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Network Connectivity Optimization for Device-to-Device Wireless System with Femto Cells

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Abstract: The demand for high data rate transmission has triggered the design and development of advanced cellular networks, such as 4th generation long term evolution (LTE) networks. However, their poor coverage and relatively high interference can significantly impair data transmission. Femtocell and device-to-device (D2D) communication are promising solutions that have recently gathered interest. Operating in the licensed spectrum, femtocells provide users with higher capacity and coverage than their earlier designs, and they will be offered by cellular operators to enable high-data-rate local services in future LTE Advanced networks. As an underlay to the cellular networks, D2D communication enables nearby devices to communicate directly with each other by reusing cellular resources, which reduces interference in the cellular network compared with communication through base stations. However, the tight integration of femtocells and D2D communication creates a challenge for existing network design and is less studied in the literature. In this paper, we propose an open-access algorithm for femtocell base stations in D2D LTE-Advanced networks, in order to optimize network connectivity. Additionally, a greedy algorithm is proposed to balance macrocell base stations and femtocell base stations to maximize network connectivity. The simulation results demonstrate the effectiveness of the proposed.
Keywords:

I. INTRODUCTION

The ever-increasing demand of user equipment (UE) and applications in cellular networks for higher data rate transmission has triggered design of new advanced cellular networks such as the 4th generation (4G) long term evolution (LTE) network. Studies show that more than 50% of voice calls and 70% of data traffic originate indoors [1]. The mobile operator faces challenges in providing in-building coverage due to poor indoor radio signal penetration and possibly crowded indoor environments such as shopping malls. In the LTE-Advanced networks, the femtocell approach is a potential solution to support higher data rate and reliable services to the subscribers, while allowing the operator to reduce data traffic on the expensive macrocell networks [1]. Femtocells can be employed as short-range, low-cost, and low-power base stations for providing cellular service within the home and enterprise environments [2]. On the other hand, to better support higher data rate local services, the cellular operator can integrate device-to-device (D2D) communication in future 4G LTE-Advanced cellular networks as an underlay. The D2D network is built by D2D UEs that do not communicate with each other via the base station (BS), which is called evolved NodeB (eNB) in the LTE architecture. In D2D networks, UEs instead communicate directly over one or more hops [3]. Enabling a D2D communication mode in cellular networks can improve system performance through better reuse of radio resources and reduced congestion when several UEs located in the same area want to communicate with each other [3]. The tight integration of femtocell and D2D communication into the LTE-Advanced cellular networks can support higher data rate services for the UE by using the limited wireless resources in a more efficient way, but it also makes the network design a challenging task. For example, network connectivity is one direct and efficient criterion for evaluating the effectiveness of the integration. In [4], a limited number of relays were placed in a wireless sensor network federation to maximize network connectivity. However, there are few connectivity optimization solutions for femtocell networks to date, and the need for integration into the D2D LTE-Advanced networks increases motivation to develop better ones [5], [6]. The selection of access control mechanisms for such a network has dramatic effects on the performance of the overall system [7], [8]. For example, controlling the idle or sleep mode of femtocells can improve energy efficiency of femtocell BSs [9]. Femtocells deployment can also save the macrocell network radio resources by macro-offloading control, thereby achieving offloading gain [10]. Furthermore, introduction of femtocells into the D2D LTE-Advanced cellular network will consequently require new access control mechanisms [11],[12].In this paper, we propose an open access mechanism for femtocells to maximize network connectivity in the D2D LTEAdvanced networks. We evaluate network connectivity by using the normalized cut and Laplacian matrix. In the D2D networks composed of nearby D2D UEs, a limited number of UEs are chosen by a greedy algorithm to connect with the macro eNB in order to maximize network connectivity. To improve network connectivity further, the femtocell in the right location is found by using a gradient method, and can turn on the open access mode to connect with a limited number of UEs chosen by another greedy algorithm. The above algorithms are conducted iteratively until the network topology becomes stable. The numerical results show that the proposed algorithms can not only significantly improve network connectivity, but also improve several system performance critera, such as aggregate link capacity, energy efficiency, and resource reuse efficiency.

II. SYSTEM ANALYSIS

A. Existing System

The ever-increasing demand of user equipment (UE) and applications in cellular networks for higher data rate transmission has triggered design of new advanced cellular networks such as the 4th generation (4G) long term evolution (LTE) network. Studies show that more than 50% of voice calls and 70% of data traffic originate indoors [1]. The mobile operator faces challenges in providing in-building coverage due to poor indoor radio signal penetration and possibly crowded indoor environments such as shopping malls. In the LTE-Advanced networks, the femtocell approach is a potential solution to support higher data rate and reliable services tothe subscribers, while allowing the operator to reduce data traffic on the expensive macrocell networks [1]. Femtocells can be employed as short-range, low-cost, and low-power base stations for providing cellular service within the home and enterprise environments [2]. On the other hand, to better support higher data rate local services, the cellular operator can integrate device-to-device (D2D) communication in future 4G LTE-Advanced cellular networks as an underlay. The D2D network is built by D2D UEs that do not communicate with each other via the base station (BS), which is called evolved NodeB (eNB) in the LTE architecture. In D2D networks, UEs instead communicate directly over one or more hops [3]. Enabling a D2D communication mode in cellular networks can improve system performance through better reuse of radio resources and reduced congestion when several UEs located in the same area want to communicate with each other.

B. Proposed System

The cellular network, and the integrating of femtocells is a kind of cell splitting. Both of these approaches can improve overall system capacity and energy efficiency by spatial reuse of the frequency resource. To determine the different links that can reuse a particular frequency resource, we first use the conflict graph [29] to represent the interference relationship between any two wireless communication links in the network. Then the resource reuse graph of the network can be obtained by inverting the conflict graph. In the conflict graph, each vertex represent one communication link in the network, and the edge between two vertices represents two wireless communication links that are interfering with each other and cannot use the same frequency resource at the same time. In traditional cellular networks, all the UEs connect with the same macro eNB in one macro eNB cell coverage, so every communication link should use different frequency resources. The integration of femtocells and D2D communication can largely improve the resource efficiency by allowing reuse of the same frequency resource with macro eNB UEs, especially in the shared reuse case.

C. Modules Description

1) *D2D Cellular Network:* The traditional cellular network, the D2D cellular network, the D2D cellular network integrated with femtocells, and the femtocells network. From the figure, we can see that the integration of D2D communication and femtocells greatly improves the aggregate link capacity by more than five times, compared to the traditional cellular network. The integration of one femtocell in the network also improves the network connectivity, which is expected to improves as the number of femtocells integrated increases.
2) *Network Scenario:* The network scenario In the two figures, each node represents one of the communication links in and one edge connects two nodes if the two corresponding communication links interfere with each other, which means they cannot use the same frequency resource at the same time. By inversing a resource reuse graph can be obtained, which means two communication links can use the same frequency resource at the same time if the corresponding link nodes are connected by an edge in As shown by the resource reuse graph the frequency resource can be reused by more than one communication link in the D2D networks with femtocells, in contrast to the traditional cellular network.
3) *D2D Communication:* The integration of D2D communication and femtocells greatly improves the aggregate link capacity by more than five times, compared to the traditional cellular network. The integration of one femtocell in the network also improves the network connectivity, which is expected to improves as the number of femtocells integrated increases. The thing that needs to be highlighted here is that the aggregate link capacity in the femtocells network without D2D shows some increase

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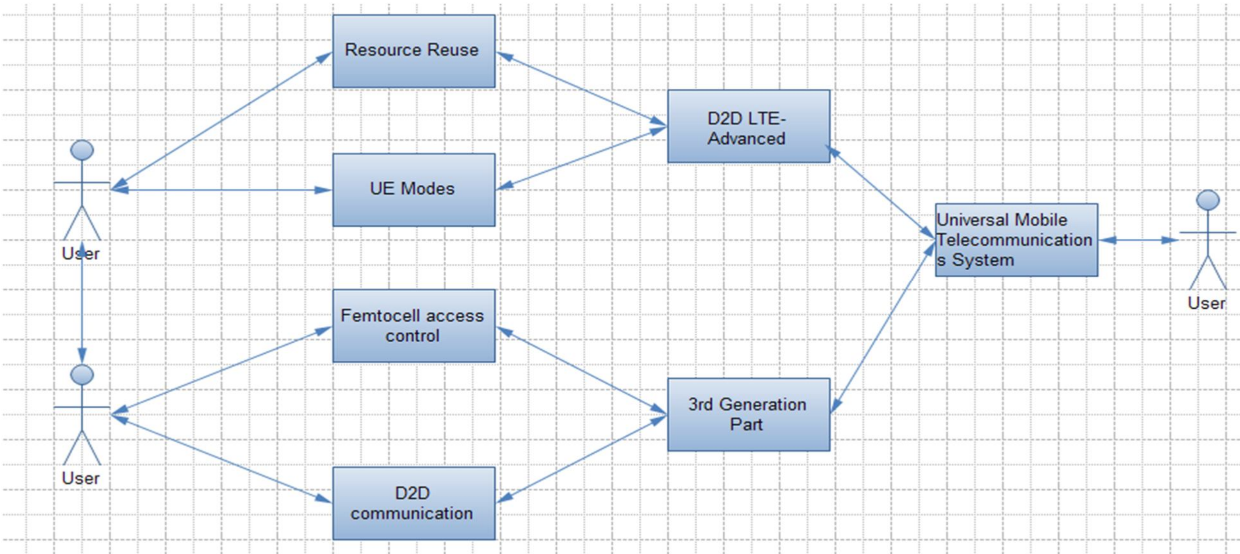
as _ varies from 0:1 to 0:9, which is different from the other networks.

D. Resource Reuse

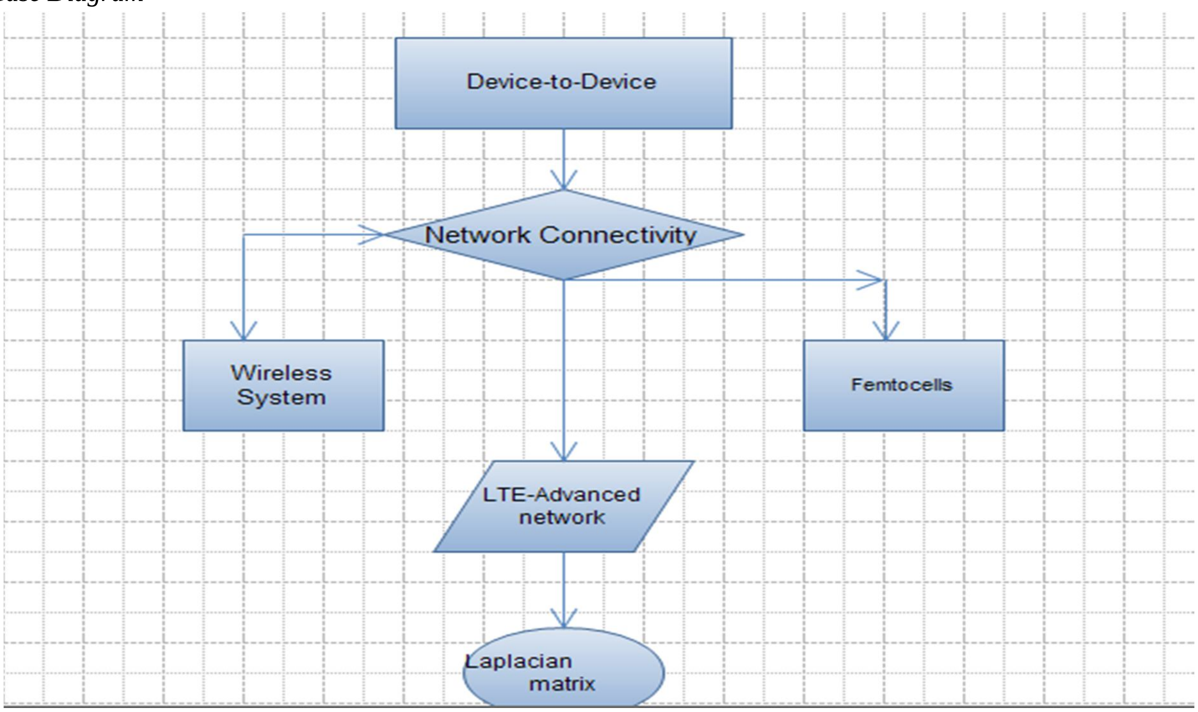
In the LTE-Advanced networks, D2D communications take place as an underlay communication to the cellular network, and the integrating of femtocells is a kind of cell splitting. Both of these approaches can improve overall system capacity and energy efficiency by spatial reuse of the frequency resource. To determine the different links that can reuse a particular frequency resource, we first use the conflict graph [29] to represent the interference relationship between any two wireless communication links in the network.

III. SYSTEM DESIGN

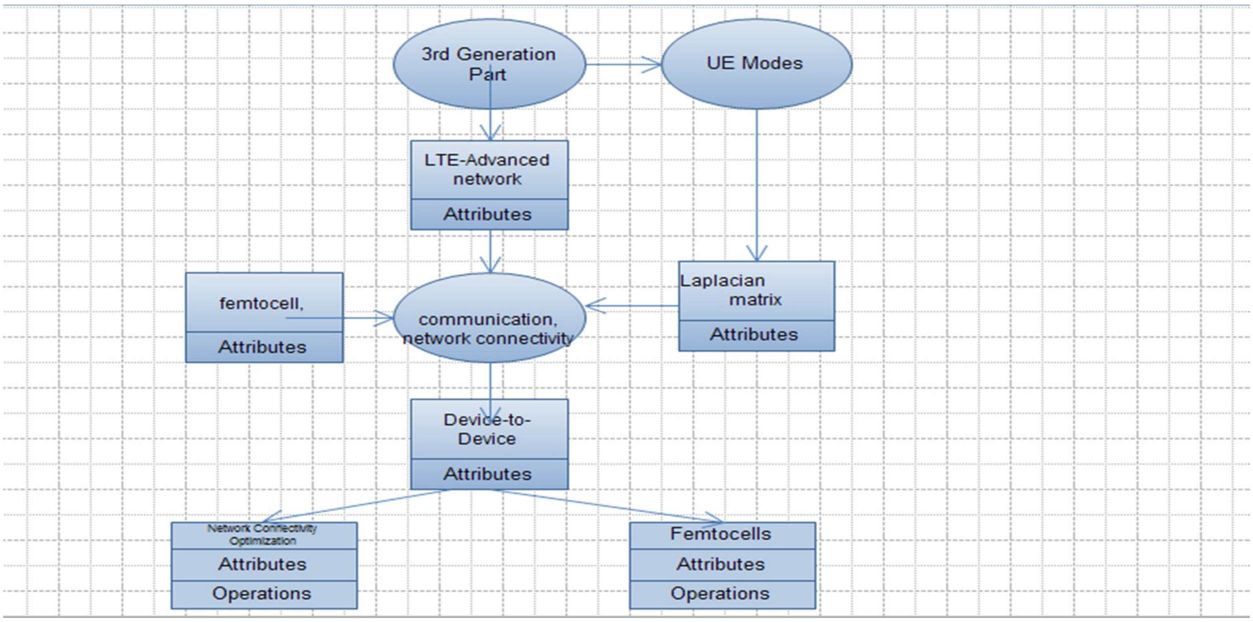
A. UML Diagram



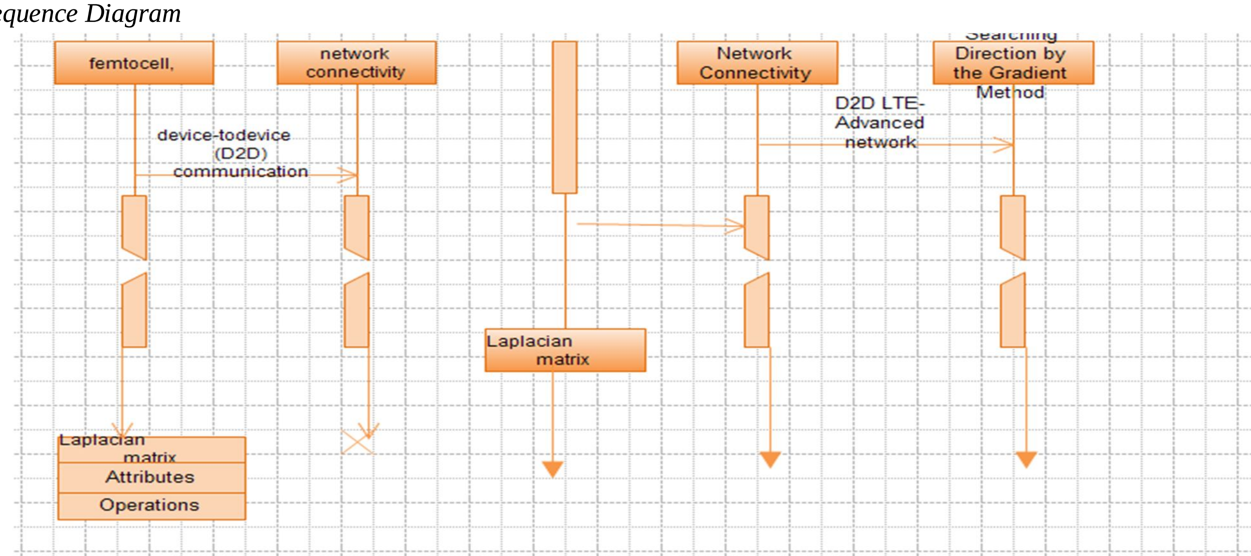
B. Use Case Diagram



C. Class Diagram



D. Sequence Diagram



IV. CONCLUSIONS

In this paper, we studied a method to optimize network connectivity via the femto eNB open access mechanism in D2D LTE-Advanced networks. We defined network connectivity and formulated the network connectivity optimization problem. We proposed our algorithms to solve the network connectivity optimization problem, which includes three-step iterations to obtain convergence results. The simulation results demonstrated the improved effectiveness of the proposed algorithms. Based on the perspectives gained from this work, in future studies we will consider interference between UEs in different UE modes. We also plan to conduct mobility analysis for the UE and the accompanying handover between different UE modes.

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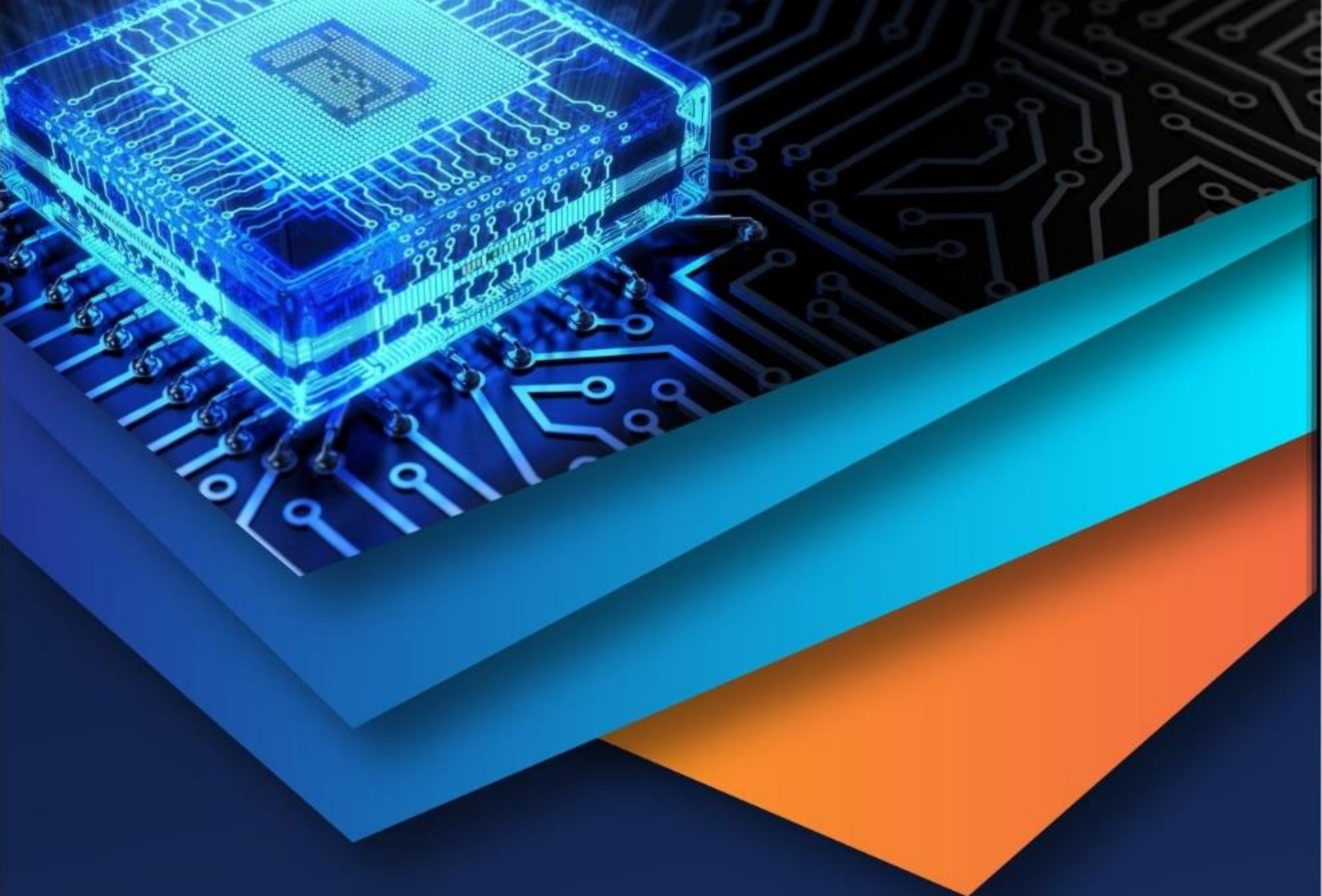

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