4G LTE D2D Communication Performance Analysis Under High Volume Traffic Scenario

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***Abstract*— With the increasing demand of high data transmission rates via wireless access for multimedia services, 4G Long Term Evolution-Advanced (LTE) cellular network has become widespread globally. The performance of the network can typically satisfy today's users needs. However, device-to-device (D2D) communication can bring LTE network more advantages by increasing spectral efficiency of the network, reducing transmission delay and network overloading. These advantages reveal great potential in combining D2D communication with a traditional cellular network. In this paper, we evaluate how D2D communication improves a traditional network model and analyze performances of networks with and without D2D communication built in through NS-3 simulations.**

I. INTRODUCTION

This paper examines D2D communication in an LTE cellular network, a promising technique to provide close range wireless peer-to-peer services, enhance spectrum utilization, increase the cellular capacity, improve throughput, and extend user equipment (UE) battery life.[1] With similar features to WiFi and Bluetooth, D2D communication allows UEs in close proximity to communicate directly via licensed and unlicensed bands without routing through a Base Station (BS) or core network. Thus, it provides a better user experience in terms of local-area services in cellular networks. The high data rate transmission, reliability, instant communication and power saving are additional advantages.[2] However, direct communication is currently restricted due to public safety problems, which have been considered critical in the overall transition process of LTE.[3] Extensive use of D2D communication harms cellular network performances as it shares the same resources and may not be able to meet its own quality-of-service (QoS) standard. Even so, D2D communication has still been identified as one of the enablers of 5G communications, which declares the necessity of assessing all these advantages as well as potential threats in this scope.[4] The main objectives of this paper are to evaluate how D2D communication benefits UEs and analyze the performance of D2D communication in an LTE network as compared to the standalone LTE network.

II. SIMULATION SCENARIO

In this scenario, the setup was designed such that 4 UEs were connected to a single base station and two of them were positioned near each other. The network performance with and without D2D communication was tested. In this scenario, with the condition of User1 and User2 being in close proximity (10 meters separation), the wireless communications between the four UEs and the base station imitated the working pattern of a traditional cellular network. Connections were set between each UE node and the hub node was enhanced for to resemble a typical bases station. In terms of the D2D simulation, a connection was set up between UE node 1 and UE node 2. Received packets, delay time and throughput for both models was collected at UE node 2 for analysis.

III. TOPOLOGY DESIGN

In the traditional cellular network model, all UEs are connected to the base station with no connection between each other. Thus, data flow from terminal to terminal must go through the base station. To enable D2D communication in this model, a direct connection was built between UE node 1 (User 1) and UE node 2 (User 2). In simulations, UDP servers and clients were chosen to imitate applications producing high volumes of traffic. Different sets of parameters were implemented according to the 4G LTE standard to make the simulations closer to practical occasions.

A. *High Volume Traffic Without D2D Communication Topology*

For the traditional 4G LTE cellular network high volume traffic model simulation, each of the 4 UEs had a direct connection to the hub node (base station). Also, each of them was designed as a data sink and sender to produce high volume of traffic. A sketch of this topology is displayed in Fig. 1.

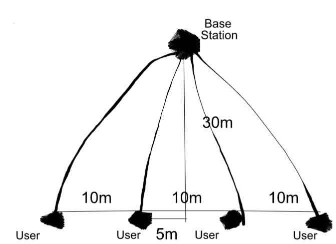

Fig. 1. High Volume Traffic Without D2D Communication Topology Sketch

B. *High Volume Traffic With D2D Communication Topology*

In addition to the connections from users to the base station, a direct communication between two users was enabled.

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While other users still remained unconnected with each other, influence on the network brought by this D2D connection can be readily perceived. A sketch of this topology is displayed in Fig. 2.

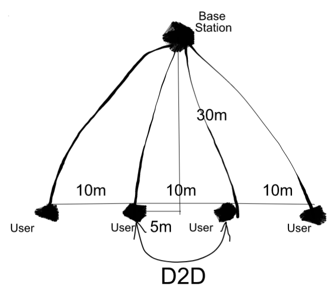

Fig. 2. High Volume Traffic With D2D Communication Topology Sketch

IV. Implementation

NS-3 is a popular discrete-event network simulator mainly implemented in C++. This paper employed this method to construct the network topologies for two different scenarios. Parameters of nodes, channels and connections set for each scenario are shown in TABLE I and TABLE II, respectively.

A. Traditional 4G LTE Cellular Network

For the traditional 4G LTE cellular network, normal propagation delay between a UE and the base station is 2ms and the data rate is 50Mbps. In terms of UDP communications between clients and servers, the max packet size was set to 1000 bytes with an interval of 50ms. The above simulation attributes and parameters were fixed in both scenarios in order to better compare their performance. TABLE I shows the specific values that were used.

Property		Value
Base Station Node	Ipv4 Addresses	10.1.1.2 - 10.1.4.2
User1	Ipv4 Addresses	10.1.1.1, 10.1.5.1
User2	Ipv4 Addresses	10.1.2.1, 10.1.5.2
User3	Ipv4 Addresses	10.1.3.1
User4	Ipv4 Addresses	10.1.4.1
Base P2P Channel	Propagation Delay	2ms
	DataRate	50Mbps
User P2P Channel	Propagation Delay	1ms
	Interval	50ms
	PacketSize	512
UDP Server	Start Time	1s
	Stop Time	10s
UDP Client	Start Time	2s
	Stop Time	10s

TABLE I
Parameters Used In 4G LTE High Volume Traffic Network Without D2D Communication Scenario

B. D2D Communications In 4G LTE network

For D2D communications, not only were the above parameters and attributes applied to the network model, but also a normal propagation delay of 1ms between a UE and the base station and a data rate of 3Gps were applied. The two connected users were located in close proximity so that a D2D connection resembling a real world peer-to-peer connection would result in notable changes in performance. TABLE II below shows the specific values used for all attributes and parameters in this scenario.

Property		Value
Base Station Node	Ipv4 Addresses	10.1.1.2 - 10.1.4.2
User1	Ipv4 Addresses	10.1.1.1
User2	Ipv4 Addresses	10.1.2.1
User3	Ipv4 Addresses	10.1.3.1
User4	Ipv4 Addresses	10.1.4.1
Base P2P Channel	Propagation Delay	2ms
	DataRate	50Mbps
UDP Attributes	MaxPackets	1000
	Interval	50ms
	PacketSize	512
UDP Server	Start Time	1s
	Stop Time	10s
UDP Client	Start Time	2s
	Stop Time	10s

TABLE II
Parameters Used In 4G LTE High Volume Traffic Network with D2D Communication Scenario

NS-3 PyViz is a live simulation visualizer that enables mobility models to be tracked without any trace files and allows the states of the simulation to be detected and visualized. PyViz has already been integrated into NS-3, and in this research, PyViz was used as the debugger to validate topology designs and check simulation status. Screen shots of designed topologies in running simulations are visualized through PyViz and displayed in Fig. 3 and Fig. 4.

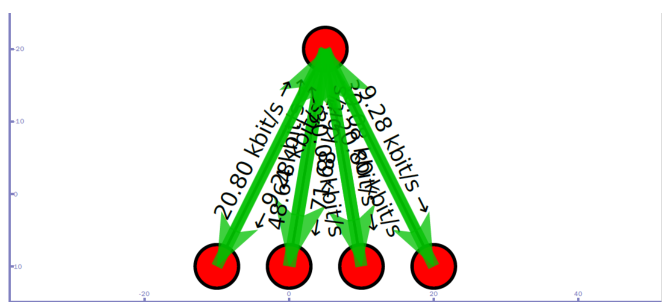

Fig. 3. Visualization Of 4G LTE High Volume Traffic Network Without D2D Communication

As shown in Fig. 3, data flows in all connections show that communications between nodes all go through the base station node. Thus, under the condition of traffic volume, neither instantaneous throughput or overall throughput of the network achieve standard performance. Fig. 4 shows data flows of the network model with the D2D connection enabled in the running simulation. Briefly, throughputs of both D2D connection and the connection from base station node to user 1 increased. More detailed analysis is displayed in the following Results and Analysis section.

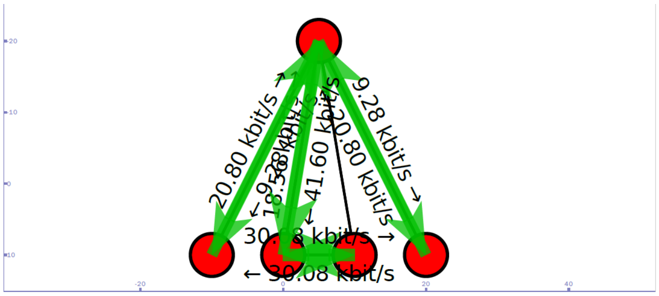

Fig. 4. Visualization Of 4G LTE High Volume Traffic Network With D2D Communication

V. Results and Analysis

The following simulation results analyze the performance of D2D communication, or more specifically, how much it reduces the delay time and increases the throughput in a high traffic volume scenario. Therefore, the program was designed to run simulations with D2D communication enabled and disabled to investigate its impact on the whole network's throughput and delay based on simulation time and packet size.

A. D2D communication increases the throughput

As shown in Fig. 5, as the simulation time increases, network devices still maintain high throughput. The throughput of the D2D connection is only approximately 0.06 percent larger than it is in traditional network when simulation time is 10 seconds. As simulation time increases, there is potential for the difference between throughputs to drop slightly. However, for the traditional network and the D2D communication network shown in Fig. 6, the total amount of received packets are very close (not considering the effect of packet loss). Upon further inspection, it becomes apparent that the throughput of the D2D communication network is always larger as the number of received packets increases. This simulation suggests that D2D communication is capable of increasing throughput[4].

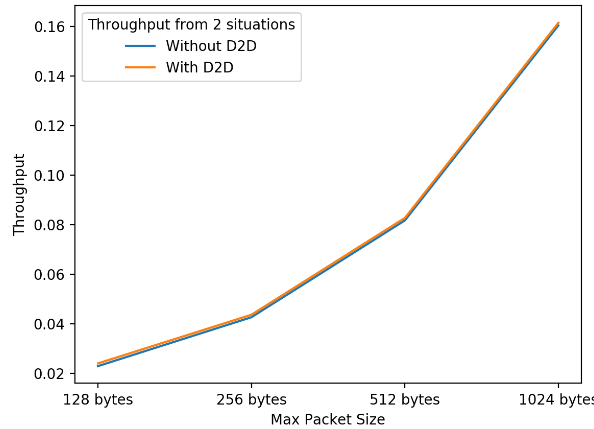

Fig. 6. Throughput Versus Packet Size From Network Without And With D2D Communication

B. D2D communication reduces the delay

Reducing delay time is one of explicit advantages that a D2D communication network offers compared to a traditional cellular network. This is illustrated in Fig. 7 and Fig. 8.

Fig. 7 indicates that the propagation delay resulting from routing through the base station is larger than it is for D2D communication. The difference increases with simulation time. Once simulation time reaches 30s, the difference between the two delay sums becomes 1.9 ms.

Fig. 8 displays that the relationship between packet size and delay sum. When packet size increases from 128 bytes to 1024 bytes, D2D communication remains steady while the delay of the traditional cellular network begins to increase as packet size increases. Additionally, the delay sum with D2D is smaller than without D2D. As a result, a conclusion can be drawn that D2D communication is capable of enhancing network performance by reducing communication delay, especially for transmission of large packets.

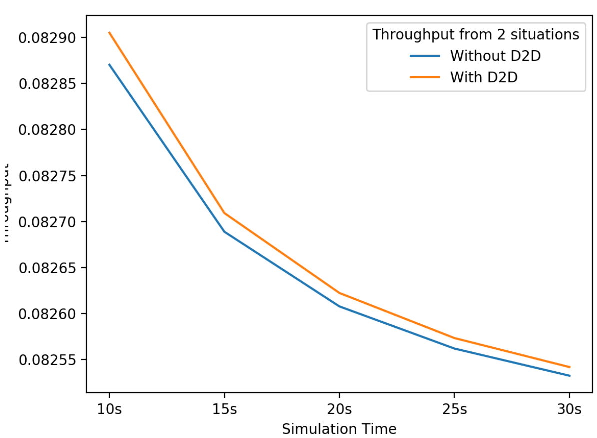

Fig. 5. Throughput Versus Simulation Time From Network Without And With D2D Communication

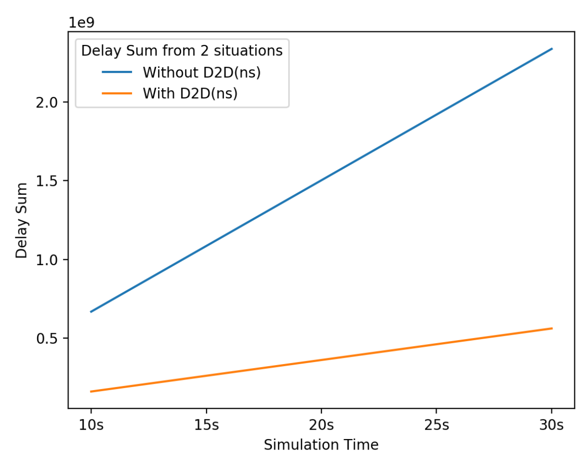

Fig. 7. Delay Sum Versus Simulation Time From Network without and with D2D Communication

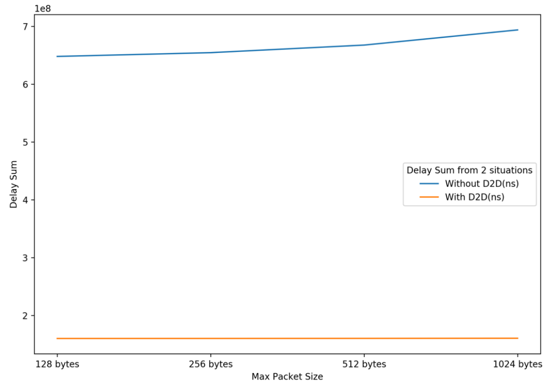

Fig. 8. Delay Sum Versus Packet Size From Network Without And With D2D Communication

Though the benefit of D2D communications is marginal in terms of throughput, its benefit in terms of latency is particularly notable. Thus, typical use cases include PvP gaming, instant messaging, and other applications where multiple users are interacting with the same content and applications where the base station bandwidth is limited.

VI. Conclusion

D2D communication is considered an efficient way to improve the performance of a cellular network. It can reduce latency, improve coverage, support high data rates, and in particular, enhance the performance of peer to peer applications.

This paper compares the D2D communication network with a normal cellular network and evaluates the performance difference. The network scenarios were constructed using the NS-3 simulator, and the experimental results indicate that applying D2D communication can increase network throughput and substantially reduce latency. Though the throughput increase in this situation is marginal, the throughput of a network with D2D communication is always larger than the network without it. Strain on the base station's resources would further accentuate this improvement, as would occasional interruptions in the connection between nodes and the base station. Furthermore, the second experiment suggests that applying D2D communication is an efficient method to reduce delay of information transmission, making it an especially suitable application for peer to peer applications.

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