Optimization of Hidden and Exposed Terminal Problems in Wireless Cooperative Networks

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Abstract

This paper addresses the problems of hidden and exposed terminals problems in traditional wireless cooperative networks. Hidden and exposed terminals increase the collisions and bandwidth wastage respectively. Such problems degrade the expected performance of cooperative networks. We propose a model to optimize the impacts of hidden and exposed terminals. Our proposed model will improve the network throughput, energy efficiency and end-to-end delay significantly over traditional cooperative networks.

1. Introduction

In wireless networks, cooperative communication technology significantly increases the network performance because it provides alternate paths [1] when the defined link fails. In cooperative communication [2], sender transmits the data packet to receiver; neighbors overhear the signal. This overheard signal is retransmitted by single/multiple neighbor(s) subsequently. The neighbor who retransmits the overheard signal called relay or helper. Cooperative communication increases reliability, transmission rate and optimize transmission power [2]. However, cooperative communications introduces some new challenges due to the notorious hidden and exposed terminal problems. These issues introduce two problems in the wireless cooperative networks.

- It causes of collisions for hidden terminal problem and
- It causes of band width wastage for exposed terminal problem.

Collisions and band width wastage degrade the throughput and overall network performance than the expected performance.

Usually, we use cooperative protocol for two cases [3]: 1) protocol switch to cooperative mode when transmission rate is better via the relay path than the direct path and 2) protocol switch to relay path when direct transmission fails. Both the cases include hidden and exposed terminal problems. Suppose, source and destination exchanges ready-to-send (RTS) and clear-to-send (CTS) in order to transmit data. The RTS and CTS define a transmission region. If a relay who lies near the periphery of defined transmission region and transmits a packet then enlarges the transmission region than the defined region. As a result, the relay may be hidden or exposed terminal for its neighbors.

In this model, we select a specific *circle zone*. The relays who lie only in the *circle zone* can participate in cooperation. We control the *circle zone* and transmission power of relay so that transmission region of relay does not enlarge the expected transmission region of source and destination. This fact optimizes the effect of hidden and exposed terminal problems.

2. Problems of Existing Cooperative Protocols

Figure 1 shows that *S* is the source node and *D* is the destination node. The retransmission of relay R_1 enlarges the transmission region than that of the expected transmission region of *S* and *D*. In such situation, following problems appear for the ongoing transmission of R_1.

- Collision occurs if node *A* transmits to node *B* because R_1 is hidden to *A* for the link AB.
- The node *B* cannot transmit to *C* if it has data to be transmitted because *B* is exposed terminal to node R_1 for the link BC.

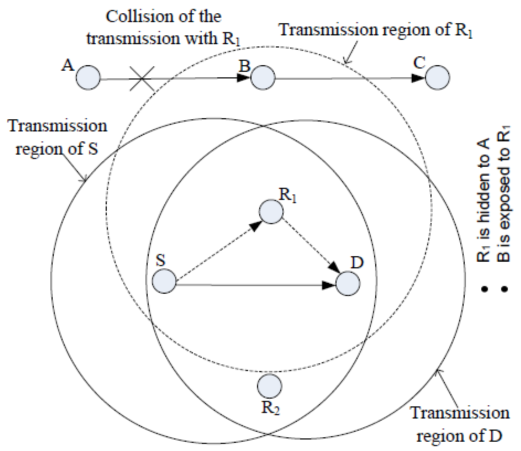

Fig. 1 Retransmission of R_1 enlarging the transmission region: hidden and exposed terminal problem appears

Relay selection process is an important part of cooperative communication. Potential relays participate in relay selection process by sending *help indication* [2] [4] signal. These signals also enlarge the transmission region than that of expected transmission region. Thus, further increases the collisions and wastage of bandwidth.

3. Literature Review

Cooperative communication has the ability to provide better performance in the domain of energy efficiency and end-to-end packet delay. Cooperative protocols work on increasing throughput or reliability transmitting through relays [2] [3] [4] [5]. However, the paper [2] investigates that relay transmission enlarges the transmission region. The papers [2], [3] and [4] select their relays exchanging some messages which further enlarge the transmission region. The enlarged transmission region causes for collision. Our proposed model optimizes the additional transmission region.

4. Proposed Network Model and Operation

Nodes are uniformly distributed in the network. SD is a single hop of a multi-hop network, shown in Fig. 2. Our work considers those nodes as potential relays who lies near the middle of SD and thus makes more energy efficient [5]. Therefore, we consider that the centre of the *circle zone* of relays in the middle of SD. We also control the transmission power of the potential relays such that relay transmission has little effect to enlarge the transmission region of S and D. The transmission power of R_i is given as follows [5]:

$$P_{TX,Ri} = d^{\alpha}_{Ri,D}\left(\frac{2^r-1}{\varepsilon^{out}}\right) \quad \dots \quad \dots \quad \dots \quad (1)$$

where α is the path loss factor, r is the given data rate in bit per second per Hertz and ε^{out} is the outage probability. We consider an optimal value of the radius r_c of the *circle zone*. The distance $d_{Ri,D}$ of equation (1) can be consider as $T_{TX,Ri} = d_{Ri,D}$ where $T_{TX,Ri}$ is the transmission range of R_i and R_i is any relay within the *circle zone*. We control the radius r_c and power $P_{TX,Ri}$ so that the transmission region of R_i does not cross the border of expected transmission region of S and D.

In this paper, we consider the IEEE 802.11b PHY layer, which can support multiple data rates of 1, 2, 5.5 and 11 Mbps [3]. It uses 2.4 GHz Industrial, Scientific and Medical band. Each node within the *circle zone*, receiving request-to-send (RTS) and clear-to-send (CTS) calculates data rate as following equation [3]:

$$B_{coop} = \frac{B_{SR_i}B_{R_iD}}{B_{SR_i}+B_{R_iD}} \quad \dots \quad \dots \quad \dots \quad (2)$$

where B_{coop} is the cooperative data rate, B_{SRi} is the data rate between source S and relay R_i and B_{RiD} is the data rate between relay R_i and destination D. If $B_{coop} \geq B_{dir}$ then the relay participates in cooperation. In this work, we allow two hop relay cooperation. Here, the source S transmits to relay R_i in the first time slot and subsequently relay R_i transmits to destination D in the second time slot. In this model, we use a back-up relay to increase the diversity. If the relay R_i fails for successful transmission then the relay R_j transmits the packet.

5. Conclusion

In our proposed model, we control the relay selection zone and relay transmission power in order to reduce hidden and exposed terminal problems. Thus, it reduces the probability of collisions and bandwidth wastage. Therefore, proposed model will increase the performance of network. Our further research is to investigate the performance evaluation using simulator ns-2.

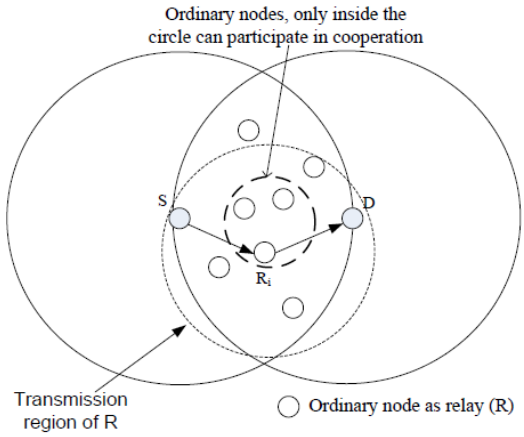

Fig. 2 Network model: transmission of R does not enlarge the transmission region of S and D

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