METIS II

Mobile and wireless communications Enablers for the Twenty-twenty Information Society-II

Deliverable D7.2
Preliminary 5G Visualization

Version: V1.0

2016-12-31

http://www.5g-ppp.eu/

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Grant Agreement Number:	671680
Project Name:	Mobile and wireless communications Enablers for the Twenty-twenty Information Society-II
Project Acronym:	METIS-II
Document Number:	METIS-II/D7.2
Document Title:	Preliminary 5G Visualization
Version:	V1.0
Delivery Date:	2016-12-31
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Keywords:	Visualization, Evaluation, Game engine, UNITY 3D, Demonstration, Dissemination, 5G, METIS-II
Status:	Final
Dissemination level:	Public

Abstract

This deliverable summarizes the concept and current status of the open source visualization platform, which at this point in the timeframe of the project is able to showcase a subset of the 5G RAN design concepts investigated in METIS-II. Different alternatives for visualization are presented and the roadmap and further steps in this topic are also discussed.

Revision History

Revision	Date	Description
0.1	2016-07-18	ToC and template created
0.2	2016-11-15	Draft version ready for internal and external revision
0.3	2016-12-05	Revision from internal and external reviewers
1.0	2016-12-15	Complete and final version of the deliverable

Executive summary

This deliverable presents the effort made in METIS-II to create the visualization platform needed in the evaluation of the 5G technology components and concepts developed in the project from the performance and techno-economic points of view. The most compelling subset of these 5G components have been implemented in the open source visualization and evaluation platform presented at the Mobile World Congress (MWC) 2016. The concept and current status of this open source visualization platform is also presented in this deliverable.

Also of high importance is the description included in the document about the interaction from non-METIS-II partners with the visualization platform. Being open source, we aim at cooperating with all 5G researchers to disseminate their results with the visualization tool provided by METIS-II. Instructions for interaction with the platform are given along the text.

This deliverable also points out all the alternatives for visualization, ranging from static to dynamic and interactive simulation material. Examples of the capability of the visualization platform are given summarizing the demonstrations made up to this point in time.

Finally, the future steps for the development of this platform are summarized. The outcomes of this remaining research work will be summarized in Deliverable D7.3 due by June 2017.

Contents

List of Abbreviations and Acronyms

3GPP	Third Generation Partnership Project
5G PPP	The 5G Infrastructure Public Private Partnership
CDF	Cumulative Distribution Function
D2D	Device to Device
CDF	Cumulative Distribution Function
eNB	evolved Node-B
ICT	Information and Communication Technology
IMT	International Mobile Telecommunications

ITU	International Telecommunication Union
KPI	Key Performance Indicator
MWC	Mobile World Congress
RAN	Radio Access Network
SINR	Signal to Interference plus Noise Ratio
UE	User Equipment
WP	Work Package
WRC	World Radiocommunication Conference

1 Introduction

1.1 Objectives of the document

In METIS-II [MET-WEB2], one of the key objectives is to enable the 5G concepts to reach and convince decision makers from non-ICT industries [MET16-D22][MET16-WP][MDB+16]. Thus, it is necessary to have easy-to-understand illustrations of envisioned 5G use cases and proposed technical solutions, targeting the non-experts. A professional 3D visualization tool enabling viewer to interact with 5G enabled scenarios [MET13-D11][MET15-D15][MET16-D11] has been introduced by METIS-II to achieve this. The selection of this tool and its main features is one of the points discussed along this deliverable.

The objective of this document is to describe the visualization approach that will be used in METIS-II. This document gives an overview about the new evaluation and visualization approach, describing the pitfalls in the conventional evaluation/demonstration methods. Further, the document discusses the role of visualization in METIS-II, providing a 5G experience comparable with real demonstrations and supporting dissemination, in particular to those groups that 5G is targeting. The document introduces UNITY 3D [UNITY-pub] as 3D visualization game engine selected by METIS-II and used to develop such visualization platform.

The document also emphasizes the implementation of the evaluation/visualization concept highlighting the users and interaction paradigms. The physical and logical components of the test cases are identified to assist visualization and the role of UNITY 3D is discussed.

The deliverable also provides a picture of the current status of the software development in UNITY 3D made in METIS-II, summarizing the information presented in the demonstrations made by the project so far. Finally, and with the lessons learnt, this deliverable provides the outlook of the future development in this research line until the end of the project.

1.2 Structure of the document

This document is structured as follows: Section 2 deals with the evaluation and visualization in METIS-II, discusses the overall METIS-II objectives of the evaluation/visualization campaign and introduces the evaluation/visualization concept. Finally, this chapter also presents how we plan the interaction with other actors outside METIS-II. Section 3 discusses 3D visualization using game engines while introducing UNITY 3D as visualization platform, outlines the different roles of visualization and interaction paradigms in METIS-II and describes the main components of the visualization layers. Section 4 deals with the implementation details of evaluation/visualization in METIS-II, showing the details of the demonstrations made so far and also describing the Android version of the platform. Section 5 deals with the next steps in the visualization development, with a thorough analysis of alternatives for dynamic interaction with the tool. A summary is detailed in Section 6, with the main conclusions.

2 METIS-II evaluation and visualization overview

This section allows the reader to understand the main objectives of the visualization approach followed in the project. Starting from the general METIS-II objectives, we then describe the specific objectives of the visualization task, including the general framework and the interconnection with other researchers outside METIS-II.

2.1 Overall METIS-II objectives

METIS-II aims at pursuing the following objectives [MET-WEB2]:

1. Develop the overall 5G Radio Access Network (RAN) design (where 5G refers to the overall future wireless communications system including evolved legacy and novel radio access technologies), with the focus on an efficient integration of legacy and novel RAN concepts into one holistic 5G system.
2. Provide the 5G collaboration framework within 5G PPP for a common evaluation of 5G RAN concepts. More specifically, METIS-II will further refine 5G scenarios, requirements and Key Performance Indicators (KPIs), develop a performance and techno-economical evaluation framework, and provide consolidation and guidance to other 5G-PPP projects on spectrum and overall 5G RAN design aspects. Further, METIS-II will develop an open-source 5G evaluation and visualization tool for illustrating the key use cases of a 5G system as such, and the benefit of the key 5G RAN solutions developed in METIS-II.
3. Prepare concerted action towards regulatory and standardization bodies for an efficient standardization, development and economically attractive roll-outs of 5G with a strong European footprint and head start.

As it can be noticed, the objectives 2 and 3 are closely related to dissemination, standardization and regulatory activities within METIS-II. In particular, objective 2 makes a reference to both the organization of a 5G collaboration framework, that METIS-II intends to build and consolidate also by means of ad hoc events, and workshops planned throughout the project's lifetime. Moreover, objective 2 explicitly is mentions the visualization tool that is an efficient way to show and disseminate project results.

Regarding objective 3, METIS-II is using its worldwide recognized brand in the 5G arena to start preparing a framework where future standardization works will be impacted; METIS-II partners are leveraging the experience gained in the project to influence the standardization of 5G in the respective standardization and regulatory bodies. The consortium is providing input to the 5G requirements work of ITU-R Working Party WP5D, and will exert a strong influence on 5G related study items and work items in 3GPP Releases 14 and 15. Furthermore, throughout the project, reports and deliverables from the METIS-II spectrum activities will exert substantial impact on World Radiocommunication Conference (WRC) 2019.

2.2 METIS-II evaluation and visualization objectives

The standard approach for cellular technology evaluation typically considers a hexagonal cell layout [ITU-R08-M2134]. There exist proprietary but calibrated link and system level simulators, commonly written in Matlab, C/C++, etc., 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 [WIN207-mod]).

However, the hexagonal cell layout might not be sufficient in some cases when it is required to reflect the intricate details of the scenarios [MRC+05] that allow for a realistic evaluation of a given technology [MFR07]. 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.

Further, some of the 5G concepts discussed in METIS-II (and 5G PPP) are abstract and difficult to demonstrate in the form of experimentation without showing interactions of different network elements in vast areas (e.g., virtualization, cloudification, etc.). There are also concepts considered which adapt to different deployment scenarios and use case specific context (e.g., context awareness) only possible when a wide range of technologies developed outside METIS-II are also integrated.

Thus, in a broader sense, the key objectives of evaluation and visualization in METIS-II are:

- To demonstrate the 5G concepts discussed in METIS-II in relevant 5G use cases under realistic evaluation models.
- To illustrate the gains for verticals and/or virtual network operators and customers and provide experience to the broad public.
- To enable and simple and effective means of interaction with other research teams outside METIS-II.

2.3 Introduction to the METIS-II evaluation and visualization concept

Since the very beginning of the design of mobile communications technologies, system simulations have been used to test different technological solutions. Their simplicity and reduced cost, as compared with prototyping, motivate their use in the early phases of the design process. To make them tractable, simulations are usually divided into link and system-level simulations, where the former primarily focuses on the physical layer aspects (mainly waveform and channel coding) of a single link, while the latter considers the evaluation of large networks with many communicating nodes, but typically using a strong abstraction of link level details.

Traditionally, from the whole set of system requirements defined for a technology, even only a subset of them is already too complicated to be evaluated analytically and this is when the simulation methods are needed. In the past, considering the IMT-Advanced (International Mobile

Telecommunication) experience, these requirements are usually related to cell spectral efficiency, cell edge user spectral efficiency, mobility and certain traffic capacity, all of them evaluated in synthetic (thus simple) scenarios consisting of a hexagonal layout of cells [ITU-R08-M2134]. The way in which the research community and engineers are representing these metrics is through Cumulative Distribution Functions (CDFs) or other statistics that could be interpreted by experts.

This typical approach has two main drawbacks derived from the use of synthetic scenarios and the type of metrics used to assess the performance of the system. (1) Concerning the scenarios, past experience with other study works performed in 3GPP have shown the need for a proper characterization of realistic effects [MIC+15]. 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 [MET13-D61][MET15-D65][MET16-D21].

(2) Regarding the representation of the performance statistics, previous experience from fairs and other events shows that engineers usually make the mistake of not being able to make 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 urgent need for tools that will demonstrate the importance and impact of the new technology components that are proposed in METIS-II and other research projects.

In contrast to past research, where mobile systems were evaluated for somehow artificial hexagonal cell layouts with static user populations, solutions for 5G will have a chance for evaluation in realistic scenarios from the very beginning, reflecting the challenges but also the opportunities that 5G will face in its deployment phase [MET13-D11][MET15-D15] [MET16-D11]. This approach will allow evaluation and visualization of scenario-specific and context-aware functionalities that would not show any benefits in regular cell layouts. An example of this would be the management of hot-spots, where a regular layout is not able to deal with all the generated traffic, whereas ad-hoc deployments usually exist and must be integrated with the rest of the network.

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, and how to present and visualize the results so that the audience can understand the achieved gains. Here, METIS-II decided to introduce a new performance evaluation and visualization approach of the radio network characteristics and capabilities based on serious game engineering using a professional rendering and gaming platform, UNITY 3D (see more details in Section 3.1).

The role of the UNITY 3D game engineering tool in METIS-II is manifold:

- it simplifies the definition, implementation and parameterization of complex 3D use cases and scenarios following a “what you see is what you get” approach,
- it allows simulating and evaluating many of the developed solutions by embedding “plug-ins” comprising models of the radio network algorithms and characteristics,

- it simplifies the visualization of the results and allow to experience the achievable performance from a user (first person) as well as bird perspective,
- it allows live interaction with running simulation helping researchers in METIS-II to better understand the impact of certain concepts,
- it enables a simple exchange and sharing of 3D models and plug-ins, thus fostering collaboration within METIS-II and with other projects and groups, and
- finally, it provides a tool for training, education and for demonstration that builds on our experience and cognitive skills developed when using games.

Being able to apply a serious game engineering approach to new concepts (like said technological advances) simply makes them accessible to wider audiences. By being accessible, the new ideas also become easier to test (in either simulated or close-to-real-life situations) and comprehend, making them open to creative input from early adapters and future users (verticals, service providers).

Application of such an approach calls for appropriate tools that would be open for wide user spectrum and easily accessible. One of the better examples is the UNITY 3D environment that is not only well forged for visualization purposes, but is also cross-platform, open source and utilized by millions of users. Though it might seem a gaming engine and development tool would be best applied to entertainment gaming, it is already used by architecture, construction and engineering industries for simulations as well as medical and security domains for building virtual environments accompanied by complex data.

To sum up, the inclusion of the 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 users for real time interaction with simulated environment. 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.

2.4 Interaction outside METIS-II

As stated in Section 2.2, one of the visualization platform's declared goals is to make it accessible to wide user spectra. As research, evaluation and use case creation aspects are the ones most outside-METIS-II parties might benefit from, it was important to think about them from the very beginning. The concept of traces responsible for definition of the scene (and objects) as well as the interactions between the elements defining use cases turned out to work well even at considerably early stage of the platform's development (roughly 6 months after that METIS-II started – Mobile World Congress (MWC) 2016 demo case). Trace-based definitions enabled all METIS-II to prepare relevant presentations visualizing concepts, KPIs and focal areas of interest.

With the above in mind the visualization platform is still evolving in the direction that would enable any entity to visualize and evaluate their concepts. After the data structure is ready to interact with any compatible data source i.e., local file, remote file, database, interfaced simulator, etc., it will only be a matter of preparing documentation guiding users on how to connect the data to the object library found within the platform's engine (this work is ongoing with first documentation version already shared between METIS-II partners) and how to tweak the data (define interactions between data portions) to reflect any use case's impact on the defined situation. It is, in consequence, natural for the platform to be ready for the outside-METIS-II interactions.

The interactive visualization and evaluation platform is envisioned to be implemented as a flexible entity with guidelines for other projects to use the platform to plug-in their respective use cases and concepts. Providing open access to the visualization platform across other 5G PPP projects and consortia is done through the METIS-II web page (https://metis-ii.5g-ppp.eu/documents/simulations/). The executables and relevant (sharable) codes are available in the server so as to reproduce the visualization made in the project. Once the interface with other simulation tools is ready, a new link to a server for exchange among researcher operating with the visualization tool will be made available to the public on METIS-II website.

Further, proper documentation and guidelines are to be hosted in appropriate places along the shared code/executables in SVN to help new users from projects outside METIS-II to have a better understanding of the platform and experience ease of usage.

3 Visualization platform overview

3.1 Introduction to UNITY 3D

UNITY 3D is a development platform for rich interactive experiences. Initially perceived as a game development engine, it quickly became a powerful tool for creating multiplatform multimedia environments, where the idea of gaming turned into a path of reaching higher goals like simulation, learning, design and evaluation (which became a strong supporting pillar for the idea of "serious game engineering").

Today with UNITY 3D's gaming market share of 45% [UNITY-pub] (4 million developers, 600 million gamers) it is safe to state that the technology is not only well tailored but perfectly suited to cater for the users' needs. While it would be risky to name UNITY 3D the standard and universal solution for creating visualization tools, it most definitely does not have the flaws of previous "supposed standards" like Flash [FLASH]. It's instantly accessible on mobile devices, its focus on 3D does not limit its 2D capabilities, it is already supported by quickly growing communities and until today no major security flaws have been detected. What is more, there are many performance tweaks that can be applied before UNITY 3D applications are launched, which opens them to wider audiences. Performance tweaks (which means quality settings and the ability to optimize the visual outcome like 3D models even after the platform has been finalized) would allow optimizing the tool to work on older or weaker machines. It could potentially also mean that some parts or aspects of UNITY 3D tool could be presented on mobile devices after changing quality settings and/or minimizing the detail level of models used for visualization. No other technology before allowed for such flexibility at the later stages of development.

UNITY 3D's market applications are not limited to gaming. Even a brief video presenting its non-game show reel (https://www.youtube.com/watch?v=CLPBFlA1DAw) can give the viewers ideas on how complex data, detailed environments and sophisticated interactions come to life, limited only by the imagination of creative minds behind each project. Architecture, interior and industrial design, management, data analysis, training and education are only a few areas where UNITY 3D is used and applied nowadays. That is what makes the platform a perfect tool for visualization and evaluation tasks within the METIS-II project.

As METIS-II is strongly aimed at showcasing the impact of future technologies on our environment and educating people on what to expect in the coming years, UNITY 3D also seems very adequate in this field. Open to both users and developers, responsive to technological changes (and strongly present in the mobile domain), compatible with open source programming and modelling software (like Blender) [BLEND], it guarantees that the outcomes and findings of METIS-II will be easily accessible and usable for future purposes (further development, evolutionary and derivative works, etc.), for instance, in further phases of 5G-PPP. It will also help the stiff models understood by industry engineers evolve into beautiful visual experiences accessible to wide audiences. What is more, UNITY 3D will make it possible to turn demonstrations into interactive tools, which in sequence should initiate faster learning processes and adaptation of concepts stemming from 5G applications in the near future.

3.2 Users and interaction paradigms

METIS-II is by nature a project targeted to both, specialists on 5G (industry engineers, technology experts) and non-specialists (technology end users, vertical industries, regular people) alike. This assumption has to have an impact on how the project's outcomes are presented and communicated.

It is presumed that there are three distinctive user groups to whom METIS-II's visualization platform is address. Each group has their own interaction paradigms as well as behavioural schemes based on their knowledge level and role they play in the process of METIS-II dissemination.

1. **The Viewers (and the Presenters)** - this group is the main target audience for the visualization platform. We presume it consists of non-specialists (wide audience presentations for end users) and specialists (operators, providers, etc.) to whom the METIS-II outcomes is presented. They do not have any active influence on the use case presentation and they experience the visualization platform assisted by an educated presenter.
   The Viewers' interaction with the platform is thus limited to picking a use case from a list and being able to pause the presentation along the show. They could also highlight the important marked presentation areas to get access to the data relevant to the use case being shown.
   The interface available for the Viewers reflects these needs and does not allow them to get access to any editing tools as it could have a negative impact on the presentation flow. The visualization platform is open for anyone as a presenter.

2. **The Editors** - this group mainly consists of specialists whose knowledge would allow rebuilding or updating the use cases with additional data or parameters. They can also have the ability to influence the placement or amount of the objects on the scene if any use case requires such alterations. After the project will be finished, they would be able to create new use cases within the set of objects and parameters already defined within the platform.
   The main challenge in defining the role of the Editors is defining the scope of creative freedom they can have in affecting the defined use cases. Too many possibilities means performance risks for the platform itself. It can also easily lead to the possibility of creating instances making no sense from the research perspective. On the other hand, limiting the creative freedom too much could turn the platform into a mere animation player. The reasonable solution should be based on the presumption that each use case has limits in which the amount of elements and the ranges of data could be applied. There could be defined "sockets" into which the new elements can be fit without risking random or unexpected outcomes. And when it comes to parameters, they can be restricted to realistic ranges and relevant to the use case at the same time.

The Editors' interface gives them access to the editing tools as well as object libraries. They are able to save the new use case instances and to test them before making them available for presentation. They also have to be able to influence the objects' parameters in order to set or test different settings of the use case and its components. The accent in such interface should be put on usability, as it would have to be accessed by different specialization experts and people of different focuses.

The Editors' access to the platform is restricted by a user / password mechanism to avoid the risks of random (or unconscious) error generation.

3. **The Developers** - this group is (at least for the duration of METIS-II) be limited to the visualization platform's developers responsible for the evaluation task. They do not need any interface, as they access the platform from the code or scripts level of UNITY 3D (or any other relevant or compatible data sources). With this presumption, not much needs to be stated at this point, as the ability to further develop the visual platform in the future would be based on the code accessibility. The Developers are responsible for determining the platform's structure, the use case definitions and performance optimization. Their task is to define the data exchange models and integration schemes. In theory, they have the unlimited control over the platform as long as it is synchronized with METIS-II's requirements.

Other than the user role definitions the overall presumptions applied to the visual platform's traits should be tied to accessibility, usability and legibility. From the very beginning the platform's visual layer should clearly communicate the use cases' focal areas. The information layer should speak to all the user groups providing them with the information they could be looking for (e.g., evaluation purposes) without overwhelming any addressee with hard-to-digest data streams.

3.3 Components of use cases and their implementation

Components refers to the parts of a scenario (e.g., pedestrians, buildings, cars, etc.) that need to be modelled as 3D objects in UNITY 3D. The components can be broadly classified into physical domain and logical domain. The components captured under physical domain are actual physical objects that can be visualized in the scenario. The table below depicts the exemplary components in the physical domain and their respective models.

Table 4-1: Table of exemplary physical components and models of their attributes.

Physical Components	Models
Traffic lights	Switching of the traffic lights, appearance
Pedestrians	Movement of pedestrians, appearance
Cars	Mobility of cars, appearance
Physical antenna	Antenna model (physical elevation, position etc.), appearance
Buildings	Building model (height, width, length, etc), penetration model, reflection model
Streets, lanes	Model describing length, width, etc.
Parks	Model describing length, width, etc.

The components captured in the logical domain are essential parts of the communication network that can belong to one of the Network Elements, Network Communication Behaviour and Status or Network Performance categories. The exemplary components in the logical domain are listed below separately for each category.

Table 4-2: Table of exemplary logical components (network elements) and their models.

Network Elements	Models
Logical antenna	Model dictating antenna steering, antenna tilt, antenna adaptation, antenna diagram, etc.
Routers	Router model (position, texture, etc.)
Wire lines, cables	Length, size, texture, etc.

Table 4-3: Table of exemplary logical components (network communication behaviour and status) and their models.

Network Communication Behaviour and Status	Models
Link	Model showing state of wireless link between users and antennas
Side link	Model describing state of a wireless link between users
Antenna beam	Model describing beam width, direction, etc.
Coverage area	Model depicting coverage area of base stations

Table 4-4: Table of exemplary logical components (network performance) and their models.

Network Performance	Models
Link throughput	A component that visualizes the throughput of a single user link
System capacity	A component that visualizes the overall system capacity
Link delay	Model describing delay in a specific link
Cell load	Model describing the load present in a cell

For the time being the implementation details and the relevant use cases are not discussed. These aspects will be covered in Deliverable 7.3.

4 Visualization platform with pre-computed simulation results

One of the main ideas behind the need of having a visualization tool in METIS-II was stepping away from “illustrative” approach in which data was interpreted first and then shown in form of graphs, schemes, slides or videos at the best. Such approach (though not invalid at the core) required starting from square one each time the data changed or was influenced by new findings and / or outcomes.

As the building blocks of 5G are driven by technological evolution, it became important for the data to be interpretable and properly visualized on almost daily basis. From this perspective it became important for the visualization platform to be able to adopt changes in the data dynamically and universally, the logical first step being interpretation and visualization of the existing pre-computed simulation results brought to the table by METIS-II’s partners.

4.1 Reflecting initial presumptions in the development process

From the very beginning it was clear that the visualization platform would have to be able to aggregate and streamline the message that was, until it was created, passed through many different visual tools and channels (2D animations, system views, separate graphs, various visual systems relevant to different technological aspects of what similar projects were to communicate). As METIS-II is a research project it was not easily possible to “gather all requirements” at the very beginning of the visualization based task. The project partners had to come up with presumptions allowing the first steps to be made.

Many of the presumptions came from the METIS project, which helped not only to narrow down the (seemingly countless) possibilities but to make them relevant from the very beginning. The presumptions defined scales at which visualizations made sense (both in quantity and quality sense) as well as enabled early UNITY 3D based prototypes to come to life. This, in sequence, made testing and evaluation processes possible from the very beginning, as well as helping to create the first METIS-II demo for ICT 2015 (“Innovate, Connect, Transform”) 2015 conference in Lisbon (roughly 3 months after the project started in July 2015).

4.1.1 Recreating "Madrid Grid" environment within 3D space

One of the presumptions mentioned above was to utilize the test environment known as "Madrid Grid" used for simulations and some demonstration purposes since the first METIS project [MET13-D61][MET16-D21]. The environment reflects (though in a simplified way) aspects of a real city conditions and its scale allows for valuable observations, tests and evaluations to be conducted. As the environment was originally described by a 2D simplified top view (restricted to rectangles representing buildings and dots acting as pedestrians, eNBs, etc.) accompanied by data definitions of building heights (needed for simulations), the challenge was to recreate it in a 3D space. Figure 4-1 represents the top-view of the Madrid Grid scenario.

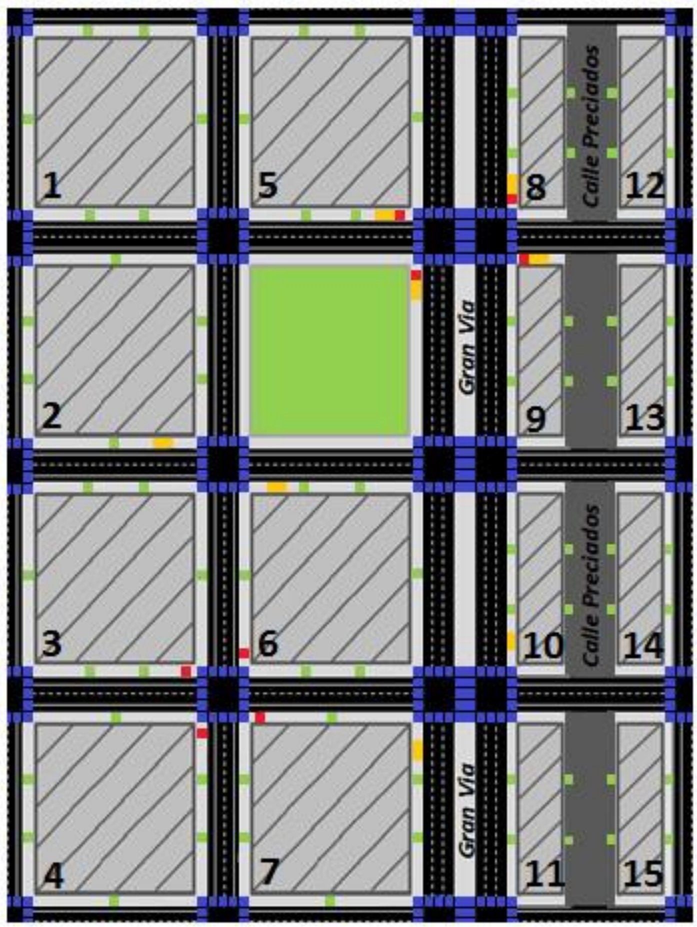

Figure 4-1: 2D top view of the Madrid Grid scenario [MET13-D61.

The purpose was not only for the environment to just look better, it was most importantly about making all the components "visible" for users. One more feature taken into account at that point was to allow for the ego perspective (or first-person view) to be introduced into the visualization platform, which in consequence would make the data analysis perceivable from any scale.

The first step to achieve this goal entailed extrusion of the 2D top view using height parameters tied with specific buildings. This created a simplified 3D model of the city, as illustrated in Figure 4-2.

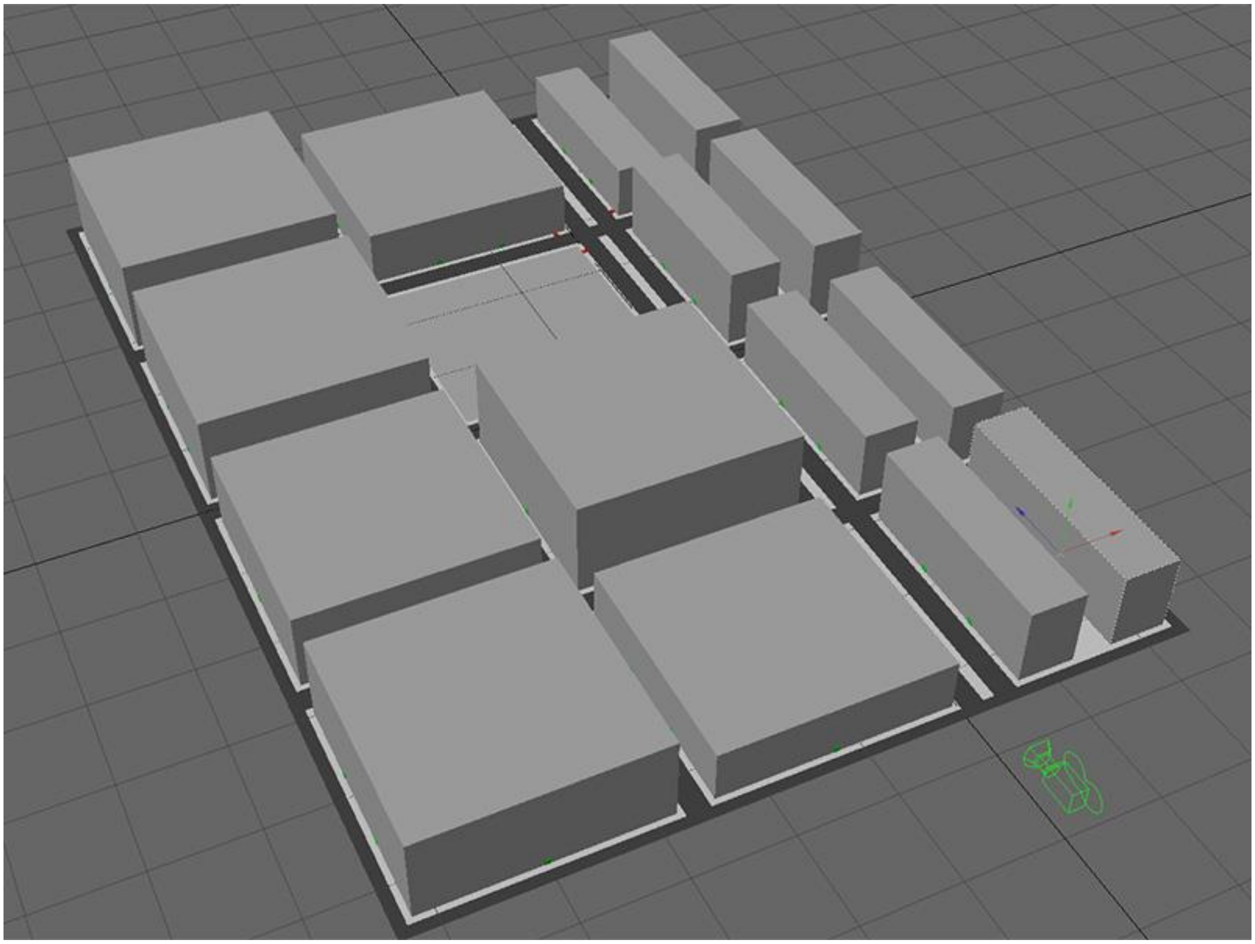

Figure 4-2: Simplified 3D model.

Next, it was about analyzing the real photos of Madrid buildings, which allowed for creation of more realistic building models and bringing them onto the scene. Figure 4-3 shows and example of one of the buildings used in the visualization tool.

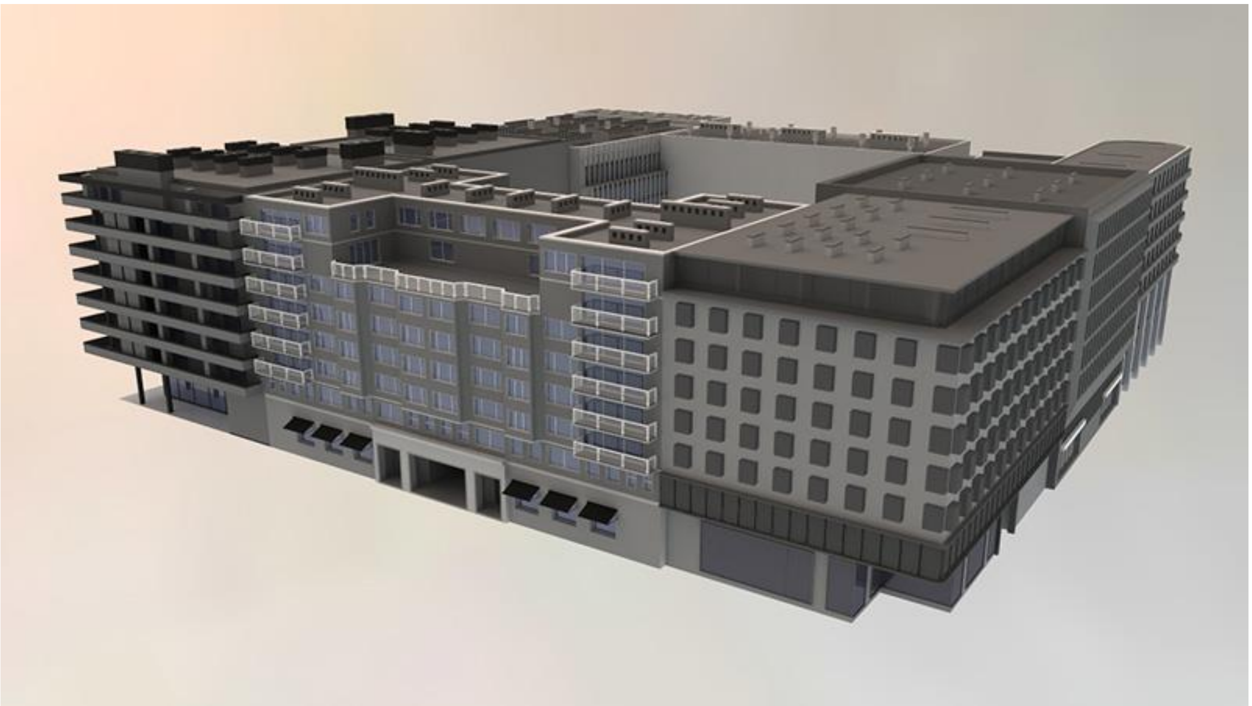

Figure 4-3: Example of a building.

Adequate representations of lamp posts, metro entrances, cars, pedestrians and buses, as well as other more detailed models, were created in 3D processing software (like the open source Blender [BLEND]), which brought the Madrid Grid closer to what users are acquainted with in real life. Fine-tuning of lighting and camera parameters coupled with the addition of sky and street textures brought the city model to life and closed the initial chapter of Madrid Grid recreation in 3D space.

Soon it became obvious Madrid Grid could easily be replaced and / or adapted in the future to achieve considerable flexibility based on a given use case's requirements.

4.1.2 Establishing basics of the information layer

Much as recreation of the test environment made it possible to bring METIS-II closer to users and wider audiences, it alone would not be enough to communicate the project's outcomes effectively. Apart from the real life objects (buildings, cars, pedestrians, etc.) needed for the demonstrations to have a valuable influence on the viewers, a set of visual language tools had to be designed to familiarize audiences with more ethereal or abstract beings such as connections, coverage ranges, signal quality designators, propagation patterns and other parameters related to the RAN area.

This became a basis for discussions on how to visualize such concepts, how to make them compatible with the already existing 3D environment and how to make their representations “speak” clearly to the Visualization Platform’s users. It was also a challenge to think ahead, as the visual language used for these purposes should be not only universal, but also ready to evolve along with the METIS-II findings.

That is when the idea of the information layer came to life, and its principles started to be established.

Figure 4-4 shows an example of information layer, where we depict links with circles and lines and the coverage of a station with a sphere. There are not actual and physical things to be perceived in a real world, but their inclusion helps the user understand better the scene.

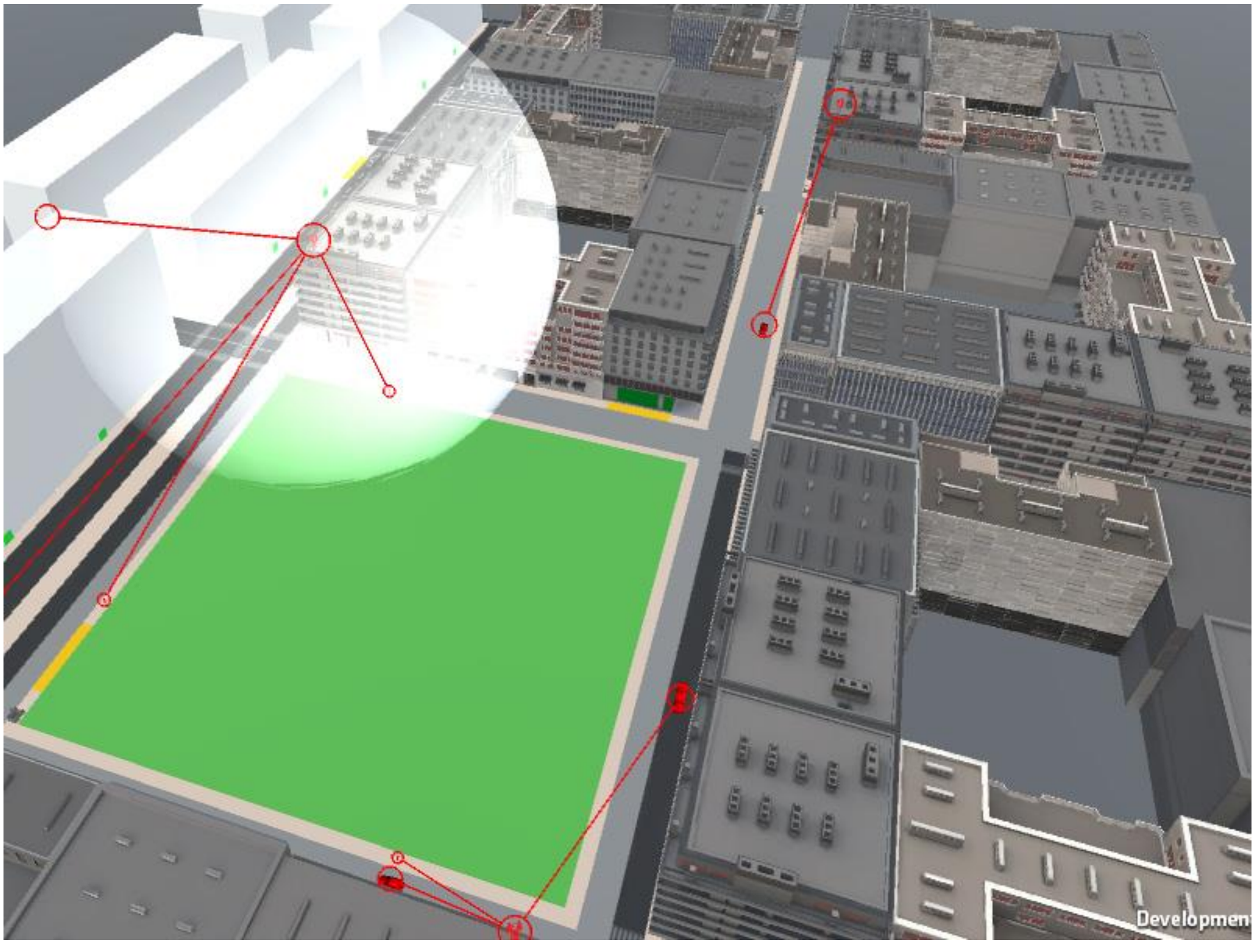

Figure 4-4: Information layer in the Madrid Grid.

Figure 4-5 shows how the Visualization Platform's layers were planned to be developed in METIS-II. Though this approach was proposed by the platform's developers, it's logically tied to how Unity works and how the best practices dictate to develop rich visual environments built on data exchange. The logical layer is (until the Visualization Platform's development is concluded at least) only accessible to the developers (thus why it's shown below the "red line"), while all the other layers are in theory opened for the outside world. It's within the layers 2, 3 and 4 where the new use-cases are defined. Layer 1 should be considered the core, where the information coming into the platform is being processed before being visualized.

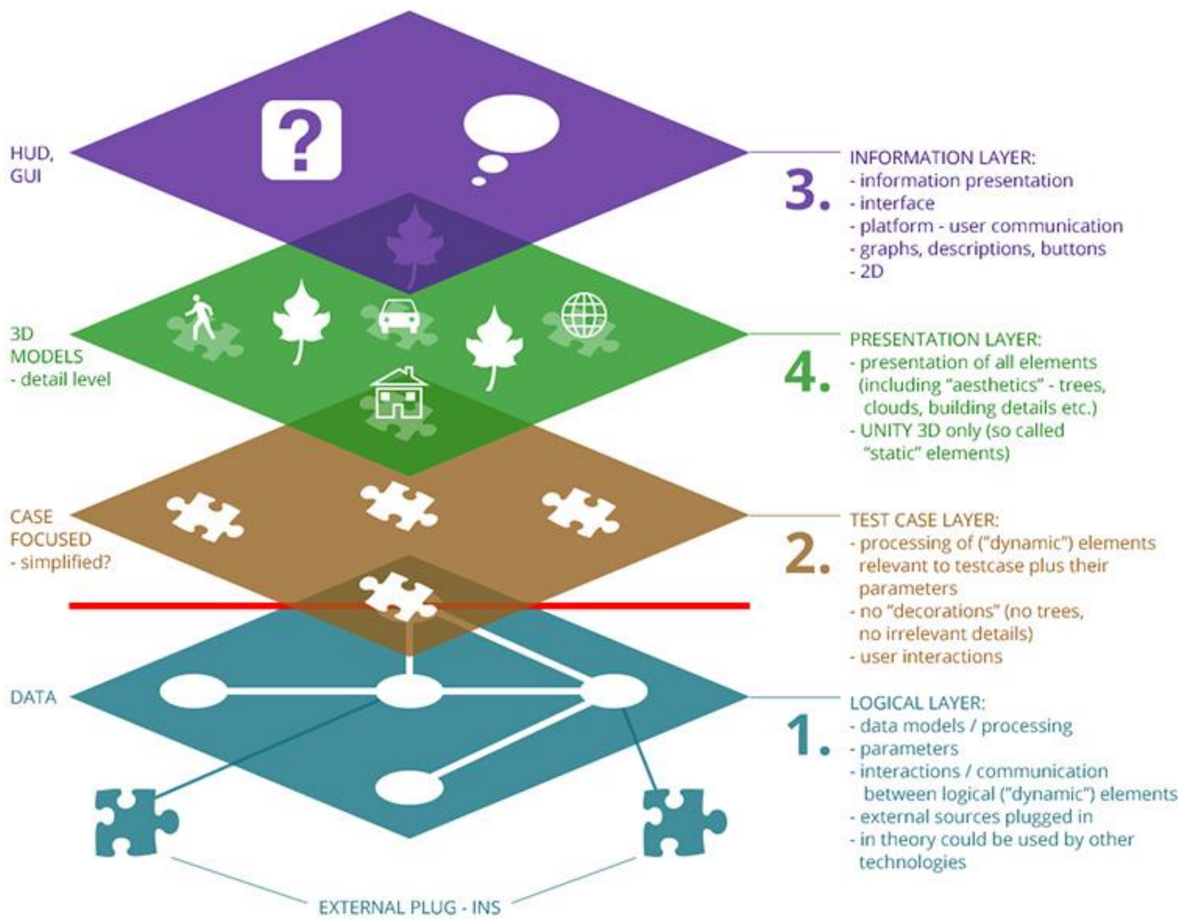

Figure 4-5: Different information layers used in METIS-II visualization platform.

Begun with the obvious consensus (lines of different colors can be used to show connections between devices) and going through more abstract decisions (e.g., how to represent different service types with icons) an initial library of graphical elements was created (Figure 4-6). The elements from then on were used to support the storylines and values critical from the use cases perspective.

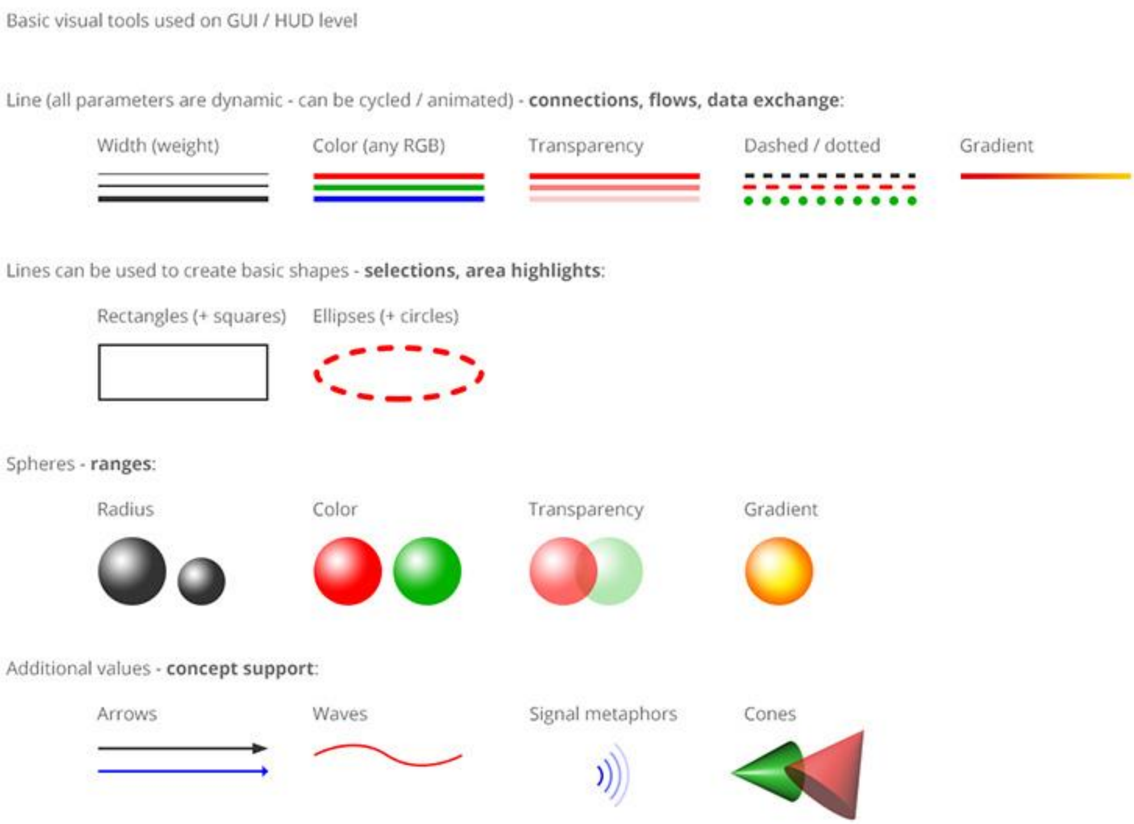

Figure 4-6: Basic visual elements used in the METIS-II visualization platform.

This approach helped enrich the 3D environment with the "visible" data elements and to establish understandable standards for the current and future visualization platform users, like shown in Figure 4-7.

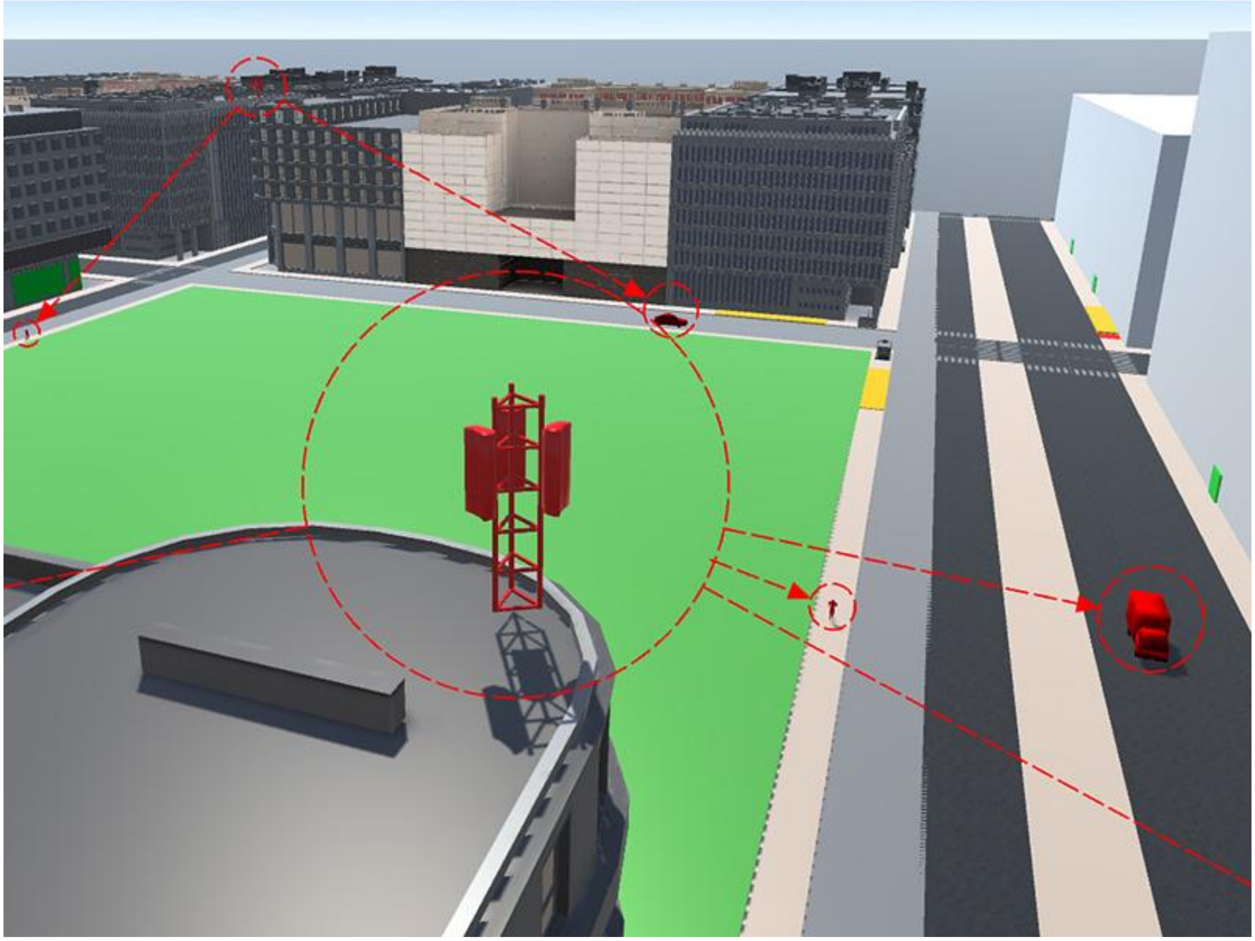

Figure 4-7: Enriched visible data elements.

4.1.3 Establishing user interface principles

Another important step in the visualization platform's development was establishing the principles of the user interface design. As the presentation and interaction layers themselves are rich with visual elements, the interface could not stand in the way of the proper perception. On the other hand, it has and had to support users in the field of navigating through the tree–structured content (use-cases divided into categories and sub - categories), minimizing the risk of them feeling lost.

The first step was to come up with the idea of a simple and easily scalable interface (Figure 4-8). It was also important for the interface not to influence the overall performance through complex visual or interactive features. With these presumptions the initial version of the user interface was created which turned out to be well perceived by the platform's users. Its simplicity allows for flexible tree structure creation and adding / removing or editing the content of the interface items is very easy. The interface elements are also behaving well independently of the resolution the platform is presented in.

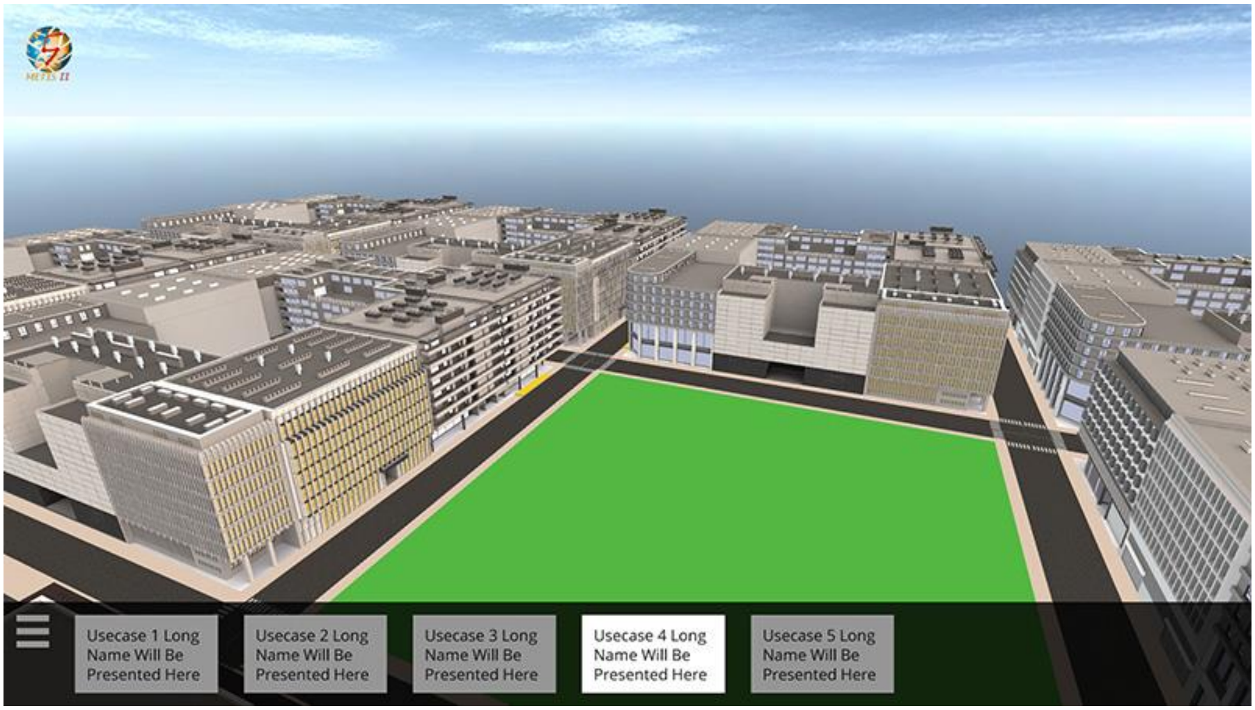

Figure 4-8: Structured contents in the visualization platform.

Later it became obvious some additional user interface elements would be needed (like the timeline control, the trace playback speed slider, side data panels, etc.), but the initial presumptions turned out to allow for flexible changes and the open user interface approach (Figure 4-9). Of course usability optimization might become necessary at the later steps, but the principles established at the very beginning seem to be passing the reality check. This approach also allowed for contextual interface element creation (like graphs used in some use-cases).

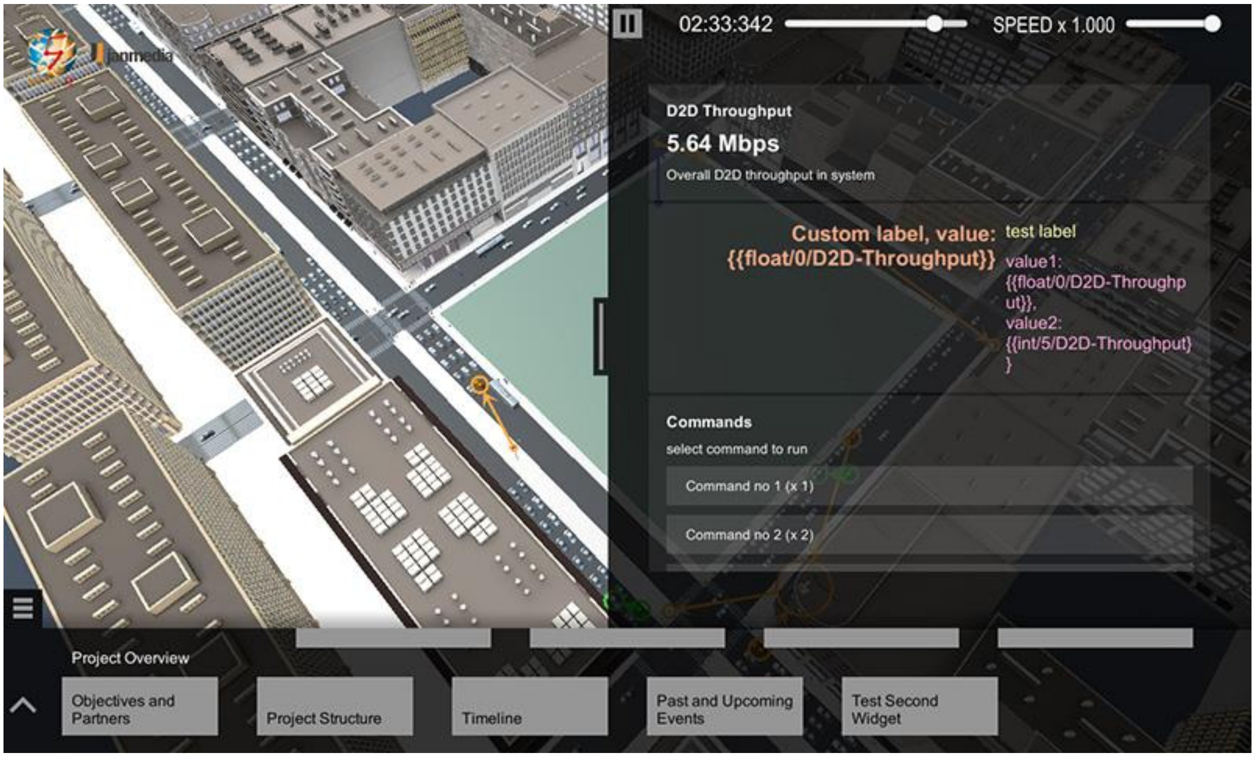

Figure 4-9: Example of interaction layers.

4.2 Early demonstrations made possible

Though at the beginning of the project it was expected the first demonstrations using METIS-II's visualization platform would be possible around month 12 of the project's lifetime, the approach and principles described in the previous chapters turned out to work in favor of the dissemination needs. The first presentation of METIS-II's outcomes and findings took place roughly 3 months after the project officially started (ICT 2015 in Lisbon) and by the MWC 2016 (only 3 months later) the visualization platform was ready to run data driven demonstrations based, in some cases, on the simulation results delivered by the consortium partners.

4.2.1 ICT 2015 – scripted demonstration

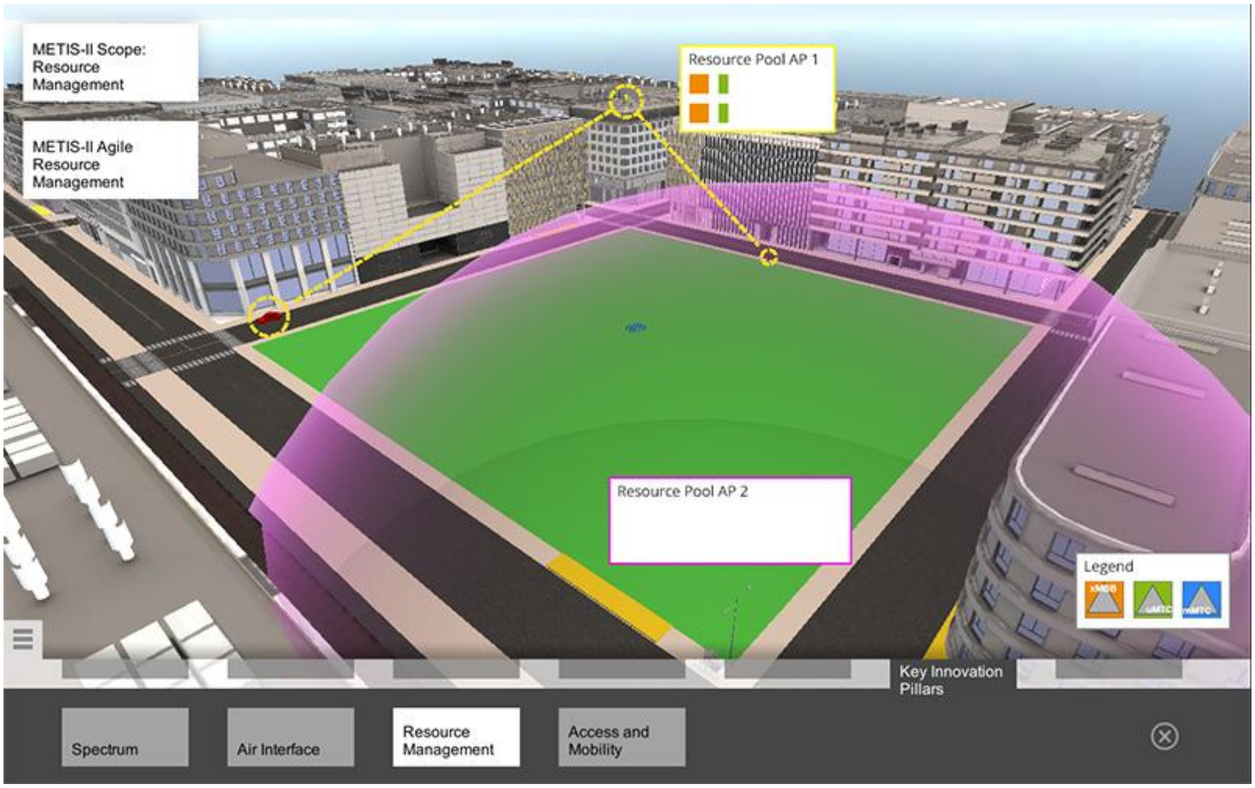

Figure 4-10: First demonstration of METIS-II visualization platform in ICT 2015.

The demonstration for ICT 2015 was based on descriptions of problems covered by METIS-II's proposal document. Though not yet showing simulation results, the demonstration turned out to communicate well with the wider audiences and allowed for flexible idea illustration. Each work package of the project summarized the storyline around which the presentations were built, and the scripted scenarios were extracted for visualization purposes.

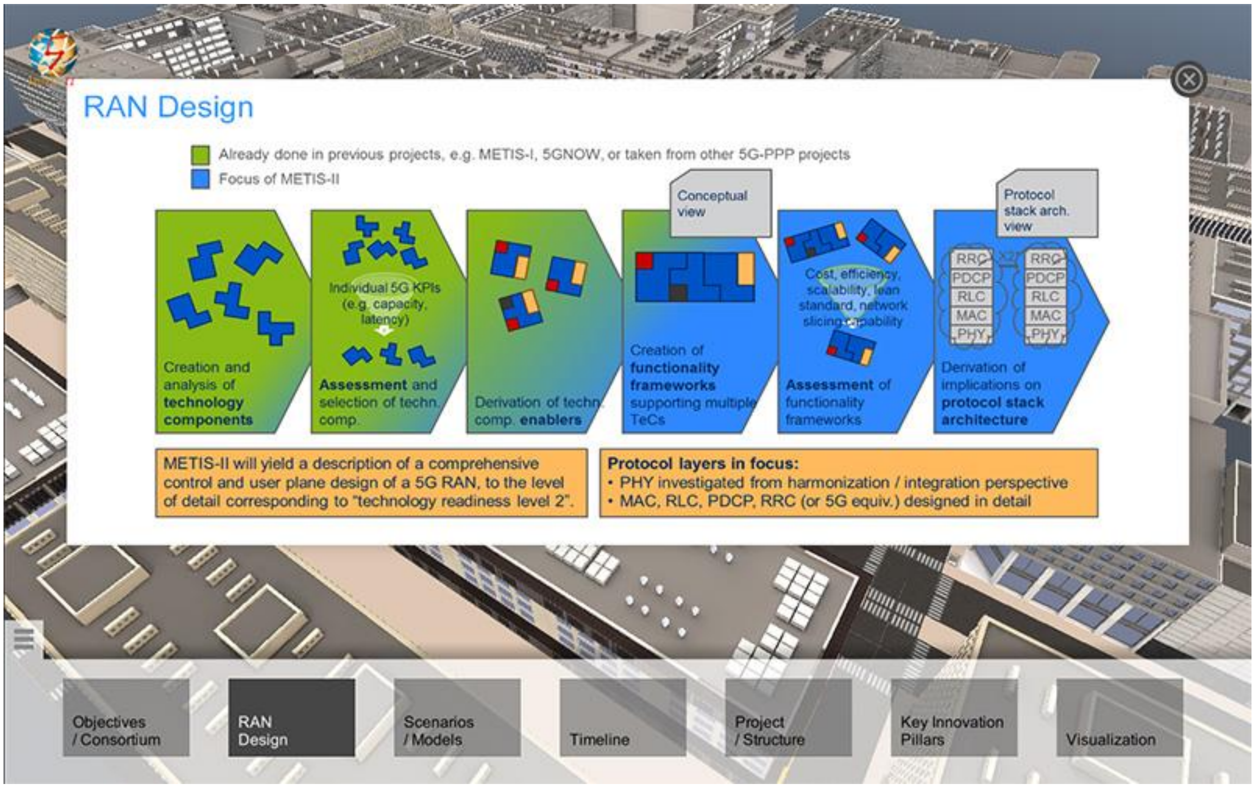

Figure 4-11: Screenshot of the static material shown at ICT 2015.

The initial phase revolved around discussions leading to high level descriptions of specific area of interest focal points. This allowed the relevant visualizations to be created. The last stage was about fine-tuning the presentation parameters to best reflect the anticipated KPIs as well as the declared innovation pillars of the project. At the same time the corresponding descriptive material was prepared and brought into the visualization platform for clarification of more data rich explanations.

4.2.2 MWC 2016 – trace based demonstration

At MWC 2016 (February 2016) the visualization platform was already able to visualize use cases based on data traces generated by the consortium partners. Thanks to xml based definition module and more open data exchange architecture the level of freedom was reached in which, in theory, any party familiar with the visualization platform's early documentation could turn their data into demonstrations.

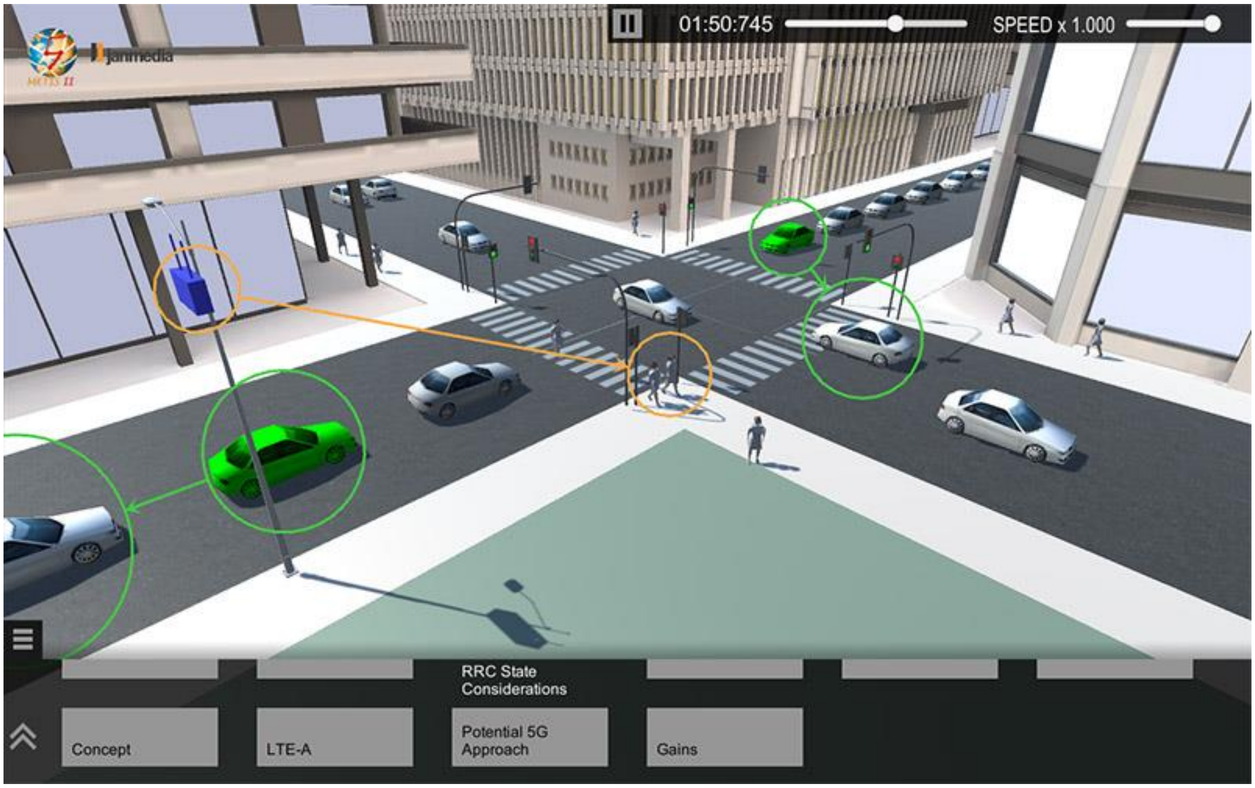

Figure 4-12: Screenshot of the trace based simulation shown at MWC 2016.

The freedom aspect allowed the parties not directly engaged in the visualization platform's development process to create presentations according to their needs and the METIS-II's objectives. Additionally, this led to the stage in which the platform could be made universally available, which was realized via the METIS-II website downloads section. In the future it might mean the visualization platform could be used for purposes reaching beyond METIS-II findings and outcomes. For example, one of the partners, after the MWC, developed their device-to-device (D2D) communication use case in their simulator. Then, the visualization platform of MWC was used to show the performance of such solution and use case.

Figure 4-13: Olav Queseth, METIS-II coordinator, showing the visualization tool to some members of the European Parliament at MWC 2016.

The MWC presentation turned out to be a success both in terms of communicating the project's initial presumptions and showcasing the first consolidated results of the research process carried out within the technical work packages. It also enabled first users to interact with the platform and to get acquainted with the knowledge base elements present behind the presentation and information layers of the demonstrative tools. More than 50 formal visits were received in which the visualization platform got most of the attention.

4.3 Android platform

MWC 2016 was also an occasion to test the elasticity of UNITY 3D environment beyond what was initially foreseen. As the project concluded, it became necessary to test the ability of the visualization platform to be moved to mobile device like a tablet. Being able to use tablets for demonstrations (phones, with their size limitations and computing power restrictions were from the very beginning not considered a priority) could simply have a very positive impact on the METIS-II's dissemination and wide reach processes, not to mention its ability to be more conveniently communicated. After a relatively short period (2-3 weeks) a stable Android application build was compiled and successfully tested on popular tablets. It was then distributed among the consortium partners and presented during the following conferences and panels. In the meantime, the “regular” visualization platform was successfully installed on a Windows-based tablet.

The porting of the platform to mobile devices has proven that the decision of developing METIS-II’s visualization platform in UNITY 3D environment was not only good from the visual perspective but also a decision that made the environment universally accessible, elastic and flexible. Given the structure of the application, it will hopefully also mean the solution will become “future-proof”, as the UNITY 3D development tools evolve along with the current technologies and devices utilizing them.

Figure 4-14: METIS-II visualization tool running on an Android device.

5 Further steps and roadmap

The next big challenge for the visualization platform in year 2 will be to go from pre-computed simulation processing to real-time data interpretation. To achieve this goal much more stress would have to be applied to data exchange mechanisms and testing phase. Though it might seem initially complicated, the first tests and conclusions seems promising. And with the ultimate goal being building the tool that would allow for universal and standardized approach, the effort should be perceived as worthwhile.

5.1 Interface to simulation tools

One of the key objectives in METIS-II project is to enable the 5G concepts to reach and convince decision makers from non-ICT industries. 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 platform allowing users to visualize 5G enabled scenarios is hence desired for better understanding of the concepts from both industrial marketing and academic perspectives.

The existing simulators do not have provision or have only limited provision for visualization of considered scenario and dynamic run-time interaction with simulators. These limitations of existing simulation frameworks 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 areas (e.g., virtualization, cloudification, etc.). 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.

The key idea is to develop a framework allowing the simulator to interface with visualization front end (specially designed UNITY 3D-game engine) to render entities assumed in simulator as visual elements at the front end. This framework will provide dynamic 3D visualization of scenarios considered in the external simulator by rendering logical and physical components assumed in simulation scenario at the visualization front end. Further, the KPIs of the considered 5G technology component will also be made available for visualization at front end, in the form of numerical graphs or plots. The interfacing of simulation can however be either dynamic (real time) or pre-generated.

Figure 5-1: Simulation scenario interfaced to visualization front end.

Figure 5-1 depicts the key idea of interfacing simulations to visualization front end. The geometry layout and UNITY 3D objects (static & dynamic) constitute the visualization scene, rendering logical components (e.g., base stations, mobile users, links, etc.) assumed in simulation, as visual elements. The dashboard allows visualization of KPIs associated with considered simulation.

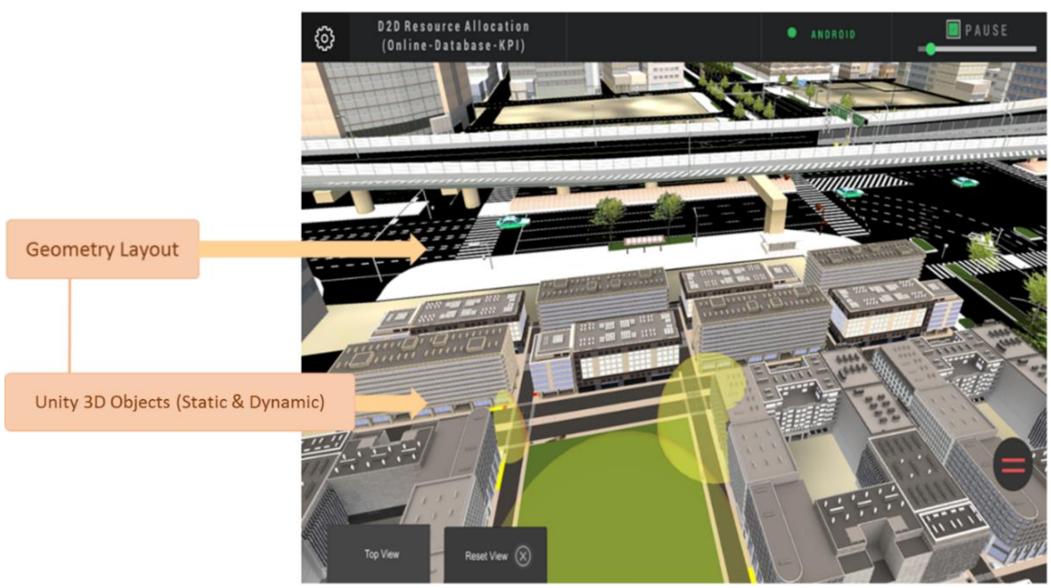

Figure 5-2: Plug and play feature.

Figure 5-2 shows another example of interfacing simulation data to visualization front end. It could be seen that based on UNITY 3D objects and geometry layout data interfaced to front end, visualization scene would change. This exhibits the potential of the platform to be used in plug and play fashion.

From the simulator perspectives, the purpose of interactions between the simulator and UNITY 3D is three-fold. The first is to provide real-time simulation results as feed to UNITY 3D. The second is to establish the signaling exchange protocols between the simulator and UNITY 3D for enabling simulation environment settings from UNITY 3D and also enabling visual evaluation of target methods which are implemented in the simulator. The third is to provide interactivity between the simulator and UNITY 3D, meaning that through user defined interface in UNITY 3D, users are allowed to re-configure simulation environment settings during run time and observe simulation results in real-time, which are generated from the simulator based the new simulation environment configuration. Based on the second and third purposes, the further steps are detailed in Section 5.2.

5.2 Run-time interaction with simulation tools

The proposed framework allows the viewer to interact with network elements and non-network objects (see the difference in Section 3.3) in the considered scenario, by immersing the viewer into the 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. Figure 5-3 shows an example of D2D resource allocation simulations interfaced with the visualization platform.

Figure 5-3: Example visualization of D2D simulation.

The front end also allows clicking on a specific UNITY 3D object (e.g., pedestrian user) to enter ego mode and experience visualization from that user's perspective as depicted in Figure 5-4.

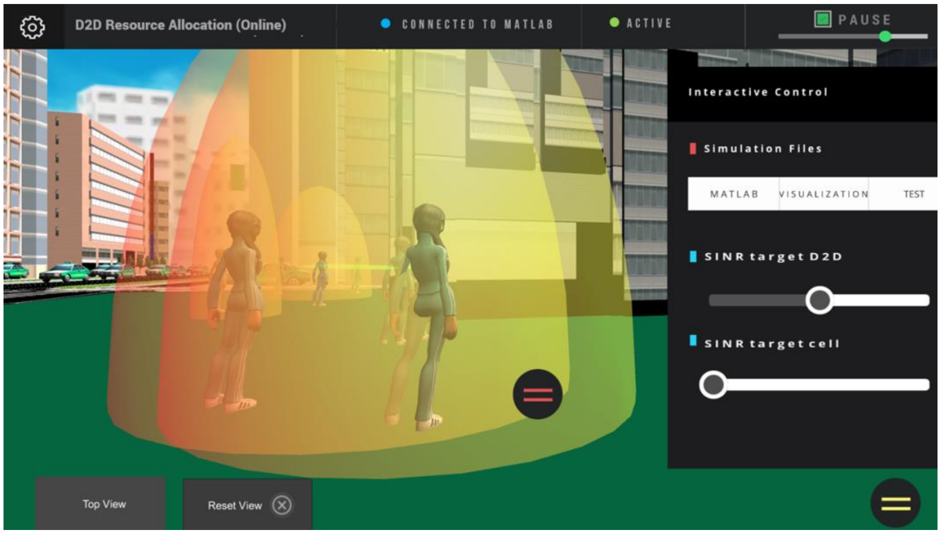

Figure 5-4: Ego view in visualization platform.

The global and local KPIs of example D2D simulation, e.g. link and cell throughput, are plotted in the dashboard as shown in Figure 5-5 and Figure 5-6, respectively.

Figure 5-5: Global KPIs (overall system).

Figure 5-6: Local KPIs (user specific).

Further, the viewer can be enabled to interact with a few simulation parameters from the visualization front end. However, this feature is not possible with pre-generated simulation traces in Section 4. Nevertheless, when the simulator is running dynamically with the visualization front end, it is possible to change the signal to interference plus noise ratio (SINR) target for UEs being in D2D mode or connected to cellular infrastructure (base station) via front end with some sliders (range: -5 to +5 dB), as shown in Figure 5-4, for the considered D2D simulation example. 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 5-5 shows a spike in total D2D throughput (highlighted in yellow) following an interactive increase in D2D SINR target at visualization front end.

There are different levels of interactions between the simulator and UNITY 3D. The first level is the real-time provision of computed simulation results to UNITY 3D. This level is almost implemented.

In the second level, users can select certain groups of simulation results, for example, overall throughput, single link throughput delay, etc., through UNITY 3D user interface, in which a certain signaling exchange between UNITY 3D and the simulator is required. In other words, the simulator should be able to reactively provide the requested simulation results to UNITY 3D. In addition, the simulator supports parameter configuration, such as number of D2D connections, moving speed of designated users, simulation scene, etc., through UNITY 3D user interface, before running a simulation, which also requires signaling exchange between UNITY 3D and simulator. To this level of interaction, the simulation accuracy can be maintained since the interaction is regarding the real-time provision of simulation results and simulation environment parameter configurations.

At the next level, flexibility is concerned wherein specific data exchange protocols are defined and specified so that the simulator obeying a certain programming pattern can automatically show the configurable parameters and corresponding values on the UNITY 3D interface.

Another purpose of interactions is to provide real-time interaction between users and the visualization platform wherein parameters can be configured in real-time. For example, the position of a designated user can be changed in real-time. In order to handle the parameter configuration requests from UNITY 3D and respond in real-time, the simulator may need new algorithms or hardware support to meet the real-time requirements. This is a potential future step once the lower levels of interactions are achieved.

5.3 Data exchange model architecture

The data exchange model proposed in the initial phase of the virtualization platform development is based on a few requirements from the side of the simulation generating environments, the computing power needed for the simulations to interact within the visualization platform on market standard machines (universal access) and the former findings of legacy research (conducted e.g. within METIS project).

What was taken into account can be summarized in a simple logical thread (see Figure 5-7). The data flow begins at the simulator (both software and hardware based), then it might (though does not have to) be stored in a database. It is then digested by an agent responsible of filtering the necessary data portions and compressing them (to minimize the impact of connection quality on the whole process). The final step is to bring the data into the visualization platform and connect it properly with the presentation (transmitters, buildings, cars, people, devices, etc.) and information layer elements (connections, graphs, ranges, signal strength indicators, etc.). For complex simulations the presence of the simulator might be substituted by trace files accessible from local or remote machines or environments.

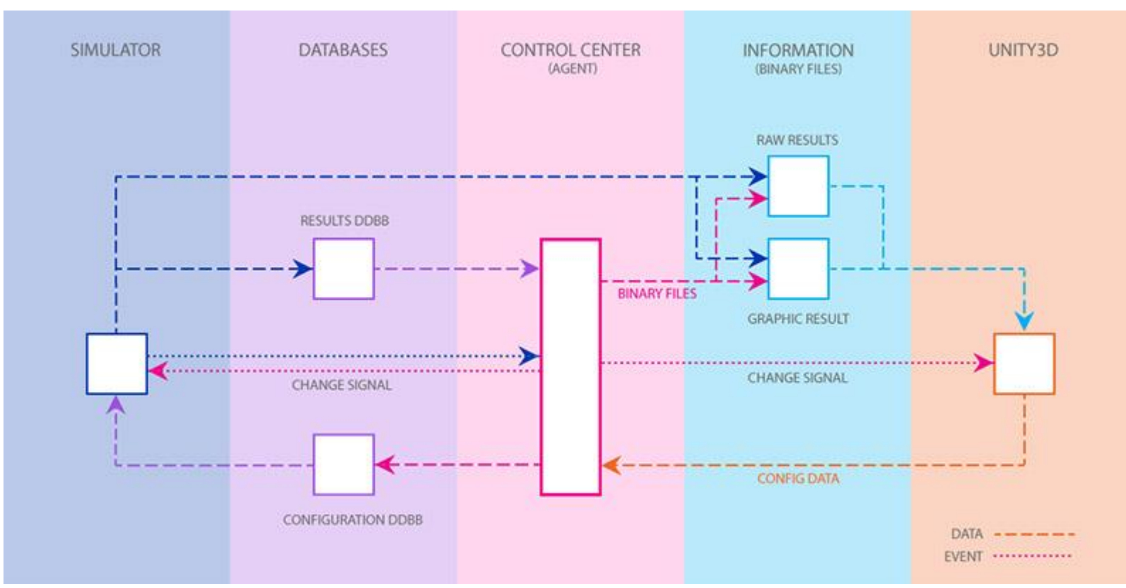

Figure 5-7: Data exchange model for close-loop interactive METIS-II visualization platform.

The above presumptions have to be accompanied by mechanisms that will enable two-way communication, as only then the interaction between the platform and the simulation tools will become possible. Therefore, from the very beginning it is important to make attempts to “close the communication loop” evolving the visualization platform in the direction of interaction, evaluation and valuable assessment.

5.4 Making the platform universally accessible – challenges and benefits

One of the ultimate goals for the visualization platform could be to become a universally accessible and usable tool. Given that the asset structure is open (so 3D models can be replaced by more precise or more abstract models, visual language elements can be redefined) and data exchange paradigms are flexible, the statement is not far from reality. As the tool documentation is being created in parallel to the development effort, the access threshold is intended to be set relatively low. The obvious benefits of such approach might turn the METIS-II dedicated tool into the universal visualization and evaluation environment used by engineers, operators and manufacturers alike. By introducing specific use cases they would be able to assess the impact of their solutions on the known real-life situations. This approach would bring the industries and researchers closer to being able to foresee the future impact of technology on scenarios inspired by everyday life, problems and high level concepts (like traffic management, public safety, etc.).

On the other hand, the clear challenges are tied to the process of defining new abstraction based beings from the data (like turning antenna ranges defined in data flow into spheres surrounding a central distribution point, adding mathematical models to visualize wave propagation as these do not exist in UNITY 3D itself, enriching the physics and material related data of the elements on the scene to get more precise evaluation means etc.). Though not impossible to be made successfully, this step is usually hard, due to the different standards used for data visualization in various environments. Another challenge is the data itself. Different data sources and structuring models might make it impossible for the universal approach to be easily achievable. It’s also important to remember about performance, as the data models and calculations needed for the visualizations are usually complex, which could easily impact the presentation in a negative way. That’s why use-case testing is always recommended at early stages.

6 Conclusions

One year after the beginning of the project, it is already obvious that the decision of developing a visualization platform able to communicate METIS-II's outcomes to the outside world was right. This statement is backed up by the positive reactions of viewers who interacted with the tool during major industry events like ICT or MWC. What is more, UNITY 3D environment is as flexible and as helpful with the project-related tasks as expected. It allows any data sources (both theoretically and in practice) to be integrated with now “live” visual results to be presented and disseminated. It also creates numerous opportunities for further development, as UNITY 3D based solutions are almost instantly multi-platform, well documented, supported by constantly growing enthusiast (as well as professionals) groups and ready for the future media consumption contexts (like virtual reality components enabled by already existing and available libraries).

What is more, the visualization platform created one more level of METIS-II consortium partners' information exchange, which adds up to the educational and cooperative value of the solution.

With all the above in mind it is natural to conclude that the visualization platform developed in METIS-II should not be only treated as the “current outcome” of the project. It is also a tool aimed at the future uses and open for other initiatives to make a good use of.

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