A Study of Mobility Management of D2D Communication* (based on paper by Barua, Shouman, and Robin Braun. 2017)

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***Abstract*—Device-to-device (D2D) communication is a promising paradigm that could be integrated in 5G cellular networks. Works have done show that D2D communications could increase spectral efficiency, reduce communication delay and increase the overall power efficiency of cellular network. Our study focus on mobility of D2D communication based on the paper by Barua, Shouman, and Robin Braun. 2017. We tried to evaluate the mobility algorithm proposed by the paper and did further analyze on handover. Our work shows that the algorithm in the paper could maintain a high percentage of D2D communication during handover process.**

Keywords—5G, device-to-device, D2D, mobility, handover.

I. Introduction

With the growth intense of cellular traffic, increasing capacity and speed of cellular networks is still a challenging task of 5G. However, 4G cellular technologies (WiMAX and LTE-A), which have extremely efficient physical and MAC layer performance, are still lagging behind mobile users' booming data demand [1] . Therefore, Device-to-Device (D2D) communication is one of the promising paradigms that could be integrated in 5th generation cellular technologies. D2D communication in cellular networks is defined as direct communication between two mobile users without traversing the Base Station (BS) or core network [1].

The prototype of D2D communication was first proposed in the paper by [5] to enable multi-hop relays in cellular networks. Later works focus on improving spectral efficiency of cellular networks, multicasting, peer-to-peer communication, video dissemination, machine-to-machine (M2M) communication, cellular offloading, and so on [1].

D2D communication is generally non-transparent to the cellular network and it can occur on the cellular spectrum (i.e., inband) or unlicensed spectrum (i.e., outband). Paper[3] and paper[4] proposed using the cellular spectrum for both D2D and cellular communications (i.e., underlay inband D2D) and dedicating part of the cellular resources only to D2D communications (i.e., overlay inband D2D). The researches on underlay D2D study on reducing interference between D2D communication and cellular communication However, in overlay D2D, resource allocation becomes important in that dedicated cellular resources are limited. Other researchers propose outband rather than inband D2D communications in cellular networks. Utilizing unlicensed spectrum, D2D communication may not interfere cellular communication. Figure 1 shows the classifications discussed above.

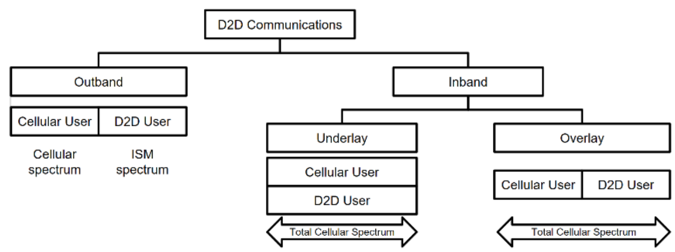


Fig1. Major classification of D2D communications.

When it comes to an issue of communication between two end users, mobility is a challenging problem. Not only including group handover from a base station to another, but also one in D2D pairs' handover, the behavior of handover failure, security configuration and etc.. Researches on mobility of D2D communication is still in early stage. A patent application publication by Balaji Raghothaman et al. gives a lot of specific scenarios of D2D mobility in wireless network. The paper [7] published two D2D mobility solution focus on two 2-dimention scenarios, which is one of the most popular paper in theme of D2D mobility. The paper we mainly referenced in our project [2] starts its work based on this paper. Paper [6] proposed a D2D mobility control plate based on SDN technology.

In Barua, Shouman, and Robin Braun. 2017, the authors propose an algorithm regarding the mobility management of D2D communication with simulation results. Their work focus on inband underlay D2D communication. In our project, we are going to study this paper, reproduce their work and do analysis on their results and our results.

Here is our milestones:

TABLE I. Milestones

Milestones	Description	Time	Main in-charge
Milestone #1	Study Background	Jan 22 – Feb 2	Zixiang Nie
Milestone #2	Construct model and algorithms	Feb3 – Feb 18	Xiao Wang
Milestone #3	Implement functions	Feb 19 – Mar 18	Miaoqi Zhang
Milestone #4	Integrate and test	Mar19 – Apr 1	Xiao Wang
Milestone #5	Simulate, analyze results and finish report	Apr 2 – Apr 15	Zixiang Nie

Section 2 is going to describe the referenced paper in detail, section 3 describes our simulation in detail. Section 4 gives the conclusion of our project.

II. Reference Paper

A. Abstract of the paper

Wireless devices connected to the networks have been increasing remarkably for the last couple of decades. Ubiquitous voice and data connection are the key requisite for the next generation of wireless technology. Device to Device communication is widely known as D2D communication which is a new paradigm of cellular communication, and it was initially proposed to boost the network performance. It takes place when two devices communicate directly without taking significant help from the base station. Similar to other wireless communication systems, mobility management for the D2D communication is a big challenge which is yet to explore properly. Mobility management of D2D communications was enlightened in few papers. It should be managed in such a smart way in a cellular network that should enable lower latency, lower power consumptions, less complexity and last but not the least possible uninterrupted data connections which are primarily the requirements of next generations mobile cellular network. This paper extends our algorithm paradigm of mobility management of D2D communication that was proposed and published previously. We come up with the simulation results in this paper that validate our proposed model. However, we also highlight the D2D communications and mobility issues within it.

B. Citations of the paper

The title of the paper is " Mobility Management of D2D Communication for the 5G Cellular Network System: A Study and Result". The authors are Shouman Barua and Robin Braun. The paper is proposed in 2017 17th International Symposium on Communications and Information Technologies (ISCIT). It have six pages in total.

In addition to that, following papers also give important reference to this paper:

S. Barua and R. Braun, "A novel approach of mobility management for the d2d communications in 5g mobile cellular network system," in 2016 18th Asia-Pacific Network Operations and Management Symposium (APNOMS), pp. 1–4, Oct 2016.

O. N. Yilmaz, Z. Li, K. Valkealahti, M. A. Uusitalo, M. Moisio, P. Lundén, and C. Wijting, "Smart mobility management for d2d communications in 5g networks," in Wireless Communications and Networking Conference Workshops (WCNCW), 2014 IEEE, pp. 219–223, IEEE, 2014.

G. Jaheon, S. J. Bae, S. F. Hasan, and M. Y. Chung, "A combined power control and resource allocation scheme for d2d communication underlaying an lte-advanced system," IEICE Transactions on Communications, vol. 96, no. 10, pp. 2683–2692, 2013.

C. Main contribution of this paper

The paper proposed an algorithm to improve the mobility performance. First, the algorithm is described to work on the scenario of D2D-aware handover solution [7]. Like in figure 2, a D2D pair is initially controlled by the same eNB. D2D receiver is in location that could communicate with both eNB and cellular user. D2D transmitter (DUETx) is moving towards another eNB. Here, D2D transmitter could only communicate with both eNB and D2D receiver. In addition, if a device moves towards out of the network coverage area but still in the proximity areas of another D2D pair, it may act as a relay.

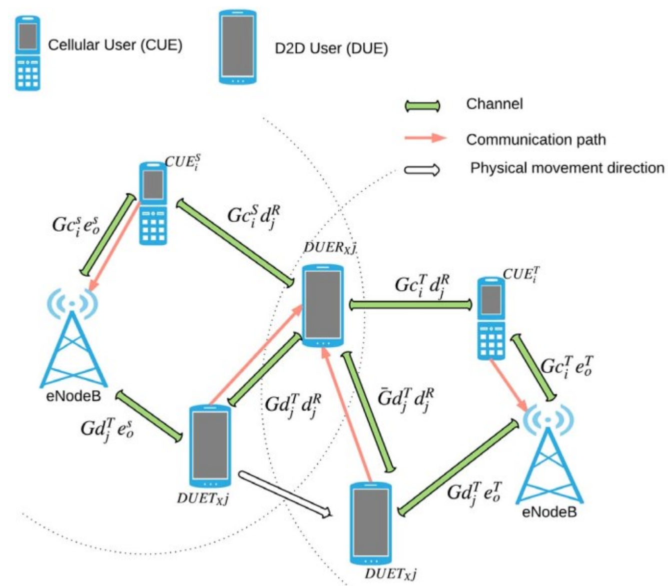


Fig2. Proposed mobility model.

Regarding the best mode selection, the paper proposed five possible operational conditions that could have occurred. These are Cellular mode, D2D mode, Relay mode, Waiting mode and Drop mode. The algorithm for the proposed simulation model to select the best operational mode are as follows.

Data:
Source eNodeB:
Total loss between D2D pairs = $SourceL_{D2D}$,
Threshold between D2D pair = $SourceTh_{D2D}$,
Total loss between D2D transmitter and eNodeB = $SourceL_{D_TeNB}$,
Threshold between D2D transmitter and eNodeB = $SourceTh_{D_TeNB}$,
Total loss between D2D receiver and eNodeB = $SourceL_{D_ReNB}$,
Threshold between D2D receiver and eNodeB = $SourceTh_{D_ReNB}$.
Target eNodeB:

Total loss between D2D pairs = $TargetL_{D2D}$,
Threshold between D2D pair = $TargetTh_{D2D}$,
Total loss between D2D transmitter and eNodeB = $TargetL_{D_TeNB}$,
Threshold between D2D transmitter and eNodeB = $TargetTh_{D_TeNB}$,
Total loss between D2D receiver and eNodeB = $TargetL_{D_ReNB}$,
Threshold between D2D receiver and eNodeB = $TargetTh_{D_ReNB}$,

if $SourceL_{D2D} \leqslant SourceTh_{D2D}$
and $SourceL_{D_TeNB} \leqslant SourceTh_{D_TeNB}$
and $SourceL_{D_ReNB} \leqslant SourceTh_{D_ReNB}$ **then**
Select D2D Mode;
else
Search for the next possible mode
end
if $SourceL_{D2D} > SourceTh_{D2D}$
and $SourceL_{D_TeNB} \leqslant SourceTh_{D_TeNB}$
and $SourceL_{D_ReNB} \leqslant SourceTh_{D_ReNB}$ **then**
Select cellular Mode;
else
Search for the next possible mode
end
if $SourceL_{D2D} \leqslant SourceTh_{D2D}$
and $SourceL_{D_TeNB} > SourceTh_{D_TeNB}$
and $SourceL_{D_ReNB} \leqslant SourceTh_{D_ReNB}$ then
Select waiting mode to observe the UE's moving direction;
else
Search for the next possible mode
end
if $SourceL_{D_TeNB} > SourceTh_{D_TeNB}$
and $TargetL_{D_TeNB} \leqslant TargetTh_{D_TeNB}$
and $TargetL_{D_ReNB} \leqslant TargetTh_{D_ReNB}$ then
Prepare and trigger for the group handover;
else
Search for the next possible mode
end
if $SourceL_{D_TeNB} > SourceTh_{D_TeNB}$ and
$TargetL_{D_TeNB} > TargetTh_{D_TeNB}$ and
$TargetL_{D_ReNB} < TargetTh_{D_ReNB}$ and
$TargetL_{D2D} \leqslant TargetTh_{D2D}$ then
Select Relay Mode;
else
Call Drop;
end

Above algorithm shows the simplified way of how modes were selected. Selection of modes depends on mainly the threshold value that is set and the total path loss from the moving device to the base station.

The evaluation in this paper is divided into three parts. The paper have designed a MATLAB(R2016a) simulation based on the proposed algorithm with the help of LTE System Toolbox. A D2D pair and a cellular user are considered in the simulation. One of the D2D users who mainly transmits are moving randomly. First, they get the results of decisions on five different modes, it indicates clearly the superiority of D2D mode which is the primary target of the algorithm. Second, the paper shows the sum-rate trend while handover is taking place. It points that handover takes place without any major degradation of data throughput. Third, they gets the results on the trend of path loss over distance. It shows that path loss is increasing when D2D transmitter is going apart from the source base station.

D. *Difference between our approach and paper's approach*

First, the paper uses LTE system tool box in the simulation. We use "setdest" add-on in ns2 for the random waypoint mobility in our simulation. Thus, we don't need tool boxes in Matlab. However, we use Matlab to do the calculation and the algorithm since that Matlab is good at complex calculating.

Second, we think the second result in the paper is not reproducible. There is no traffic pattern described in the paper, thus, we don't know the number and type of packets are sent when they do the simulation.

Third, we think that lacking of part of the result could make our work weak, we do an extra experiment evaluating how different thresholds affect the percentage of D2D mode.

III. Simulation Description

Basically, authors of this paper use MATLAB (R2017a) to implement all mathematical algorithms and construct the 3-D model of mobility scenario with the help of LTE System Toolbox. However, we use NS-2 to simulate the D2D user movement in the Random Waypoint Model and obtain the coordinates variation in the file named 'setdest'. After that, we make a MATLAB file named 'readfile.m' to fetch coordinates data from 'setdest' and generate new data files.

Taking these data as input variables, we calculate the total path loss and different communication thresholds in the view of various distances between the D2D pairs, the source/target eNodeB base station and the D2D user. Here follows the description in details:

A. *Simulation with NS-2*

We use "setdest" add-on in ns2 to generate the mobility path. "setdest" is a module in ns2 to generate random waypoint mobility path. When implementation, we use parameters: "./setdest -n 1 (one node) -p 1 (pause time is 1 second) -s 5 (max speed of walking is five) -t 500 (simulation time is 500 seconds) -x 100 -y 100 (simulation space is 100×100×100)". After that, we wrote a python script to extract the locations for the mobility file generated by "setdest", then put them into Matlab for further usage.

B. *Simulation with MATLAB*

We make 5 implementing MATLAB files named 'readfile.m', 'totalloss.m', 'runalgorithm.m', 'runalgorithm2.m' and 'totallossline.m', respectively.

After running 'readfile.m', a new file named 'dmatrix' which contains 6 groups of distances is generated in the current folder, as shown by figure 3. Meanwhile, we obtain a picture of 3D model of the moving track, which applies the Random Waypoint Model, as shown by figure 4.

In fact, we don't use Simulink to generate the animation of the proposed model, because it is unnecessary to focus on all of the communication links among different nodes in the simulation space, which is shown in the original paper.

With the file named ‘totalloss.m’, we take the distance from ‘dmatrix’ as input and calculate the total path loss with the algorithms shown below.

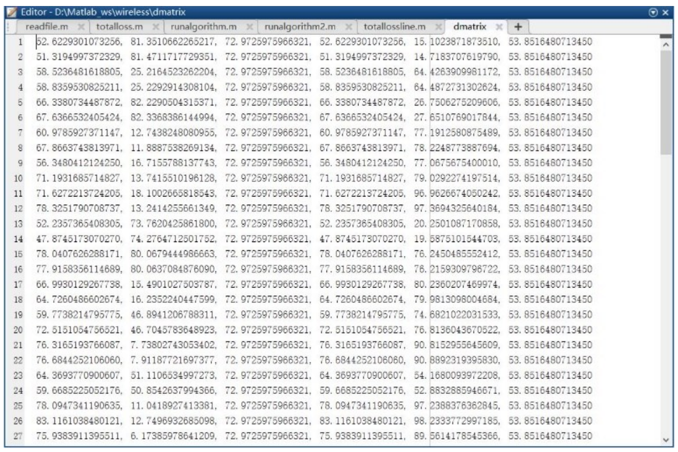
$$\text{Pathloss(PL)} = \alpha.PL_{LOS} + (1-\alpha).PL_{NLOS},$$

$$PL_{LOS/NLOS} = K_1 + K_2.\log_{10}.d,$$

$$L(r) = R(\Delta r).L(r-\Delta r) + \sqrt{1-(R(\Delta r))^2}.\sigma.X,$$

$$ML = 10\log(-\log Y),$$

Algorithm 1 Calculation of the path loss, shadow fading and multi-path loss


Editor - D:\Matlab_ws\wireless\dmatrix
readfile.m | totalloss.m | runalgorithm.m | runalgorithm2.m | totallossline.m | dmatrix

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52.6229301073256, 81.3510662265217, 72.9725975966321, 52.6229301073256, 15.1023871873510, 53.8516480713450
51.3194997372329, 81.4711717729351, 72.9725975966321, 51.3194997372329, 14.7183707619790, 53.8516480713450
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75.9383911395511, 6.17385978641209, 72.9725975966321, 75.9383911395511, 89.5614178545366, 53.8516480713450
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Fig3. Data contained in file named ‘dmatrix’.

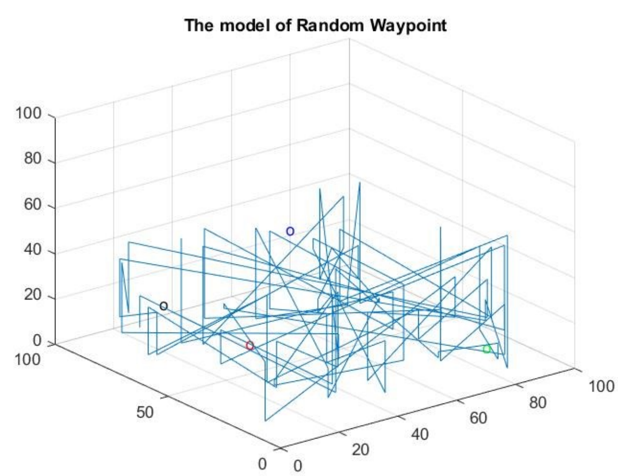

Fig4. The model of Random Waypoint

Most of parameters used in Algorithm 1 are mentioned in the paper, but some functions like $R(\triangle r)$ and $L(r)$ are missing. In this case, we contact the authors and get some help from them to solve this problem. Within the file named ‘runalgorithm.m’, we implement the process of mode selection proposed in the paper and get the frequency of occurrence for each mode, as shown by figure 3.

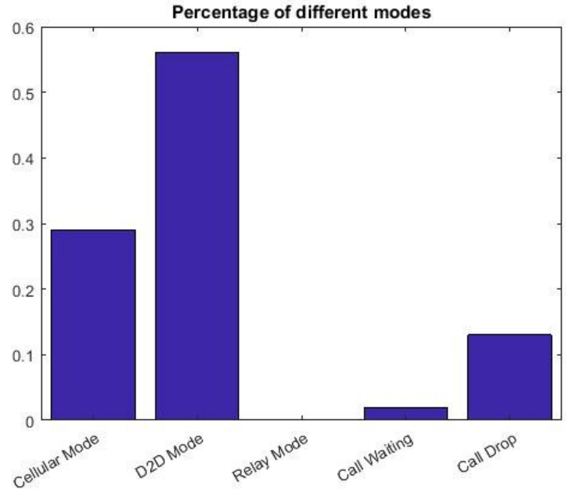

Fig5. Percentage of occurrences.

There are 6 different thresholds used in the process of mode selection, while the paper provides only one threshold value in the parameter table. Hence, we get confused with this point and have to do experiments for many times to get appropriate values for different thresholds. Indeed, we obtain the same conclusion as the original paper that the D2D mode takes the dominant part in the process, and this verifies their conjecture.

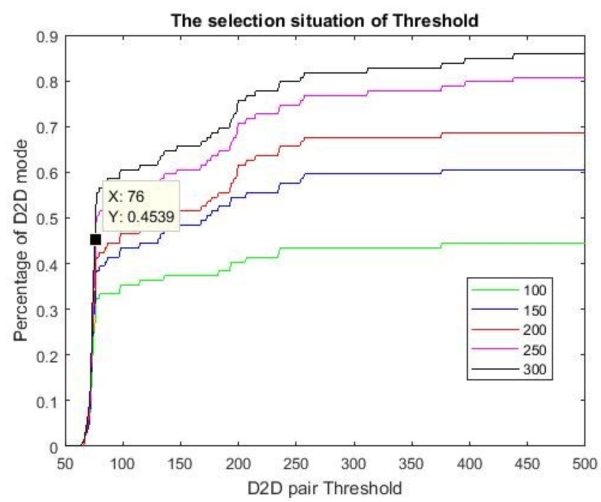

Fig6. The selection situation of threshold.

Within the file named ‘runalgorithm2.m’, we make further study on the threshold value. The figure above is the output of the file named ‘runalgorithm2.m’, and it shows the percentage of D2D mode variation with the change of thresholds used during the communication between the D2D user and the eNodeB (DtoE). The x-axis shows the threshold value of D2D pair (DtoD), while lines in different colors represents different threshold values of DtoE. We originally construct this algorithm and find that the percentage of D2D mode is increasing before DtoD is less than 80dB, and then converges to the limit after that. This conforms to the fact in the original paper that they set the handover threshold to be 80dB.

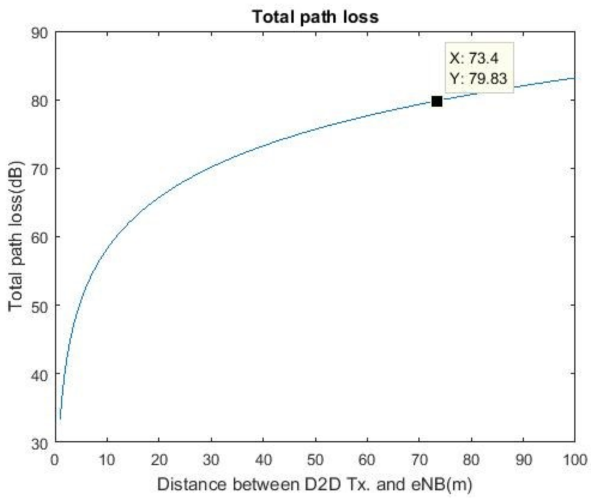

Fig7. Plot for the pathloss.

In the file named 'totallossline.m', we implement all of the functions to calculate the total path loss and obtain its relationship with the distance between D2D transmitter and eNodeB. As the last result parameter in the original paper, we strictly follow their steps and algorithms, but still get a curve with different shape for our figure, shown above.

In our simulation, we don't get the figure of mobility throughput of D2D users which is one of the original paper's results. Since the author says they mainly focus on the upper link and they never mention about the traffic capacity, necessary parameters for calculating are missing.

C. *Comparison with the original paper' s results*

To make a logical analysis of the original paper, we strictly follow all mentioned steps in the text and try our best to find all missing parameters from other references.

- We complete all of functions for calculating the total path loss.
- We originally make an algorithm to selecting the appropriate values in order of making up the ambiguous expression of the handover threshold.
- We modify the animation model of mobility process and make it more logical.
- We abandon one of figure result in the original paper and find out its defects.
- Do not confuse "imply" and "infer".
- The prefix "non" is not a word; it should be joined to the word it modifies, usually without a hyphen.

IV. CONCLUSION

A. *Dissussion on selected simulator*

After we did this project. We learned a lot about D2D communication, mobility in cellular networks as well as the research methods. In terms of simulation tools, We find that Matlab, ns2 have different emphasis on simulation. Matlab emphasis on communication simulation such as duplexing on channel, MAC protocol, MIMO and etc. However, ns2 emphasis on large scale network simulation, like small cell, satellite and etc. We could chose different simulator when doing different types of works.

B. *Difficulties*

Firstly, some formulas in this paper are explained implicitly and lack some key derivations. It is hard for us to follow the paper's work with these formulas. Thus, we need to find more resources to derive the formula.

Secondly, the simulation need a lot of programming with MATLAB. When considering the handover model, it needs six thresholds to analyze the results of the percentage of the D2D mode through the comparison of these thresholds.

C. *Final division of labor*

Basically, we do everything together but we different emphasis on our works.

Zixiang Nie: Simulate the handover model through MATLAB and generate mobility path through ns-2.

Xiao Wang: Implement the mathematical derivation and computes the path loss of the models.

Miaoqi Zhang: Analyze the result shown by ns-2 and matlab, propose the improvements of the existed handover model.

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