed algorithm, the decision making is separated into two steps: the destination deciding to incorporate relay and the source choosing relay. We assume that the control messages contain the channel estimates between two communicating nodes. The motivation behind the decision separation is that if the destination decides to transmit directly, the protocol can still operates in a normal CSMA/CA fashion without additional overheads.

3.1. Decision to employ cooperative communication

The first step is to decide whether to transmit through relay or not. The condition for employing cooperative communication is:

$$t_{over\,head} < t_{gain}$$

$$\left(\frac{1}{r_{si}} + \frac{1}{r_{id}}\right) < \frac{1}{r_{sd}} - \frac{t_{over\,head}}{L} \quad (1)$$

Here, $t_{over\,head} = 7\,SIFS + 5\,t_{CM} + 16\,t_{slots}$ is overhead of the control messages and the reduced time delay is defined as: $t_{gain} = \frac{L}{r_{sd}} - \left(\frac{L}{r_{si}} + \frac{L}{r_{id}}\right)$ where t_{CM} is the transmission time for control messages (CMs), $t_{slots} = 9\mu s$ is the time for relay contention slots and $SIFS = 16\mu s$.

In (1), the destination has only information on channel estimate and achievable data rate r_{sd} about sd link and the data packet length L of data transmission phase. The destination has no information about the potential relays' channel estimates and data rates, r_{si} .& r_{id} . And collecting information of all potential relays n will incur more overhead and impractical. Therefore, the decision cannot be made deterministically and we need a standard measure to make comparison.

For any transmission between node i and j, there is a standard set of achievable rates $R = \{r_0, r_1, \cdots, r_k\}$ where r_0 and r_k stands for minimum and maximum achievable rates respectively. Let X_r be the standard measure set of achievable rates per bit and each element x be defined as:

$$x = \left(\frac{1}{r_a} + \frac{1}{r_b}\right) \quad (2)$$

Using (2), we can fill X_r with every possible combination of two different rates whose number of element is $(k+1)!$. Now, we can use cumulative distribution function (c.d.f.) of X_r to make the decision. The probability that a relay which satisfies the constraint in (1) is given by:

$$P\{t_{over\,head} < t_{gain}\} = P\left\{x < \frac{1}{r_{sd}} - \frac{t_{over\,head}}{L} \text{ , } x \in X_r\right\} \quad (3)$$

From (3), we can set a threshold to ensure cooperative communication is used only when likelihood of success is high.

3.2. Choosing the relay

The second step which is selecting relay out of a potential set of relays n is quite straight forward [1]. As mentioned above, we assume that *RCM* contains channel estimates of si and id links. So, for worst case scenario, bottleneck policy can be used to obtain end-to-end channel quality of relay i:

$$h_i = \min\{|a_{si}|^2, |a_{id}|^2\} \quad (4)$$

This end-to-end channel quality is inversely proportional to timer value T_i of each relay which is used for relay contention period according to the following equation:

$$T_i = \frac{\lambda}{h_i} \quad (5)$$

Here, λ is a constant in units of time which has values of microseconds and the best relay i is chosen as:

$$h_b = \max\{h_i\} \Leftrightarrow T_b = \min\{T_i\}, i \in [1 \cdots n] \quad (6)$$

Therefore, the best relay will contend first in the contention period. But still in case the potential relays cannot hear each other's control messages there can be collision and the collision probability of relay contention in each slot is given by:

$$p = 1 - (1 - \tau)^{n-1} \quad (7)$$

where $\tau = \frac{2}{W+1}$, if $n \le W$ and $W = 16$ is number of contention slots. When two potential relays collide in the relay selection phase, they will defer from contention and go to sleep. And if $n > W$, the probability of collision will increase.

4. Conclusion

In this paper, we proposed a distributed relay selection algorithm which separates the decision making into two steps. The first decision at destination makes sure that cooperative communication is used only when existence of a potential relay is higher than threshold probability. The second decision at source would choose the best relay for cooperation if the destination chose to transmit through relay. In our future works, we will try to employ probabilistic algorithms in both decision making steps.

Acknowledgement

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by MEST (No. 2010-0027645). Dr. CS Hong is corresponding author.

References

[1] A. Bletsas, A. Khisti, D. P. Reed, A. Lippman, "A Simple Cooperative Diversity Method Based on Network Path Selection," IEEE Journal on Selected Areas in Communications, Vol. 24, No. 3, pp 659-672, March 2006.

[2] Pei Liu, Zhifeng Tao, Sathya Narayanan, Thanasis Korakis, Shivendra S. Panwar, "CoopMAC: A Cooperative MAC for Wireless LANs," IEEE Journal on Selected Areas in Communications, Vol. 25, No. 2, pp 340-354, February 2007.

[3] G. Bianchi, "Performance Analysis of the IEEE 802.11 Distributed Coordination Function," IEEE Journal on Selected Areas in Communications, Vol. 18, No. 3, pp 535-546, March 2000.