QoS for Device-to-Device communication in 4G LTE-A network.

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***Abstract*----Device to device (D2D) communication is a technology model that enables mobile devices to communicate directly with each other without the intervention of a base station or enabled Node B (eNB). It helps the reuse of LTE-Advanced radio frequency resources of the network.**

With this paper, we simulated two metrics in delay and throughput.

According to simulation results, D2D mode is the best option for communication when two mobile devices are close to one another but far from the eNB.

Keywords--- D2D communication, LTE-A, QoS

1. Introduction

Device to device (D2D) communication is a technology model that enables mobile devices to communicate directly with each other without the intervention of a base station or enables Node B and helps the reuse of radio frequency resources of the network (1).

Nowadays, device to device communication is seen as a promising area in terms of fourth generation of cellular network 4G LTE-A(Long Term Evolution –Advanced).

The fourth generation was introduced in networking in the 2000 years and mostly used for IP based data communication(2).

LTE is a 4G a worldwide standard technology, which transmits digital broadband packet over Internet protocol and offers a maximum data rate of 100 MBPS in the 3rd Generation Partnership Project 3GPP release 12, developed LTE-A which is Long Term evolution Advanced as the next step in the continuity of mobile technology standards and comes after 2G which is the second generation and 3G the third generation.

The optimal support of Packet Switched services is the primary focus of LTE. In 2004, the initial phase of the standardization process for LTE identified the primary requirements for the design of an LTE system(3).

The LTE requirements for data rate and spectrum efficiency are summarized in the table below

DOWNLINK (20MHZ)			UPLINK (20MHZ)		
Unit	Mbps	bps/Hz	Unit	Mbps	bps/Hz
Requirement	100	5.0	Requirement	50	2.5
2x2 MIMO	172.8	8.6	16QAM	57.6	2.9
4x4 MIMO	326.4	16.3	64QAM	86.4	4.3

Table 1 LTE requirements for data rate and spectrum efficiency(3)

From the table above, we find that LTE requires:

-**Data Speed**: for 20 MHz spectrum allocation, peak data rates should be 100 Mbps downlink and 50 Mbps uplink, with two receive antennas and one transmit antenna at the terminal.

-**Throughput:** the target for average user throughput per MHz in the downlink is three to four times higher than 3GPP Release 6.The target for average user throughput per MHz in the uplink is two to three times higher than 3GPP Release 6.

- **Spectrum efficiency**: 3 to 4 times better than 3GPP Release 6 is the downlink target. Uplink target is superior to 3GPP Release 6 by two to three times.(3)

LTE is commonly acceptable as 4G-LTE on technological market level.

The Long term evolution-Advanced LTE-A is a 4G LTE technology with significant features and improvement compared to 4G LTE in accordance with 3GPP in release 10.

The increase of data rate is achieved by employing Orthogonal Frequency Division Access (OFDA) based technology, which provides latency, high data rate, and packet optimized radio access.

Mobile network operators MNO are trying to accommodate the existing demand of mobile users and new change in terms of big data sharing which require a high-speed network for users in the same vicinity

In addition to that, 4G cellular technologies such as Wimax and LTE-A (4) which have extremely efficient physical and MAC layer performance are still fighting to have a great place in the boom data opportunities.

D2D communication is one of the available technology that are promising to leverage the barrier of sharing data in proximity area for users using 4G LTE-A(5) [6].

Device-to-Device deployment in 4GLTE-A presents different challenges. To bring up few of them, there is interference management when multiple ISP use outband frequencies at the same time (2), security with key management (3) deployment presents more difficulties.

The study will look at the needed improvement to achieve the planned quality of services in terms of throughput and delay planned by 3GPP release 12 Technical report TR and technical specifications TS(6).

The general objectives of this research article is to evaluate the discovery model and the existing resources allocation plan for D2D communication in 4G LTE-A, and find out the improvement to add on the scheme to come up with the Quality of Services (QoS) submitted by 3GPP release 12 Technical report TR and technical specifications TS.

The research development approach is illustrated on the diagram below:

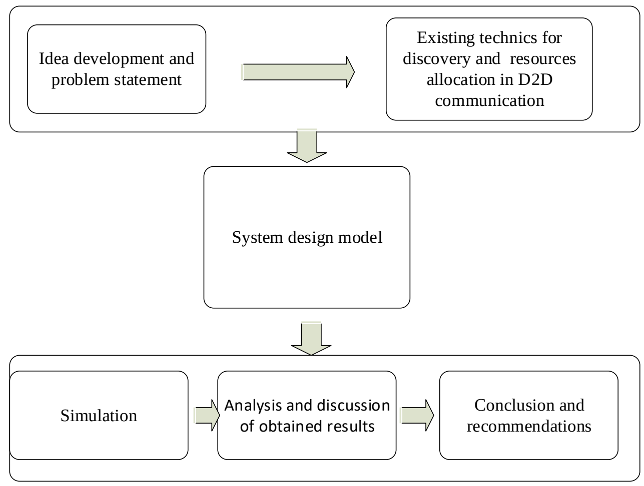

Figure 1. Research development approach

The remaining portion of this article is organized such as, section 2 illustrate the system model. Simulation results and analysis are displayed in section 3. At the end of the article, the section 4 presents the conclusion and briefly presents the recommendation for future works on the research topic.

Due to the complexity of the research article, we employed a number of data collection method, which include primary data and secondary data. The primary data will come from simulation results; secondary data will include documentation analysis.

The information to use with this research will be taken from journals, papers, books and other information available on internet. This will include different works carried out in the research area and pass through different solutions proposed by authors in device to device communication as well as LTE field.

1.1 LTE-A network Architecture

The high-level network architecture of LTE comprises the following three main components: the User equipment(UE), the Evolved UMTS Terrestrial Radio Access network(E-UTRAN) and the Evolved packet Core(EPC)(7).

User equipment (UE)

The architecture of User equipment (UE) is the same as the one that UMTS and GSM use, and it is called a Mobile Equipment (ME).The essential modules of the ME are the following:

- Mobile Termination (MT): This takes care of everything related to communication.
- Terminal Equipment (TE): This equipment ends data streams.
- Universal Integrated Circuit Card (UICC): this is the LTE equipment SIM card. The Universal Subscriber Identity Module (USIM) software runs on it.

A USIM, like a 3G SIM card, stores user-specific data. This stores, among other things, the phone number, identity, and security keys of the user's home network.

The Evolved UMTS Terrestrial Radio Access network (E-UTRAN)

Only the evolved base stations, also known as eNodeB or eNB, make up the E-UTRAN, which manages radio communications between the mobile and the evolved packet core.The mobiles in one or more cells are controlled by each eNB, which serves as a base station.The serving eNB is the base station that is interacting with a mobile device.

Evolved packet Core(EPC)

The Evolved Packet Core (EPC) connects to private corporate networks, the Internet, and IP multimedia subsystem as well as other external packet data networks. EPC is responsible of the operation of services like Voice over IP (VoIP).

A QoS is usually associated with an EPS bearer, and a user can have multiple bearers set up to connect to different PDNs or different QoS streams. A user might be making a voice (VoIP) call while also browsing the web or downloading files via FTP. The best-effort bearer would be suitable for the web browsing or FTP session, while a VoIP bearer would provide the necessary QoS for the voice call.

The interfaces between the different parts of the system are denoted Uu, S1 and SGi as shown below(7):

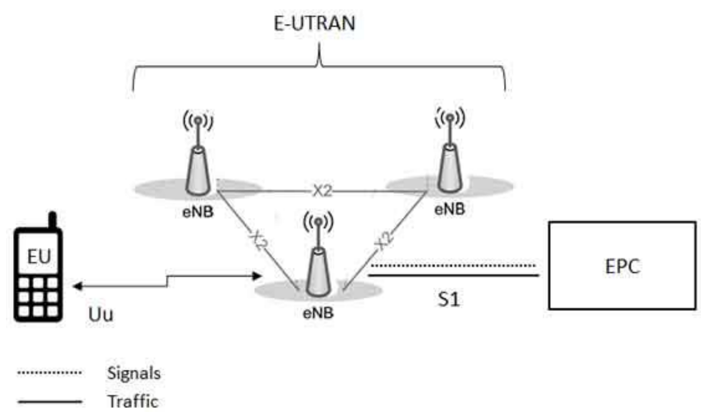

Figure 2. LTE network architecture

1.2 Discovery of the User Equipment in D2D communication

A technology that enables communication between multiple D2D devices or users without the need of a base station or other intermediary devices on a network is referred to as D2D communication.(8).
Using LTE radio technology, D2D discovery enables devices in close proximity to

discover each other.In most cases, this discovery occurs within the LTE network's coverage and under the operator's control. However, it is also desirable that the discovery be carried out with either partial (in which the network covers one UE of the D2D pair while another is not) or no coverage.

When compared to other wireless D2D technologies like Bluetooth and Wi-Fi Direct, LTE D2D may support a much greater discovery range.

Device discovery is challenging in a D2D network when multiple devices coexist. Channel information, location, and the number of devices are all discovered in a visually impaired setting(9).

1.3 Resources allocation in D2D communication

The UEs can function in one of the following traditional modes in D2D communications:

• Reuse Mode: D2D UEs directly transmit data by reusing some of the radio resources that cellular UEs use to make better use of the spectrum.

• Dedicated Mode: to avoid interfering with cellular UEs, D2D UEs use a separate spectrum band to transmit data directly between themselves.

• Cellular Mode: D2D UEs transmit their data through the base station, like cellular UEs. (10)

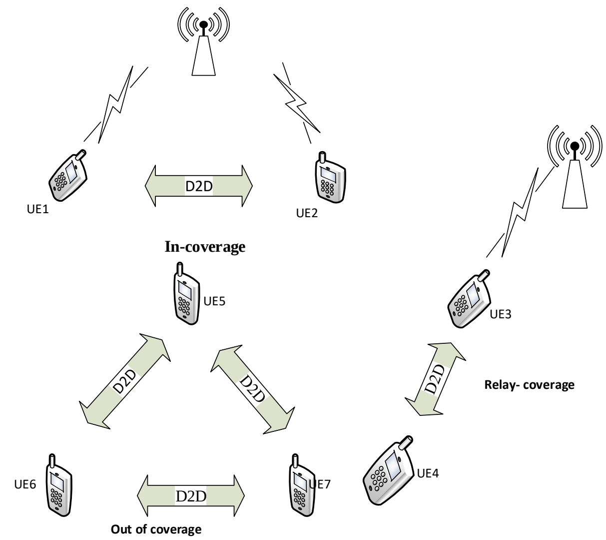

Figure 3: D2D communication application scenario

There are two types of D2D communication: in-band D2D (also known as LTE direct) and out-band D2D. In in-band, D2D communication takes place in licensed spectrum that has been allocated to cellular operators. The licensed spectrum can be accessed by either D2D users (UEs) in a dedicated mode (also referred to as an overlay or orthogonal mode in the literature) or a shared mode (also referred to as an underlay or a non-orthogonal mode). D2D communication in the case of out-band D2D makes use of the unlicensed spectrum that is utilized by other wireless technologies that support direct communication, such as Bluetooth (based on IEEE 802.15) and WiFi direct (based on IEEE 802.11).(11)

2. SYSTEM MODELLING AND ARCHITECTURE OF NETWORK SIMULATION

In this research article, we used different scientific methods: qualitative or quantitative. Design and simulation of an experimental approach were used. The related works helped the researcher to come up with a suitable approach and was an

opportunity to discover more knowledge about the subject matter.
The experiments are achieved in simulation using 4G LTE-technology acting with different devices under the same eNB cell and devices outside the eNB cell.
This work is evaluating the QoS in Device-to- device communication under LTE-A, considering different parameters.
In order to perform the required analysis, two main scenarios will be considered, one scenario is when two UEs are located within the same cell using the same eNB, the second scenario is when two UEs are communicating and located in adjacent cells.

We will use a software OMNET ++ with different libraries such as INET and SimuLTE.
OMNET++ which has become a reference in network simulations for several years (12)

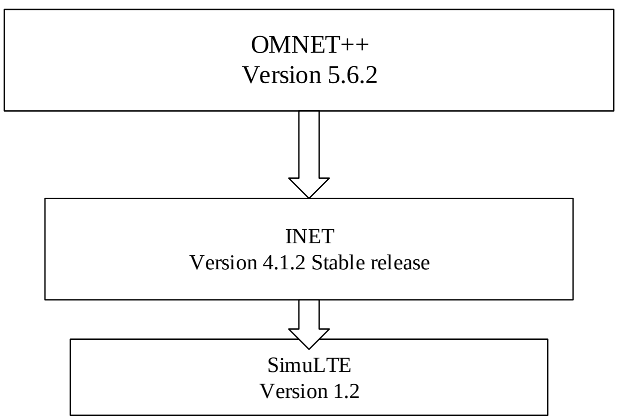

Figure 4: INET and SimuLTE work based on OMNET++

D2D communication simulation is done with INET and SimuLTE module which are based on OMNET++.

Overview of OMNET++ in simulation environment

OMNET++ is a C++ based open source discrete event simulator that makes use of the simulation class library. It can be applied to a variety of problem areas, including 32-way large-scale wired and wireless communication. Additionally, it contains numerous simulation models.

Figure 5: Screenshot of OMNET++ simulation environment

The following components make up the OMNET++ architecture of the simulated networks:
• Simple module: a single component, like the UDP layer, that enables us to define the algorithm for a specific purpose.
• Compound Module: A simple module or multiple simple modules connected by gates form a compound module.
• Channel: through a configurable channel, nodes exchange messages with one another. Examples include a bandwidth, propagation delay, and other variables.(12)
In the OMNET++ folders, three types of files are used to configure the network topology, that is, module algorithms, channel configuration, and parameters. Users can either create new files or edit the existing ones. These files are *.ini*, *.cc* and *NED* (Network Description).
The NED file is represented in two modes of views: source view with codes and design view represented by graphical images of network components.

```
# Enable D2D for the eNodeB and the UEs
involved in direct commulteNications
*.eNB*.nicType = "LteNicEnbD2D"
*.ueD2D*[*].nicType = "LteNicUeD2D"
```

```
**.amcMode = "D2D"
```

Example of configured parameters for eNB and UE NIC cards

Performance metrics

The QoS analysis of data traffic between devices in a 4G LTE-A environment is the topic of this article. The eNB may switch between two links while communicating with two UEs. This work determined the optimal state for MS implementation between Relay Path and Side Link by analyzing QoS parameters of communication.
During our simulation, we limit our demonstration to two network performance metrics: throughput and delay.

Simulation parameters or criteria

Criteria	Value
Frequency	2 Gigahertz
Bandwidth	5 Megaheltz
eNB Transmission Power	46dB
UE Ttransmission Power	24dB
Cable Loss	2dB
eNB Antenna Gain	18dB
User Equipment Antenna Gain	0dB
Mode of mobility	Stationary
Simulation Time	50s

Table 3: simulation criterias

The simulation is done using OMNET++ version 5.6.2, INET 4.1.2, and SimuLTE 1.2.

Simulation scenario cases

Case 1: UEs moved gradually side by side
There are two different simulations in this case. UEs use Relay Path to communicate in the first one and use direct link to communicate in the second one.
Initially, two UEs are located at a distance of 0 m from one another and the eNB. Then, the UE distance is increased by 20 m while the eNB does not change the location.

Case 2 UEs located farther from eNB

Both Relay path and direct link are simulated. The distance between UEs are 40m and they are located at a distance of 20m from the eNB.

3. SIMULATION RESULTS AND ANALYSIS

This article uses delay and throughput as performance metrics to support the analysis of the simulated cases' QoS performance. In case 1 and 2, which made use of both direct link and Relay Path communications, changes in distance between two UEs and the eNB are shown to have an impact. Each step is separately simulated four times, and the average of the results is calculated for reliable results.
In order for Relay Path and direct link to locate two UEs at different intervals from the eNB and from one another, case 1 attempted to meet various conditions.
Horizontal movements every 50 meters, the distances between the UEs and the eNB are equal to half of the D2D distance. For instance, the horizontal distances between the UEs and the eNB are 20 meters when the D2D distance is 40 meters

Results of Delay:

At short distances, the delay associated with Relay Path is noticeably higher than the one associated with D2D, as depicted in Figure 5. This corroborates the D2D communication's advantages of lower delay (up to 100 meters). Packets in D2D communication take less time to arrive because they are sent directly to their destination. In Relay Path mode, on the other hand, packets are sent to the eNB and must be sent to the receiver node after being assembled in the NIC layers of the eNB in accordance with (13) which necessitates a longer transmission distance and longer reception time for the receiver. The state of the channel's quality determines how many bits assigned to RBs. As a result, the capacities of the RBs decrease when UEs are located at greater distances with lower SINR. As a result, more RBs are required to send a packet, which takes longer to carry all data traffic.

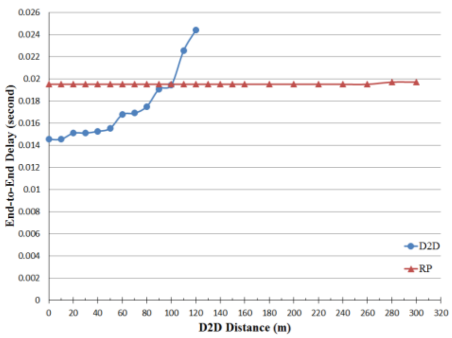

Figure 6: Delay in Direct link

Results from Throughput:

Figure 7 demonstrates that, at short distances, D2D throughput performs better than Relay Path throughput. It performs 32526 bps at 40 m, but from 50 m to 70 m, its performance decreases drastically. At30 m, they seem to have the same performances. Relay Path throughput performs less than D2D until 30 m, but remains the same up to 220 m and starts decreasing shortly with around 35Kbps. Even though it descends quickly, it still outperforms Relay Path throughput up to 30 meters. After that, it descends nearly at the same rate up to 50 meters.

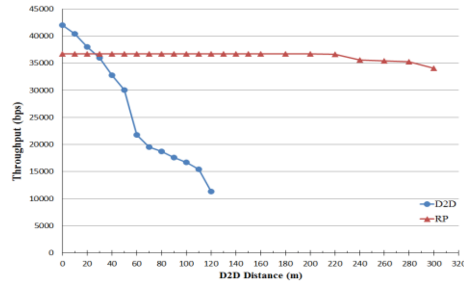

Figure 7: Throughput in Direct link

Results analysis for case 2

Case 2 is used to account for a variety of UE distribution scenarios within the eNB's cell coverage area. In fact, the purpose of this scenario is to investigate how D2D metrics behave when the UEs are closer together but farther away from the eNB.

Results of Delay

Figure 8 shows how D2D communication outperforms Relay Path communication when it comes to delay. It is evident that data packets take less time to arrive in D2D mode than in Relay Path mode across all distances. In addition, after 110 milliseconds, the Relay Path delay begins to descend upward, indicating that D2D's QoS for traffic is superior in these situations.

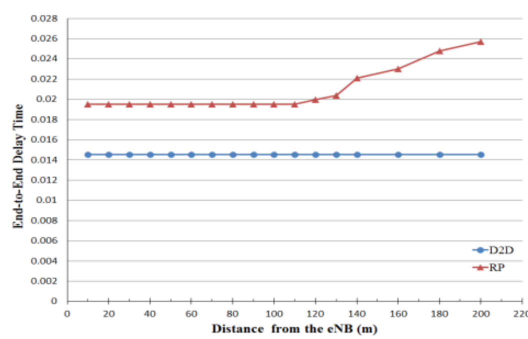

Figure 8: Delay in Relay mode

Results from Throughput

D2D throughput rises more than RP throughput, as shown in Figure 9, and it remains high across all intervals. On the other hand, Relay Path throughput remains high up to 120 m corresponding to 45,000 bps or 45 kbps before beginning a steep downward tilt.

The throughput results show that, at all intervals, the D2D communication mode performs better than Relay Path.

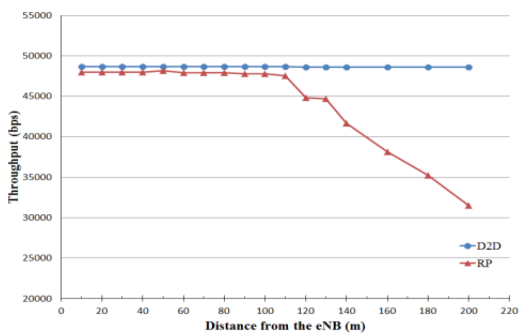

Figure 9: D2D throughput in Relay path mode

4. Conclusion

In this paper, we presented the QoS behavior related to two metrics throughput and delay.

OMNET++ was used to simulate different scenarios where two UEs were located in different positions. When two mobile devices are close to one another but far from the eNB, simulation results indicate that D2D mode is the most effective mode for communication.

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