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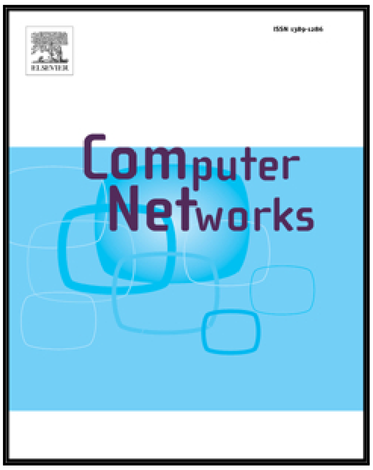

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Design and Stochastic Geometric Analysis of an Efficient Q-Learning Based Physical Resource Block Allocation Scheme to Maximize the Spectral Efficiency of Device-to-Device Overlaid Cellular Networks

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Abstract

Device-to-Device (D2D) communication empowers direct communication between two proximal users and helps in offloading network traffic. It is considered as one of the most promising 3GPP Long Term Evolution (LTE)-Advanced technologies for improving the spectrum and energy efficiency of Proximity-based Services (ProSe). However, due to interference posed by the D2D transmitters to the primary cellular users, intelligent resource allocation techniques need to be incorporated for the betterment of the overall system. Overlay D2D communication avoids the interference between cellular and D2D users by dedicating resources for D2D users. With this approach, efficient use of the dedicated Physical Resource Blocks (PRBs) among D2D users is still a concern. To handle the issue of optimum spectral efficiency, efficient allocation of spectrum resources is essential among D2D users. For the first time, we address this problem and propose a PRB allocation scheme that maximizes the PRB utilization among D2D users. The proposed scheme spreads the PRB requirement of a D2D pair over multiple PRBs while reducing the transmit power over each PRB, thereby reducing the overall interference and improving the spectral efficiency of the network. Extensive simulations demonstrate that our scheme does better than the conventional PRB allocation scheme (of assigning PRBs based on their data rate demand), by increasing the overall throughput and energy efficiency of the network. To analytically evaluate the proposed PRB allocation scheme, we present a stochastic geometry based framework to analyze the coverage and average rate of the network, and conclude that the link SINR of the D2D pairs is actually improved on employing our proposed scheme which results in high coverage and overall rate of the system. Finally, we propose a Q-Learning algorithm that learns the optimum number of PRBs to dedicate for overlay D2D communication based on the PRB demand of the cellular and D2D users. Extensive simulations reveal that the proposed algorithm efficiently allocates PRBs to the D2D pairs when compared to the conventional static scheme of dedicating fixed number of PRBs.

Keywords: Cellular Network, overlay D2D communication, channel assignment, power control, energy efficiency, Q-Learning.

1. Introduction

With the advent of smartphones and electronic tablets, mobile traffic has been on the rise due to the emergence of new data-intensive applications for fulfilling users data rate requirements. Over recent years, proximity based applications are one such area that has become a major source of such data surge. To support proximity based services and help the operators in offloading the traffic, Device to Device (D2D) communication in cellular networks has been introduced and is expected to be an integral part of the 3GPP Long Term Evolution (LTE)- Advanced networks [1]. D2D communication enables two users in proximity to transmit signal directly without going through the base station. Advantages of such a form of communication are increased spectral efficiency, reduced communication delay, reduced network load and increased energy efficiency. However, implementing D2D communication in cellular networks also leads to some issues, such as co-channel interference, which needs to be addressed, before harvesting the aforementioned benefits.

Various studies in literature indidate that D2D pairs use either licensed or unlicensed frequency resources for communication [2, 3]. When licensed band is used for communication, it is called as Inband D2D communication, and when unlicensed band is used, it is termed as Outband D2D communication. Based on the spectrum used, the studies conducted earlier can be broadly divided into two categories. First being, the interference control between D2D and cellular communication, in a typical inband scenario [3–10]. The second deals with the interference control between D2D and surrounding unlicensed (ISM) band communication, in a typical outband scenario [11]. While most of the studies have focused on frequency