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Results of Second Open Call

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Deliverable D5.4
Results of Known experiments and Second Open Call

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Abstract

The TRIANGLE Project ran two further Open Calls for the purposes of gathering feedback from real-world users of the Testbed and to increase the capabilities of the Testbed. These results of calls provided valuable feedback to the consortium on the benefits available from using the Testbed and also in identifying issues and improvements to the Testbed for future users.

Keywords

Open Call; Experiment; Extension

Executive summary

The TRIANGLE project ran two waves of Open Calls in 2017 and 2018. This document primarily discusses the second wave of Open Calls OC3 and OC4.

The first Open Call (OC1) was for experimenters to use the TRIANGLE Testbed infrastructure with experiments starting in April 2017 and completing in September 2017 (October 2017 for one). These experiments comprised two Mobile Apps and one Connected device. The Second Open Call (OC2) was for extensions to add additional functionality to the TRIANGLE Testbed. The selected extension began in May 2017, with a first release of the technology delivered by end of September 2017 in time for the second release of the Triangle Testbed (R2). The second part of the extension has been delivered in April 2018 and is available for use for new experimenters for OC3/4/5 and external users.

The second wave of Open Calls for experiments OC3 and extensions OC4 ran during the summer of 2018 with a number of high quality applications. The consortium chose to select the top six applicants for experiments, with a mix of IoT devices, mobile app developers and experimenters interested in running a number of different networking experiments. The consortium feels that this Open Call was a good indicator of the diverse set of experiments that can be run on the Testbed.

A number of the selected experimenters have completed using the Testbed, with some keen to use the Testbed again in the future, having attained good results and insights. Other experimenters have run into issues with their experiment and will complete a little later in the summer as outlined in the description. The positive quotes from the users of the Testbed continue to indicate that TRIANGLE is providing value to the experimenters using it.

The consortium selected two excellent extensions to add to the Testbed, one in the area of Mobile Edge Computing, which builds upon work from the first extension from TNO and will be of use for one of the experimenters in OC4 and other users. The consortium is delighted to see immediate value in these extensions.

This report gives and overview of the experiment setup, results and the business benefits derived from using the TRIANGLE Testbed. The output of these early testbed users with real world usage requirements has provided valuable feedback to the consortium on improvements that are planned for future TRIANGLE Testbed versions. Work is already underway to incorporate this feedback into the testbed for future users.

This deliverable generalizes the information captured by the experimenters. The Individual experiment results are kept confidential as they are directly related to the specific experiment application or products.

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1 Introduction to TRIANGLE Open Call process

This document outlines the results of the first set of Open Calls for the TRIANGLE Testbed. The Open Call process is outlined as well as a description of the applications that were received and the applicants that were selected by the selection committee.

The main objective of the third Open Call (OC3) is testing the TRIANGLE testbed with **Experiments** that are co-created with companies such as application developers and device manufacturers. Example experiments could include application developers testing 5G scenarios such as low latency to facilitate VR, or an IoT device maker who wants to benchmark their devices against other low power devices. The experiments have helped in developing the TRIANGLE Testbed to meet the diverse needs of experimenters, and will continue to evolve the technical integration in the TRIANGLE Testbed at the University of Malaga (Spain) and to other TRIANGLE Testbed locations.

The fourth Open Call (OC4) is for testbed **Extensions**, where the main objective is adding additional capabilities to the TRIANGLE Testbed to facilitate extensions. The extensions will help improve the TRIANGLE Testbed as a whole to match other needs of experimenters. Extensions will evolve the existing TRIANGLE testbed and integrate with additional TRIANGLE Testbed components.

For more information about the current capabilities of the testbed and what types of experiments it can run see the Testbed overview at [1].

1.1 Open Call process updates

After the completion in 2017 of OC1 & OC2, the consortium felt that more details were required at the application stage for the reviewers to make a more effective judgement on the benefits and feasibility of the idea and also for the TRIANGLE Technical team to have a better understanding of the application. Some additional questions were added to the proposal form, in particular to outline the 5G features that were proposed to be evaluated during the experiment, or provided by an extension.

During the previous open calls a number of phone calls were carried out during the application process and after selection to determine technical feasibility. With the increased number of OC3 & OC4 applications the consortium felt that there would not be time to have a many calls with each applicant. To ensure that applications could be adequately analysed some additional information was added to the applications to help to determine technical feasibility and relation to 5G.

Based on the experience from OC2 (extensions) the consortium developed a prefeasibility document for extensions where potential applicants would fill out a longer description of their proposed extension. During the application stage the TRIANGLE Technical Evaluation Team would continually review these documents and in a small number of cases have a call with the applicant where further clarity would be needed to make a determination on initial feasibility. This phase helped to improve communications and made the selection phase more scalable as fewer calls were required and were shorter in nature. The contents of the prefeasibility document then formed part of the final proposal for reviewers to evaluate.

A small number of experimenter applicants also chose to fill out this optional document for additional feedback, but this document was required only extensions to be considered. The applicants were also required to mention on the final application if the TRIANGLE Technical Committee had indicated whether the proposed extension would appear to be technically

suitable, based on the submitted document.

In addition to the prefeasibility section, the application questions for Experiments and in particular for Extensions, were increased considerably. An example of the revised set of applications questions can be found in the appendix along with the full extension proposal document.

Based on comments by the reviewers at a review meeting after the OC3 / OC4 selection phase was completed, the process has been again modified for OC5, as will be outlined in the next Deliverable (D5.5) that describes these experiments and their selection process.

1.2 Open Call Timeline

The Open Call 3 and Open Call 4 revised timeline is presented in the table below. In each Open Call period, the diagram below shows that there is a period foreseen as a setup phase. In this setup phase, experimenters are getting familiar with the Testbed, have access to technical information and complete the legal contract review before their experiment(s) can actually begin.

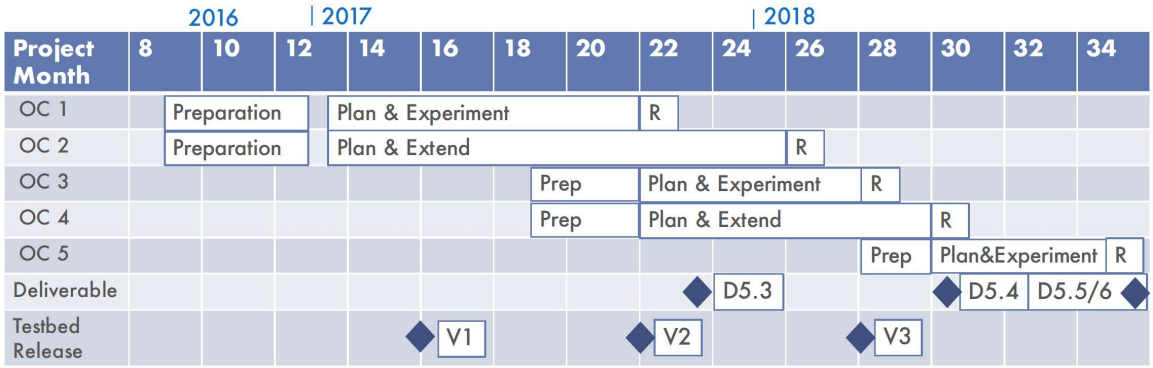


Figure 1– Open Call Timeline

At the end of each Open Call, a period is planned in which experimental data is processed and results are determined and consolidated into a report which is shared with the consortium. Extract of the reports are included in the public deliverable such as this one and D5.3 in the past and D5.5 in the future.

1.3 Open Call 3 & Open Call 4 Applications Summary

A summary of the Open Call 3 and 4 applications is shown in the table below

Table 1 - Open Calls summary

Open Call	Official Applicants	Selected
Open Call 3	16	6
Open Call 4	12	2

1.4 Briefing and Evaluation Calls

As per the Open Call process defined in D5.1, the consortium decided to select 6 independent evaluators to help in the selection process. They come from different background such as from

academia and industry, all releated to telecommunication. The list of selected evaluators has been shared with the EC project officer but is kept confidential to protect their anoymity.

After the deadline for presenting applications, the consortium had a briefing call in July 2017 outlining the TRIANGLE Testbed to the evaluators. The call took place over WebEx and was recorded for an expert evaluator who was unable to attend the call. This call addressed the project and what makes a good experiment and extension for the project.

After explaining the TRIANGLE Testbed and the scoring criteria, the evaluators began the process of evaluating the applications that were assigned to them, over the course of a week.

Evaluators were encouraged to add notes, where relevant, to the applications; but these notes would not be visible to the applicants, only to other evaluators. After the selection process has concluded and the applicants are selected, companies that were not selected are allowed to see the scores and comments from the reviewers.

Each evaluator scored the applications that they were assigned to according to the agreed criteria (these are outlined in D5.1). The chairman evaluated the scores and presented the applications with the highest score to the consortium for Technical and Privacy & Ethics review.

During the review phase a number of expert reviewers had to excuse themselves from certain reviews due to potential conflicts of interests. These reviews were distributed across other reviewers. The process has been summarised in the Open Call 3 and 4 Process Overview in the Appendix of this document. Based on input from the project review, the process has been modified slightly for the third wave of Open Calls OC5.

1.5 Technical Review

Each selected application was later evaluated based on the technical feasibility of using the TRIANGLE Testbed. The selection process allows the TRIANGLE Technical Review Committee to refuse applications based on the result of the technical review when proposals are deemed to be unfeasible.

Each of the selected applicants were requested to develop an extended proposal with more technical detail than the original proposal in order to achieve more clarity on the proposal that may not have been explicit in the proposal. An email exchange between the Technical Review Committee and each applicant was setup to discuss any potential technical issues. In addition, each applicant had a call with the Technical Review Committee members. This call helped identifying any potential technical limitations with the experiment or extension.

During the Technical feasilbility phase the committee determined that there were serious feasibility problems with one of the applications. The team contacted the applicant and asked them to suggest a revised proposal, this was received and deemed to be not suitable as the functionality of the experiment was reduced by approximately 50%. The Technical Committee resolved to take the next highest scoring application on the list as an alternative.

1.6 Application Summary

1.6.1 OC3 – Experiment Applications

The following table outlines the selected applicants for OC3 in green, with some applications making the final shortlist and others being excluded due to low scoring or being determined to be technically infeasible.

Table 2 - OC3 Applications

ID	Name	Domain
OC3_1	WiSyLab	Selected
OC3_3	CNIT - UniCT	Selected
OC3_11	Inova DE GmbH	Selected
OC3_7	ComSensus	Selected
OC3_5	IS-Wireless	Selected
OC3_6	Infolysis	Selected

1.6.2 OC3 – Experiment Applications

The following table outlines the selected applicants for OC4 in green, with Orange applications making the final shortlist and red being excluded due to low scoring. In the case of OC4 the committee decided to accept two extensions after a budget modification from one of the applicants.

Table 3 – OC4 Applications

ID	Name	Domain
OC4_11	StreamOwl	Selected
OC4_5	CNIT-S3ITI	Selected

2 Open Call Experiments Results

2.1 Results of Open Call 3 and 4

The selection process for Open Calls 3 and 4 completed on September 1st 2017. Experiments and extensions started at various points in 2018, with experimenters having access to the documentation to start experiment planning from late 2017. In total, at the time of writing this report, three successful set of experiments have completed, or nearing completion with another three ongoing or due to be delayed due to technical issues as explored later in this document. The results of these experiments as documented by each of the Experimenters and Extensions are outlined in the following section.

2.1.1 Infolysis: Experiment – 5G-Bot

2.1.1.1 Experiment Summary

The objective of the 5G-Bot experiment was to test the behaviour of chatbot applications under different mobile reception conditions, network traffic, processing power schemes and battery utilisation plans in order to quantify and assess their impact on the QoE level as perceived by the user and to stress the reliability of the chatbot app (e.g. connection losses, delay, communication errors) under different conditions. Therefore, the experiment focused on performing a set of experiments in the controlled environment that TRIANGLE project offers, and follow a step-by-step approach of the various parameters that may affect the performance of the chatbot application.

In the case of Infolysis experiment it was mandatory to install the Viber application and register a user to the Viber servers. However, during the early stages of the experiment preparation it was observed that when the Viber application was installed via the TRIANGLE platform and not from the Google Playstore, it not was not possible to initiate any chat, possibly due to security restrictions.

As outlined later in this document, while this initially presented some challenges and limitations, the TRIANGLE Consortium were able to assist with device-level, instead of App-level automation and have added additional features to the Testbed in anticipation of needing this type of configuration in the future for similar situations.

INFOLYSIS performed a wide variety of experiments under a range of conditions, these can be summarised as:

1. Objective 1. Providing performance results of the executed experiments including objective metrics for each experiment, such as:
2. Objective 2. Benchmark of chatbot app performance in different realistic network scenarios
3. Objective 3. Measurement of chatbot app power consumption in unexpected network scenarios
4. Objective 4. Automation of chatbot benchmarking tests
5. Objective 5. Testing of chatbot app on a set of popular phones

2.1.1.2 Experiment Preparation and Design

Three different types of chatbots over Viber platform have been used for the deployment of the 5G-BOT experiment, each one having a different degree of complexity and requirements:

- Informative Chatbot
- Contest Participation Chatbot

- Order Placement Chatbot

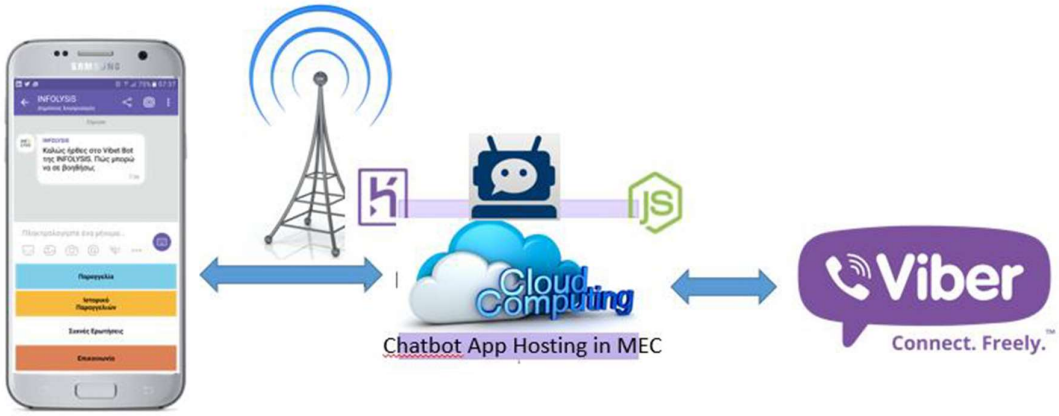


Figure 2– Infolysis High Level Architecture

The experiments evaluated the performance in the following network scenarios have been used in the corresponding environments:

1. Suburban: Festival, Shopping Mall Busy Hours, Shopping Mall off Peak, Stadium
2. Urban: Traffic Jam, Internet-café busy hours, Internet-café off peak, Office, Pedestrian
3. A 5G-Bot Custom made extreme conditions scenario

The diagram below in Figure 3 illustrates how the Infolysis application experiment was deployed in the TRIANGLE Testbed

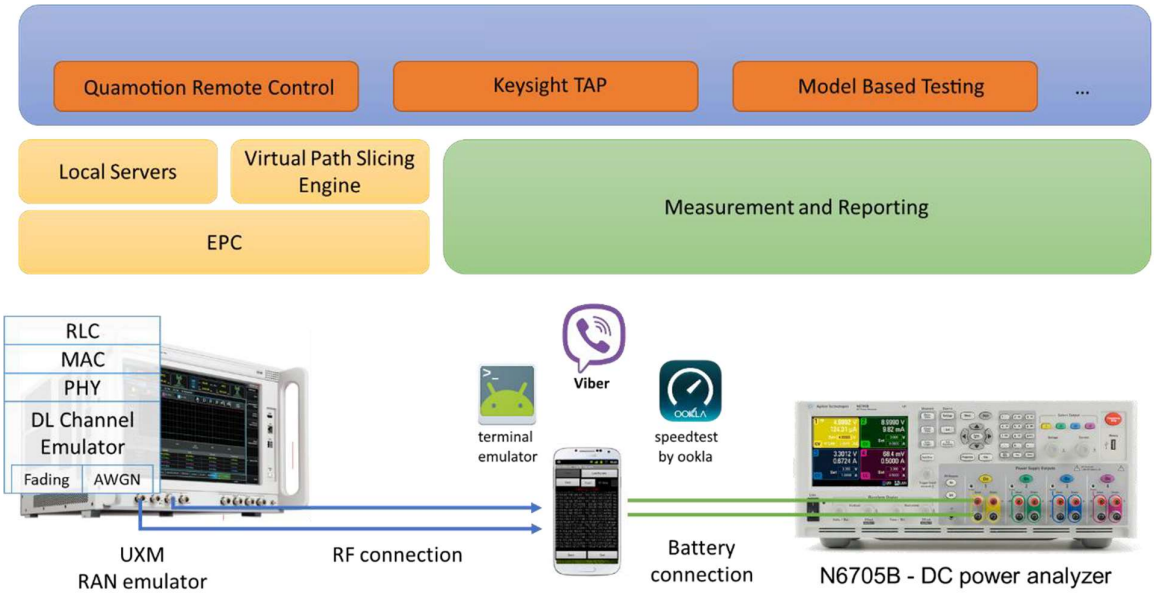


Figure 3 – Infolysis Setup in Testbed

2.1.1.3 Experiment timeline

The timeline for the Infolysis experiment is illustrated below in Figure 4.

5G-Bot Gantt Chart in months	Sep	Oct	Nov	Dec	Jan	Feb
5G-Bot proposal Acceptance (26 Sept 2017)	■					
Contract Preparation		■				
Contract signed (21/11/2017)			■			
Starting of 5G-Bot Experiment (1 Dec 2017)				■		
Experiment Execution (1 Dec 2017 - 31 Jan 2018)				■	■	
Reporting period (15 Jan 2018 - 28 Feb 2019)					■	■
Successful Completion of 5G-Bot Experiment (28/02/2018)						■

Figure 4 – Infolysis Timeline

2.1.1.4 Key results and Insights gained from Testing (edited for confidentiality)

Upon the successful completion of the experiment, Infolysis acquired experience and documentation on which factors and parameters may affect the performance of chatbot apps and up to what degree of severity.

2.1.1.5 Business benefits

The results of the 5G-Bot experiment assisted Infolysis to gain additional knowledge on its chatbot products and ensure the quality of service and experience they provide to the end users. In addition, Infolysis acquired knowledge that added value to its chatbot products and further reinforced its internal business processes and functions in parallel with the applied PaaS business model for mobile application such as chatbots.

2.1.1.6 TRIANGLE testing value identified

Upon the successful completion of the experiment, Infolysis acquired experience and documentation on which factors and parameters may affect the performance of chatbot apps and up to what degree of severity.

2.1.1.7 TRIANGLE benefits identified

Based on their previous experience with the Testbed and the acquired knowledge Infolysis suggested very interesting features to add to the Tesbed. Since they are using a commercial application whose source code cannot be instrumented, they suggested to use the PowerShell script to detect errors in the expected behaviour of the application (without this feature they have to capture the errors by looking at the screen). For example, PowerShell scripts were used to check if an image or a text message has appeared in the screen and include this information as part of the results offered by the testbed. This new feature opens a new dimension in the testing of the apps which is very interesting. They also suggested other improvements which can be introduced in Release 4 of the testbed without much effort and that will improve the usability of the testbed.

2.1.1.8 Planned further use of the Testbed

During the initial experiment period, some of the experimentation required manual input for app setup and registration. After this step conversations were automated. Infolysis are planning to rerun some of their experiments under fully automated conditions under the new automation facilities permitted by the TRIANGLE Testbed that will be available in late May.

2.1.2 WiSyLab: Experiment - DualRoC

2.1.2.1 Experiment Summary

DualRoC: Dual-Radio Radio-over-Copper Remotisation for Multi-RAT Centralized- RAN Architecture in 5G Deployments

DualRoC is the proprietary integration method and device of Multi-RAT into a copper-based FH architecture, the objective of the experiment was to validate and quantitatively assess the limits of the proposed all-analog C-RAN based on LAN cables.

Experiment goals were:

1. To evaluate the performance degradation introduced by the copper-cable FH by performing an end- to-end benchmarking between proposed *DualRoC* and conventional mobile communication systems
2. To demonstrate the feasibility of MIMO LTE-plus-Wi-Fi signal relaying over cable and evaluate the impact of each one of the two technologies (i.e., either LTE or Wi-Fi) on the other.

2.1.2.2 Experiment Preparation and Design

For DualRoC, the TRIANGLE testbed has been used in the typical device-testing configuration as illustrated below in Figure 5 below, with the only difference that a 4-pairs RJ45 Cat-5e LAN cable has been inserted between the RF output ports of the UXM and the RF connections at the device to show the performance degradation introduced by the all-analogue relaying over copper.

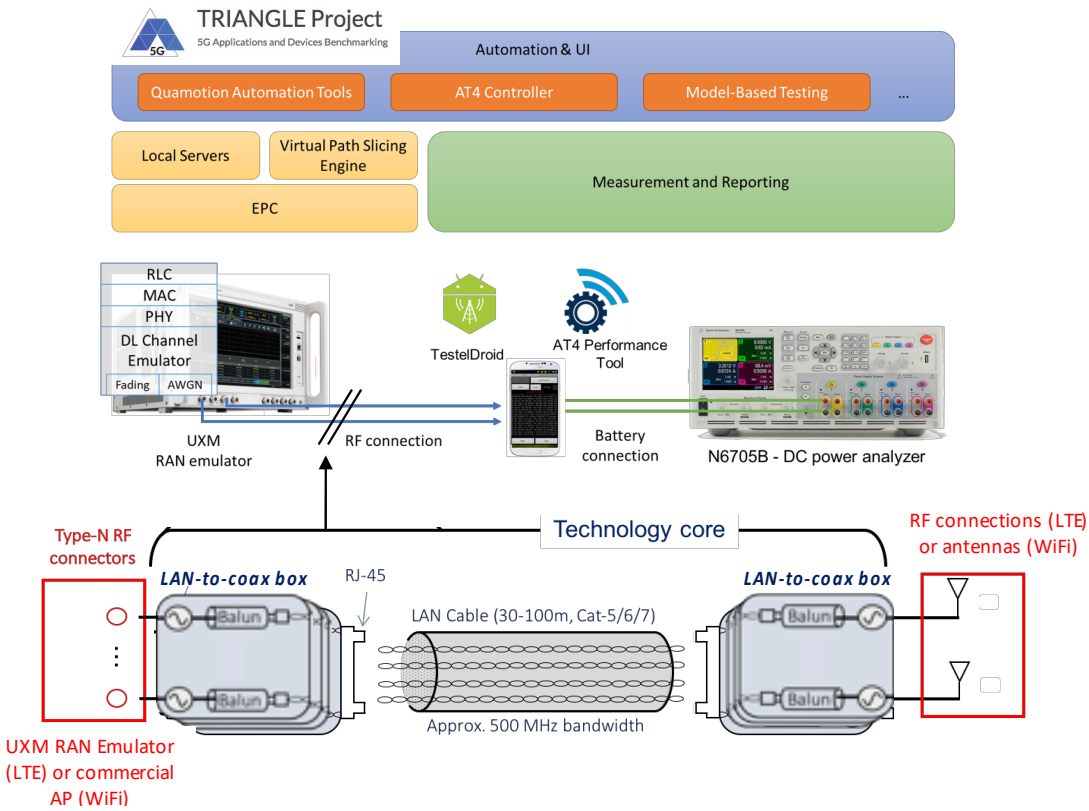


Figure 5 – WiSyLab High level Setup

For the Wi-Fi testing, a commercial Wi-Fi Access Point (AP) was used for signal generation, and the transmission from the second LAN-to-coax box to the device (see Figure 6 below) was over-the-air (OTA).

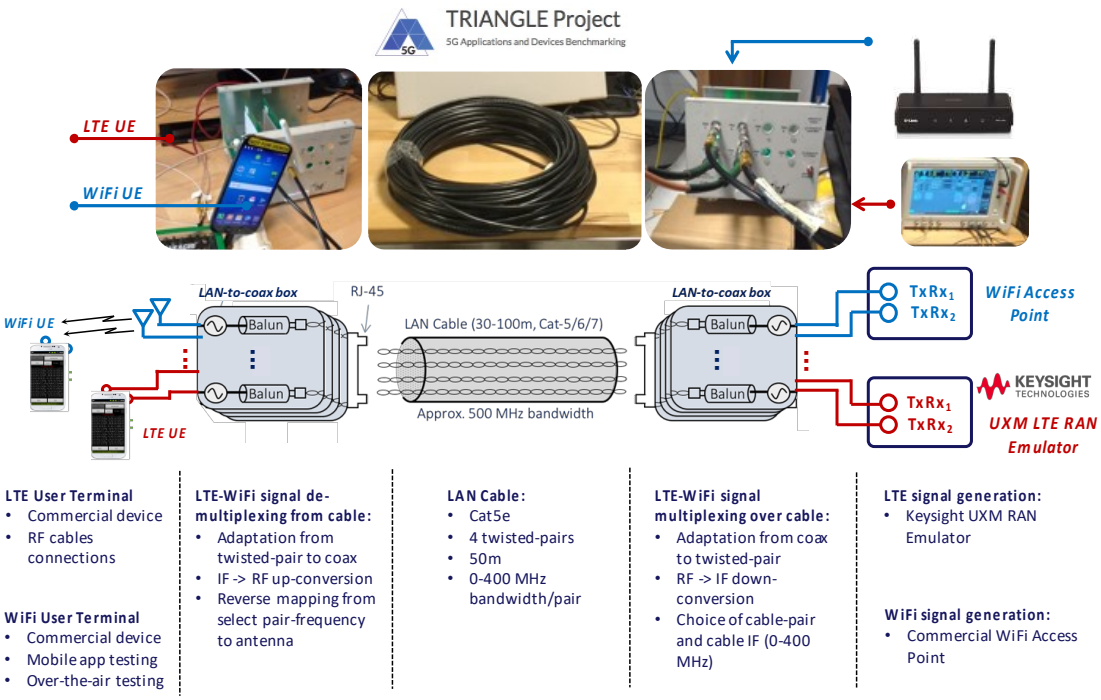


Figure 6 – WiSyLab High-level Setup

2.1.2.3 Experiment timeline

The project timeline is illustrated below in Figure 7 in the Gantt chart.

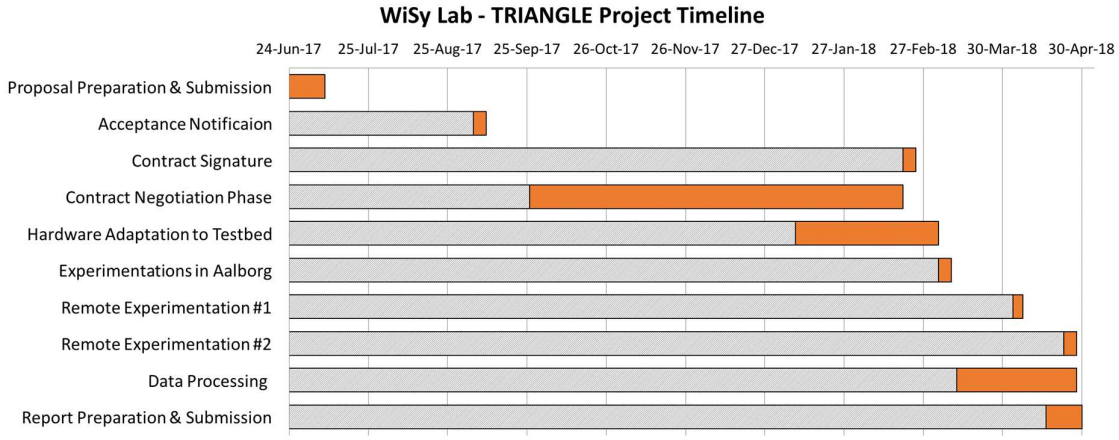


Figure 7 – WiSyLab Timeline

2.1.2.4 Key results and Insights gained from Testing (removed for confidentiality)

2.1.2.5 Business benefits

Being academic researchers, their first “product” are scientific publications aimed to enrich the research community and others with their innovative contribution. From this perspective, the first value perceived from this experiment is represented by the novel experimental results obtained, which the experimenters feel are all worthy to be published. Moreover, the proposed experiment played a fundamental role in validating all their previous numerical analysis. By creating and testing their hardware device, they acquired the knowledge of many practical aspects that can be now introduced into the system level analysis. They had the possibility to understand both strengths and weakness of their technology, and this open to further improvements and developments.

2.1.2.6 TRIANGLE testing value identified

The experimental results proved the feasibility of DualRoC to all-analogue (i.e., without latency and transparently) relay LTE, Wi-Fi, and LTE+Wi-Fi signals over a common LAN cable in an all-analogue fashion.

2.1.2.7 TRIANGLE benefits identified

The value perceived from this experiment has been already incorporated in their research activities. In fact, supported by the TRIANGLE project, they have been able to tune a first prototype able to demonstrate their technology, which is mandatory to elevate their idea to the upper levels of technological readiness, and this represents a first significant step towards the developing an actual product or cooperate with other industry for a joint development.

2.1.2.8 Planned further use of the Testbed

They are currently planning publications for dissemination purposes for the experiment results. They are confident that this will give them more visibility both in the industrial and academic environments. If it would be possible, they do not exclude the possibility to use TRIANGLE facilities again in the future, after they make some modifications to their system.

2.1.3 ComSensus: Experiment - CellularGrid

2.1.3.1 Experiment Summary

CellularGrid: Cellular Networks for Real-Time Monitoring of Smart Grid.

ComSensus, is an SME that develops power management solutions for the smart grid sector and has developed Phasor Measurement Unit (PMU) and Power Quality Meter (PQM) devices for the use in distribution grid segment, which typically lacks dedicated/appropriate connectivity infrastructure. For this reason, one of the characteristic devices’ feature is the support of cellular and unlicensed radio interfaces, i.e. LTE Cat-3, LTE Cat-M1, LTE Cat-NB1, and LoRa. A particular wireless interface is selected at the time of production based on application and the required support of legacy protocols to ensure interoperability with centralized monitoring and control systems such as SCADA and WAMS. However, with respect to the NGNM 5G use case categories, PMU in general, classifies as ‘Ultra-high reliability & ultra-low latency’ device and PQM classifies as ‘Massive low-cost/long-range/low-power MTC’ device.

2.1.3.2 Experiment Preparation and Design

The Device Under Test (DUT) was connected to the UXM via RF coaxial cable. Although 2x2 MIMO for downlink is supported by the DUT only one antenna/cable configuration was used as the application only requires uplink. A secondary data connection for experiment control was made via the DUTs Ethernet port and testbed network. DUT was powered with a 230VAC/12DC power adapter. The mains measurements connectors were left unconnected.

For experiment control and sequencing the Test Automation Platform (TAP) was used. Special scripts were written for controlling DUT via SSH.

The connection of devices in the testbed looked as depicted in Figure 8 below.

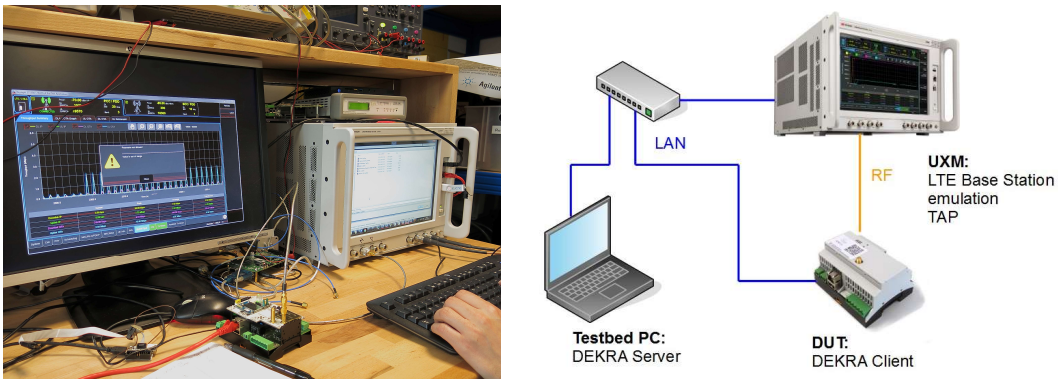


Figure 8 – ComSensus Setup

The Device Under Test (DUT) was connected to the UXM via RF coaxial cable. The Urban-pedestrian LTE network scenario was chosen as it was the one that reassembles the DUTs target environment the closest.

The DEKRA Performance Tool was used as a traffic generator and KPI calculator. DEKRA server was run on a testbed PC, the client was run on DUT.

2.1.3.3 Experiment timeline

The following figure depicts the tasks execution. Orange tasks represent RTD activities and experiment execution, green tasks represent other support activities and yellow task represents management activities. Heavy colouring represent periods of intense effort and light colouring represents start, wrap-up or idle periods of a given task.

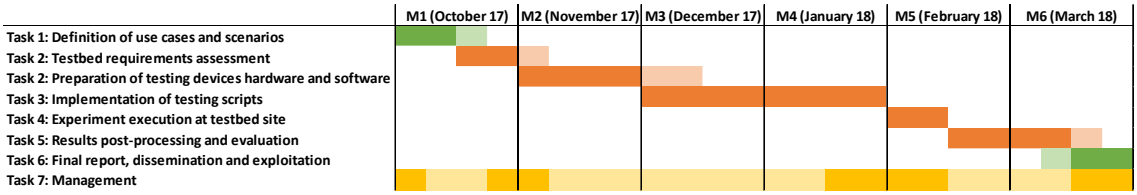


Figure 9 – ComSensus Timeline

2.1.3.4

2.1.3.5 Key results and Insights gained from Testing (removed for confidentiality)

2.1.3.6 Business benefits

The inclusion of new narrowband cellular interfaces in the commercial devices represents an important decision milestone for the company to proceed with the introduction onto the market of attractive, competitive and fully capable solution. The experiment allowed ComSensus to emulate the LTE devices, previously only tested for basic functionality, under different real life scenarios and thereby appropriately select the technology and/or adjust their design.

The value gained with the conducted experiment reflects in the following:

- Gained hands-on knowledge on wireless testing equipment provided by Keysight.
- Increased competence building in relation to different LTE technologies performance in various channel conditions.
- Experimentation with LTE Cat-3 in controlled environment and performance benchmarking to real operating environment.
- Gained the opportunity to experiment with high bandwidth scenarios, which may be a costly exercise in case of commercial network.

2.1.3.7 TRIANGLE testing value identified

Integrating the DUT in the testbed was straight forward. Depending on which connection was established first (LTE or Ethernet) packets were routed only through that connection. Special TCP packet routing rules were added on the DUT to send DEKRA test stream over LTE connection and all other traffic thorough Ethernet connection.

The direct value of the conducted experiment for the company is in competences building, pre-commercial prototypes testing in a controlled environment, and initial collection of measurement data that will be used in business modelling. Indirectly the value also reflects in gaining the experiences with the measurement equipment, tools and testbed, parts of which will for sure be reused in the planned follow up activities.

2.1.3.8 TRIANGLE benefits identified

This project was the first ultra-high reliability IoT project that the Testbed needed to support.

2.1.3.9 Planned further use of the Testbed (edited for confidentiality)

The company has high interest in a follow-up use of the TRIANGLE facilities for smart metering using NBIOT

2.1.4 IS Wireless: Experiment - PHYSCHED

2.1.4.1 Experiment Summary

PHYSCHED: Design space exploration and performance testing for PHY and scheduler.

The LTE eNB Scheduler is a software library consisting of the two configurable scheduling algorithms: simple round robin (designed for benchmarking) and advanced channel-aware proprietary scheduling algorithm. LTE eNB Scheduler interacts with LTE eNB protocol stack through a Small Cell Forum (former Femto Forum) compliant interface (FAPI) extended to support Carrier Aggregation. LTE eNB Scheduler is going to be a base for the implementation of RAN controller in ISW Software-Defined Radio Access Network (SD-RAN).

LTE PHY Lab is one of the software components of the ISW's 5G Toolset. It is a link-level simulation tool that provides a comprehensive implementation of the E-UTRA physical layer according to 3GPP Release 8, with substantial elements of Releases 9 and 10 (such as extended MIMO and Carrier Aggregation). LTE PHY Lab is compatible to run under two popular numerical computing environments: MATLAB and Octave.

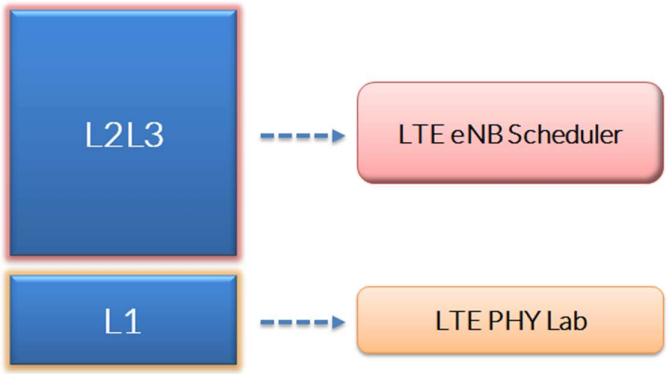


Figure 10 – Experiment Scope

The objectives of the experiments were as follows:

Objective 1: Design space exploration of standard-compliant environment for LTE eNB Scheduler optimization and further development.
All activities related to this showcase are covered by **Showcase 1** (SC1). The aim of SC1 is to observe the scope of the measurement parameters changes in various conditions. The results this experiment would give them a strong base in the researched subject and will be a valuable input for the further Scheduler development.

Objective 2: Testing and validation of LTE PHY Lab downlink receiver processing chain.
All activities related to this showcase are covered by **Showcase 2** (SC2). The aim of SC2 is to verify the compliance of LTE PHY Lab algorithms with 3GPP standard
In SC2, the special interest is given to carrier aggregation functionality, which is considered as a new LTE PHY Lab feature.

This document is an intermediate report and contains the description of work performed in the first half of the experiment duration period. Since the Showcases were planned to be performed sequentially (due to different hardware setup), the technical description and results are mostly related to the SC1 work.

2.1.4.2 Experiment Preparation and Design

The setup for SC1 is presented on Figure 3. The hardware and software components used for the SC1 are described in Figure 12.

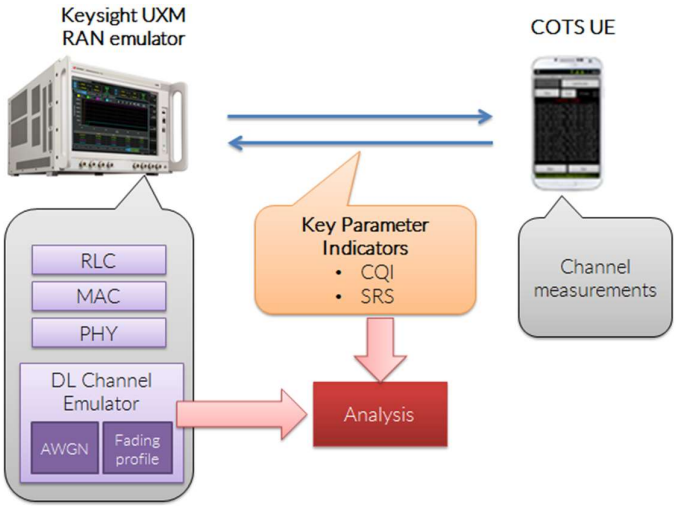


Figure 11 – IS Wireless Architecture

The SC1 experiment consisted of multiple test scenarios. Each of them can be identified by the parameters configuration for RAN emulator and DL Channel emulator (both provided by Keysight UXM). RAN emulator was used to simulate the scheduler activity by:

1. selection of spectrum bandwidth
2. assignment of specific resources for the user
3. selection of the Modulation and Coding Scheme (MCS).

DL Channel emulator was used to model the channel influence by adding the noise (AWGN) and applying one of the fading profiles defined in 3GPP specification (pedestrian, vehicular or high-speed train). During the transmission, the KPIs returned by UE were measured and returned by both UXM and TACS4. The UXM and COTS UE were wire connected.

Table 4 – Experiment Components

Component Number	**Component**	**Application**
1	Keysight UXM Wireless Testset	This device was used as a RAN emulator and DL Channel emulator
2	Commercial off-the-shelf LTE mobile terminals (COTS UE) - Samsung S7	This device was used to measure the KPIs of the transmission.
3	Mobile Device Monitoring software: DEKRA TACS4 Performance Tools	This software was used for collecting measurement data from UE device.
4	Keysight Test Automation Platform	This software was used to control the parameters of UXM and for the test atomization.

2.1.4.3 Experiment timeline

The Gantt Chart presenting the milestones and activities for the project is presented below in Figure 12.

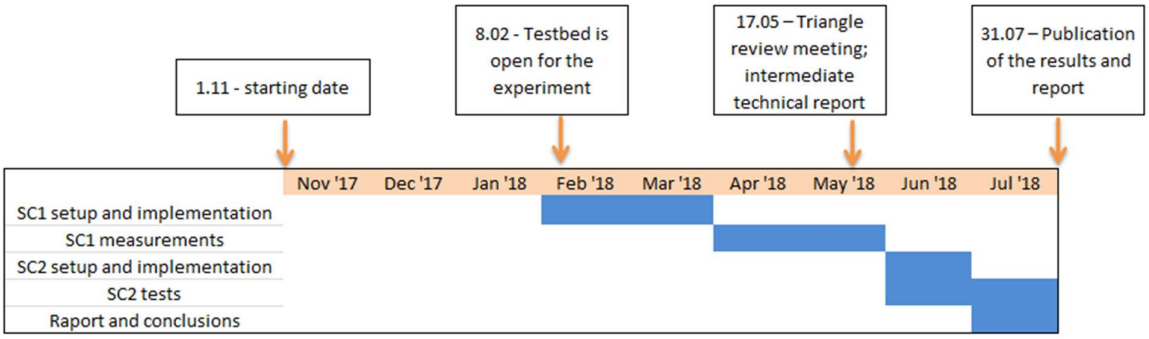


Figure 12 – IS Wireless Timeline

2.1.4.4 Key results and Insights gained from Testing (edited for confidentiality)

The results were collected from both sources (UXM and TACS4) and processed by the implemented scripts. They carried out two main experiment types and at the time of writing are carrying out additional measurements.

1. SC1, the work was dedicated to better understand the functionalities provided by the testbed equipment and to adjust the TAP plans.
2. SC2 is focused on the measurements and results collection

The SC1 experiment outcomes and achievements:

- The KPIs were measured for multiple scenarios
- The KPI results correspond to the expectations in regards to various scheduling decisions
- The results confirm the assumptions used in LTE eNB Scheduler
- UXM and Test Automation Platform from Keysight were successfully evaluated in terms of testing eNB procedures. We consider this setup as a powerful and useful tool for research purposes, especially in terms of the further development of our products: LTE eNB Scheduler and SD-RAN.

Table 5 – Summary of setting parameters

(removed for confidentiality)

2.1.4.5 Business benefits

IS Wireless had the opportunity to use Keysight UXM. They also received few training sessions on TAP usage provided by DEKRA. It allowed them to get a deeper insight into tools' capabilities and gain the experience in working with them. It was especially important for them as they are currently interested in such equipment which would help them to develop and improve their solutions.

The direct value for their company is the knowledge and experience gained in terms of scheduling testing. They expect to incorporate this value soon in future development of ISW's LTE eNB Scheduler.

The indirect value is the is the possibility to get a deeper insight into Keysight UXM capabilities.

2.1.4.6 TRIANGLE testing value identified (removed for confidentiality)

2.1.4.7 TRIANGLE benefits identified

This experiment was the first attempt at supporting three active testbed instances and three locations, Denmark, UMA and a new site used for this experiment at DEKRA. In this particular case, there were delays due to shipping and configuration and setup of VPNs. This will be valuable experience in supporting future experiments at other sites. The company also requested use of software and hardware that was not strictly part of the Testbed components, the Triangle consortium were able to support these requests. There were also delays as the UMX used did not support all of the required capabilities for the experiment, something that will be addressed in future experiment allocations.

2.1.4.8 Planned further use of the Testbed

The SC1 experiment is ongoing. The next rounds of measurements are required in order to collect more data, remove the transmission errors returned for some MCS and perform the comparative analysis of the obtained KPI results. This is scheduled to continue into May 2018.

They are considering to use this facility for future research experiments and products evaluation after the current round of experiments completes.

2.2 Additional Open Call 3 Experiment Status

After some initial work the additional Open Call applicants have run into some technical difficulties that have required them to move into the timeframe for the next open Call OC5. These applications are:

1. Innova DE
2. CNIT - UniCT

2.2.1 CNIT-S3ITI: Extension - MEC

2.2.1.1 Extension Summary

The purpose of this extension is to extend the TRIANGLE testbed to support and to host Mobile Edge Computing (MEC) services. The provided framework will allow experimenters:

1. To specify MEC application performance and operating requirements/policies (i.e., latency from the User Equipment, “migrate upon UE handover”, etc.);
2. To upload their own MEC services through an OpenStack-like dashboard;
3. To manage the MEC service lifecycle and test environment, in terms of Points of Presence (PoPs - i.e., each one realized with a single server) available to MEC services and their features (e.g., where are “virtually” deployed according to the test network topology, which is the latency/hop from base stations, etc.);
4. To monitor, benchmark, and certify the service under test performance

The extension of the TRIANGLE testbed towards MEC technologies will allow experimenters to upload the “mobile edge” counterpart of the applications running on User Equipment (UE) to the TRIANGLE facilities, and consequently testing and validating the entire ecosystem in a highly flexible and controlled environment.

The service chain definition will be made available by means of a dashboard similar to the one provided by OpenStack. Then, the service chain is instantiated and test steps can be defined and run in the TRIANGLE testbed by means of a TAP plugin. The testbed extension will enable the proper run of such tests and the management of the whole MEC service lifecycle

The work builds upon work on the H2020 project Open Virtualization Operating Layer for Cloud/fog Advanced NetwOrks (OpenVolcano) framework[2]. OpenVolcano is already in a mature state of development/debug/ troubleshooting (it has been adopted as MEC platform in the 5G-PPP Phase-2 MATILDA Innovation Action [3]), and it is fully integrated with 4G Radio Access Network and Enhanced Packet Core. To the best of their knowledge, OpenVolcano is one of the first open-source prototypes for personal applications in MEC/fog environments with support for NFV

OpenVolcano will also be adopted as MEC system in the 5G-PPP Phase 2 MATILDA Innovation Action.

2.2.1.2 Extension Preparation and Design

To allow experimenters to create their MEC service chains two solutions are available.

The first solution considers using code from the OpenVolcano Pyroclast module [4], which is a patched version of the OpenStack Horizon dashboard with few further auxiliary OpenStack components (for storage, accounting, etc.).

The second solution regards the usage of DevStack [5], a GitHub-based deployment of OpenStack that can run in a VM. The choice between the two solutions depends on the number of servers in the TRIANGLE testbed made available for this extension. Since in the current deployment one server has been dedicated to the MEC extension, the latter solution has been selected.

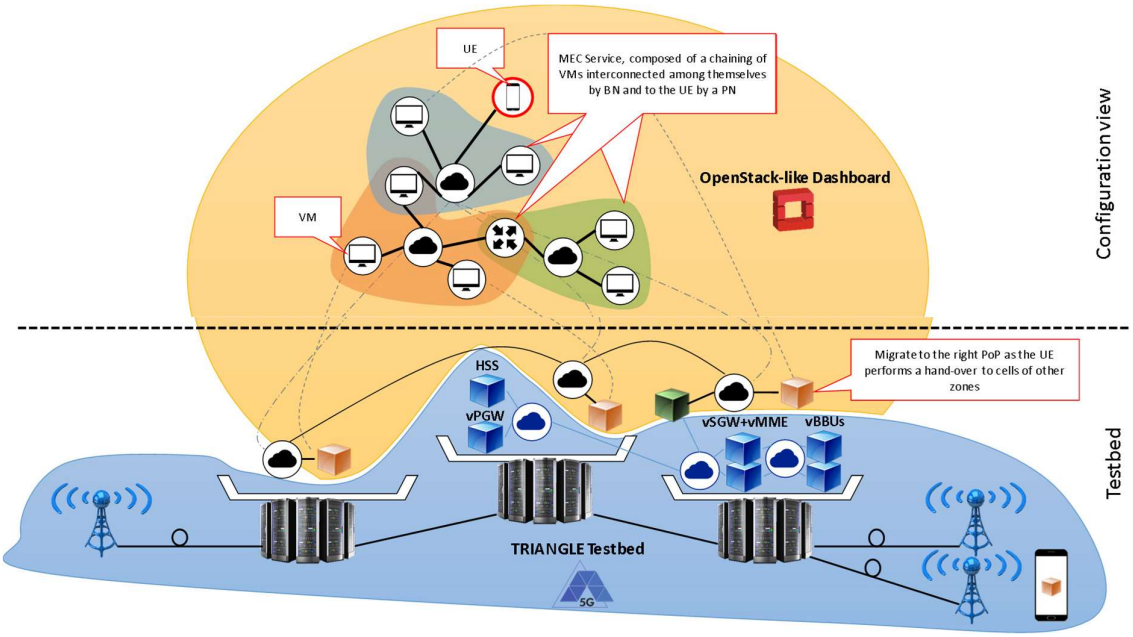
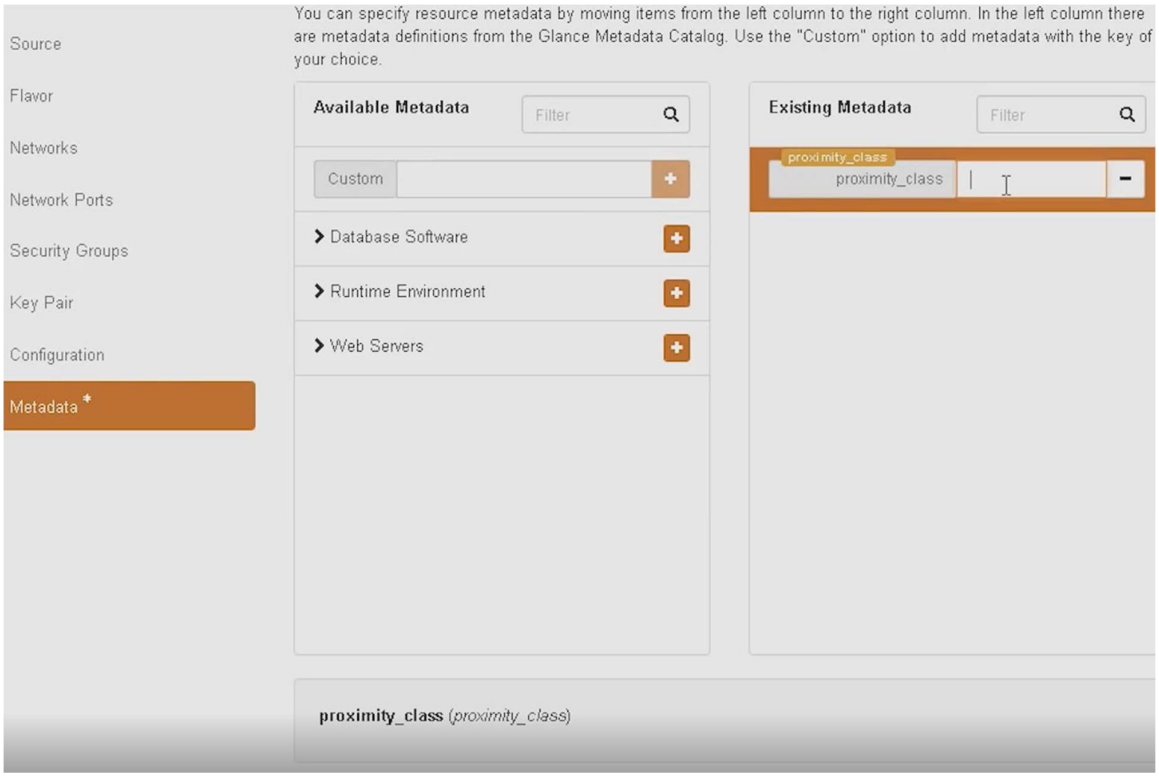


Figure 13 – TRIANGLE MEC Architecture

Once connected to the dashboard, the experimenters will be able to upload their VMs, connect them to the UE PN and among themselves through BNs, and, if needed, to assign additional constraints to each VM. For example, in Figure 14 below, we can see the assignment of a "proximity class," which represents the allowed maximum distance (in terms of latency delay) from the UE.



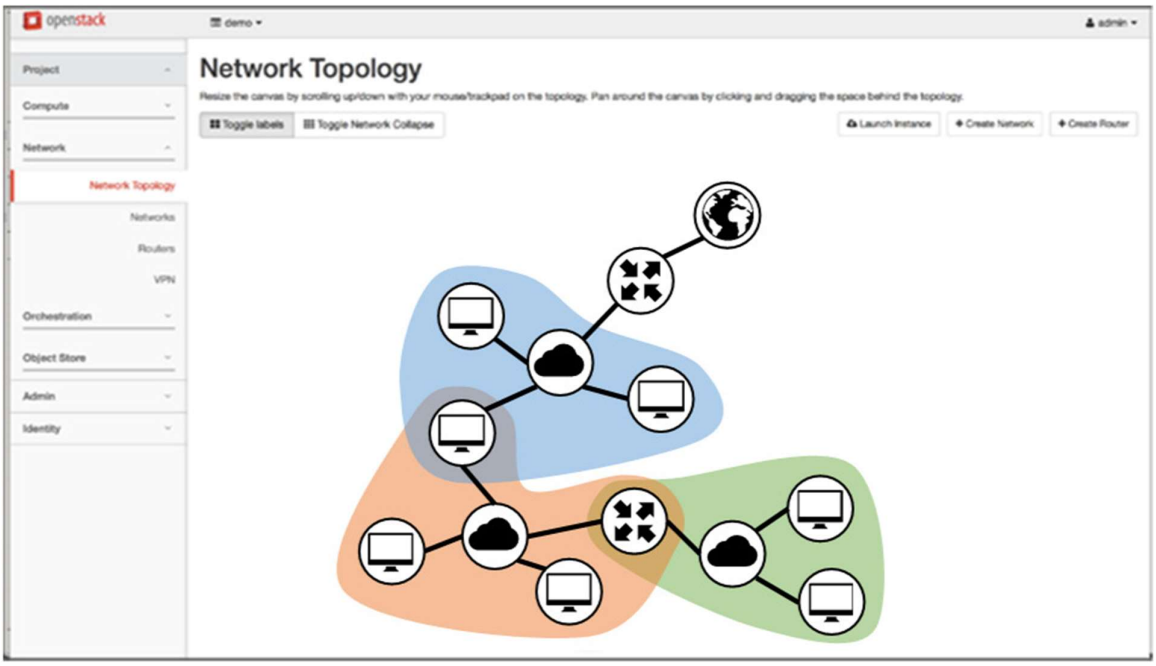


Figure 14 – Screenshots of the OpenStack Horizon dashboard embedded in OpenVolcano

CNIT are designing a Test Automation Platform (TAP) plugin for configuring and running the tests. In more detail, the plugin allows the experimenters to define the testbed configuration, e.g., the number of PoPs, the initial service chain placement, etc., and additional performance constraints, such as, for example, network latency among PoPs or towards base-stations. Then, the plugin is also used to perform the lifecycle operations on the service chains, such as instantiate/de-instantiate, migrate, etc., by means of TAP test steps

2.2.1.3 Extension timeline

The following timeline describes the CNIT Extension as outline below in Figure 15

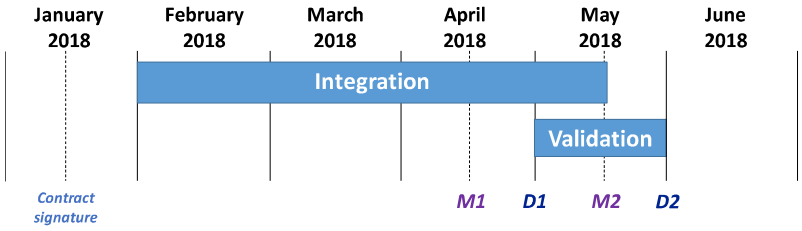


Figure 15 – WiSyLab Timeline

2.2.1.4 Key results and Insights gained from Testing

CNIT have stated that they think they have a lot of results and very interesting features identified to say that this experiment has been a success.

Table 6 – Summary Experiment Status

(removed for confidentiality)

2.2.1.5 Business benefits

This extension has been a tangible opportunity for CNIT to promote and to bring the OpenVolcano project ahead by interfacing it in a different environment with respect to the previous research activities, which has allowed to develop/extend APIs, interfaces and capabilities.
Moreover, an additional benefit could be provided by the wider user community that can interact with the OpenVolcano framework and might adopt it in their research activities

2.2.1.6 TRIANGLE testing value identified

This extension has been a tangible opportunity for CNIT to promote and to bring the OpenVolcano project ahead by interfacing it in a different environment with respect to the previous research activities, which has allowed to develop/extend APIs, interfaces and capabilities.

“Thanks to Triangle, we had a chance to interact with a completely new environment for the first time, and face both technical and organizational challenges that otherwise could have occurred in the future and in more critical contexts.

2.2.1.7 TRIANGLE benefits identified (removed for confidentiality)

2.2.1.8 Planned further use of the Testbed

Since OpenVolcano will also be adopted as MEC system in the 5G-PPP Phase 2 MATILDA Innovation Action, which will require its integration in at least two testbeds, the integration activities performed within Triangle will surely be beneficial in the near future activities. Given the chance, CNIT will be willing to use Triangle facilities again in the future.

2.2.2 Streamowl: Extension - SQUARE

2.2.2.1 Extension Summary

SQUARE: Service Quality monitoring of video streaming services with active and passive probes.

The purpose of this extension is to extend the TRIANGLE testbed to assist with evaluating the Quality of-Experience (QoE) of popular video streaming services (e.g. YouTube, Netflix,) with active and passive measurements. Special emphasis is given to adaptive video streaming using a number of formats.

The developed extension integrates the StreamOwl OTT probe with the infrastructure and tools of the TRIANGLE project. The StreamOwl probe monitors the internet traffic in a passive and/or active and unobtrusive way by processing the network packets and capturing the displayed video and evaluates the impact of service parameters and technical KPIs (e.g. video bitrate, network degradations, type of service, etc.) on the perceived user quality, based on novel algorithms for quality assessment in IP-based applications for adaptive video streaming.

Therefore, the proposed extension provides the opportunity for third parties, which plan to use the Triangle testbed and propose new solutions for 5G networks, to evaluate the video QoE for a variety of video streaming services and video formats and quantify the improvements of their proposed solutions in terms of perceived quality. The diagnostic information that is provided by the extension also gives them the opportunity to troubleshoot any bottlenecks in network delivery and optimise the video transmission toolchain.

The output of the video information captured and analysed by the StreamOwl probe will serve as input in the the QoE handling process for TRIANGLE as will be outlined in future Deliverables.

2.2.2.2 Extension Preparation and Design

The StreamOwl probe captures and processes the network traffic (at the packet level) and processes the packet headers (and if necessary the video payload, when it is not encrypted) to extract information (e.g. frame sizes, bitrate, video content complexity, packet loss, packet delay) about the video quality. The probe can parse many different protocols, such as HTTP/TCP (for OTT), RTP/UDP/IP (for multicast IPTV), and it can also extract QoE parameters from emerging protocols, such as QUIC. The probe is provided in software form, and the input to probe are the IP packets, which can be captured from the mobile client directly using the TRIANGLE TestelDroid tool or Android-native packet capturing capabilities

Alternatively, the StreamOwl probe can be executed as a standalone application if there is access to the IP packets (e.g. through a switch port configured in SPAN mode). The output of the probe is video-related KQIs, such as re-buffering rate, start-up delay, segment quality, and audio/video Mean Opinion Score (MOS) based on novel algorithms for video quality assessment for adaptive video streaming.

The block diagram of the proposed extension is depicted in Figure 16: a mobile device (e.g. a smartphone or a tablet) periodically requests a video from a popular video streaming service (e.g. YouTube, Netflix, BBC, etc.). The video is played back either via an embedded video player, which provides the required libraries (e.g. using the YouTube player API) for monitoring the video performance, or the native video player of the application/service is employed (e.g. in the case of Netflix and BBC) and the KQIs are extracted by processing the video packets at the network level using the StreamOwl quality monitoring probe.

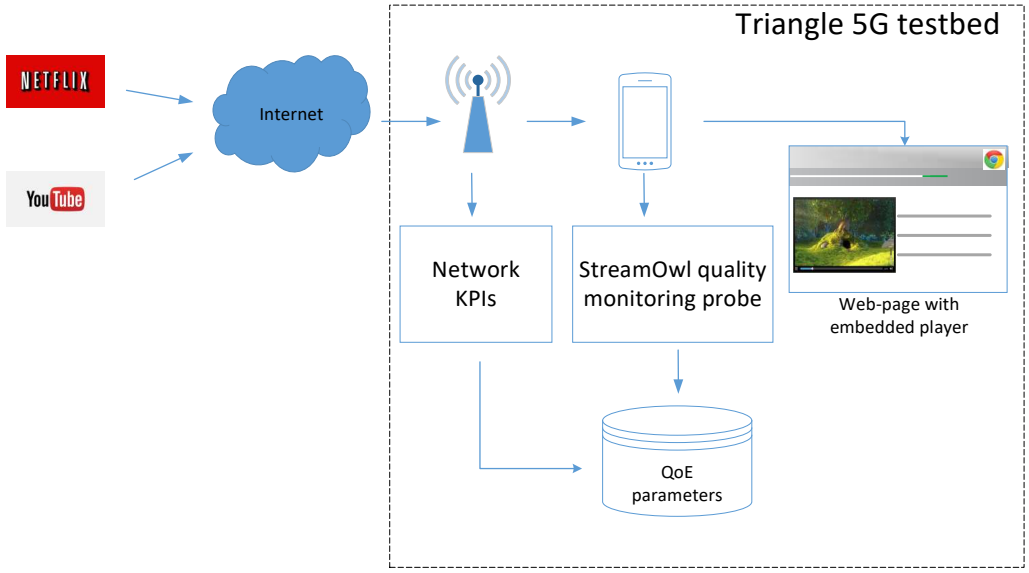


Figure 16 – StreamOwl Architecture

2.2.2.3 Extension timeline

At the time of writing this report the extension is at the point of being integrated into the Testbed environment, from a standalone deployment, though the extension is expected to run past the original proposed timeline, but is expected to be ready for OC5 and external users.

The following timeline describes the CNIT Extension as outline below in Figure 15

Month	1	2	3	4	5	6
Design of extension						
Extension development, integration, testing						
Validation and documentation						
Final report, code, and documentation						

Figure 17 – StreamOwl Timeline

2.2.2.4 Key results and Insights gained from Testing

The project has increased StreamOwl's technical expertise at the border between services, networks and users, and thus contribute to successful R&D and consulting activities in the field of QoE for national and international private sector partners, which will thus get exposed to project results as well.

Most importantly, they have improved their expertise on development of mobile applications for Android, and they have built a prototype that can be used as the basis for further product development.

Business benefits

The project has greatly supported StreamOwl in highlighting the importance of QoE to its customers, understanding the development of service assessment over time from a user's point of view, and modelling the impact of technical parameters and realistic settings of IP services beyond traditional metrics, such as the MOS, in order to quantify user satisfaction and acceptance.

TRIANGLE testing value identified

StreamOwl have indicated that while they could have developed their idea could have been developed without the Triangle testbed. However, in that case, it could have taken more time to develop and it would not be validated in platform which provides functionalities for automated testing.

TRIANGLE benefits identified

The integration of the extension is still ongoing as will further work on integrating the outputs of the video KPIs and metrics into the QoE evaluation and benchmarking for the Testbed.

StreamOwl has recently acquired licenses of the ITU-T Recommendation P.1201, the international standards for quality assessment in IP-based applications, from Deutsche Telekom, the owner of the licenses. StreamOwl has developed the "StreamOwl IPTV probe" and "StreamOwl OTT probe" for quality monitoring of IPTV and OTT services, respectively, based on these Recommendations, which ensures the highest possible validity and accuracy of the monitoring results.

Planned further use of the Testbed

The deployment of the StreamOwl OTTProbe will enable the marketing of a new product which enables QoE measurements from mobile phones and can be deployed easily and rapidly to help the interested stakeholders validate the benefits of new network technologies, such as the ones introduced in 5G networks.

StreamOwl intent to use Triangle facilities again in the future if they have the opportunity

3 TNO Extension

Deliverable D5.3 outlined the extension developed by TNO, this extension has now been deployed and is ready for use by experimenters.

The motivation to extend the TRIANGLE testbed was two-fold:

1. Deliver and validate a universal, scalable platform (the cloud), ready to serve various workloads from the TRIANGLE testbed users (the experimenters) who can use the tool (the orchestrator) to fully manage the lifecycle of their network services.
2. To equip the TRIANGLE testbed with facilities (deployed on top of the aforementioned platform) which allow for experimentation with demanding media applications and which enhance a content-consumer experience due to the integration with the orchestrated cloud itself. Figure 18 illustrates the TRIANGLE testbed before TNO extension while in Figure 19 the added elements are marked with the purple rectangles with red dotted borders. The infrastructure-related elements which assure deployment ease, flexibility, and reproducibility for the experimenters are the OpenStack-based cloud with the orchestrator (ETSI OSM) along with the TAP plugin. The media-related elements are DANE (to give suggestions to the video clients about the video quality they should choose in order to maximize all clients QoE), the client application and the video and visualisation servers (depicted as virtual functions instantiated within the cloud. Technically speaking, DANE itself is also a virtual function but is plotted below as a separate block outside the cloud due to the interaction it has with the orchestrated cloud infrastructure itself).

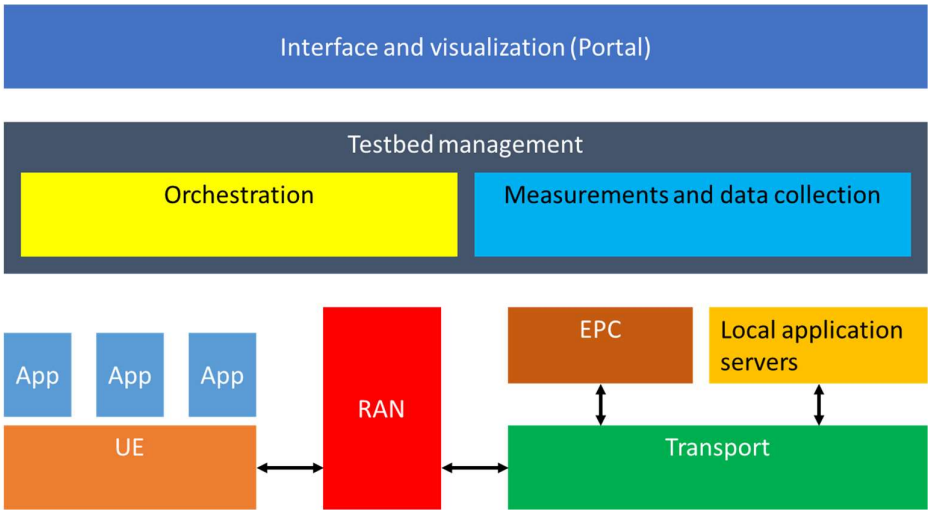


Figure 18 –TRIANGLE Testbed Before TNO extension

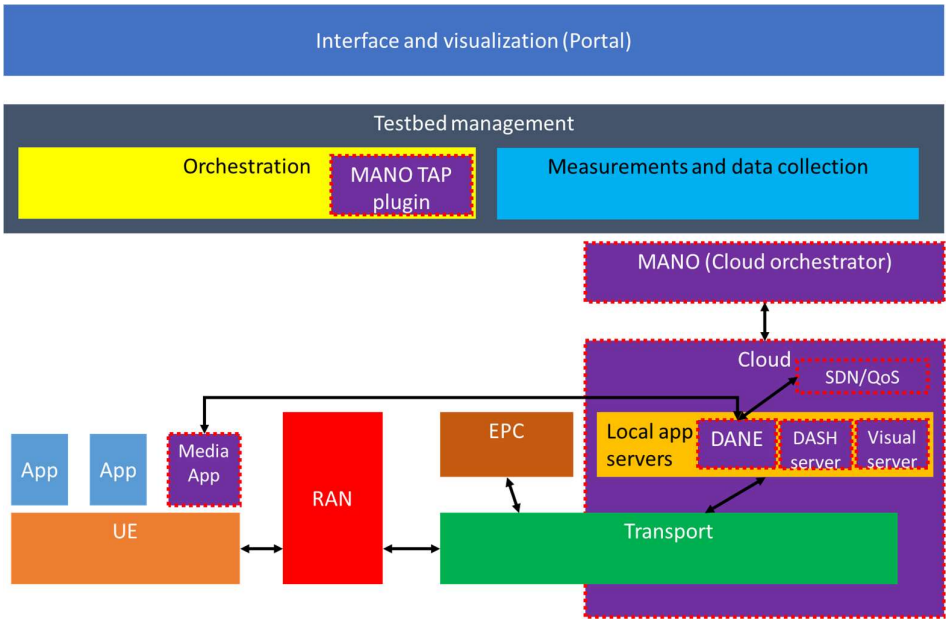


Figure 19 – TRIANGLE Testbed with TNO extension

4 Summary of Results of Open Call 3 & 4

The consortium felt that both OC 3 and 4 went well and continue to go well. Due to the increased number of applicants in OC3 and 4, The TRIANGLE consortium had a number of initial technical challenges to face in supporting the diverse setup of application areas and ensuring that the testbed was ready to support these application types.

As part of the evaluation process each testbed user is required to give their feedback on their experience using the testbed and suggestions that they may have for improving the testbed. Since the testbed is maturing and some of the applicants had a diverse set of testing challenges, it was inevitable that these users encountered some issues, especially at the outset of testing that are normal when real world usage of a new platform. In general, the issues found were small in terms of the seriousness and in most cases, quickly resolved by the technical support teams at the various TRIANGLE Testbed locations.

Suggestions for improvements are one of the key motivations for having early users and the consortium was happy to receive these suggestions and plan to address some of the suggestions in upcoming Testbed release, or in some cases, these have already been addressed. A summary of these suggestions, as well as of the issues identified, is listed in the following sections.

4.1 Summary of recommendations for Improvement

In this Section, the summary of all the issues and wishes provided as feedback by the Experimenters is presented. The TRIANGLE consortium has identified, in order to address such feedback, three action types defined as follows:

- Planned in a future TRIANGLE Testbed Release (e.g. R3 or R3')
- Will not be act upon in the frame of the EC project
- Will be addressed on a case by case basis on demand

In the case of [2], certain requests from the experimenters are well received but deemed outside of the scope of the EU research project context. As an example, a request to support many phone brands would not add value for the research portion of the project but would be mandatory feature for a commercial release of such testbed. We are therefore making a difference between requests which are research content and requests which are deemed important for a commercial service but which will not be developed or released in the frame of the TRIANGLE EU project.

Table 7 – Summary of recommendations for Improvement

Testbed Component	**Issue**	**Suggestion**	**Action**	**Plan**
DEKRA Performance Tool	Not all the TCP and UDP measurements were exposed through the API.	Add additional measurements to export	Expose on demand more API trough TAP	On demand
UXM	Uplink channel modelling on the UXM was missing		We will add channel impairment at transport level	R3
	The UXM supports carrier aggregation feature but no		Move the experimenter to	Solved

	AWGN profile is supported for the second component carrier		the main testbed which does support it, (distributed testbed does not support this capability)	
	When selecting the modulations to be used in the modulations loop, it would be quicker to have the possibility to select directly all of them instead of having to select them one by one.		It is a very specific request. Can be mitigated through consultancy	Closed
	It would have been useful to have the possibility to generate WiFi signal by the UXM itself.	UXM is not meant to generate Wifi signal	Alternative WiFi infrastructure exists in the Testbed outside of the UXM	Closed
TAP	Different requests around fine grain access to scenario creation (scheduling details)	Features to be improved in TAP with detailed documentation need	Improve TAP plugin to incorporate this functionality	To be discussed as specific case
	The error messages returned by TAP were sometimes unclear and misleading, what required additional time to investigate the issue	Improve error handling capability, specific use case	It is a very specific request. Can be mitigated through consultancy	In progress
	The modification of the essential transmission parameters in TAP requires changing more than one position in the setup, what sometimes might be unintuitive for non-experienced users	Add additional documentation and improve error handling	It is a very specific request. Can be mitigated through consultancy	In progress
	There is problem with importing the CQI-MCS mapping table from a CSV file,	Resolve import issue and improve documentation	TAP technical support looked into this issue and assured to fix it in the future software release.	In progress
	The modification of the essential transmission parameters in TAP requires changing more than one position in the	Add additional documentation and example how to improve	Improve documentation	In progress

	setup, what sometimes might be unintuitive for non-experienced users.	modification of parameters		
	There is difficulty in changing the channel bandwidth in one of the TAP instructions. Once the signal bandwidth was changed, TAP did not automatically change the number of RBs and, in particular, the value of another parameter used to define the number of RBs to be actually used (it was something like IFxxx). This is not a big deal, but if TAP changed by default such parameters it would be more intuitive	TRIANGLE team to investigate workarounds to this issue	Improve documentation and TAP plugin functionality improvement	R4
UE & Mobile Devices	Some additional control could be useful for the experimenter, like e.g. switching the device on/off, checking the battery status, verifying if the device is properly connected to UXM	Triangle can add more facilities to monitor and control mobile devices	For app developer this is available via the portal. For researcher we are adding this functionality in the testbed calibration step	R3 R4
	As a suggestion, I think it would be useful to have the availability of some “UE emulator” instead of a commercial device, in order to have more control on the UE-side.	Triangle can add a UE emulator	TRIANGLE can use a range of Android emulators and will evaluate to benefit in adding these to the Testbed portal as an option to run instead of a real device.	Under discussion
Server Infrastructure	The only limitation was represented by the number of servers dedicated to our extension.	TRIANGLE can support a number of VM instances for experimenters, there are many virtualised services available, and some	Triangle will examine sourcing additional servers, however where an experiment will require a high number of servers, or dedicated servers, this will	Under discussion

		dedicated servers	need to be examined as being contributed to from the experiment budget. Or from the experimenters providing their own hardware or environment.	
Portal	Device automation offered by Quamotion.	Support for device automation needs to be added to the Portal, similar to app automation	This has already been implemented, final integration is pending	R4
Quamotion & Web Driver	It was difficult to generate scripts that simulate a scenario with many user inputs and waiting for the application response, before proceeding to the next step.	TRIANGLE to improve documentation and samples to outline how to better handle these actions and to respond to events	TRIANGLE to add additional examples	Part of the device automation point above
Testbed Booking System	Automated booking system for reserving the resources needed for every experimental try	TRIANGLE to add an automated booking system	This has already been implemented	R3
Documentation	It could be useful to have the documentation and some “how to start” guide (especially for UXM and TAP) before accessing the testbed.	Triangle to add some additional documentation for UXM and TAP	Triangle will look at adding some introductory documentation for these resources in addition to the standard manuals for both. This may be complex as each user requires different functionality from both	User manuals are already shared, including help files. We disagree on this comment

	Documentation updates related to the current architecture of the infrastructure and practical examples of applications and/or configurations would be helpful.	Triangle to add some additional documentation for different application types where possible	Triangle will look at adding some introductory documentation for a set of sample application types. This may be complex as each user requires different functionality	Extension which anyway require detailed discussions.
	1) we would have liked to have documentation, along with more “real world” examples, specifically based on the Triangle testbed. 2) some form of repository, maybe collected with the support of previous experimenters/extensions, with helpful examples of practical applications, configurations, etc. might be a helpful addition to the available documentation.	Triangle to add some additional documentation for different application types where possible	Triangle will look at adding some introductory documentation for a set of sample application types. This will be based on Triangle benchmark applications as a guide, or popular Open Source apps and devices	Promote the use of benchmark applications. More documentation and examples
	further details should be added in the Portal User Guide regarding the creation of automation scripts and the error messages interpretation.	Triangle to add some additional documentation	Triangle to add some additional documentation	Promote the use of benchmark applications More documentation and examples
General	It could be very beneficial for the experimenters if the consortium provides the consultancy service that guides through every stage of the experiment: starting from the idea, through adjusting the test scenarios, helping to understand the results and supporting in dissemination activities	Triangle to add some additional consultancy	Triangle is exploring this engagement strategy as part of the business model	We agree and intend to offer consultancy service, see business model

4.1.1.1 Business Benefits and TRIANGLE Business Model

In addition to the technical and usability feedback each Experimenter also provided feedback on the financial benefits for them as a company and their competitiveness and also on the financial model for the TRIANGLE Testbed to operate as a commercial service in the future. The output of this input is not addressed in this document as it has been explored in more detail in the Business Plan for the Testbed, which is explored in D6.1.

5 TRIANGLE Experimenter Support

5.1.1 Support during the experiments

All the experimenters complemented the ease and efficiency of the support process during the experiment. Each Experiment had a corresponding project created in Redmine and individuals from each experiment team were added to the project in various roles.

Each Experiment also had a member of TRIANGLE assigned to be the main liaison on technical issues and to coordinate testbed access based on testbed availability. In the event of a technical issue, the Experimenter logged an issue on Redmine and the TRIANGLE liaison contact assigned the issue to an appropriately individual to resolve or to clarify with the reporter. In some cases, email and occasionally phone calls were scheduled to resolve issues or to clarify questions more efficiently.

5.1.2 Support for the Testbed Scheduling

One of the areas that has been improved from the previous Open Call is the ability to more efficiently and effectively manage multiple Open Callers requesting to use the TRIANGLE Testbed. In the UMA testbed, where that majority of the experiments are run, large parts of this process are now automated, with the ability to book through a calendar interface for booking time slots, with some checks to ensure testbed availability and operational state before access is branded and an experiment can start. The UMA team and the experimenters that use it find this to be a valuable feature.

5.1.3 General Experiment administration and communication

In addition to a technical lead for each experiment UCL coordinated and finance, admin, reporting and contracting tasks. Each Experimenter indicated that this aspect of the project was good to adequate. One experimenter commented that “The follow-up meetings were appropriated and perfectly scheduled according to our expectations for an experiment with short timeframe”.

Another experimenter mentioned that: “The administrative work was clear and timely, greatly alleviating the experimenters of any non-technical work that might obstruct the smooth conducting of the experiments. Further, feedback was also timely and targeted, with solutions usually being provided in a matter of minutes. While there was a delay to the starting of the experiment, the process was smooth from start to end.”

According to another experimenter: The support process was extremely efficient. All the documentation is publicly available online, devices under test were setup in the testbed environment with the support of expert. The possibility to perform the experiment on site seems more efficient that endless teleconferences and remote debugging.

5.1.4 Documentation

The main source of Documentation to support experiments is a combination of public documents on the TRIANGLE website that describe the testbed and its components and in a shared Redmine project that is accessible to all registered users that have been assigned Redmine accounts for experiments.

Overall it was commented that the documentation was adequate but that additional documentation in some certain areas would be useful. The use of getting started and guides based around sample applications would be useful. The consortium is actively involved in an ongoing process of generating more comprehensive documentation based on the suggestions outlined in Table 7.

5.1.5 Requests for Support during the experiments

Open Callers have used a combination of email, calls over Skype, the Triangle Booking System and Redmine for communication. Where possible, for issues and tasks the consortium has requested that Redmine be used for visibility and tracking purposes. This tool has been very useful for the consortium to maintain visibility of project, task and issue status and for document sharing. For each communication and Issue is opened on Redmine, a summary of these issues and the origin is outlined below in Figure 20.

IS Wireless did not make use of Redmine during the project, so their interactions were not recorded in the figures illustrated below but did indicate that they would have found a bug tracking tool to have been a more productive tool for communication with the consortium.

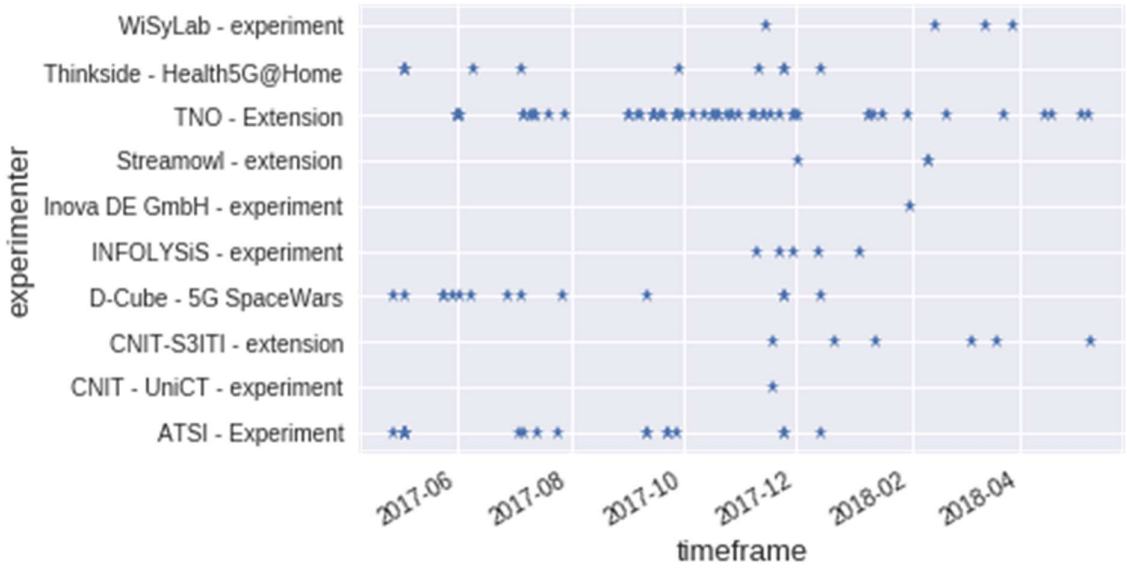


Figure 20 – Summary of All TRIANGLE Support communication in Redmine

As Redmine is used for a number of communication tasks when considering real support requests and not for other communication the breakdown of issues is as follows in Figure 21

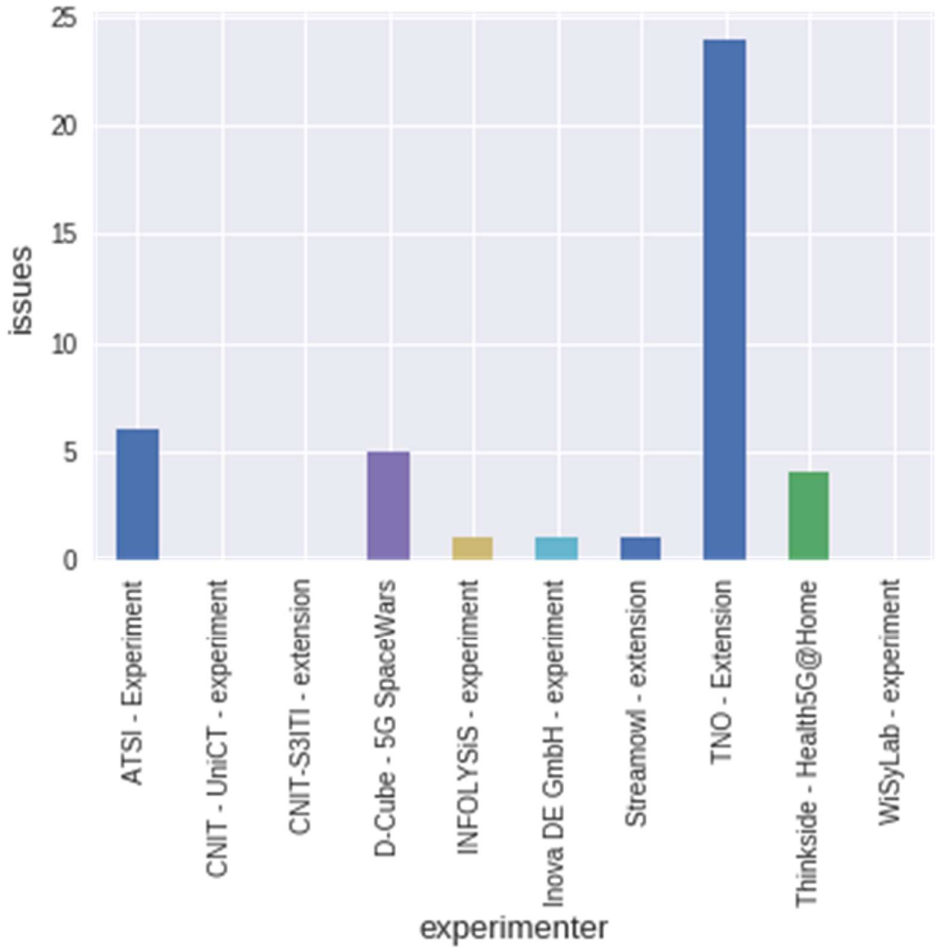


Figure 21 – Summary of TRIANGLE Support Requests in Redmine

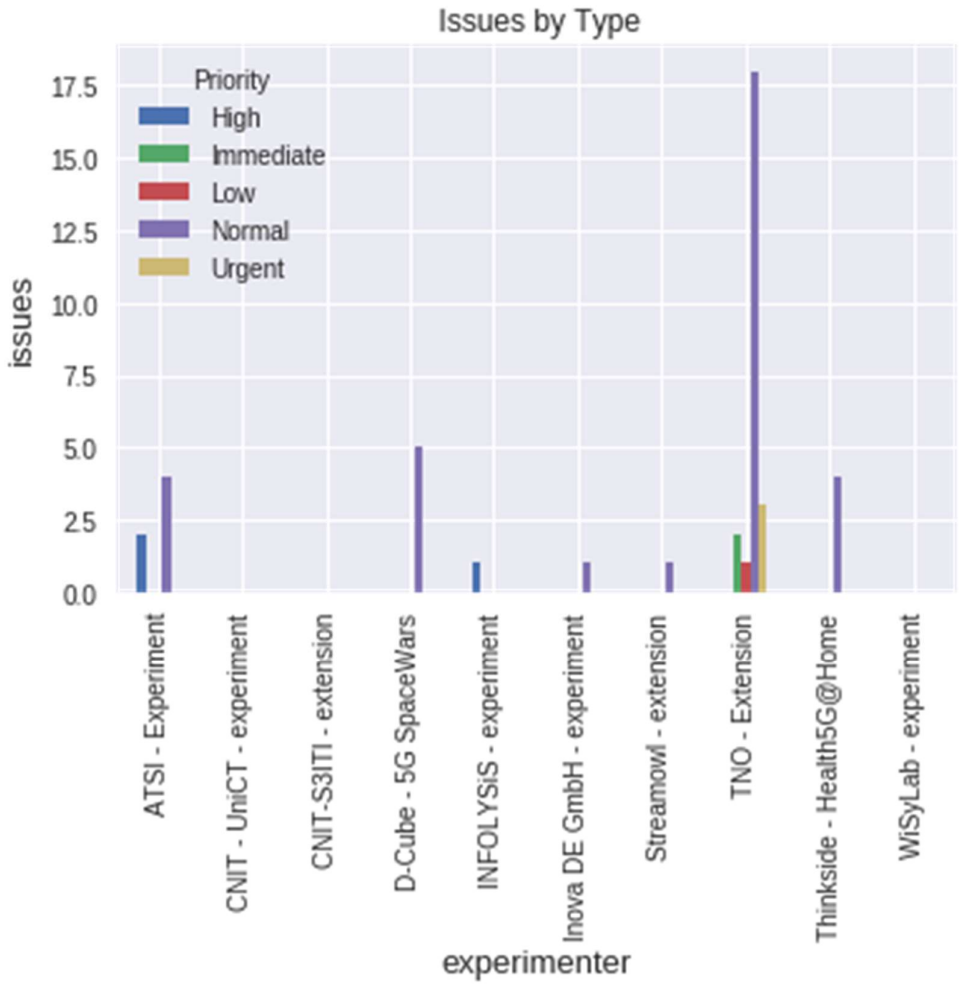


Figure 22 –Support Requests by Priority

6 Additional use of the Testbed outside of Open Calls

During the Open Call the TRIANGLE Testbed was also used by other users who had not applied, or been selected for the Open Call. This was done to maximise feedback from early testers. These testbed users used the testbed when the main experimenters did not require testbed access and have a second tier or priority to the testbed than those companies selected from the Open Call process. The TRIANGLE Consortium hopes to maximise testbed use and to extend the access of companies to the Testbed, on an unpaid basis and when not in use.

This has been facilitated as the Testbed has additional resources in the Keysight lab in Denmark and at a Dekra site (part of the distributed testbed feature) and some spare devices in the UMA lab, with Open Call applicants having priority. The TRIANGLE website now has a link on the top level to request Testbed Access and there is a short form for companies to fill out if they wish to request access.

At the time of writing this report the use of the TRIANGLE Testbed by other companies outside the Open Call process is at an early stage and is too early to have meaningful outputs for this report. We intend to have feedback from these external users in the next Deliverable D5.4.

Some of these experimenters are also keen on using the extensions in the Testbed with TNO also being requested by one applicant and others to use the MEC component, once deployed.

The identity of these experimenters is confidential, but they include:

- A major Mobile Operator
- A University very active in 5G research
- A major equipment provider
- A world-leading supplier of intelligent energy and water metering solutions
- A company providing software defined radio devices
- Additional extensions are also being added into the Testbed from a number of software and hardware providers

7 Quotes from TRIANGLE Experimenters

As part of the experiment report each experimenter was asked to summarise the benefit of the Testbed for the particular experiment that they ran or that they felt the benefit was in general. These quotes are summarised here and will be used for a set of promotional purposes, such as marketing and to be put om the TRIANGLE website.

Table 8 – Summary of Quotes

We chose TRIANGLE because it clearly was a great opportunity: TRIANGLE was not only providing the availability of instruments and tools that would have been otherwise unaffordable for us, but it was also giving the necessary funding for realizing the experiment, building the hardware adaptations, travelling etc. Another reason why we chose TRIANGLE is that after talking with TRIANGLE experts at EuCNC 2017, we realized that the tools they were offering were a perfect match to enable a real-world implementation of our concept.
Thanks to the experiment I conducted within Triangle, it was possible to bring the academy closer to the industry, thus bridging the gap between theory and practice and getting unique results!
The first time it was quite complicated to set up and run the experiment, but it was mainly due to the fact that some critical issues needed to be solved to adapt our device to the testbed and vice versa. Anyway, the support of Keysight experts at Aalborg was essential to be able to establish a stable connection with the device within the first day of experimentations. After those first issues, everything went well without any particular complication, so that we have been to complete the experimentations and even to perform them remotely.
Without TRIANGLE, we would have been forced to rely on some “home-made” solution which surely would not have allowed us to reach professional reliable results such as those that we have right now in our hands.
By creating and testing our hardware device, we acquired the knowledge of many practical aspects that can be now introduced into the system- level analysis. We had the possibility to understand both strengths and weakness of our technology, and this open to further improvements and developments.
There is not any official documentation available by Viber, Facebook or Skype, which describes the network condition requirements and operational values of the chatbot applications in order to reassure a smooth and acceptable QoE and QoS level. This was a major value/asset missing by our chatbots and it would not have been tested/verified without TRIANGLE testbed infrastructure. Without TRIANLGE, chatbot apps would continue to be valuable and dominant in the mobile apps market but user’s QoE and QoS

would potentially remain vulnerable to external and undocumented factors such as mobile phone models, network and environmental conditions.
Redmine usage and the prompt responses of the TRIANGLE team were more than valuable and played a vital role to the successful completion of 5G-Bot experiment!
Thanks to Triangle, we had a chance to interact with a completely new environment for the first time, and face both technical and organizational challenges that otherwise could have occurred in the future and in more critical contexts
Triangle was the best possible option for Infolysis in order to perform its 5G-Bot experiment … the Triangle platform and the existing pre-defined case scenarios, were in direct match to our experiment specifications and requests, while having a great availability of tools and support options, being all of them available to us by Triangle team.
Supported by the TRIANGLE project, we have been able to tune a first prototype able to demonstrate our technology, which is mandatory to elevate our “idea” to the upper levels of technological readiness, and this represents a first significant step towards the developing an actual product or cooperate with other industry for a joint development.
The technical offering was more than the expectations. We have been invited to perform our experimentations at the Keysight Laboratory in Aalborg, which is fully equipped with all the RF equipment we needed for our purposes, and personnel was incredibly collaborative.
Overall the access to the testbed infrastructures was easy, straightforward and reliable
I’ve been able to interact with an encouraging environment to further improve the application potentials of my MEC solutions.
The TAP SDK is fairly simple to use, at least for simple plugins.
The TAP SDK is the one that has proved to be the most useful tool for our extension.
Access to the infrastructure was granted in a timely manner
[Regarding TAP] The overall experience with this tool was excellent. It was the main tool for controlling the experimental process. Easy to modify the experiment needs using a user-friendly GUI. The positive aspects
If it wasn’t for the TRIANGLE Testbed, [we] wouldn’t have been able to develop solutions for the upcoming trend of data-demanding and connectivity-demanding apps to be needed

in the environment of 5G networks. Moreover, the lack of mechanisms to control different network scenarios would prevent us from collecting insights to be consider in our future work while developing new solutions for upcoming 5G networks.
[Regarding QuaMotion] it is a tool with many features. Among others, we found very useful the spy feature which facilitates the process of creating automation scripts
Many thanks for the great responsiveness and assistance of the TRIANGLE team and their high degree of professionalism and expertise.
It is virtually impossible to collect useful insight if there were no availability of a high performance mobile network testbed like TRIANGLE with the capability to control a highly heterogeneous environment, ensure security and trust, identity, and privacy.
The UXM has the great advantage to be an extremely technical tool allowing to control any possible system parameter, but at the same time it provides a very intuitive and user-friendly interface. It takes really few minutes to understand how to use it. There are not much instruments in the market that allow to accomplish such task, and, above all, they all are extremely expensive for academia.
TAP was fundamental to automatize the process of running experiments, generating and saving results. In particular, it was very useful to run the same experiment several times by looping over some specific set of parameters. For example, we used TAP in order to evaluate the performance of LTE transmission over cable by trying al the possible modulations and coding schemes, but also to run YouTube video streaming tests by playing the same set of videos several times. By TAP, we have been even able to simultaneously run and get results from two different devices one playing YouTube videos by WiFi, and the other performing an LTE transmission.
It has been very useful to keep track of all the communications related to the project by the TRIANGLE Web Portal. This has been fundamental to provide the effective timeline for the experiment. The TRIANGLE experts who supported us during all the project replied to our queries in a very timely manner thought the portal.
we had some issues during the contract negotiation phase, but TRIANGLE people have always proved to be willing to help and to find a common ground, so that at the end we found a solution and we could complete the experimentations within the project timeframe.

8 Conclusion

The TRIANGLE project ran a second set of Open Calls in order to test the usability of the testing service and get insight from potential customers about the business viability and technical and commercial interest on the market.

During the second year of the project two Open Calls have been opened for submission, evaluated, and executed. As a result, the project financed six experiments and two testbed extensions.

The experiments were focused on much diverse use cases, from Content Streaming, to M2M, to IoT devices and Fronthaul researchers. This diversity allowed the consortium to get insight on which types of companies and applications are interested in moving towards experimenting with 5G. Furthermore, most experiments, selected through an external panel of experts, are coming from SMEs. Continuing the trend from the previous Open Calls, showing how market-wise the SME ecosystem is getting ready for tackling the 5G financial market.

The valuable feedback from these experimenters has been evaluated and the (largely minor) issues and suggestions will be actioned, or are already addressed in the Testbed evolution, leading to a more versatile and experimenter-friendly offering. This experience is important as the consortium moves towards a commercial Testbed as a service offering being explored in the evolving Business plan in WP 6.

The testbed core functionality and current and evolving testbed extensions will improve the networking and service side of the testbed, incorporating the initial capabilities for supporting NFVs and NFV testing into the testbed and multiple connectivity options leading the Testbed to a more 5G-focused testing system.

9 References

[1] TRIANGLE Testbed tools [online] http://triangle-project.eu/tools

[2] OpenVolcano Project http://openvolcano.org

[3] Mailda Project https://5g-ppp.eu/matilda/

[4] A. Abdelrazik, G. Bunce, K. Cacciatore, K. Hui, S. Mahankali, F. Van Rooyen, “Adding Speed and

Agility to Virtualized Infrastructure with OpenStack,” White Paper, Apr. 2015

[5] DevStack, https://wiki.openstack.org/wiki/DevStack.

10 Appendix A – Experiment Application Questions

1. Experiment lead: Full name
2. Experiment lead: Email address
3. Experiment lead: Country of residence
4. Experiment lead: Legal registration number
5. Experiment lead: Participant Identification Code (PIC) issued by the European Union (or a business registration extract for organisations)
6. Are you applying to the Triangle open call on behalf of an organisation (business, research or other)? If yes, details for that organisation...
7. Please enter the names of all of your team members, along with their countries of residence (proof of eligibility will be required in the ca...
8. What is the title of your experiment idea?
9. Describe your idea and testing objectives from using the Triangle tested, outline what KPIs are to be measured.
10. What 5G features are you interested in experimenting with (note that not all features are standardised or available in the Testbed)?
11. Describe how your idea benefits from 5G technologies.
12. Outline who will benefit from your idea.
13. Describe how you think the Testbed would help to improve the QoE (Quality of Experience) for your application or device. (500 characters)
14. Describe how this experiment may impact your business and product development by indicating the way how this experiment fits in your activity
15. Outline your planned activities in a list and your timeplan.
16. If you wish to support your plan with a (max 1 page) pdf planning document, you may upload that document, this is not mandatory but is useful
17. Does your experiment proposal intend to use any data that may be protected under EU privacy laws?
18. Describe your Experiment Group, how are you organised, what skills and resources do you have.
19. Describes your company, organisation or research institution, include an overview of the activities, your qualifications, technical expertise.
20. Upload any additional supporting documentation e.g. architecture diagrams, that would help to further explain your proposal.(Optional)
21. If your project requires expenses such as travel to the Testbed please enter approximate costs here

11 Appendix B – Extension Application Questions

- Experiment lead: Full name
- Experiment lead: Email address
- Experiment lead: Country of residence
- Experiment lead: Legal registration number
- Experiment lead: Participant Identification Code (PIC) issued by the European Union (or a business registration extract for organisations)
- Are you applying to the TRIANGLE open call on behalf of an organisation (business, research or other)? If yes, details for that organisation
- Please enter the names of all of your team members, along with their countries of residence
- What is the title of your experiment idea?
- Describe your extension idea and objectives from working with the Triangle tested, outline what KPIs are to be measured.
- What 5G features is your extension in providing
- Describe how your idea relates to 5G technologies.
- Which of the Triangle tested components do you intend to integrate with with and how you integrate with them?
- Outline how the Triangle testbed will benefit from your idea.
- 1. Describe how this experiment may impact your business and product development by indicating the way how this experiment fits in your activity
- Outline your planned activities in a list and your time plan.
- If you wish to support your plan with a (max 1 page) pdf planning document, you may upload that document, this is not mandatory but is useful
- Does your experiment proposal intend to use any data that may be protected under EU privacy laws?
- Describe your Experiment Group, how are you organised, what skills and resources do you have.
- Upload your budget for the project, using the template provided: http://www.triangle-project.eu/experiments/BudgetTemplateExtensions.xls
- Would you propose an experiment without the funded open call?
- Please fill out and attach this document http://www.triangle-project.eu/wp-content/uploads/2017/06/TriangleOC3OC4_call-proposal_templatev2.1...

12 Appendix C – Extension Proposal Template

Annex A: Proposal Template
Green highlighted areas to be filled/modified

Innovative Experiment/Extension

Full title of the existing project you wish to join: 5G Applications and Devices Benchmarking
Acronym of the existing project: TRIANGLE
Grant agreement number of existing project: 688712

Full title of your project
Acronym of your proposal (optional)

Date of preparation of your proposal: xx/yy/2017
Version number *(optional):*

Your organisation name: Your organisation name
Your organisation address: Your organisation address
Name of the coordinating person: Name of the coordinating person
Coordinator telephone number: Coordinator telephone number
Coordinator email: Coordinator email
(this will be the email address to which the Acknowledgement of Receipt will be sent)

Project Summary

(Maximum 300 words– summary of your proposed work)

Remark: The information in this section may be used in public documents and reports by the TRIANGLE consortium.

Detailed Description and Expected Results

This section describes the details on the planned experiment or extension (what do you hope to obtain, how, why is it relevant). This section should also include all information with respect to the State-of-the-Art to show the innovative character of the experiment and the expected business impact. Suggested sections include:

Concept and objectives

Describe in detail the objectives of your proposed experiment/extension. These objectives should be achievable within your proposed action, not through subsequent development. Preferably they should be stated in a measurable and verifiable form.

In the case of experiments, this section should include information on the expectations regarding QoS and QoE (what will be measured, what is expected to be improved thanks to the experiments, ..)

In the case of extensions, this section should include information on how the testbed users will obtain benefits regarding QoS/QoE (new measurement capabilities, new control procedures, ..)

Business impact

Describe how this experiment may impact your business and product development.

Description of State-of-the-Art

In the case of experiments, this section should include information on current ways that the proposer is testing the applications or devices, and which advantages are expected from TRIANGLE. If no testing work is done with other methods, some ideas on testing methods for the kind of application or device is expected.

In the case of extensions, describe why your proposal is innovative with respect to other choices to solve the same problem.

Methodology and associated work plan

Provide a work plan which eventually can be broken down into work Tasks[1]. Provide clear goals and verifiable results and also a clear timing.

Requested TRIANGLE components that you plan to use (max. 1 page)

Provide a list of the features or tools that expect to use as experimenter and the components of the testbed that you need to interact with as an extension proposer.

Please review the TRIANGLE Testbed to complete this section http://www.TRIANGLE-project.eu/tools/

[1] A Task is a major sub-division of the proposed work with a verifiable end-point - normally a deliverable or a milestone in the overall action.

You may ask additional (confidential) information as part of the feasibility check if required to prepare your proposal.

Feasibility check (max. 1 page)

This section contains the feedback from the TRIANGLE consortium. Open callers should contact the TRIANGLE consortium in order to check the viability of their experiments before submission. Experiments should provide a draft proposal. The proposal will be evaluated and, eventually, a member of the TRIANGLE consortium will get in contact with the proposer to request or provide more information about the experiment. A member of the TRIANGLE consortium will issue a statement declaring that the experiment has gone through the feasibility check. This statement, and any feedback supplied by the TRIANGLE Consortium should be included in this section.
This section is mandatory for extensions.

Background and qualifications (target length 1-2 pages)

This section describes the proposer and includes an overview of the activities, your qualifications, technical expertise and other information to allow the reviewers to judge your ability to carry out the experiment.

Expected feedback to the TRIANGLE Consortium (target length 1-2 pages)

This section contains valuable information for the TRIANGLE consortium and should indicate the expected feedback the TRIANGLE consortium can expect form the use of the TRIANGLE testbed after carrying out your experiment. This information is essential in view of the sustainability of the testbed and use of tools and procedures. TRIANGLE consortium expects from you a clear description of the benefits that you get from using TRIANGLE. Note that the production of this feedback is one of the key motivations for the existence of the TRIANGLE open calls.

Requested funding (1 page)

This section provides an overview of the budgeted costs and the requested funding. A split is made in personnel costs and other costs (travel, consumables,..).
Note that extensions will be active until the end of the project and the allocation of some resources to support the extension is expected.
Please show your figures in euros (not thousands of euros)

Budget Experimenter:

	Total PM	**Cost**
1. Personnel costs (incl. indirect costs)		
2. Other costs (incl. indirect costs)		

3. Total costs (Sum of row 1 and 2)	

In row 1, insert your personnel costs for the work involved.
In row 2, insert any other costs, for example equipment or travel costs.
All cost numbers must include indirect cost. Indirect costs shall follow the H2020 guidelines and are defined as a flat rate of 25% of your eligible direct cost.

13 Appendix D – Experiment Report Template

Triangle Experiment Report

Full title of your project
Acronym of your proposal (optional)

Date of preparation of your proposal: xx/yy/2017
Version number *(optional):*

Your organisation name:	Your organisation name
Your organisation address:	Your organisation address
Name of the coordinating person:	Name of the coordinating person
Coordinator telephone number:	Coordinator telephone number
Coordinator email:	Coordinator email

(this will be the email address to which the Acknowledgement of Receipt will be sent)

Project Summary

This section provides an executive summary of the experiment objectives, implementation and main results. Remark: The information in this section will be used in public documents and reports by the Triangle consortium. The length of this section is restricted to 1 page.

Detailed Description

This section describes the details of the experiment/extension

Concept, Objectives, Set-up and Background

There is no page limit for this section as you are invited to describe the concept, objectives and setup in as much detail as you wish to do. Please also include graphs and figures were needed.

Concept & objectives

Describe in detail the concept and objectives of your experiment.

Gantt Chart

Simple Gannt chart showing the milestones and activities such as: contract signature, measurement campaign, experiments 1, experiments 2, processing of data, reporting, etc.

Set-up of the experiment

Describe in detail the set-up of your experiment. What was the technical design of the experiment? Please include a general overview or architecture figure to explain the set-up include any Triangle components that are a part of the setup.

Background / Motivation

Outline the relevance of this experiment / extension in your business or research activity. Why did you want to execute this experiment / extension? How did this experiment fit within the strategy of your company / institution?

Technical Results & Lessons learned

Describe in detail the technical results of your experiment or extension and the lessons learned.

There is no page limit for this section as you are invited to describe the concept, objectives and setup in as much detail as you wish to do. Please also include graphs and figures (where relevant).

Key points to cover include:

i. *technical challenges encountered and overcome*
ii. *QoE evaluation for the application*
iii. *impact of QoE based on different network conditions*
iv. *key KPIs are to be measured (where possible refer to the KPIs defined by Triangle)*
v. *Service levels identified*
vi. *How the app/device adapts to different network conditions*

Business impact

Describe in detail how this experiment may impact your business and product development.

Value perceived

What is the value you have perceived from this experiment (return on investment)?
E.g. gained knowledge; acquired new competences; practical implementation solutions such as scalability, reliability, interoperability; new ideas for experiments / products; etc.

What was the direct or indirect value for your company / institution? What is the time frame this value could be incorporated within your current product(s) range or technical solution? Could you apply your results also to other scenarios, products, industries?

If no testbed infrastructure would be available, how would this have affected your product / solution? What would have been the value of your product / solution if the experiment was not executed within Triangle? What problems could have occurred?

Are there any follow-up activities planned by your company/institution? New projects or funding thanks to this experiment? Do you intend to use Triangle facilities again in the future?

Funding

Was the allocated budget related to the experiment to be conducted high enough (to execute the experiment, in relation to the value perceived, etc.)?

Did you receive other funding for executing this experiment besides the money from the Triangle open call (e.g. internal, national, …)?

Would you (have) execute(d) the experiment without receiving any external funding?

Would you even consider to pay for running such an experiment? If so, what do you see as most valuable component(s) to pay for (resources, support, …)?

Feedback to Triangle

This section contains valuable information for the Triangle consortium and describes your experiences by running your experiment on the available testbeds. Note that the production of this feedback is one of the key motivations for the existence of the Triangle open calls.

Resources & tools used

Did you make use of all requested testbed infrastructure resources, as specified in your open call proposal? If not, please explain.

What was the ratio between time reserved vs time actually used for each resource? Why does it differ that much (e.g. for interference reasons, other)?

Tools

Describe in detail the tools you have been using, resources used, how many nodes, …

Tools	*Description?*	*Used?*	*Please indicate your experience with the tools. What were the positive aspects? What didn't work?*
TAP	Experiment Controller		
Triangle Web Portal	User interface		
UXM	eNodeB emulator		
LTE Small Cells	RAN testing		
Wi-Fi APs	WLAN coverage		
Polaris EPC	LTE Core Network		
SMU	Power analyzer		

TestelDroid	Android monitoring tool		
DEKRA Performance Tool	Traffic generator and sink; data KPI calculator		
QuaMotion	Mobile UI automation		
Android UEs	Recent smartphones		
LTE modems	RAN connectivity		
Virtual Machines	For installation of any supporting software		
Please list below other tools used			

Feedback based on design/set-up/running your experiment on Triangle

Describe in detail your experiences concerning the procedure and administration, set-up, Triangle portfolio, documentation and support, experimentation environment, and experimentation execution and results. This feedback will help us for future improvement.

Procedure / Administration

How do you rate the level of work for administration / feedback / writing documents / attending conference calls or meetings compared to the timeframe of the experiment?

Setup of the experiment

How much effort was required to set up and run the experiment for the first time? Did you need to install additional components before you were able to execute the experiment (e.g. install hardware / software components)?

Triangle testbed

Was testbed sufficient to run your experiment?

Was the technical offering in line with the expectations? What were the positive and negative aspects? Which requirements could not be fulfilled?

Could you easily access the requested testbed infrastructures?

Could you make use of all requested testbed resources as was proposed in the description of the experiment? If not, how many times did this fail? What were the main reasons it failed (e.g. timing constraints, technical failures, etc.)?

Documentation and support

Was the documentation provided helpful for setting up and running the experiment? Was it complete? What was missing? What could be updated/extended?

Did you make use of the Redmine portal for support?

Experiment environment

Was the environment trustworthy enough for your experiments (in terms of data protection, privacy guarantees of yourself and your experiment)?

Did you have enough control of the environment to repeat the experiment in an easy manner?

Did you experience that the Triangle environment is unique for experimentation and goes beyond the lab environment and enables real world implementation?

Did you share your experiment and/or results with a wider community of experimenters (e.g. for greater impact of results, shared dissemination, possibility to share experience and knowledge with other experimenters)? If not, would you consider this in the future?

Experiment execution and results

Did you have enough time to conduct the experiment?

Were the results below / in line with / exceeding your initial goals and expectations?

What were the hurdles / bottlenecks? What could not be executed? Was this due to technical limits? Would the federation or the individual testbeds be able to help you solving this problem in the future?

Other feedback

If you have other feedback or comments not discussed before related to the design, set-up and execution of your experiment, please note them below.

Why Triangle was useful to you

Describe why you chose Triangle for your experiment, which components were perceived as most valuable, and your opinion what you would have liked to have had, what should be changed or was missing.

Execution of the experiment

Why did you choose Triangle for your experiment? Was it the availability of budget, ease of access, quality of facilities available, access to resources that otherwise would not be affordable, availability of tools, etc.? Please specify in detail.

Could you have conducted the experiment at a commercially available testbed infrastructure?

Added value of Triangle

Which components did you see as highly valuable for the experiment/extension? Please rank them in order of importance.

Which of these tools and components should Triangle offer to allow experimentation without funding?

What is missing from your perspective?

What would you have liked to have had within Triangle (tools, APIs, scripts, documentation …)? Which tools and procedures should be adapted? What functionality did you really miss?

Is there any other kind of support that you would expect from the consortium, which is not available today e.g. some kind of consultancy service that can guide you through every step of the process of transforming your idea into an actual successful experiment and eventually helping you to understand the obtained results?

Other feedback

If you have further feedback or comments not discussed before how Triangle was useful to you, please note them below.

Quote

We would also like to have a quote we could use for further dissemination activities. Please complete the following sentence.

Thanks to the experiment I conducted within Triangle ...

Feedback to 5G Community

This section contains valuable information for the community of developers and researchers in the area of 5G application and device development and describes your experiences by running your experiment on the available testbeds. Note that the production of this feedback is one of the key motivations for the existence of the Triangle open calls

5G Use Cases Explored

Outline the 5G features of your experiment and any recommendations for other developers in this area (power consumption, latency, trade-offs, recommendations etc. Please use as much space as needed as all feedback is valuable)

5G Use Case	**Relevant (tick with X)**	**Comments and recommendations**
Heterogeneous connectivity		
Network slicing of a service		

Network Function Virtualisation		
Ability to adapt to network conditions in real time		
Massive Internet Of Things		
Ultra-reliable Communications		
Extreme real-time communications		
Higher user mobility		
High quality video streaming		
Mobile Edge Computing		

Other		

Other feedback to the community

Other feedback to the 5G community If you have further feedback/recommendations/lesson learned/best practice on your experiences

14 Appendix E – Open Call 3 & OC4 Process Overview

TRIANGLE Open Call Review Process Overview

Introduction to TRIANGLE Open Call process

The main objective of the third Open Call (OC3) [3] is testing the Triangle testbed with **Experiments** that are co-created with companies such as application developers and device manufacturers. Example experiments could include application developers testing 5G scenarious such as low latency to facilitate VR, or an IoT device maker who wants to benchmark their devices against other low power devices. The experiments will help develop the Triangle testbed as a whole to match the needs of experimenters, and will evolve the technical integration in the Triangle testbed at the University of Malaga (Spain).

The fourth Open Call (OC4) [4] is for testbed **Extensions**, where the main objective is adding additional capabilities to the Triangle testbed to facilitate extensions that are co-created with companies such as application developers and device manufacturers. The extensions will help develop the Triangle testbed as a whole to match the needs of experimenters. Extensions will evolve the existing Triangle Testbed and integrate with additional Triangle testbed components.
For more information about the current capabilities of the testbed and what types of experiments it can run see the testbed overview at [2].

The presentation slides that will be presented on the briefing call will contain details about the specific type of areas being looked for in the Triangle testbed extensions.

TRIANGLE Open Call process overview

The Open Call process consists in four main phases, the last of which has two separate parts. An overview of the process can be seen in Appendix C. Independently from the nature of the Open Call itself, being Experiments or Extensions, the process is identical, with only details on the content of the experiments differing from one to the other.

Each Experiment Group will have an appointed Experiment Lead, who coordinates the group and is responsible for providing the Triangle project management with reports and feedback for the relevant European Commission auditing.

TRIANGLE Application Evaluation Committee

Responsibility for the initial Open Call application review and evaluation will lie with the TRIANGLE Application Evaluation Committee (AEC). This consists of invited experts and a TRIANGLE nominated chairman. The experts will receive an invitation to the F6S [1] portal for application review using a LinkedIn account or email & password and see each application that they are assigned to review. The reviewer can view information about the company (or groups of companies if applying as a group), the answers to the application questions (see Appendix A and B) and any accompanying documents such as the budget spreadsheet,a planning timeline PDF and any additional supporting documentation(if supplied).

For convenience the documents on F6S have been combined into a single document and the allocated application will be emailed to each reviewer.

The reviewers will then score the applications based on the Evaluation Criteria, outlined later in this document. The chairman will then evaluate the scores and present the applications with the higest score to the consortium for Technical and Privacy & Ethics reviews.

A contract will be issued to each reviewer and details on renumeration. If any reviewer believes that they have a conflict of interest in reviewing any of the applications, they should inform the Open Call co-ordinator.

Briefing and Evaluation Calls

The consortium will have briefing call for evaluators to outline the TRIANGLE Testbed to the reviewers, this call will take place over WebEx and be recorded for experts who are unable to attend the call. This call will address the project and what makes a good experiment and extension for the project.

After explaining the Testbed and the scoring criteria the Evaluators will have evaluate the applications that have been assigned to them. A further call may be necessary to discuss the evaluations and scores allocated.

Reviewers are encouraged to add notes, where relevant, to the applications, these notes will not be visible to the applicants, only to other reviewers.

14.1.1 Evaluation Criteria for Experiments and Extensions

The Evaluation Criteria for the scoring applications is aligned with EU scoring criteria [5] and will be evaluated based on three aspects: the quality of your idea, the expected effect or impact of your proposed experiment, and whether your plan is feasible (i.e. is it realistic in light of the technical facilities available, as well as in regards to time, human and financial resources). Below we list points evaluators will consider under each of these aspects.

Idea (0-5 points)

- Have you described your idea convincingly?
- Does your proposed idea include innovative elements (for example, development of new products, processes, data or services, adapting a solution to a new context...)?
- Does 5G enable your idea?

What is the impact of your idea?

- In which ways can your experiment use the features of the Triangle testbed?
- Will your application/device/system benefit from 5G technologies, in particular, what features/improvements would it bring beyond existing technologies
- Relevance of the idea to the 5G Use Cases and application areas that have been identified in the Appendix
- The KPIs (Key Performance Indicators) that are to be measured
- How does your idea impact the European societal development towards 2020?

Feasibility of your idea (0-5 points)

- Is your idea technically ready for experimentation?
- Need for testing/Are the Triangle testbed tools available suitable for your experiment?

- Are the experience and skills you and your team have sufficient to develop the experiment?
- Is your budget and plan realistic in relation to the activities listed?

Each evaluator will score the applications that they are assigned to according to the above criteria. The chairman will then evaluate the scores and present the applications with the highest score to the consortium for Technical and Privacy & Ethics reviews.

Technical Review

Each application will need to be evaluated based on the technical feasibility of using the Triangle testbed. Certain Use Cases may not be feasible based on a number of scenarios:

- The Triangle testbed may not have the necessary equipment to accommodate certain types of experiments or measurement criteria or accuracy levels
- The Triangle testbed may not be at a mature stage technically to accommodate certain types of experiment for the first Open call
- The type of device or application may not be suitable for the type of testing that is facilitated by the Triangle testbed
- The Use Case may have an external dependency that is not feasible to reliably test in any meaningful way
- The Use Case may involve proximity to certain devices or networks that are not practical to reproduce in the Triangle testbed
- The behaviour of the application or device behaviour may not be practical to automate for testing purposes.

Given the wide variety in nature of both the experiments and the technology extensions, the cases listed above are not an extensive list of all potential issues that could arise. It is not practical to predict, in advance, all possible reasons why a single experiment or component would not be feasible, given the existing testbed

conditions at the time of the application. A more specific set of criteria will be defined for the external experts to review before the opening of the Open Call.

The Triangle Technical Review Committee can refuse applications based on the result of the technical review.

Ethics and Privacy Review

Members of the Triangle consortium will in parallel to the technical review conduct an Ethics and Privacy review according to the same EU directives required by every H2020 project. Applications that the experts and the consortium feel do not adequately comply with the Privacy and Ethics criteria will be refused.

References

[6] f6s platform (http://f6s.com)

[7] TRIANGLE Technical overview (http://triangle-project.eu/tools)

[8] TRIANGLE Open Call 3 overview (http://www.triangle-project.eu/open-calls-open-call-3/)

[9] TRIANGLE Open Call 4 overview (http://www.triangle-project.eu/open-calls-open-call-4/)

[10] EU scoring criteria http://ec.europa.eu/research/participants/data/ref/h2020/call_ptef/ef/h2020-call-ef-ria-ia-csa_en.pdf

Appendix A – Experiment Application Questions

1. Experiment lead: full name
2. Experiment lead: email address
3. Experiment lead: country of residence
4. Experiment lead: your registration number (national ID or passport number)
5. Experiment lead: Participant Identification Code (PIC) issued by the European Union (or a business registration extract for organisations)
6. Are you applying to the Triangle open call on behalf of an organisation (business, research or other)? If yes, details for that organisation: name, registration number and registered address.
7. Please enter the names of all of your team members, along with their countries of residence (proof of eligibility will be required in the case of successful applications).

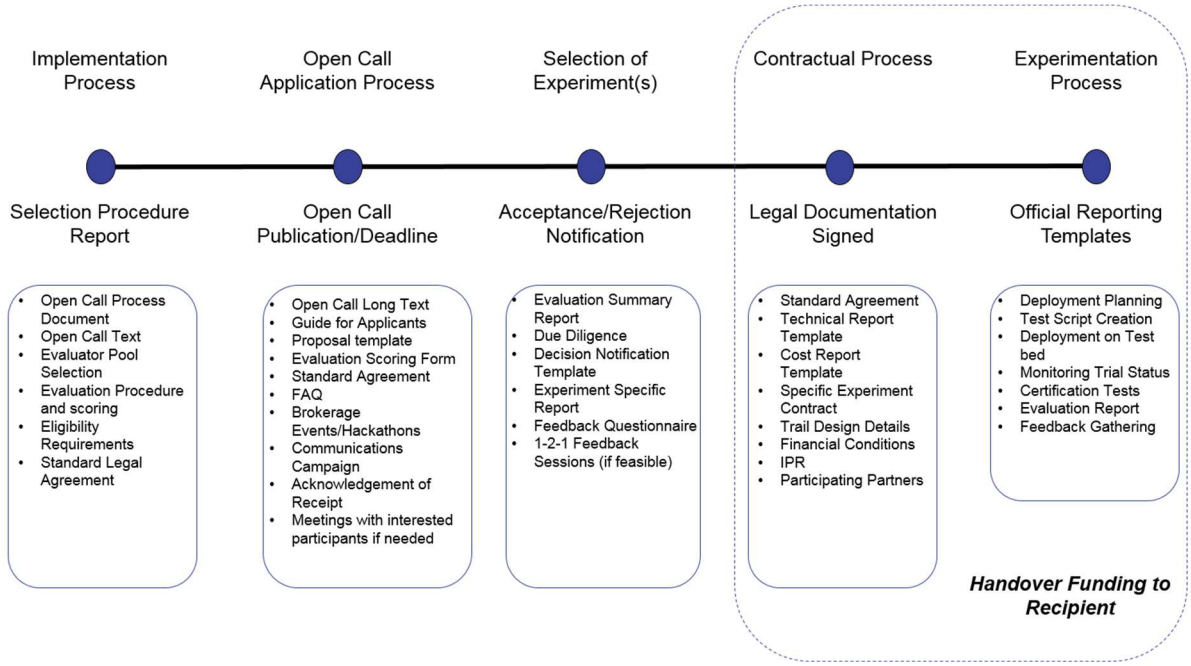
8. What is the title of your experiment idea?
9. Describe your idea and testing objectives from using the Triangle testbed, outline what KPIs are to be measured (3000 characters)
10. Describe how your idea benefits from 5G technologies. (2000 characters)
11. Outline your planned activities in a list and your timeplan. (1500 characters)
12. If you wish to support your plan with a (max 1 page) pdf planning document, you may upload that document, this is not mandatory but is useful.
13. Which of the Triangle testbed components do you intend to experiment with and how you will use them? You can find more info about the Tools and Data sources from http://www.triangle-project.eu/tools. (6000 characters)
14. Does your experiment proposal intend to use any data that may be protected under EU privacy laws? (Yes/No with more detail required if the answer is "yes" If "yes" you must include any considerations around ethics and privacy.) (200 characters)
15. Outline who will benefit from your idea. (500 characters)
16. Describe your Experiment Group, how are you organised, what skills and resources do you have. (3000 characters)
17. Upload your budget for the project, using the template provided http://www.triangle-project.eu/experiments/BudgetTemplate.xls.

Appendix B – Extensions Application Questions

1. Experiment lead: full name
2. Experiment lead: email address
3. Experiment lead: country of residence
4. Experiment lead: your registration number (national ID or passport number)
5. Experiment lead: Participant Identification Code (PIC) issued by the European Union (or a business registration extract for organisations)
6. Are you applying to the Triangle open call on behalf of an organisation (business, research or other)? If yes, details for that organisation: name, registration number and registered address.
7. Please enter the names of all of your team members, along with their countries of residence (proof of eligibility will be required in the case of successful applications).
8. What is the title of your experiment idea?
9. Describe your idea and testing objectives from using the Triangle testbed, outline what KPIs are to be measured (3000 characters)
10. Describe how your idea benefits from 5G technologies. (2000 characters)
11. Outline your planned activities in a list and your timeplan. (1500 characters)
12. If you wish to support your plan with a (max 1 page) pdf planning document, you may upload that document, this is not mandatory but is useful.
13. Which of the Triangle testbed components do you intend to experiment with and how you will use them? You can find more info about the Tools and Data sources from http://www.triangle-project.eu/tools. (6000 characters)
14. Does your experiment proposal intend to use any data that may be protected under EU privacy laws? (Yes/No with more detail required if the answer is "yes" If "yes" you must include any considerations around ethics and privacy.) (200 characters)
15. Outline who will benefit from your idea. (500 characters)
16. Describe your Experiment Group, how are you organised, what skills and resources do you have. (3000 characters)
17. Upload your budget for the project, using the template provided http://www.triangle-project.eu/experiments/BudgetTemplateExtensions.xls

18. Please add any additional documents that you feel would be helpful (this is not required)

15 Appendix F – Open Call process



16 Appendix G –Feedback from Application reviewers on OC3 and OC4 applicants

Removed for confidentiality

17 Appendix H – Experiment Report Summary

TRIANGLE: 5G Applications and Devices Benchmarking

Experiment Overview

DualRoC: Dual Radio-over-Copper Remotization for Multi-RAT Centralized-RAN Architecture in 5G Deployments

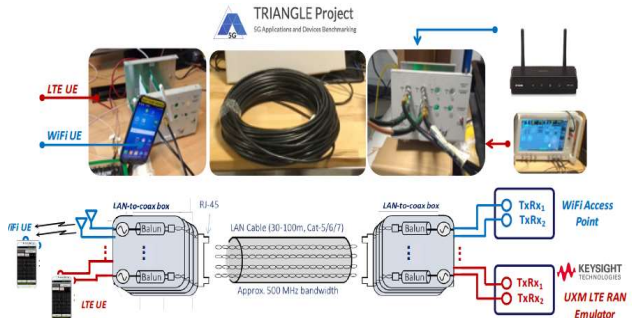
Motivation – Next generation (5G and beyond) communication networks are expected to incorporate the pre-existing LTE and WiFi connectivity of all the interconnected devices with multiple available interfaces, guaranteeing high-rate/low-latency communications. In this context, Dual-RoC is the integration of Multi Radio Access Technology (RAT) into a copper-based Centralized Radio Access Network (C-RAN) architecture.

Key Objectives

The objective of Dual-RoC Experiment is thus to experimentally observe and demonstrate the feasibility of the interplay between an all-analog C-RAN architecture based on LAN cables and Multi-RAT.

How Does It Work?

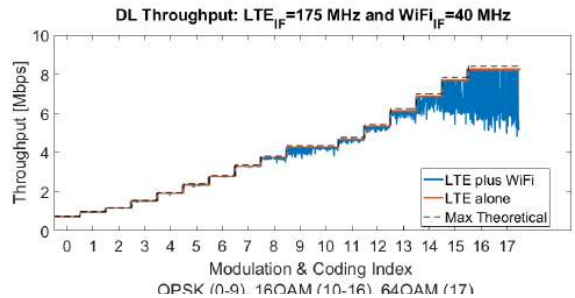
For Dual-RoC, the TRIANGLE testbed has been used in the typical device-testing configuration, with the only



difference that a 4-pairs RJ45 Cat-5e LAN cable has been inserted between the RF output ports of the UXM and the RF connections at the device to show the performance degradation introduced by the all-analog relaying over copper. The adaptation between RF connections and LAN cable is performed by the so-called LAN-to-coax boxes, which have been developed to enable Dual-RoC.

Key Results

Dual-RoC demonstrates the feasibility of carrying both MIMO LTE and WiFi signals over the same LAN cable using an all-analog relaying by a purposely selected mapping of IF frequencies onto the cable twisted pairs, iii) the performance degradation experienced for high



MCS and high IF is mainly due to the low signal power received at the user device due to the attenuation introduced by the analog relay over cable

Testbed Components Used

UXM RAN Emulator	Test Automation Platform (TAP
Wi-Fi Access Points	TestelDroid
TACS4 Performance Tool	Android UEs

Facts			
Company:	WiSyLab – Politecnico di Milano	POLITECNICO MILANO 1863	
Coordinator:	U. Spagnolini	**Company Mission:**	Research and Education
Duration:	01/01/2018 - 01/05/2018		

Experimenter's Impression: "Thanks to the experiment I conducted within Triangle, it was possible to bring the academy closer to the industry, thus bridging the gap between theory and practice and getting unique results!

TRIANGLE: 5G Applications and Devices Benchmarking

Experiment Overview

5G-Bot: Evaluation of 5G on QoE of Chatbot applications

Motivation – The objective of the 5G-Bot experiment was to test the behaviour of chatbot applications under different mobile reception conditions, network traffic, processing power schemes and battery utilisation plans in order to quantify and assess their impact on the QoE level as perceived by the user and to stress the reliability of the chatbot app under different network conditions.

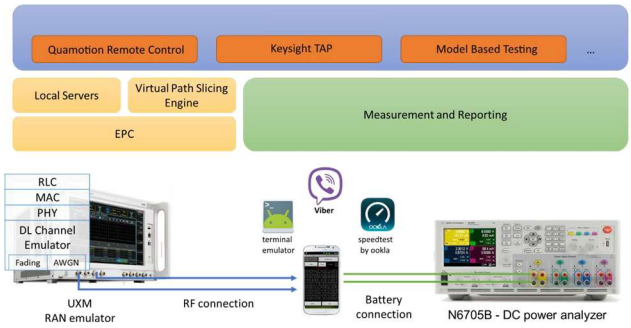
Key Objectives

The objective of experiment was to measure and benchmark chatbot app performance and QoE in different realistic network scenarios while measuring power usage

How Does It Work?

Three different types of chatbots over Viber platform have been used for the deployment of the 5G-BOT

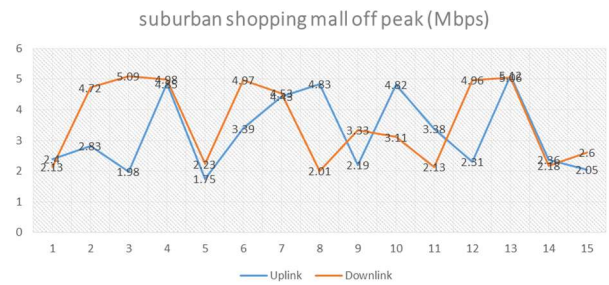
- Informative Chatbot
- Contest Participation Chatbot
- Order Placement Chatbot



These were run in a number of network scenarios:

4. Suburban: Festival, Shopping Mall Busy Hours, Shopping Mall off Peak, Stadium
5. Urban: Traffic Jam, Internet-café busy hours, Internet-café off peak, Office, Pedestrian
6. A 5G-Bot Custom made scenario

Key Results Overall, chatbot performance and functions were not remarkably affected upon changing factors/scenarios such as mobile phone models, environment conditions, reception conditions, network traffic, processing power schemes and battery use Infolysis acquired experience and documentation on which factors and parameters may affect the



performance of chatbot apps and up to what degree of severity. 5G-Bot experiment gave the opportunity to Infolysis to create a performance map under different scenarios, KPIs and metrics

Testbed Components Used

UXM RAN Emulator	Test Automation Platform (TAP
Quamotion WebDriver	TestelDroid
DC Power Analyser	Android UEs

Facts			
Company:	infolysis		
Coordinator:	V. Koumaras	**Company Mission:**	Provide IT cutting edge innovative solution
Duration:	01/01/2018 - 01/05/2018		

Experimenter's Impression: "I added value to the performance credibility of chatbot applications and improved users QoE!"

TRIANGLE: 5G Applications and Devices Benchmarking

Experiment Overview

PHYSCHED: Design space exploration and performance testing for PHY & scheduler

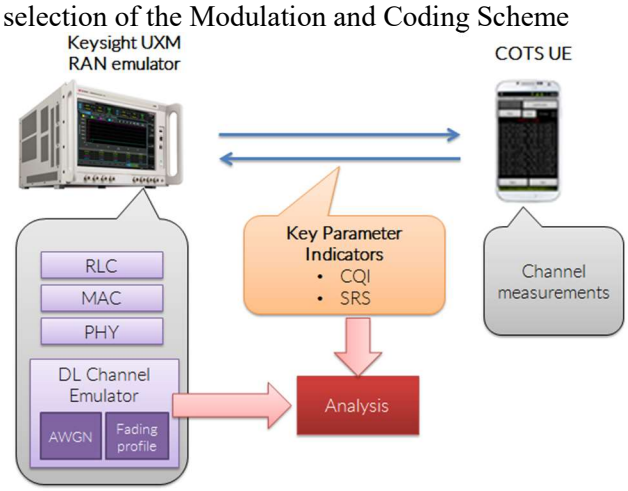
Motivation –The motivation of the experiment was to explore the design space for improvement and further implementation of a LTE eNB scheduling algorithm that is going to be a part of Software-defined RAN for 4G and 5G, developed by IS-Wireless and to perform advanced 3GPP conformance testing of link-level simulation tool, which is a key software component of ISW's 5G Toolset

Key Objectives

There were two objectives for the experiment
1) Design space exploration of standard-compliant environment for LTE eNB Scheduler optimization
2) Testing and validation of LTE PHY Lab downlink receiver processing chain.

How Does It Work?

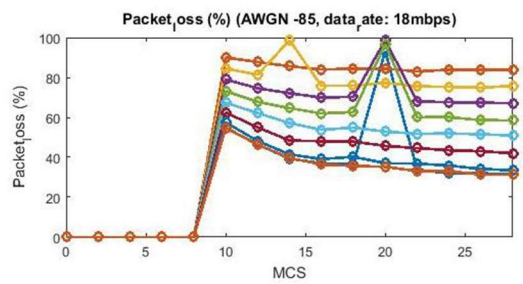
The UXM RAN Emulator was used to simulate the scheduler activity by selection of spectrum bandwidth, assignment of specific resources for the user and selection of the Modulation and Coding Scheme



DL Channel emulator was used to model the channel influence by adding the noise (AWGN) and applying fading profiles defined in 3GPP specification such as (pedestrian, vehicular or high-speed train

Key Results

Work is still ongoing on the LTE-PHY experiment, but for the Scheduler experiment The KPIs measured and returned by both UXM and TACS4 were analyzed dependent on the transmission configuration and known channel profile for multiple scenarios.
i) The KPI results correspond to the expectations in



regards to various scheduling decisions
ii) Results confirm the assumptions for the Scheduler

Testbed Components Used

UXM RAN Emulator	Test Automation Platform (TAP
TACS4 Performance Tool	Android UEs

Facts	
Company:	IS Wireless
Coordinator:	L. Kwiatkowski
Duration:	01/01/2018 - 01/07/2018

Company Mission:	IS-Wireless develops algorithms, protocols and tools for 4G and 5G mobile networks

Experimenter's Impression: "we had the opportunity to use the specialized equipment to explore a design space for the scheduling algorithms we have gained a solid ground for improvement and further implementation of our solutions for 4G/5G base stations"

TRIANGLE: 5G Applications and Devices Benchmarking

Experiment Overview

CellularGrid: Cellular Networks for Real-Time Monitoring of Smart Grid

Motivation – The scope in the smart grid industry has been extended to cover also elements like distributed energy resources, electric vehicles, protection relays, and metering devices, where wired communication is not cost effective to install and maintain. 5G can have comparable performance to wired infrastructure, allowing to discretize and network individual grid elements, which can then implement intelligent sensors and switching decisions to isolate faults, reroute power and self-heal the grid. This project evaluates the connectivity requirements of smart grid applications in 5G.

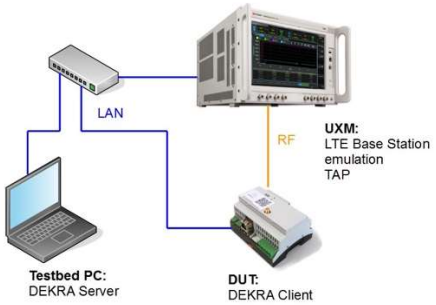
Key Objectives

The objective of the experiment will allow Comsensus to emulate their PMU/PQM devices use in different real life (LTE Cat-3, LTE Cat-M1, LTE Cat-NB1) network scenarios and thereby appropriately select the technology and/or adjust their design.

How Does It Work?

The DEKRA Performance Tool was used as a traffic generator and KPI calculator. The DEKRA server was run on a testbed PC, the client was run on DUT connected to the UXM via RF coaxial cable. The Urban-pedestrian LTE network scenario was chosen as it was the one that reassembles the DUTs target environment the closest

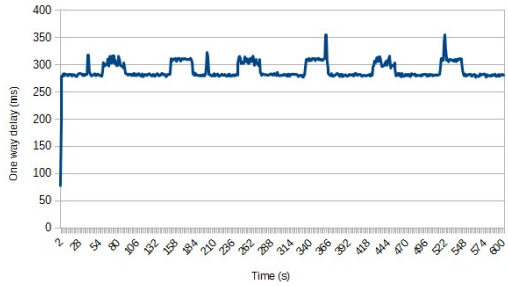
The two protocols evaluated were evaluated



i) the IEEE C37.118-2014 protocol and
ii) the IEC 61850-9-2 Sampled Values protocol both using TCP and UDP traffic.

Key Results

The Testbed was used to test the wireless link performance for different location and user density. The KPIs measured during the experiment include end-to-end delay and throughput. The results of the experiment confirmed that low throughput uplink with real-time constraints are viable using LTE Cat-3 even in the case



of challenging channel conditions. In the high throughput scenario the target throughput could not be reached in any of the predefined channel conditions.

Testbed Components Used

UXM RAN Emulator	Test Automation Platform (TAP
TACS4 Performance Tool	

Facts			
Company:	Comsensus		COM SENSUS
Coordinator:	M. Smolnikar	**Company Mission:**	deliver in depth understanding of your business process. Increase your operational efficiency with our customized IT solutions!
Duration:	01/01/2018 - 01/05/2018		

Experimenter's Impression: "Thanks to Triangle we were able shorten the product design cycle, obtain a set of measurements in a controlled environment & experiment with technologies not yet available commercially"