TRIANGLE White Paper

5G BaaS – Benchmark as a Service

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1   Introducing Benchmark-as-a-Service for 5G

In this white paper we explain the workings of the TRIANGLE testbed for 5G services. As the next generation of telecommunications to the year 2020 and beyond, 5G promises to deliver far greater throughput, much lower latency, ultra-high reliability, much higher connectivity density, and higher mobility range than its predecessors 3G and 4G. This enhanced performance is expected to bring new business models and opportunities to operators, applications developers and device manufacturers such that they can create new services and devices. But without a 5G network in place, how can an application developer test their application, how can a device manufacturer test their device? Indeed, how can an operator accept new devices and develop and roll out new services? Companies need to compare and benchmark their product against a set of performance metrics. This will allow them to improve their product and give it a rich set of capabilities. Operators need to experiment with different network configurations before they can roll out new services ensuring good user satisfaction.

This is where the TRIANGLE testbed comes in – a fully controlled end-to-end setup which allows application developers to test and benchmark their application and device manufacturers to test and benchmark their device in a realistic 5G scenario, and obtain scores against a set of pre-defined KPIs (Key Performance Indicators). It also allows operators to develop the network according to their configuration requirements and then experiment with the reliability, latency, service slicing and capability of the different configurations and benchmark the services they wish to roll out. This benchmarking result is the "TRIANGLE-MARK" which we explain in this white paper. Not only can companies and institutions test and benchmark their products but it allows them the freedom to experiment on a testbed in order to improve the performance and capabilities of their product, whether it is an application or a device, ahead of the 5G marketplace.

2   Why 5G Testing and Benchmarking

2.1 Addressing the 5G Market with new applications and devices

5G networks are currently being developed and expect to be near completion by 2020, in line with EU and industry initiatives which are intended to stimulate the evolution to 5G. The 5G networks have high performance targets and the key performance indicators defined by the industry[1] are:

- 1000 times higher mobile data volume per geographical area.
- 10 to 100 times more connected devices.
- 10 to 100 times higher typical user data rate.
- 10 times lower energy consumption.
- End-to-End latency of < 1ms.
- Ubiquitous 5G access including low density areas.

Testing and benchmarking will allow developers to improve and position their product performance in a pre-5G era. There are a number of aspects to consider such as network performance, optimisation, comparative studies as well as go-to-market factors.

The network performance is important from both a device and an application point of view. Let's look at an application example. Imagine an application from an IoT device which includes a camera for live video monitoring of critical agriculture events (e.g. a lamb being born in a field). This device will create high bandwidth demand on the network in a rural area for a short duration (perhaps an hour or more). It is important that the uplink capacity is available at a sufficient bit rate (e.g. 1Mbps), on-demand, when the event takes place. Testing such a device would require access to a network that is configurable in terms of uplink bandwidth and quality of service. This scenario can be tested out on the TRIANGLE testbed, a laboratory testbed with devices configured as in a telecommunications network by such application developers.

Using the TRIANGLE tools, a device or application developer can tune the parameters of their system to optimise performance under different conditions. Such conditions could include network load or factors affecting radio power and these are conditions that could be emulated on the TRIANGLE testbed.

TRIANGLE can enable comparative studies of device behaviour in different conditions. Profiles can be established and system behaviour can be measured, analysed and compared to reference applications on the TRIANGLE testbed. This gives a benchmark and an understanding of product position to the tester. Such comparative studies could help device or application development for the 5G market.

New product entrants are often in a race to be early into the market to get an established position and early customer wins. TRIANGLE can help with this process and reduce the risk in bringing new products to market.

Being ready for the rollout of 5G in 2020 means in part understanding the technical behaviour of a new 5G product or application as well as the network capabilities. TRIANGLE provides Benchmark-as-a-Service support to help new entrepreneurs and established suppliers 'tool-up' for 5G.

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[1] https://5g-ppp.eu/kpis/

2.2 Benchmarking for 5G products

Figure 1 shows the TRIANGLE Benchmark-as-a-Service (BaaS) process or user journey from start to finish in order to obtain benchmark results. Firstly, the interested operator, 5G device or application stakeholder registers online and selects a profile. Then training is set up and the testbed can be booked. The device can be shipped to the testbed and/or the application can be uploaded. The facilities can be accessed remotely or in person with support from the TRIANGLE team. The benchmarking results can be produced following testing and analysis.

As an example, companies developing 5G applications and devices will get critical help to test and benchmark their new mobile applications and devices against a controlled but realistic 5G wireless network. The TRIANGLE framework will enable QoE (Quality of Experience) evaluation which will ultimately enable certification for new mobile applications and devices.

Operators will also be able to test new services and assess how these are influenced by 5G network configuration and concepts such as SDN (Software Defined Networks) and NFV (Network Function Virtualisation).

Channel model and users mobility has an important impact on the performance of data and control channels. So this testing is of maximum interest during the evaluation of pre-5G products. The LTE/LTE-A application software supports integrated channel emulation inside the network emulator. This channel emulator allows testing of the performance of pre-5G products under different propagation conditions covering pedestrian, vehicular, urban and high speed scenarios based on ITU and 3GPP models. These models include the effect of multipath induced fading, time dispersion and Doppler shifts that arise from UE movement. Moreover some of these parameters can be customized to further adapt the channel models to specific use cases.

The channel emulator can also add Additive White Gaussian Noise (AWGN). The interference effects from multiple neighbour cells are traditionally modelled by AWGN with a power spectral density that depends on the channel signal-to-noise ratio (SNR), a parameter that can be also configured.

Cell densification also increases the complexity of network deployments, where macro cells and small cells coexist. To allow for fair coexistence in these heterogeneous networks, a certain amount of coordination is required to reduce the interference between cells by introducing coordination schemes in the transmission of the difference cells. This coordination is known as Inter-Cell Interference Coordination (ICIC) and can be tested using the network emulator. It not only provides the ability to define sets of time allocations reserved for aggressor and victim cells, but also provides customizable behaviours in Almost Blank Subframes (ABS) and finer grain interference modelling in the time domain, with different interfering powers being configurable at OFDM symbol resolution.

Accurate radio channel emulation and interference generation will allow the services to be tested under realistically controlled degraded conditions. That will help gather insights on usage scenarios that otherwise would require expensive and complex tests deployments in the field.

Figure 1 TRIANGLE Service Delivery Process

3   What is TRIANGLE-MARK

TRIANGLE offers the "TRIANGLE-MARK" as a pre-standards benchmark or pre-certification tool to provide an indicator of performance of an application or device capability in a 5G network emulation environment against a set of key performance indicators (KPIs). This TRIANGLE-MARK ensures that a mobile application or device operates in the future 5G mobile broadband networks with a guaranteed QoE.

The TRIANGLE-MARK (shown here in green indicating good performance) can be obtained after an assessment which covers most relevant performance indicators. See Figure 2.

An application will be tested on different hardware platforms (i.e. UE devices) to verify very different performance indicators such as

Figure 2 TRIANGLE-MARK

stability, security, reliability or the performance, both in terms of time behavior and in the use of resources. The application will get a final score that allows the tester to compare its performance with a similar application.

Devices will be tested using a set of reference applications defined in TRIANGLE to verify performance indicators such as power consumption and other specific QoE performance indicators.

When a product gets the TRIANGLE-MARK, it will interwork and perform satisfactorily in the growing ecosystem of 5G networks, devices, services and applications.

3.1 Benchmark-as-a-Service Example

An example of an application to be tested on the TRIANGLE testbed is given here. Let's assume the application developer has created a new application which demands real time communication between the UE (User Equipment) and another location. The developer can initially test the performance of its application in a controlled environment and then test with real users. The developer creates an account on the testbed and books a time to access the testbed. Then the developer uploads the application to the testbed portal. S/he uses the recording tool to record usage patterns to be reproduced during the tests and can run behavioural tests, networking tests (i.e. Office, pedestrian, stadium, high speed train) and power consumption tests. The testbed will be configured automatically to run the tests. The testing is made easy for the user, with high level configuration and pre-defined scripts The user will be notified when the testbed is ready to start the executions of the tests. At the end the testbed will provide a benchmark, a report and the logs of the testbed.

3.2 BaaS results illustrated

Once the testbed has generated a wide set of measurement data about the end-to-end performance of the system, it is now time to convert the scattered pieces of information into a coherent and concise set of metrics that can be easily understood and manipulated by the users, as displayed in Figure 3.
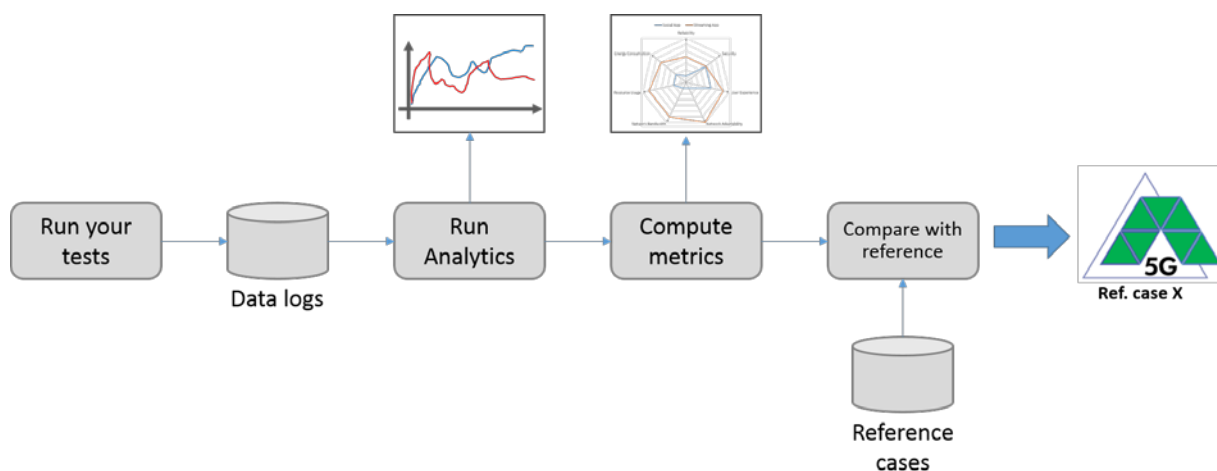
Figure 3 TRIANGLE Benchmark Flowchart for testing

The TRIANGLE testbed is equipped with an analytics tool that is able to automatically summarize the collected data into detailed plots that can give partial, but in-depth, insights into specific aspects of the system under test.

Analytics are just the first step of the process leading to a global overview of the performance. There is a huge quantity of processed data so it would be difficult to provide a clear and synthetic overview just with analytics. For this reason, we have decided to go a step further and investigate the best set of high level metrics that would be representative of the system as a whole, and be easily plotted into a unique diagram. To this end, we capture the characteristics of the product under test in our "Spiderweb" diagram as shown in Figure 4.
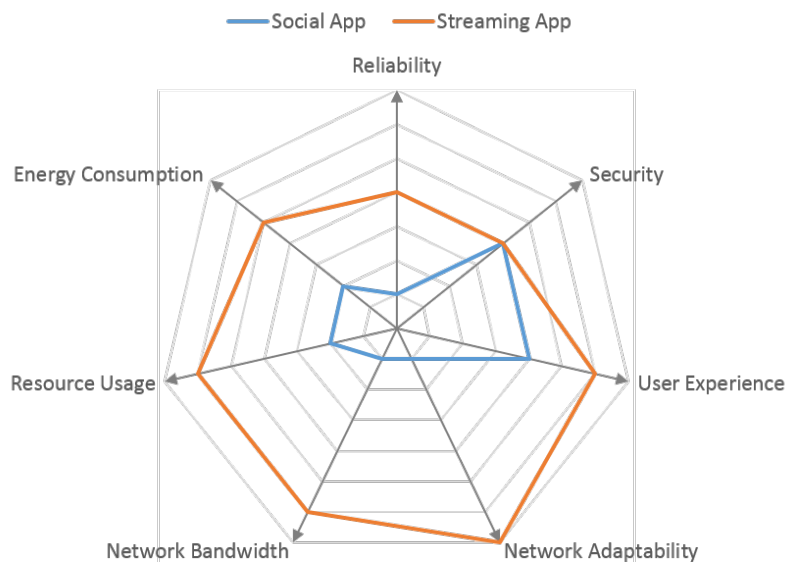

Figure 4 Example of TRIAGLE-MARK Spiderweb for Mobile Apps

In Figure 4 an example of the Spiderweb for Mobile applications is depicted. Two well-known reference cases, a social app and a streaming app have been chosen to explain the concept. As illustrated in the diagram, a social media application would normally consume low resources

energy and device-wise, but would have much higher requirements for security and user experience. On the other hand, a video streaming application would have a higher resource consumption but also have higher demands of the user experience, since nothing is more irritating for a user than a "laggy" video.

While the testing and illustration of high level metrics is useful for testing and eventually evaluating the performance of a product against expected values, the journey is not over yet. In order to get the TRIANGLE-MARK the product needs to be validated against a set of reference, off-the-shelf equivalent systems. In this way the product can be benchmarked and the tester can get an insight of the performance level compared to the market standard.

Finally, comparing the high level metrics against a set of standardized values for each specific use case, the tested product can get the TRIANGLE-MARK. The standardized values will be chosen by the TRIANGLE experts, with the help of relevant telco market players, based on relevant requirements for well-established and known use cases.

3.3 The Benefits of TRIANGLE testing

The benefits of TRIANGLE-MARK for 5G applications and devices are multi-fold. First and foremost, the developer can get a real sense of how their product is performing on a realistic 5G development mobile network. Testing on the TRIANGLE testbed gives developers the advantage of getting ahead of the competition with a product that needs to be market-ready by 2020.

TRIANGLE testing and benchmarking is unique because it has a new holistic approach encompassing everything from the mobile application and device to the mobile network (EPC) and the network services. It is not an independent sub-system test but a performance evaluation of the element and its impact on the overall system in a fully controlled end to end realistic wireless 5G condition.

The testing is made easy for the user with pre-defined configurations and the ability to define new configurations.

4   Future Internet Research & Experimentation TRIANGLE testbed

The TRIANGLE testbed is an extension of the current FIRE testbed PerformLTE at University of Malaga[2] which is part of FIRE project FP7-FedFIRE and FP7-FLEX. The description and components of the initial testbed components can be found on the webpage www.ict-fire.eu.

4.1 Testbed Description

Figure 5 represents the main components of the new testbed TRIANGLE, including the execution flow from the user inputs (for instance the app and additional parameters) and the final verdict (the TRIANGLE-MARK and additional detailed reports). The figure focuses on applications but the same approach is valid for benchmarking devices.
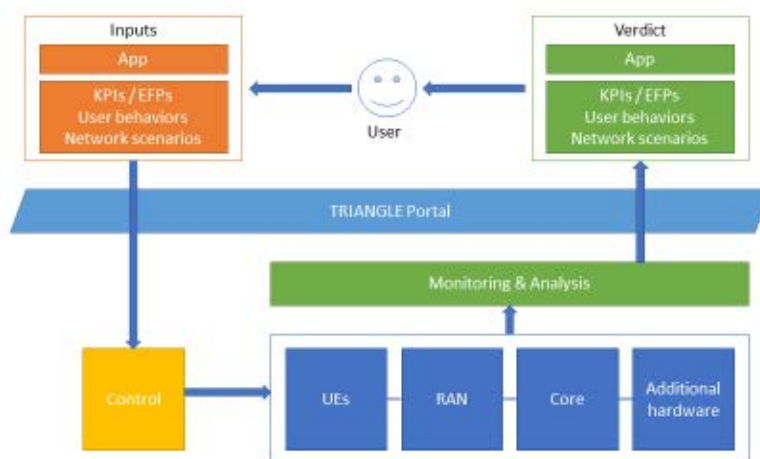

Figure 5 TRIANGLE Testbed in Malaga

The TRIANGLE portal is a user-friendly interface for remote interaction with the testbed. It provides a view of the testbed that is adequate for each user profile, hiding unnecessary complexity. The inputs given by the user (in orange, in Figure 5) are processed and transformed into inputs for the different components of the underlying architecture:

- User behaviour for interacting with apps running on the device (dark blue). There are several ways of describing this behaviour, which is required to drive the testing of apps.

- Network hardware and related components (light blue). These components will be configured according to the high level network scenarios selected by the user.

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[2] http://performnetworks.morse.uma.es/

- Monitoring and processing of results (green). The UEs, network components and other hardware will be monitored in order to measure the relevant KPIs and extra-functional properties. The TRIANGLE Mark and other reports will be derived from these results.

- Testbed automation and orchestration (yellow). These components are responsible for executing the experiments by configuring and coordinating the rest of the testbed components.

The TRIANGLE testbed provides a set of tools to test and benchmark applications in different usage scenarios. LTE and Wi-Fi handover, over-the-top content services and mobile edge cloud are some of the networking scenarios which will be considered in the project.

The use cases the project will work on take as a starting point the use cases defined by NGMN in "5G White Paper", Next Generation Mobile Networks (NGMN), 2015". In this white paper, the uses cases are described generally and do not have detail or clear metrics to evaluate if they meet (pass or fail) specific criteria. One of the objectives of the project is to derive specific metrics to provide means for such an evaluation.

The orchestration framework of the testbed is based on tools promoted by the FIRE community: OMF [3] (Orbit Management Framework), OML [4] (Orbit Measurement Libray), OEDL [5] (OMF Experiment Description Language) and LabWiki[6].

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[3] http://omf.mytestbed.net

[4] http://oml.mytestbed.net/projects/oml/wiki/

[5] http://groups.geni.net/geni/wiki/GEC18Agenda/LabWikiAndOEDL/Introduction)

[6] http://groups.geni.net/geni/wiki/GEC18Agenda/LabWikiAndOEDL/Introduction

5 Conclusions

This white paper describes how an operator, application developer or device manufacturer might access the TRIANGLE testbed, test their product(s) and gain a TRIANGLE-MARK benchmark and pre-certification. The benefits to the developer are that they can get a sense of how their product is performing and allows operators and developers to fine tune their application or device for the demands of the 5G mobile network in order to meet new capabilities and offer exciting new high performant services as a result. Companies who use the testbed can then be ready to launch their service as soon as the 5G network is rolled out by operators.

TRIANGLE testing and benchmarking is unique because it has a new holistic end-to-end approach encompassing everything from the mobile application and device to the EPC and the network services.

TRIANGLE provides all the tools necessary to test and benchmark 5G mobile technology in different usage scenarios.

For more information about the TRIANGLE Benchmark-as-a-Service for 5G and the TRIANGLE-MARK please contact:

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