A Novel Serious Game Engineering Based Interactive Visualization and Evaluation Platform for Cellular Technologies

Pratip Chakraborty, Nandish P. Kuruvatti, Hans D. Schotten
Institute for Wireless Communications and Navigation
University of Kaiserslautern
Email: {chakraborty,kuruvatti,schotten}@eit.uni-kl.de

***Abstract*—In today's world, mobile communication has become a ubiquitously used technology, currently on the verge of its fifth generation (5G). 5G anticipates higher traffic volume and connected device density than present. It further envisions variety of service types and use cases arising from them. Various 5G concepts are being developed in order to satiate the aforementioned challenges. One of the key tasks for 5G consortium however, is to present the developed technology and concepts to wider audience (academia, industry) and even convince decision makers from non-information and communications technology (ICT) industries. Thus, it is desired to have easy to understand illustrations of envisioned 5G use cases and proposed technical solutions, targeting the non-experts. The contemporary simulation framework has limited or no provision to dynamically visualize and interact with the simulation scenario, rendering it difficult to be used for marketing as well as academic purposes. In this paper, we propose a serious game engineering based 3D visualization and evaluation framework, which allows dynamic and interactive visualization of simulated scenario. The proposed framework is simulator agnostic which enables viewer to immerse oneself into the simulated scene, visualize key performance indicators (KPI) in almost real time and even interact with simulator by changing key simulation parameters. These features equip the proposed interactive visualization/evaluation platform (IVEP) to demonstrate the 5G use cases and developed concepts better, paving way for easier understanding and evaluation of the concepts even by non-experts.**

***Index Terms*- 5G, Simulation, Visualization, Evaluation, Game engineering**

I. Introduction

Mobile communications is one of the most ubiquitously used technologies in the contemporary world, which has undergone technological evolution through various generations and is on the verge of its fifth generation (5G). A higher traffic volume, around 1000 times more than present and 10-100 times more number of connected devices are envisioned in 5G [1]. Further, there are new service types anticipated in 5G to support machine type communications (e.g. Industrial plants, vehicular safety etc.), along with conventional human centric broadband users [2]. Thus, 5G needs to tackle the problems arising from variety of use cases and requires meeting different service criteria. There are new concepts being developed in 5G mobile communications in order to meet the aforementioned challenges.

One of the key objectives in 5G-PPP (5G Infrastructure Public Private Partnership) projects is to enable the 5G concepts to reach and convince decision makers from non-ICT industries [3]. Therefore, it becomes necessary to develop illustrations of envisioned 5G use cases and proposed technical solutions which are easy to understand even for the non-experts. A visualization tool allowing viewer to interact with 5G enabled scenarios is hence desired for better understanding of the concepts from both industrial marketing and academic perspectives.

The conventional approach for cellular technology evaluation typically considers a hexagonal cell layout [5]. Several proprietary but calibrated link and system level simulators exist, which are used for evaluation of a certain technology or technical solution. The source code for selected parts might be shared or made public (e.g., channel models in WINNER project [6]). However, the hexagonal cell layout might not be sufficient in some cases, when it is required to reflect the intricate details of the scenarios (e.g. buildings, roads, parks, mobility pattern etc. in scene) that allow for a realistic evaluation of the given technology. The contemporary simulation framework allows only for evaluation of the considered technical solution with specified simulation parameters and outputs key performance indicators (KPI) at the end of simulation, which are then used to compare performance of considered technical solutions. These results are subsequently used for marketing of the technical solutions and for academic purposes.

The existing simulators do not have provision or have limited provision for visualization of considered scenario and dynamic run-time interaction with simulator. These limitations of existing simulation framework pose a challenge for the 5G experts to provide non-expert audience with a better understanding of 5G concepts and convince the decision makers. Another key issue is that some of the 5G concepts discussed in 5G-PPP projects are abstract and non trivial to be demonstrated in the form of experimentation, without showing interactions of different network elements in vast area (e.g., virtualization, cloudification, etc.,) [3]. Thus, it is desired to use a new, more realistic approach for evaluation and visualization, while reusing data from existing technology evaluation methods whenever it is applicable.

In this paper, we propose a simulator agnostic interactive vislualization/evaluation platform (IVEP), which allows dynamic 3D visualization of the simulation scenario. The proposed framework allows the viewer to interact with network elements and non network objects in considered scenario, there by immersing the viewer into the simulated use case. Further, the framework provides real time visualization of KPIs, both system specific (global) and user specific (local), also allows viewer to vary some key simulation parameters from visualization front end, to experience interaction with considered use case. These features allow the proposed visualization/evaluation platform to demonstrate the 5G use cases better, paving way for easier understanding and evaluation of the concepts under consideration, even by non-experts.

The remainder of this paper is organized as follows: Section II deals with architecture of IVEP, discusses key building blocks of framework. Section III describes usage of proposed IVEP with a concrete example of D2D use case, and Section IV provides a conclusion and indicates future work.

II. Architecture of Visualization/Evaluation Framework

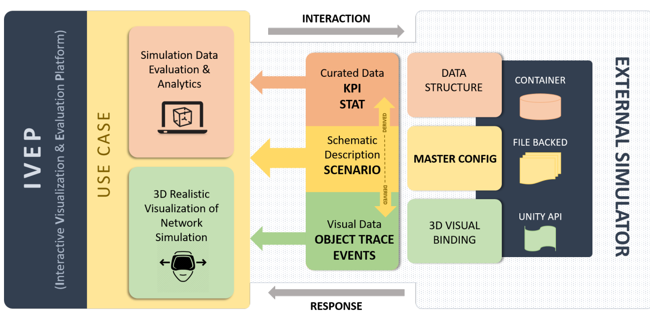

Fig. 1. IVEP architecture

Architecture of proposed platform is as depicted in figure 1. The building blocks of the architecture can be functionally decomposed into three major groups namely:

1) External simulator: The block where use case and concepts are simulated.
2) Logic and data back end: The functional block enabling interfacing of simulator with visualization front end.
3) Visualization front end: The front end of platform to visualize use case being simulated. A game engine called UNITY 3D [4] is chosen for this.

The key features of each block and dynamics among them to enable interactive visualization is discussed in detail in subsequent subsections.

A. Simulator

The external simulator in the framework can be any standardized open source or proprietary simulator. The framework is agnostic to the external simulator being plugged in. However, the simulator should require simple modification to allow data generated (e.g. KPIs, mobility information etc) to be bundled as simple data structure and be curated (e.g. Java script object notion-JSON).

B. Logic and Data Back End

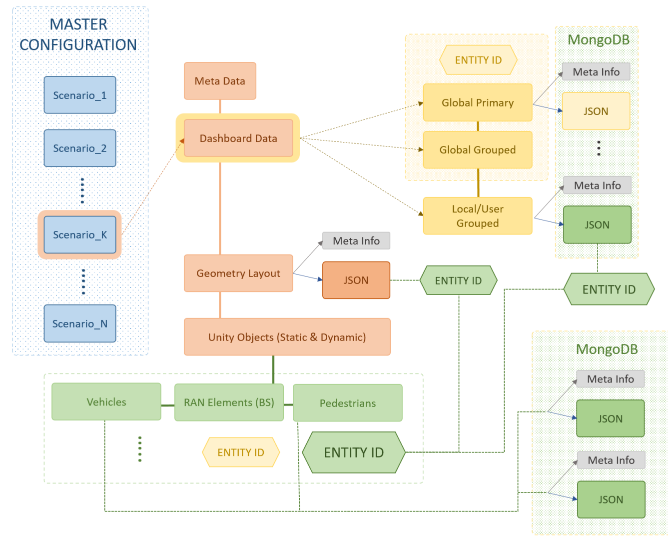

Fig. 2. Logic and data back end

Logic and data back end constitutes the most important part of IVEP. This facilitates bundling data and logic from external simulator in a way understandable at visualization front end. Figure 2 describes the intricate details of logic and data back end. A file backed master configuration will allow the platform to choose a desired simulation scenario from the list of possible scenarios available at simulator. Further, each scenario which needs to be plugged into visualization front end requires to provide the following information:

1) Dashboard data: This comprises of data from simulator which needs to be displayed on the dashboard of visualization front end. This consists of KPIs from simulator (global and local). Global denotes KPIs of entire scenario and local is specific to a user in the simulated scene. These KPIs can further be grouped based on their logical similarities.
2) Geometry layout: The features of visualization layout such as buildings, parks, roads etc., their positions and physical dimensions are contained here.
3) Unity objects: The features of static and dynamic objects in scene namely: vehicles, base station and pedestrians are encompassed here.

Meta data and meta info are used to control non-data features of visualization (e.g. color, texture etc). All these three logic and data entities are curated as JSON structure and communicated along with meta data to visualization front end. This communication can be carried out via files or data base. In our architecture, we recommend usage of NoSQL data base (MongoDB), since it provides easier parsing of simulation data (JSON) and is easier/agile to handle than files.

C. Visualization Front End

A UNITY 3D game engine is devised as visualization front end. The curated content from logic and data back end

Fig. 3. Logic and data back end interfaced to visualization front end

is fetched from file/database to this block. This content is subsequently processed, and utilized to create and control visual elements accordingly. Figure 3 describes an example of visualization front end, guided by curated logic and data back end information. It could be seen that dashboard data dictates the numerical display (KPI) and meta data determines type of graph (pie chart, bar graph etc), color of dashboard and other features. Curated information of geometry layout and unity objects together dictates visualization scene, thus enabling dynamic visualization of simulated use case.

It is further possible to immerse into the visualization scene by zooming in and out of the scene or rotating the scene in any desired direction. The front end also allows clicking on a specific unity object (e.g. pedestrian user) to enter *ego mode* and experience visualization from that user's perspective. Local (user specific) KPIs can also be visualized in this mode.

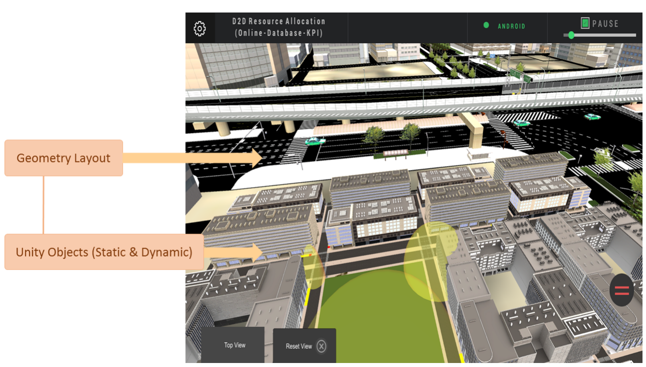

Fig. 4. Plug and play feature of visualization front end

Figure 4 shows another example of interfacing logic and data back end to visualization front end. Based on contained geometry layout and unity objects' information, it could be seen that a completely new scenario is resulted compared to figure 3. This demonstrates the plug and play capability of IVEP.

Another key feature made possible in IVEP is to dynamically interact with the simulator from visualization front end. Provision could be made to change few simulation parameters from front end (e.g. via pre-defined sliders). Changes made to these parameters are communicated to the simulator via file/database and subsequently one can observe the changes in KPIs of further simulation.

III. Interfacing of Use Case Simulation

In this section a concise example of interfacing a simulator with IVEP is detailed. A simple 5G use case on D2D communications is simulated in a MATLAB simulator which is being interfaced to IVEP, following procedures mentioned in section II.

A. Simulation on D2D Communications

In this section a use case with Device-to-Device (D2D) communications is simulated. D2D feature is already available in LTE-A release 12 [7] but continues to be a predominant use case in 5G. D2D communications commonly refer to the technologies that enable devices to communicate directly without base stations or infrastructure of access points, and with/without the involvement of wireless operators [7]. The physical proximity of devices is exploited for D2D communications which leads to improvement in coverage, data rates, resource utilization, QoS etc [8]. In order to realize the implementation of this technology, new methods for peer discovery, radio resource management algorithms, and various signaling protocols at different layers are required. However, the most important procedure for establishment of D2D communication is allocation of radio resources for peers to communicate.

A distance based D2D resource allocation scheme is simulated as an interfacing example with IVEP. In the considered simulation, uplink physical resource blocks (PRB) from the cellular users (C-UEs) is co-allocated to the D2D pairs based on separation (distance) between them. To limit interference from C-UEs to D2D receivers (D-UEs), resource allocation has to ensure that there is a sufficiently large physical separation between C-UE and D2D transmitter before radio resources can be shared. In this scheme, the network assigns a certain D2D link a PRB of C-UE, which is at a distance $(L > L_{min})$. L_{min} is the pre-selected distance constraint to control interference from selected C-UE to D2D link using same PRB [9]. The distance based resource allocation is illustrated in figure 5.

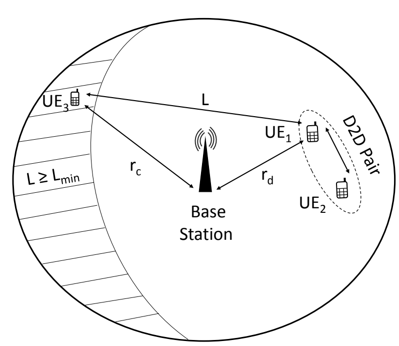

Fig. 5. Distance based resource allocation

For simplicity, we have extended the distance based resource allocation in such a way that when radio resources of all C-UEs at distances greater than L_{min} are being reused by D-UEs, then remaining D-UEs can reuse radio resources from rest of C-UEs. This is done in order to establish maximum number of D2D pairs in a cell and achieve resource reuse factor of 1.

TABLE I
SIMULATION ASSUMPTIONS

Parameter	Value (C-Mode)	Value (D-Mode)
Number of UEs	35	40 (20 pairs)
Transmit Power (eNB)	46 dBm	46 dBm
Max Transmit Power (UEs)	24 dBm	24 dBm
Power Control	Open Loop [10]	Open Loop [10]
Noise Figure	5 dB	7 dB
SINR Target (Rx)	-4 dB (eNB)	-2.5 dB
Channel Model	3GPP [12]	3GPP [11]

A system level simulator written in MATLAB is used to simulate the aforementioned D2D resource allocation scenario. A single cell with radius of 500m is considered with base station equipped with LTE technology at its centre. The simulation assumptions are listed in Table I. Further, the LTE system with 10 MHz bandwidth and 50 PRBs is considered [12]. The resource reuse factor is 1, which means a D2D pair can reuse a PRB from only one unique C-UE. The C-UEs and D-UEs are pedestrians walking with average velocity of 3 km/h.

In order to facilitate proper visualization, users' mobility trace used in simulation is generated such that the users are not obstructed by buildings and other non network elements considered in scene. The idea of this procedure is depicted in figure 6. Top left of the figure depicts origin points of all users. Top center of figure depicts trajectories of user following random way point. It could be seen that several trajectories would be obstructed by buildings in considered scene. Such trajectories are adapted to fit the visualization scene better and one such resulting trajectory of a user is shown in top right. Adapted mobility traces of selected four D2D pairs is shown in bottom of figure 6. Such adapted mobility traces are used/generated in the simulator. It has to be noted that such simulator has no provision for dynamic visualization or interaction with the scenario being simulated.

B. Traces

In order to visualize the scenario being simulated in a simulator, following three important traces are required at visualization front end:

1) Geometry trace: This describes visualization scene layout with position and/or features of network elements (e.g. base station, mobile users) and non network elements (e.g.buildings, roads, park etc).
2) Mobility trace: This describes mobility of users in the scene with respect to time.
3) KPI trace: This trace comprises of KPIs generated from the simulator with respect to time.

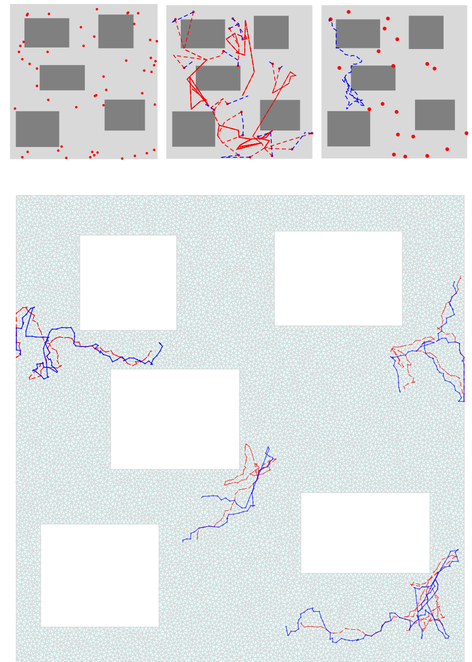

Fig. 6. Generation of mobility trace

A simple segment of geometry trace describing characteristics of a building is described below:


```
{
   "name": "home1",
   "type": "building",
   "geo_x": 100,
   "geo_y":5,
   "geo_z": 657,
   "geo_x_r":0,
   "geo_y_r":0,
   "geo_z_r":0,
   "length": 5,
   "width": 5,
   "height": 5
},
```


Similarly, features of all envisioned elements in scene (buildings, parks, roads etc) can be communicated to the IVEP.

Mobility traces for D-UEs and C-UEs are generated following the mobility trace generation and adaptation explained in section III-A. A segment of such mobility trace for a C-UE is shown below:


```
{
"0": [
       {
         "id": "CUE-1",
         "data": {
            "ObjectType": "Pedestrians",
            "x": 85.6724,
            "y": 457.378,
```

```
                "speed": 1.47795,
                "angle": 1.38563,
                "conn": "BS-1"
                }
        },.....
]
}
```


In the considered example, (x-co-ordinate,y-co-ordinate, speed, angle) data of a C-UE with id CUE-1 at time stamp 0 is described. Similarly mobility information for all users (D-UEs and C-UEs) at all time stamps can be described.

The KPIs generated by the simulator at each time stamp needs to be communicated to visualization front end. In considered simulation, following user specific local KPIs are generated: (D-bps, IN-D, BS-bps, IN-BS), describing D2D throughput, interference at D2D link, cellular user throughput (uplink throughput at base station) and interference at base station, respectively. Further, system specific global KPIs (D-bps-G, CUE-bps-G, overall-bps, D-conn, CUE-conn, overall-conn) describing global D2D throughput, CUE throughput, overall throughput, number of D2D connections, number of CUE connections and total connections are communicated to visualization front end. Below is an example of KPI trace at time stamp 3. Similarly, KPIs need to be communicated throughout the simulation run at all time stamps.


```
{
        "data":{
        "TimeStamp": 3,
        "Did": [DUE user ids],
        "Cid": [CUE user ids],
        "D-bps":[147336,...... ]
        "IN-D": [-119.4,......]
        "BS-bps": [39379.2,...... ]
        "IN-BS":  [-114.13,......]
        "D-bps-G": 3298108.8,
        "CUE-bps-G": 1914712.8,
        "overall-bps": 5212821.6,
        "D-conn": 20,
        "CUE-conn": 29,
        "overall-conn": 49,
        },...
}
```


These traces can either be communicated to visualization front end via files or data base. Further, it can either be pre-generated or real time (dynamic). It was observed that data base allows more modularity and flexibility than files and easily accommodates dynamic communication and visualization. Further, in considered example, mobility and KPI traces are communicated to visualization front end with a time step of 1 second. Mobility of users is made smooth at visualization front end via interpolation, to avoid abrupt jump of user positions.

C. Visualization Front End

Once the data traces from simulator are available at visualization front end, the scene being simulated can be visualized along with network and non network elements in it. Figure 7

Fig. 7. View of simulated scenario at IVEP front end

depicts the front view of simulation scenario with several buildings and park around it, embedded in a vast urban area. A macro base station is present on top of one of the buildings. D-UEs and C-UEs (pedestrians) are visible in the scene. D2D pairs are connected via a link and highlighted by a sphere around them. C-UEs are connected to base station by links (green). These users follow the mobility trace as generated by simulator and move in scene with time. The simulated scene can be zoomed into and rotated in any angle (0-360), thereby giving an experience of immersion into the simulated scene. The top view of the scenario is shown in figure 8.

Fig. 8. Top view of simulated scenario at IVEP front end

Further, a user (D-UE or C-UE) can be clicked to enable *ego-mode*, which allows viewer to visualize the scene from perspective of clicked user. This is shown in figure 9.

Figure 10 shows the global KPIs associated with simulation scene as graphs, as well as numerical display. When in ego-mode, it is possible to visualize user specific local KPI graphs as shown in figure 11.

Further, viewer can interact with few simulation parameters from visualization front end. However, this feature is not allowed with pre-generated simulation traces. Nevertheless, when simulator is running dynamically with visualization front

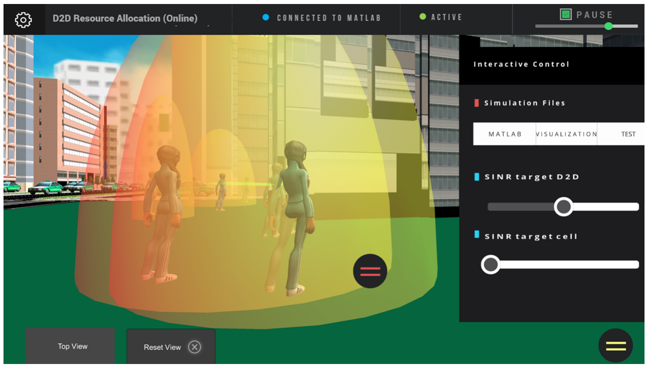

Fig. 9. Ego user view

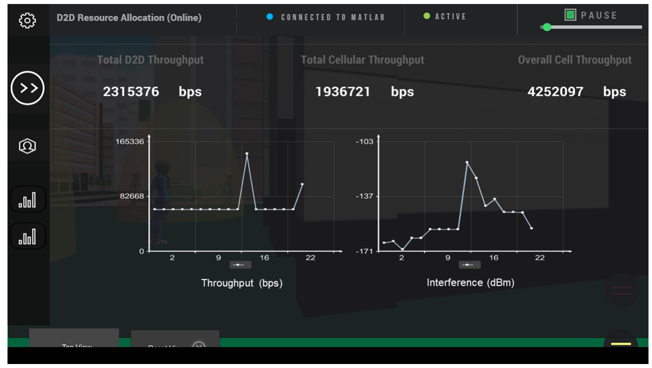

Fig. 11. Dynamic Local KPI graphs

Fig. 10. Dynamic Global KPI graphs

end, it is possible to change the SINR target for D2D and C-UEs (range: -5 to +5 dB) from front end via sliders, as shown in figure 9. Any changes in these parameters are fed back to simulator via file. Based on these interactions, the resulting change in system KPIs can be visualized in subsequent time steps. For instance, figure 10 shows a spike in total D2D throughput (highlighted in yellow) following an interactive increase in D2D SINR target at visualization front end.

Thus, IVEP allows interactive visualization and evaluation of use case being simulated in a simulator. Similar to the example demonstrated in this section, it is possible to integrate any use case and any simulator into IVEP platform, by following aforementioned procedure.

IV. Conclusion and Future Work

Mobile communications is on the verge of its fifth generation (5G). Higher traffic volume, more connected devices are anticipated with various service types and use cases. Various 5G concepts are being developed to cope up with these demands. However, one of the key objectives for 5G consortium is to show case these developed concepts and use cases to wider audience, including non-ICT industries. Thus easy to understand demonstrations of such concepts are essential. Existing simulators have limited or no provision to visualize and interact with the simulated scene, rendering them difficult for marketing and educational usage. In this work, we proposed a serious game engineering based interactive visualization and evaluation platform (IVEP), to enable interactive visualization of simulations. The architecture of this simulator agnostic framework was discussed, highlighting key building blocks of the platform. A D2D use case simulation example was integrated with IVEP, demonstrating visualization and interaction capabilities of the platform. The key procedure for such integration was discussed in detail. The platform was shown to provide an experience of immersion into the simulated scene, thereby making it better suited for providing easy to understand demonstrations of 5G concepts and use cases. The future work is to include network hardware into the loop, thereby enabling visualization of the real network data and possibly enabling adaptation of hardware from visualization front end.

V. Acknowledgment

Part of this work has been performed in the framework of the H2020 project METIS-II (H2020-ICT-2014-2, topic ICT-14-2014) co-funded by the European Commission. The authors would like to acknowledge the contributions of their colleagues.

References

[1] Ericsson, *More than 50 billion connected devices*, white paper, Feb., 2011.
[2] METIS, *D1.1 - Future radio access scenarios, requirements and KPIs*, May, 2013, available online: https://www.metis2020.com.
[3] METIS, *D2.1 - Performance evaluation framework*, Jan, 2016, available online: https://metis-ii.5g-ppp.eu/wp-content/uploads/METIS-II_D2.1_v1.0.pdf.
[4] UNITY 3D *Release notes of Unity 5.3.1*, Dec, 2015
[5] ITU-R Report M.2134, *Requirements related to technical performance for IMT-Advanced radio interface(s)*, 2008
[6] WINNER II, D1.1.2, *WINNER II Channel Models*, Sept 2007
[7] E. Seidel, *3GPP LTE-A Standardisation in Release 12 and Beyond*, Nomor white paper, Jan 2013
[8] N.P. Kuruvatti, A. Klein et al., *Robustness of Location Based D2D Resource Allocation Against Positioning Errors*, VTC-Spring 2015, Glasgow, Scotland, May 2015
[9] H. Wang and X. Chu., *Distance-constrained resource-sharing criteria for device-to-device communications underlaying cellular networks*, Electronics letters 48.9, pp. 528-530, 2012
[10] ETSI TS136.213, *LTE Evolved Universal Terrestrial Radio Access (E-UTRA)- Physical layer procedures*, 2009
[11] 3GPP, *Discussion on UE-UE channel Model for D2D Studies*, 2013
[12] 3GPP TSG RAN, *Further advancements for E-UTRA physical layer aspects (Release 9)*, TR 36.814 V9.0.0, March, 2010.