MODELING AND PERFORMANCE ANALYSIS OF DEVICE-TO-DEVICE CELLULAR NETWORKS

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Certificate

This is to certify that the thesis entitled **“Modeling and Performance Analysis of Device-to-Device Cellular Networks”** being submitted by **Sandeep Joshi** to the Department of Electrical Engineering, Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy** is the record of the bona-fide research work carried out by him under my supervision. In my opinion, the thesis has reached the standards fulfilling the requirements of the regulations relating to the degree. The results contained in this thesis have not been submitted either in part or in full to any other university or institute for the award of any degree or diploma.

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Abstract

Device-to-device (D2D) communication which involves direct communication between the cellular users in proximity, thus bypassing the network infrastructure, i.e., the base station (BS) is envisaged to be an important part of the fifth generation communication network. In this thesis, we analyze the downlink performance of a D2D-enabled cellular communication network with the D2D communication links assumed to be under Nakagami-m fading, using the tools from stochastic geometry, in terms of the coverage probability. The coverage analysis is presented with the devices placed randomly according to Poisson point process (PPP) for the dedicated scenario, wherein, the frequency resources are allocated separately for both the D2D and the cellular users, and for the shared scenario, wherein, the frequency resources are shared between the D2D and the cellular users. The coverage analysis is further extended to include the case of dense cellular networks for both the dedicated and the shared communication scenarios.

Although, most of the performance analysis of D2D communication systems is studied assuming the device locations to be PPP distributed due to the advantages of tractability of the analysis, the PPP modeling has limitations in providing the complete network description. Also, the PPP modeling of devices does not capture the non-homogeneity in the device location which is effectively modeled by the Poisson cluster process (PCP) and is more close to the depiction of the practical wireless heterogeneous networks. To account for the spatial correlation between the devices, we provide the coverage and the interference analysis of the D2D links assuming the device locations to be distributed as PCPs which is realistic but more complex in comparison to the PPP device modeling. We derive the intra and the inter cluster Laplace transforms

and using them we further derive approximate closed-form expressions for the coverage probability with devices modeled as PCPs for the dedicated network scenario. We also derive the closed-form coverage expressions for the special case of Rayleigh fading. We also show the dependence of the coverage probability on various system parameters.

We provide a useful addition to the available stochastic geometry toolbox for the D2D coverage analysis by giving an alternate way to compute the coverage probability using the interference functional approach. Further, the interference functional approach is compared with the commonly used Laplace transform approach and we observe that both the approaches show similar coverage behavior. The interference functional approach provides the additional advantage of less complexity in the numerical and analytical computation. Additionally, we also provide a bound on the coverage probability using the Alzer's inequality which is helpful in the coverage calculations for higher fading parameter values.

Relaying in wireless networks is an effective way to reduce fading and increasing the coverage range. We study the performance analysis of a cooperative D2D network with downlink non-orthogonal multiple access and fixed gain amplify-and-forward relaying considering that a direct link exists between the D2D user and the BS. We derive novel closed-form expressions of the outage probability and the system throughput for the D2D users considering a general framework of Nakagami-m fading.

सार

डिवाइस-टू-डिवाइस (डी२डी) संचार में सेलुलर उपयोगकर्ता जो निकटता में हैं उनके बीच प्रत्यक्ष संचार शामिल है , इस प्रकार नेटवर्क के बुनियादी ढांचे, यानी बेस स्टेशन (बीएस) को दरकिनार कर देते हैं , डी२डी संचार को पांचवीं पीढ़ी के संचार नेटवर्क का एक महत्वपूर्ण हिस्सा होने की परिकल्पना की गई है। इस थीसिस में, हम कवरेज संभावना के संदर्भ में स्टोकेस्टिक ज्योमेट्री से उपकरणों का उपयोग करते हुए, डी२डी संचार लिंक जो की नाकागामी-एम फेडिंग के तहत है, डी२डी-सक्षम सेलुलर संचार नेटवर्क के डाउनलिंक प्रदर्शन का विश्लेषण करते हैं। कवरेज विश्लेषण को पॉइसन बिंदु प्रक्रिया (पीपीपी) के अनुसार यादृच्छिक रूप से रखे गए उपकरणों के साथ प्रस्तुत किया गया है, समर्पित परिदृश्य के लिए , जिसमें, डी२डी और सेलुलर उपयोगकर्ताओं के लिए आवृत्ति संसाधन अलग से आवंटित किए जाते हैं, तथा साझा परिदृश्य के लिए, जिसमें, डी२डी और सेलुलर उपयोगकर्ताओं के बीच आवृत्ति संसाधन साझा किए जाते हैं। घने सेलुलर नेटवर्क के लिए कवरेज विश्लेषण को समर्पित और साझा संचार परिदृश्यों को शामिल करने के लिए आगे बढ़ाया गया है।

हालांकि, डी२डी संचार प्रणालियों के अधिकांश प्रदर्शन विश्लेषण का अध्ययन डिवाइस स्थानों को पीपीपी वितरित कर किया जाता है, विश्लेषण के स्थायित्व के फायदे के कारण, पीपीपी मॉडलिंग की नेटवर्क विवरण को पूर्णता प्रदान करने में सीमाएं हैं। इसके अलावा, उपकरणों के पीपीपी मॉडलिंग डिवाइस के स्थान में गैर-विषमता को कैप्चर नहीं करते हैं जो कि पॉइसन क्लस्टर प्रक्रिया (पीसीपी) द्वारा प्रभावी रूप से की जाती है और व्यावहारिक वायरलेस विषम नेटवर्क के चित्रण के अधिक करीब है। उपकरणों के बीच स्थानिक सहसंबंध को उजागर करने के लिए, हम कवरेज और डी२डी लिंक के इंटरफेरेंस विश्लेषण प्रदान करते हैं कि डिवाइस स्थानों को पीसीपी के रूप में वितरित किया जाए जो पीपीपी डिवाइस मॉडलिंग की तुलना में यथार्थवादी लेकिन अधिक जटिल है। हम इंट्रा और अंतर क्लस्टर लाप्लास ट्रांसफॉर्म को रूपांतरित करते हैं और उनका उपयोग करते हुए हम समर्पित नेटवर्क परिदृश्य के लिए पीसीपी के रूप में तैयार किए गए उपकरणों के साथ कवरेज संभावना के लिए अनुमानित क्लोज्ड-फॉर्म

अभिव्यक्ति प्राप्त करते हैं। हम रेले फेडिंग के विशेष मामले के लिए क्लोज्ड-फॉर्म कवरेज अभिव्यक्तियों को भी प्राप्त करते हैं। हम विभिन्न सिस्टम मापदंडों पर कवरेज संभावना की निर्भरता भी दर्शाते हैं।

हम इंटरफेरेंस फंक्शनल दृष्टिकोण का उपयोग करके डी२डी कवरेज विश्लेषण के लिए कवरेज संभावना की गणना करने के लिए उपलब्ध स्टोकेस्टिक ज्योमेट्री टूलबॉक्स में एक अतिरिक्त और उपयोगी वैकल्पिक तरीका प्रदान करते हैं। इसके अलावा, इंटरफेरेंस फंक्शनल दृष्टिकोण की तुलना आमतौर पर इस्तेमाल किए जाने वाले लाप्लास ट्रांसफॉर्म दृष्टिकोण के साथ की गयी है और हम मानते हैं कि दोनों दृष्टिकोण समान कवरेज व्यवहार दिखाते हैं। इंटरफेरेंस फंक्शनल दृष्टिकोण संख्यात्मक और विश्लेषणात्मक गणना में कम जटिलता का अतिरिक्त लाभ प्रदान करता है। इसके अतिरिक्त, हम अल्जर की असमानता का उपयोग करते हुए कवरेज संभावना पर भी एक सीमा प्रदान करते हैं जो उच्च फेडिंग पैरामीटर मानों के लिए कवरेज की गणना में सहायक है।

वायरलेस नेटवर्क्स में रिलेइंग, फेडिंग कम करने और कवरेज रेंज बढ़ाने का एक प्रभावी तरीका है। हम डाउनलिंक नॉन-ऑर्थोगोनल मल्टीपल एक्सेस और फिक्स्ड गेन एम्पलीफाइ-एंड-फॉरवर्ड रिलेइंग के साथ एक सहकारी डी२डी नेटवर्क के प्रदर्शन विश्लेषण का अध्ययन करते हुए मानते हैं कि डी२डी उपयोगकर्ता और बीएस के बीच एक सीधा लिंक मौजूद है। हम नाकागामी-एम फेडिंग के एक सामान्य ढांचे पर विचार करते हुए डी२डी उपयोगकर्ताओं के लिए आउटेज संभावना और सिस्टम थ्रूपुट के नवीन क्लोज्ड-फॉर्म अभिव्यक्तियों को प्राप्त करते हैं।

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