On the Use of Serious Game Engineering for 5G System Performance Evaluation

Carlos Herranz, David Martín-Sacristán,
Jose F. Monserrat, Narcís Cardona
iTEAM research institute
Universitat Politècnica de València
Valencia, Spain
carhercl@iteam.upv.es

Saúl Inca
National Institute for Research and Training in
Telecommunications - INICTEL
National Engineering University - UNI
Lima, Peru
sinca@inictel-uni.edu.pe

Abstract—**This papers summarizes the current proposal of the METIS-II project on the use of serious game engineering approach for the evaluation and visualization of 5G technologies. Based on UNITY 3D, a realistic scenario has already been implemented, including a portion of a city with every level of detail. This article discusses the representation of results and interaction with a conventional simulation tool, showing clear cohesion between these two entities.**

Keywords—METIS-II, 5G, simulation, serious game engineering, UNITY-3D

I. INTRODUCTION

System simulations are typically used to test different technological components of wireless systems. Their simplicity and reduced cost in comparison with direct prototyping of new ideas, motivate their use in the design process and in some ulterior phases. Moreover, simulations are often split into two levels of abstraction, namely link and system-level simulations. Link-level simulations focus mainly on the performance of the physical layer, whereas system-level simulations assume a complete network with several base stations and mobile terminals while simplifying link level details.

This typical approach has two main drawbacks derived from the use of synthetic scenarios, based on hexagonal layouts of cells [1], and from the type of metrics used to assess the performance of the system. Concerning the scenarios, past experience with other studies performed in 3GPP have shown the need for a proper characterization of realistic effects [2]. Some conclusions reached with synthetic simulations have turned out to be incorrect once the proposed techniques were applied to the field. In this sense, it seems beneficial to use realistic scenarios that allow a proper evaluation of the potential of some new technological concepts.

Regarding the representation of the performance statistics, previous experience from fairs and other events shows that engineers usually fail in making their thoughts understandable for the general public. This challenge is of a special relevance with respect to the 5G revolution, since this implies a strong change in the communications paradigm and there is an urgent need for tools that will demonstrate the importance and impact of the new technology components that will be proposed, for instance, in METIS-II and other research projects.

The challenge is also how to ensure that the chosen realistic scenarios are representative for all scenarios that could appear in practice and how to model these realistic use cases in evaluation tools without wasting too many resources in complex scenario parameterizations. In this sense, METIS-II has introduced a new evaluation and visualization approach based on serious game engineering.

The application of such approach requires appropriate tools. An excellent candidate is the UNITY 3D development platform, which is not only suitable from the visualization point of view, but is also open source and widely adopted by the design community.

Visualization tools will be mainly used for a simplified simulation of the technology components developed in METIS-II and other 5G-PPP research projects, allowing the tool operator to interact with the simulated environment in real time. If detailed simulation accuracy is needed, the second alternative of use could be approached via pre-computed traces obtained with sophisticated simulation tools. The visualization tool will be then fed with these traces, allowing for a demonstration of the outputs of these simulations with a lesser extent of interaction.

This paper presents the latter approach as followed in METIS-II, explaining the characteristics of UNITY 3D and the level of interaction reached so far in the project.

II. UNITY 3D FOR SERIOUS GAME ENGINEERING

UNITY 3D is a multi-platform game engine created by Unity Technologies. As a development framework, it can be used in multiple operating systems, and allows creating games for Windows, OS X, Linux, iOS and Android, among others. With two available versions, the Unity Personal is open source and is granted with all the required capacities to create a game from scratch.

Initially conceived as a game engine, it is currently being used in several fields of engineering and arts, because of its multi-platform philosophy, its rendering power and its built-in physics engines capable of providing components that handle

the physical simulation. This is today a supporting tool for the idea of "serious game engineering".

Moreover, with more than 45% of gaming market share [3] the widespread community supporting the tool makes very easy to access documentation, examples and new approaches for dealing with complex problems. All these facts make UNITY 3D platform a perfect tool for visualization and evaluation tasks within the METIS-II project.

As METIS-II is to create an open-source solution for the 5G system performance evaluation, UNITY 3D feature of compatibility with open source programming and modelling software ensures that the results and findings of METIS-II could be accessible and usable for other future purposes, like in next phases of 5G-PPP activities.

III. METIS REALISTIC MADRID GRID URBAN SCENARIO

The simulation activity in METIS started with the definition of the simulation scenarios [4]. One of those, the 'Madrid grid' scenario, is an extension of the Manhattan Grid model [5] and contains blocks of buildings of different sizes and heights and an open park area with a grid of roads and sidewalks. It also specifies traffic models for vehicles and pedestrians aiming at reproducing a typical European dense urban environment.

Total dimensions for Madrid Grid is 387 m (east-west) and 552 m (south north) assuming only one sidewalk, parking lane and road lane between edge buildings and the layout border. The building height is uniformly distributed between 8 and 15 floors with 3.5 m of height each.

A. Deployment

The basic network deployment consists of a single three-sectorial macro station operating on a central carrier frequency of 800 MHz or 3.5 GHz. Antenna elements of macro station are positioned on the edge of the top of a central building. The antenna gains of the three sectorial antennas are 17 dBi.

Macro cells are complemented with 12 micro/pico cells operating at central carrier frequency of 2.6 or 25 GHz. Antennas of micro/pico station are positioned on the lamppost, 10 m above the ground.

B. Mobility patterns

A configurable number of cars, with dimensions 1.8 m x 4.3 m, are uniformly distributed in the scenario. Each car has a number of users inside chosen uniformly from the interval [1,5]. Cars maximum velocity is 50 km/h, while car acceleration is 2.9 m/s^2 and deceleration is 7.5 m/s^2. Cars do not turn at cross streets, but move always along the same street. When cars reach the scenario borders, they bounce back and drive along the opposite lane, in the opposite direction. Collisions with potential vehicles are avoided. In fact, cars stop at red traffic lights and also when there is another vehicle less than 2.5 m in front.

All vehicular traffic lights in the grid switch simultaneously with a pattern which repeats every 90 s. The switching pattern for vehicular traffic lights is described in TABLE I.

TABLE I. TRAFFIC LIGHT PHASES FOR VEHICLES

Time period (s)	Horizontal streets phase	Vertical streets phase
0-37	Green	Red
37-42	Yellow	Red
42-45	Red	Red
45-82	Red	Green
82-87	Red	Yellow
87-90	Red	Red

Fig. 1 View of the UNITY 3D representation of a Manhattan grid

A minimum yellow phase duration of 4.5 s has been calculated as the time needed by a bus driving at a speed of 50 km/h to stop before the traffic light considering a specific deceleration of 4 m/s2 and a reaction time of 1 s. To be conservative a phase of 5 s is considered.

Also, a minimum duration of 2.5 s for the red phase overlap between horizontal and vertical traffic lights has been calculated as the time needed by a bus driving at a speed of 50 km/h to go over a distance equal to the largest street width plus the width of a pedestrian crossing and the bus length (42 meters in total). To be conservative, we have considered a phase of 3 s.

Vehicular traces were generated with Simulation of Urban Mobility (SUMO) [6], a road traffic simulator. The Madrid grid scenario with its roads and sidewalks was introduced in the simulator with the abovementioned turn probabilities to obtain the mobility traces for a given number of vehicles.

C. Virtual representation in Unity3D

Fig. 1 illustrates a virtual recreation in Unity3D of the realistic scenario. To make use of Unity 3D's light engine, light sources were placed following the location, tilt and azimuth of the sectorial macro cell base stations. Note the macro cell requires three light sources, one source for each sector. Unity 3D allows defining materials to objects in the scenario that interact with light differently, so it is possible to emulate the penetration and reflection losses of a given material. This property also enables modelling the light properties of the material for different system operation frequencies. This light intensity can be translated to path-loss using a calibrated

transformation function. With higher frequency, the transformation function becomes more direct until reaching a very close behaviour between light attenuation and propagation loss.

IV. VISUALIZATION TOOL VIEWS

While developing the serious game-based simulation tool in Unity3D, intermediate performance evaluation results will be visualized in the platform. A group of so-called editors will be able to modify existing visualization of defined use cases in order to reflect the impact of selected solutions on given metrics (both coming from user and infrastructure). The intermediate results must be pre-computed using any sort of simulation platform and adapted to the target use case. The obtained data results must be formatted in such a way that the visualization platform can represent data as intended in the view of the use case.

In the visualization, different kind of logical layers of information could be added according to the selection of the operator. While the simulation trace is represented and users/cars are moving around, the viewer can switch to a system mode of operation in which the information layer represents global aspects, like congestion, coverage, average satisfaction and so on. By using a context menu, one or several KPI can be depicted on top of the simple layer of physical elements in the scenario. Most of the performance metrics corresponds to this view mode, and it is therefore expected to represent results like CDF or average values. Upon request of the viewer, the visualization can change to the details of a certain transmitter, either a Base Station (BS) a Mobile Station (MS) or a moving node. In this case, the visualization layer can switch to a first-person mode, illustrating the real time performance stored in the traces, including for instance active links, instantaneous throughput, latency, and so on. It is too early to state all the parameters to be represented in the different views, but there is a general consensus in the fact that this mode of operation with the visualization tool still presents a good degree of interaction with the game operator.

Currently, the visualization tool is able to show the Madrid-Grid scenario with a set of pedestrians, cars and buses moving around. Over this real view, other logical information can be depicted, including coverage areas represented by a hemispherical transparent helmet and links represented by lines with different colours and styles. On top of this views, current visualization tool shows an information layer comprising valid information about the project structure and research approach. This slide-like representation is quite useful for the support of the discourse, and is currently controlled by a configurable menu.

A. Global view

The first view is the global one, in which the camera is far enough to have a quick look to the whole scenario. A set of
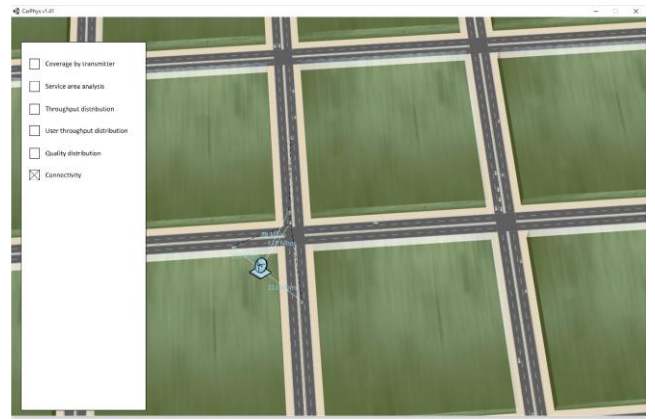

Fig. 2 Connectivity information display in the global view

visualization parameters will be displayed and selected, being in principle possible to select some of them simultaneously. Fig. 2 shows an example of this view. Among the possible layers, we include the following:

• Coverage by transmitter: shows in different colours a layer indicating the area where each transmitter is the best server. In a second layer of control, the viewer can activate or deactivate some of the transmitters to simplify the view.

• Service area analysis: on clicking over this layer, further information should be provided. The viewer selects then the set of services that what to visualize and then a new 2D layer with identification of service area is depicted, showing the positions in which a certain service could be potentially provided. An example of some services could be (1) data rate over 100 Mbps, (2) VoIP, Vehicle to Vehicle (V2V) communications with packet load of 1600 Bytes and latency less than 100 ms.

• Throughput distribution: this 2D layer represents a map with different colours a group of throughput values.

• User throughput distribution: in this case, users/machines/vehicles modify their colour according to the previous legend. This is not a 2D map as before, but rather a colour activation of users.

• Quality distribution: this is a 2D map representing different levels of reliability, in terms of packet error rate, maximum latency, or a combination of both.

• Connectivity: in this view, users are linked with a line with all the transmitters from or towards which they have data exchange. Different colours are used to distinguish the links. Of course the same user can be connected with different sources/sinks. This view allows also distinguishing Device to Device (D2D) links, moving network, and cellular links, using different kind of lines. Fig. 2 shows a simplified illustration of this idea.

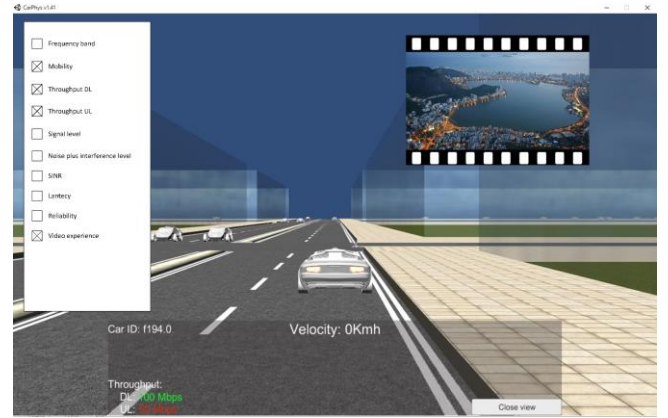Fig. 3 Example of MS focus view.

Fig. 4 Example of first person mode view.

Fig. 5 Example of information display in cell view.

B. Focus on mobile station view

On clicking over a specific UE/vehicle/machine the view changes by zooming to the specific user. This view is well-suited to represent the active links of the user (see Fig. 3), plus other parameters of interest per link, like the frequency band, throughput, signal level, noise plus interference level, Signal to Interference plus Noise Ratio (SINR), latency, and reliability, among others. Note that the representation of these metrics could be just a simple instantaneous value, or also another graphical representation including the instantaneous value and some statistics, like the average, maximum value, minimum and standard deviation.

C. Mobile station first person view

On a different clicking mode (for instance double-clicking), the view switch to a first person view. This view also allows for a dynamic representation of the experience of the user for a certain service. Therefore, apart from the previous parameter, additional representations of end user experience could be represented on top. As an example, Fig. 4 shows a capture of the first view in a car, in which a film is being played. Transmission errors or latency could affect the end-user experience of the film visualization, which will be seen as the end user in the live more.

D. Cell view

On clicking over a specific cell, the view changes by zooming to its coverage area. Under this view, the transmitter and all user/machines/vehicles connected to it are identified with the same colour. We can see cell-specific statistics and instantaneous values like the load of the cell, SINR experienced by users in the cell, throughput in downlink and uplink, latency, reliability and coverage. Again, instantaneous values could be accompanied with bars representing the statistics of the whole set of values. We could also play with colours to highlight the outage status, as show in Fig. 5, where red font colour is used to depict a throughput below the outage threshold.
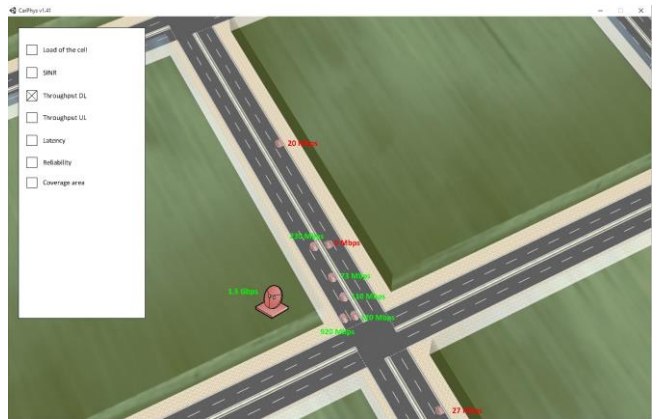
V. SIMULATION TO VISUALIZATION INTERFACE

Simulation results obtained from realistic deployment scenario can be easily plugged to METIS-II visualization tool. The specific format has been agreed upon the partners [7], and currently includes the following items:

- Mobility traces.
- Loss maps and loss maps parameters.
- Packet generation/reception files.
- Per mobile entity KPIs file.
- Per station KPIs file.
- Global KPIs file.

Next subsections provide an insight into those items, including the current agreements on their main features.

A. Mobility traces

In the visualization platform, we assume the existence of three different kinds of mobile entities: cars, buses, and pedestrians.

There will be one mobility trace file for each kind of mobile entity. The mobility traces describe the evolution of the position, speed and orientation of each mobile entity in the simulation.

In the mobility traces, one row contains the data for one entity. The data within one row consists of tuples of four values containing: time stamp in seconds, X coordinate in m, Y coordinate in m, orientation in degrees. Each field is delimited by a blank space. The orientation angle is in the range [-180, 180]. The convention for the orientation is: 180º means north direction, 90º means east direction, 0º means south direction, and -90º means west direction.

We assume that a fixed time step is used to obtain the position samples. Therefore, in general, the time stamps for the same entity will have a fixed time step. Additionally, we assume that at each sampling time the position of all the entities is recorded. Therefore, all the rows will have the same number of elements, and the time stamp values in the same column will be equal to each other.

B. Loss maps

A loss map represents the losses in dB from the position of the fixed station to a set of points distributed over an x-y plane in a specific z coordinate.

In the visualization platform, we assume the existence of a loss map for each fixed station in a set of relevant z coordinates. The relevant z coordinates are assumed to be a sequence of values having a fixed spacing, with the first z coordinate having an offset with regard to the ground level (coordinate 0). This offset is used to represent the actual position of wireless communication devices.

The set of points whose loss values are represented in a loss map are assumed to be the central points of the rectangles obtained as a result of the division of the scenario under study in a grid with a specific x-spacing and y-spacing.

The loss map file comprises as many rows as loss samples in y-axis, and as many columns as loss samples in x-axis. An increasing row index means an increasing y position, while an increasing column index means an increasing x position.

C. Packet generation/reception files

In order to store information about the generation and reception of individual application layer packets, two file formats are defined.

The packet generation file has 3 columns and multiple rows. Each row represents a generated packet. The first column indicates the generation time of the packet with a time_stamp in seconds (precision of microseconds). The second column is a packet identifier that cannot be equal for two different packets. The third column is the identifier (id) of the entity that has generated the packet.

The id of the transmitting/receiving entities should be in the range [0, nbStations-1], where the nbStations is the number of cars plus the number of buses and the number of pedestrians.

The mobile entities are assumed to be numbered from 0 to nbStations-1, starting with the cars, next the buses and finally the pedestrians. It is also assumed that the row with the mobility trace of each entity is ordered in the mobility trace file in ascending order of identifier.

The packet reception file includes 3 columns and multiple rows. Each row represents the correct reception of a packet by a simulated receiver. The first column indicates the reception time of the packet with a time_stamp in seconds (precision of microseconds). The second column is the packet identifier. The third column is the id of the entity that has received the packet.

The different entries (rows), of both the packet generation and reception files, are assumed to be sorted by ascending order of generation time.

VI. CONCLUSIONS

This paper has presented the current visualization and simulation framework of the METIS-II project. The proposed methodology relies on the use of UNITY 3D as a serious game engineering tool capable of simplifying the emulation of some physical aspects of wireless communication systems. For instance, path loss can be estimated via the use of the light propagation engines. The proposed framework is also simple and open source, which is essential to guarantee the widespread adoption of this approach.

REFERENCES

[1] ITU-R Report M.2134, "Requirements related to technical performance for IMT-Advanced radio interface(s)", 2008.

[2] J. F. Monserrat, S. Inca, J. Calabuig, and D. Martín-Sacristán, "Map-Based Channel Model for Urban Macrocell Propagation Scenarios", International journal of Antennas and Propagation, 2015.

[3] https://unity3d.com/public-relations

[4] METIS D6.1. "Simulation guidelines". ICT-317669 METIS Deliverable 6.1 Version 1, October 2013.

[5] ETSI Technical Report "Universal Mobile Telecommunications Systems (UMTS); FDD Base Station (BS) classification (3GPP TR 25.951 version 10.0.0 Release 10)", May 2011.

[6] http://www.dlr.de/ts/en/desktopdefault.aspx/tabid-1213/

[7] METIS-II D2.1. "Performance evaluation framework". ICT-671680 METIS-II Deliverable 2.1 Version 1, February 2016.