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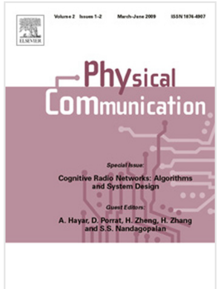

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Transport Capacity of Cooperative Cognitive Radio Ad Hoc Networks

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***Abstract*—It is more challenging for improving the traditional performance metrics for the 5-th generation network (5G) because of more congestible frequency spectrum. How to improve the network capacity without using more spectrum has become one of important studies in 5G. In this paper, the transport capacity of cooperative cognitive radio ad hoc networks is studied. In order to characterize the transport capacity, a half-slotted ALOHA multiple access protocol is introduced. In each slot, secondary users are divided into cooperative secondary users and ordinary users dependent on the positional relationship between them and primary transmitters. Primary transmitters send their packets in the first half slot while keep silence in the second half slot. Ordinary secondary users send their packets at a probability p in the whole slot. Cooperative secondary users receive the packets from their corresponding primary transmitters in the first half slot and forward them to the primary receivers in the second half slot. The closed-form expressions of the bounds of primary transport capacity and mean secondary transport capacity are derived based on the protocol. Furtherly, the optimal problem of the performance is analyzed about two important parameters: primary and secondary coverage radius. Theoretical results show that an optimal primary coverage radius could be found to maximize the transport capacity of primary network. While the transport capacity of secondary network increases with the increasing secondary coverage radius. The analysis reveals that the transport capacity could be improved by secondary cooperation because of higher successful transmission probability.**

***Index Terms*—Transport capacity, cognitive radio, ad hoc, cooperative.**

I. INTRODUCTION

It is well known that frequency spectrum will be more and more tense with the rapid development of mobile communications for 5G. Heterogeneous network and millimeter wave (mmWave) technology are two established effective methods to solve this problem. Cognitive radio (CR) networks is considered to be one of the typical heterogeneous networks which could release the conflict between spectrum scarcity and the inefficient use of most licensed spectrum bands [1]. In CR networks, unlicensed or secondary users (SU) are allowed to access the licensed spectra when they do not cause unacceptable levels of interference to licensed or primary users (PU). The framework of CR networks also poses many new challenges in research despite its superiorities in broad applying prospect.

The capacity of CR networks has been a hot spot all the time because of its importance in analyzing the network performance. Since the seminal work of Gupta and Kumar [2], the capacity of ad hoc networks has been extensively explored. In [2], they present the transport capacity of ad hoc networks in the order sense based on signal to interference plus noise ratio (SINR) model. As λ being the density of transmitters in the network, they certified that the transport capacity scales as $\Theta\left(\sqrt{\lambda}\right)$. Based on the results, the scaling law of CR networks are widely studied in [3], [4], [6]. In [3], a tradeoff was testified to exist between throughput and delay in a overlaid wireless network. In [4], the scaling law $\Theta\left(\sqrt{n}\right)$ is achievable for both the primary network and the secondary network by using percolation theory [5], where n is the number of nodes in the network. In [6], the throughput of coexist two networks could achieve the same scaling law in a two-tier network which is same to that of single network.

The other primary concern of the capacity of CR network is the closed-form expression which is first derived for the capacity of ad hoc networks in [7], [8]. In [7], Weber *et. al.* analyze the transmission capacity of single-hop network based on the theory of stochastic geometry [9]. By modelling the locations of the nodes in ad hoc networks as a Poisson point process, they give the exact expressions of the bounds of transmission capacity. In [8], Baccelli *et. al.* proposed the spacial density of progress to measure the capacity of multi-hop networks. In the study, Poisson point process is also used to formulate the distribution of nodes in ad hoc networks and an ALOHA protocol is adopted to analyze the spacial density of progress. Furtherly, more closed-form capacity formulas are studied in CR networks [10], [11]. In [10], the exact closed-form expression for the ergodic capacity is derived by assuming Racian fading for the secondary link and Rayleigh fading for the secondary-to-primary link channel. In [11], the capacity region is characterized for the Gaussian channel in