Computer Communications 127 (2018) 13–19

Contents lists available at ScienceDirect

Computer Communications

journal homepage: www.elsevier.com/locate/comcom

SSCSMA-based random relay selection scheme for large-scale relay networks

Li Guo[a], Zhiliang Zhu[*,b], Francis C.M. Lau[c], Yuli Zhao[b], Hai Yu[b]

[a] School of Computer Science and Engineering, Northeastern University, Shenyang 110819, China
[b] Software College, Northeastern University, Shenyang 110819, China
[c] Department of Electronic & Information Engineering, Hong Kong Polytechnic University, Hong Kong

ARTICLE INFO

Keywords:
Relay selection
Cooperative communication
Large-scale relay networks
Outage probability
SSCSMA
Transmission rate

ABSTRACT

Effective relay selection is a way to achieve considerable performance gains in cooperative communication. However, in practice, the best relay may not always be selected due to the difficulty in collecting accurate network information when the network scale is very large or when the channel information is time-varying. In this paper, we propose a suboptimal relay selection scheme where the only information available to the source is the destination location. The proposed scheme consists of three phases. During the first phase, the area of relay selection is narrowed down based on the outage probability and target transmission rate. In the second phase, a node within this region is selected using the Successive Slotted Carrier Sense Multiple Access (SSCSMA) protocol. In the third and last phase, data is transmitted from the source via the relay to the destination. We present a detailed analysis of the transmission rate and the outage probability. Simulation results have shown that our method using SSCSMA outperforms Random Access based Blind Relay Selection (RABRS) in terms of transmission rate. The results have also indicated that both the outage probability constraint and the source-destination distance affect the transmission rate.

1. Introduction

With the rapid development of wireless communication technology, cooperative communication applying relays in a wireless network has attracted a great deal of attention over the past years. The most important part of cooperative communication is relay selection which is an effective way to achieve considerable performance gain. When the source-destination (SD) link has a poor quality, one or more relays should be chosen to cooperate with the source to ensure the reliability of the overall transmission. A variety of relay selection schemes have been proposed according to different constraint functions, design issues and channel information assumptions which are based on the channel state information (CSI).

Relay selection schemes can be categorized into three representative types according to the processing method at the relay nodes: amplify-and-forward (AF) [1], decode-and-forward (DF) [2] and compress-and-forward (CF) [4]. In [1], a new AF relaying scheme adaptively selects between AF relaying and retransmission in order to achieve a lower outage probability. Luo et al. have proposed a selective DF relay scheme called “best-selection relay” in which only the node with the highest mean signal-to-noise ratio (SNR) to the destination is chosen to cooperate with the source [2]. The relay is selected from the “decoded set” in which the nodes can decode the information from the source successfully. Combining DF and AF, Bai et al. [3] have proposed a new relaying scheme termed as incremental hybrid decode-amplify-forward relaying (IHDAF) for the conventional three-node cooperative relaying system. In the scheme, the relay is chosen to keep silent or transmit the received information using DF or AF protocol based on the qualities of the channels among source, relay and destination. In CF relay strategy, the relay cannot decode the message sent by the source, but can assist by compressing and forwarding its observation to the destination. Raja et al. have presented a new CF scheme with backward decoding in which the relay node compresses the received signal in blocks [4].

According to various constraint functions (e.g. harmonic mean, reliability of the transmission, throughput, etc.), many different relay selection schemes have been proposed in the literature [5–13]. Ibrahim et al. [5] have developed a new cooperative communication protocol which can help the source selecting an optimal relay. The target relay should possess maximum instantaneous scaled harmonic mean function of its source-relay and relay-destination channel gains based on the available CSI. Similarly, the relay with the largest harmonic mean of the source-relay channel gain and the relay-destination channel gain can be selected to transmit message to the destination using AF and selective DF (SDF) [6]. In order to ensure the reliability of received information, a practical relay selection scheme which can minimize the average sum bit-error-rate (BER) of the two end users in a two-way relay channel has

* Corresponding author.
E-mail address: zhuzl_neu@163.com (Z. Zhu).

https://doi.org/10.1016/j.comcom.2018.05.006
Received 1 December 2017; Received in revised form 20 April 2018; Accepted 15 May 2018
0140-3664/

been investigated in [7]. Analogously, Selvaraj et al. [8] have presented a hybrid selection which is mainly based on the CSI of the source-relay (SR) link and relay-destination (RD) link. They have also derived the exact symbol error probability (SEP) of the selection scheme. Throughput is another important metric that measures the network performance. In [9], Zhang et al. have proposed a cooperative Automatic Repeat reQuest (ARQ) protocol in which the relays that can not receive information from the source but can listen to the retransmission and decode the packet are utilized. This protocol can decrease the packet loss rate and retransmission probability. Li et al. have offered an optimal scheme using joint relay selection and power allocation to achieve maximum system throughput for conventional wireless communications [10]. Taking the packet buffering into consideration, another method to mitigate throughput loss has been studied in [11]. In this scheme, the relay with the shortest buffer length is chosen for reception and the relay with longest buffer length is chosen for transmission which can decrease the outage probability and average delay. In recent years, more attention has been paid to energy conservation. A new energy-efficient metric for relay selection in random wireless sensor networks is proposed and studied by Li et al. [12]. They have selected an appropriate node, which can maximize the effective transmitting distance per unit energy consumption, to cooperate with the source. For the sake of achieving maximum cooperation efficiency, a novel distributed cooperative Medium Access Control (MAC) protocol in which the optimal relay is determined based on the instantaneous channel quality has been presented in [13].

The CSI which reflects the comprehensive condition of the channel is a crucial criterion for relay selection in the schemes mentioned above. Nevertheless, for large networks, collecting the CSI of all candidate relays will consume more energy and cost more time overhead due to the increase of the relay number and the network scale. Random access provides a simple solution of transmission for these networks without collecting CSI. ALOHA is the earliest type of random access protocol in which each node transmits its own information if there is a request. The node does not detect whether the channel is idle or not, and if a collision occurs the node will back off. The ALOHA protocol cannot reach a high channel utilization but Carrier Sense Multiple Access (CSMA) can overcome partially its inadequacy. CSMA is put forward by Kleinrock and Tobagi [14]. It requires the nodes to sense the channel and transmit only when the channel is idle. In [15], Zhu et al. provide a brief explanation on slotted CSMA/CA of the IEEE 802.15.4 MAC mechanism. In IEEE 802.15.4, nodes do not sense the channel until the backoff counters decrease to 0. Then they conduct at least two clear channel assessments (CCAs) before transmitting information. Only if the channel is sensed idle during both CCAs can the nodes start transmission.

Recently, several works have been presented for the analysis of random access protocols in wireless networks. The relay selection scheme using the random access protocol requires much less information from relays compared with the schemes mentioned above. A spatial region called the quality-of-service (QoS) region is first obtained for random relay selection [16]. Then in this region, all nodes satisfying the outage-probability constraint will be selected randomly to cooperate with the source. In [16], the selection guideline ensures a target QoS and reduces the signaling overhead as well as the relay selection delay. A random access based blind relay selection (RABRS) scheme has been proposed by Ouyang et al. [17]. In RABRS, only one relay within the narrowed area can access the channel successfully according to the transmission rate. In [18], the authors take the spatial distribution of relays into account and each relay can use the location information to determine independently its own back-off time and a forwarding probability. Moreover, the scheme outperforms the pure probabilistic scheme in terms of the success probability of relay forwarding the packet to destination.

The RABRS scheme proposed in [17] greatly reduces the network cost and help the networks to reach an expected transmission rate which is almost as good as that of the upper bound in view of the considered parameters. However, too many candidate relay nodes satisfying the requirements will result in the increase of collisions. As a consequence, the transmission rate and the probability of selecting an appropriate relay may become limited when the number of candidate relays increases. So in this paper, we propose a new relay selection scheme for the network in which a large number of relays are distributed uniformly. In our scheme, the candidate relays use a random access protocol called Successive Slotted Carrier Sense Multiple Access (SSCSMA) to access the channel randomly. The SSCSMA protocol can manage the collisions effectively by determining the channel is idle or not before transmitting data and further increase in transmission rate of the network as well as the successful transmission probability. Specifically, we find a QoS region for our scheme according to the proposed metric before relay selection.

The remaining of the paper is organized as follows. Section 2 presents the system model of the proposed random relay selection. Section 3 presents the detailed analysis of transmission rate and outage probability. Simulation results are provided in Section 4, followed by some concluding remarks in Section 5.

2. System model and relay selection scheme

2.1. System model

Referring to Fig. 1, we consider a network with only one source, one destination and many candidate relay nodes distributed uniformly with a node density λ. All nodes have one transceiver with a single antenna. A node is either transmitting or receiving but not both simultaneously, i.e., half-duplex mode for information transmission. Instead of collecting the channel information all over the network, each node is assumed to have no CSI.

In many relay selection schemes, both the relay and the source transmit information to the destination [19], even though the channel quality between source and destination may be not good. In our the model, we assume that the channel quality between source and destination is very poor, and the source cannot transmit information to the destination directly. As a consequence, the reliability of the transmission completely depends on the chosen relay. Therefore, we eliminate the nodes that cannot decode the information from the source successfully at the beginning of the relay selection process.

The location information of the relay nodes also has a great effect on the selection process. We consider a model in which the location of

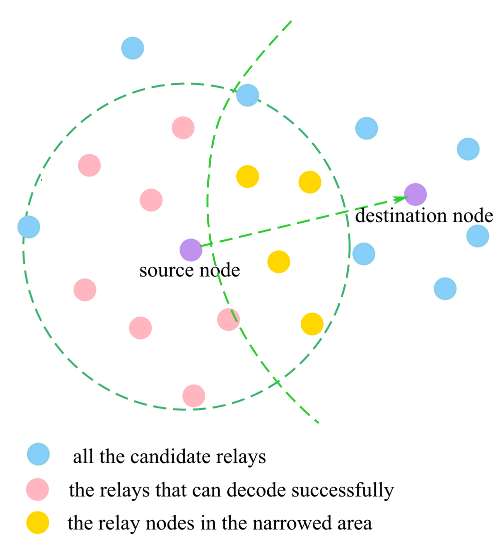

Fig. 1. The potential relay nodes distributed uniformly around the source and destination.