Enhanced Relay Selection and Scheduling for Better Load Balancing in Multi-Hop Networks

Soumaya Hamouda, MEDIATRON Lab, University of Carthage, Carthage, Tunis, Tunisia
Tarek Bejaoui, MEDIATRON Lab, University of Carthage, Carthage, Tunis, Tunisia

ABSTRACT

Relaying technology is likely to bring real progress to the next generation cellular networks due to its capability of boosting the system capacity and coverage. However, despite recent advances in relay deployment, some challenging problems still remain such as radio resource allocation and relay selection. The authors investigate both relay selection and scheduling strategy in order to improve the system radio capacity as well as the network load balancing. They propose a new path selection scheme based on the radio channel quality and the relay station load criteria. Performance analysis showed that the authors approach outperforms the existing path selection algorithms in terms of outage probability and global throughput in the system, especially in high traffic conditions. It is revealed that most of the cell edge users which would be rejected when applying common selection scheme, can now have access to a selected relay station and achieve a high end-to-end throughput. A new scheduling strategy is proposed in the second part of this paper, on the basis of a dynamic subframe partitioning. Simulation results show that the outage probability is reduced and more balanced resource allocation is provided. Simulation results showed that some relay stations which were not able to offer any service with the fixed subframe partitioning, can achieve a high data rate with the authors proposed dynamic scheduling strategy.

Keywords: Dynamic Scheduling Strategy, Load Balancing, Multi-Hop Relay Networks, Relay Selection, Relaying Technology, Scheduling

INTRODUCTION

Relaying is a promising technique for the next generation cellular networks. For instance, it is introduced in IEEE 802.16j standard (Steven et al., 2009) and it is highly recommended in 3GPP LTE-Advanced because it is expected to satisfy the ever growing capacity and coverage demands in a cost-efficient way. In fact, in classical Point-to-Multipoint topology, required data rates need a high received signal-to-interference-and-noise-ratio (SINR) which is hard to achieve at the cell edge. By including multi-hop capabilities in the system, not only the cell coverage is enlarged, but also both radio capacity and cell-edge user throughput are improved. However, in order to fully exploit the benefits of relaying, many technical issues should be examined such as the relay selection, and the radio resource sharing between the serving Base Station (BS) and the Relay Stations (RSs).

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The relay selection process is done by a local procedure initialized by a mobile device to ensure a certain end-to-end quality of service. So, the more efficient is the relay selection, the better is the data transmission. On the other hand, the backhaul link and the access link are generally time division and the radio resources for both serving BS and RSs are fully multiplexed. The RSs are operating in half-duplex mode. In the first time slot, all sub-channels are allocated to the serving base station while the RSs remain silent. In the second slot, both serving BS and RSs transmit on the same frequency bandwidth. Therefore, a static sub-channel repartition between the serving BS and the RSs is no longer suitable to ensure a better radio resource sharing nor a load balanced network.

In this paper, we present a new relay selection scheme aiming at reducing the outage probability at the cell edge and offering a more load balanced system. We propose then a new dynamic scheduling strategy in order to share the radio-resources more efficiently between the serving BS and the RSs.

This paper is organized as follows: related works regarding both relay selection and scheduling in multi-hop networks are presented first. Then the system model is described. Afterwards, the new proposed multi-hop relay selection scheme is described and its performance is analyzed. Our proposed scheduling strategy and its performance evaluation are presented afterwards. Then finally concluding the paper.

RELATED WORKS

The path selection problem for mobile stations has been discussed in different documents belonging to the IEEE 802.16’s relay task group and 3GPP LTE-Advanced. Multi-hop routing protocols using different cost metrics have been also proposed in several contributions (e.g., Perkins & Bhaguat, 1994; Perkins & Royer, 1999; Cao et al., 2008; Lee et al., 2009), such as shortest-path routing, load-aware routing, SINR-based selection or throughput-based selection.

**Shortest-path routing:** This routing algorithm described in Perkins and Bhaguat (1994) and Perkins and Royer (1999) aims at finding the route with the minimum hop count value. It assigns a path with the least number of hop-counts to a Mobile Station (MS); it has been widely used in both wired and wireless networks. The most important feature of the shortest path is that it usually has the minimum communication delay and is easily implemented. However, the use of the minimum hop count for path cost is not always perfect. Many researches show that this kind of protocols degrades network performance due to congestion on these selected relays along the minimum hop path (Bharadwaj et al., 2011).

**Load-aware routing:** The load-aware routing protocols is presented in Lee and Gerla (2001) and Cao et al. (2008); this protocol aims at discovering routes with the minimum traffic load. It selects the path that cumulates the least consumption. These load-aware routing protocols use different cost metrics to measure traffic load of a route. For example, they used the number of packets buffered at intermediate relays along the route as a route selection metric. Thus, load-aware routing protocols can avoid congestion by denying access to relays with high traffic load. Considering the path selection on the basis of a minimum load, may however not be very efficient. In fact, this selection can add more delays and does not guarantee high data rate, especially when the user is located at an important distance from the selected relays.

**SINR-based selection:** In Ge et al. (2009), the authors proposed some selection algorithms based on distance, path-loss and SINR. The relay with the highest SINR is selected at each hop. The coverage improvements obtained due to proper RS selection and transmit power selection is guaranteed in this scheme. It also shows the throughput improvement due to relaying with best performance based on SINR, path-loss and distance. However, it is known that this strategy results in highly unfair resource utilization and eventually, it will violate the quality of service (QoS) requirements of those overly-used relays when they have their own service to serve.
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