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TRIANGLE Business Plan

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Abstract

The business plan Deliverable is a written document that describes in detail how the TRIANGLE business may achieve a set of business goals with its testbed for benchmarking 5G applications and devices. It lays out a written plan from a market size, customer type and marketing, financial and operational viewpoint as a fundamental tool that any new business needs to have in place prior to beginning its operations. As a good business plan it starts with an executive summary of the business; includes a detailed description of the business opportunity, then details the companies involved and its combined services and products offered; analyses the marketplace and states how the business intends to achieve its goals. It provides an overview of the industry of which the business is part of, and how it distinguishes from its potential competitors.

It includes the market size of 5G device and applications testing, a competitive analysis, and the business model approach.

This Deliverable is a consensus agreed business plan for the partners and personnel involved in the project, and a set of guidelines on potential future for the business.

Several sections have for confidentiality reasons be removed from the public version of the document and replaced by a few sentences explaining their content.

Keywords

Business Plan, customer profile, business scenarios, end users, market size, target market, forecast, sales, marketing, finances, Deliverable

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1 Executive summary

This deliverable details the business concept and opportunity, as tackled by the TRIANGLE project and describes the solution offered to the market, the size and competition of that market as well as the business approach best thought to work for a profitable business. The document is intended to explain how some of the project partners might proceed to make a viable business from the 5G testbed created as part of the TRIANGLE project or from some of its components.

Exploitation plans and subsidised research business of individual partners are not included here because we focus on the testbed services as a whole business.

In this business plan, we describe the business opportunity presented by the need for 5G testing and benchmarking in the marketplace, that marketplace (and whether certification of 5G devices and applications is going to be imposed by GCF), the testbed itself and services of testing and benchmarking, how each partner has a role to play in the testbed, the customer profiles, the potential end users of the testbed. We look at the marketplace of existing testbeds in 4G and 5G with details of the size of the competitive market and how TRIANGLE offers an advantage.

Then we describe the various business scenarios or models which might work looking at who might own the business, the equipment and how the customer might be charged to use the testbed so that a profitable business can emerge.

Then, we select the best business model having explored all the options in detail.

In conclusion, a business case is established for the selected business model and we detail how we might proceed as a profitable business in the area of 4G/5G testing and benchmarking.

Business plan are a good reflection of the future strategic plans of the company and consortium. Given the fact that this document is fully public, certain sections have been replaced by a short high level description of its content without revealing the core information. A confidential version of this document has been reported to the EC.

2 Introduction to the Business Concept of the TRIANGLE Project

Connected mobile applications will be a dominant software component in the 5G domain. Ensuring a correct and efficient behaviour of the applications and devices becomes a critical factor for the mobile communications market to meet the expectations of final users.

While radio related certification of mobile devices has a strong standards-based ecosystem, thanks to the collaboration among the European Telecommunication Standards Institute (ETSI), 3rd Generation Partnership Program (3GPP), Global Certification Forum (GCF), vendors and test houses, there is still a lack of consensus on the benchmarking or performance testing methods at the apps level.

Currently, the existing test environments do not cover the performance of devices and applications with commonly accepted test requirements. Therefore, existing solutions for testing applications represent a very fragmented market with many ad-hoc tools associated to vendors. There is an excellent opportunity to cover this gap with a set of performance test requirements and a testbed implementing them that bring consensus to the industry. Such a testbed should help application developers and device manufacturers in the evolving 5G sector to test and benchmark new mobile applications, devices, and services. The testbed would evaluate Quality of Experience as part of the design verification and enable certification for new mobile applications and devices.

The Key Performance Indicators (KPIs) and techniques to perform such kind of testing for devices and applications could be rather different than the certification methods associated with 3GPP standards for mobile devices, partially due to the proprietary nature of many widely-used applications, lack of a testing methodology and lack of standardized interfaces.

The TRIANGLE project is building a framework that implements the above-mentioned testbed. The primary objective of the TRIANGLE project is to promote the testing and benchmarking of mobile applications and devices in Europe as the industry moves towards 5G and to provide a pathway towards certification, in order to support qualified apps and mobile developments, using existing FIRE testbeds as a testing framework.

The actors involved in producing and exploiting mobile applications are different in number and categories compared with those involved in mobile device manufacturing and integration. Thousands of Small and Medium Enterprises (SMEs) build apps compared to the few big vendors who build devices. Then, the business models used to commercialize the TRIANGLE testbed have to be adapted to this diverse ecosystem, providing solutions different than the traditional test equipment sale. Alternative solutions such as rental and test services delivery have to be also contemplated.

3 Business Opportunity Description

4G and 5G technologies differentiate from previous communication generations in the use of ultra-broadband, low-latency and massive machine-type communications. Current verification and certification of terminal devices cover the following aspects:

- RF parametric
- Protocol
- Functionality
- Field Testing in real networks

Performance of devices and applications becomes essential for the efficient use of the network resources and fulfilment of the expected requirements of the new technologies (use of ultra-broadband, low-latency and massive machine-type communications). None of the current verification and certification address conveniently, the performance testing of devices and applications. Functional and field testing are not enough to show the real capabilities of a device or an application and the fulfilment of the expectations.

Then, the performance testing of 4G and 5G devices and applications represents an opportunity to provide the following:

- Verification testing to device manufacturers (chipsets, modules and end devices), network operators, researchers and application developers to allow them to create high quality devices that operate according to the expectations.
- Certification testing to industry associations and users to show compliance with requirements. This certification will ensure that the products meet a minimum level of quality.
- Technical approval testing to network operators to verify that the minimum level of quality required by the devices and applications that they accept in the network is met.

3.1 Certification Requirement

The introduction of the performance testing of devices and applications in the scope of certification of any of the cellular certification schemes (GCF and PTCRB) represents an excellent opportunity. This means that performance testing is mandatory for every 4G and 5G terminal or applications that is certified. The testbeds intended to implement this performance testing will have to be validated by GCF and/or PTCRB. This ensures that testing is performed according to the established requirements (by GCF and PTCRB) in a repeatable and stable manner.

Validation of the testbed creates an entry barrier for some low-level competitors to access to the certification market. This increases the market opportunity for the vendors of the validated testbeds as well as the size of their market.

The validation of the testbed for performing such type of testing would be an enormous opportunity to motivate manufacturers (chipsets, modules and end devices), integrators and application developers to acquire the testbed or to request testing services with the testbed.

In order to introduce the performance testing in the certification schemes, it will be necessary to discuss the performance gap in the current certification scheme and the convenience of including performance testing for 4G and in the future 5G, with the certification institutions. The test requirements would need to be discussed and agreed with the certification institutions in order to complete the scheme according to their strategy.

In addition to the adoption of the performance testing by certification institutions, it would be possible to discuss with network operators to include the performance testing in their technical approval schemes. Network operators such as Telefónica, Vodafone, AT&T, T-Mobile, Verizon, etc. can be targeted for the adoption of performance testing. The authorization of the testbed for performing such type of testing would be a big opportunity to move manufacturers (chipsets, modules and end devices), integrators and application developers to acquire the testbed or to request testing services with the testbed.

3.2 Testing of Applications

Mobile applications are becoming more and more important as soon as bandwidth requirements increase and our way of living is changing. Applications are becoming part of our lives and we are more and more dependent on them. This is happening now with 4G and it is expected to exponentially grow with 5G.

The global growth of apps and app revenue is expected to continue due to worldwide expansion of smartphones and consumers interested in consuming and using mobile apps. According to the App Research Provider App Annie [1], the forecast for App Store Revenue is expected to reach $139 Billion by 2021 (see Appendix 1: Figure 2).

The breakdown of the Application Categories according to Digi-Capital [2] is shown in Appendix 1: Figure 3.

Figures in Appendix 1: (compiled by Priori Data and Statista [3]) show the importance of mobile applications today.

According to Statista and Priori Data, the applications for iPhone are generating a large revenue in the US (see Figure 4). Audio & video streaming and games are the applications generating the most revenue. Pandora generates over $18 million per month, $2.04 million more than the second most lucrative, Candy Crush Saga.

Figure 5 [4], shows the top 10 grossing Android applications with almost doubling the revenues of iPhone. For Android, the application generating the most revenue is the game Candy Crush Saga with over $30 million per month in the US.

Regarding the most used applications, they generate a huge number of downloads from the network according to Statista and Priori Data [5] and [6]. These applications are for e-mail, instant messaging, sharing experiences and audio & video streaming. The number of downloads of each application per month can be around a few millions per month for iPhone in the US (see Figure 6).

In the case of Android and according to Statista and Priori Data, the applications for Android can generate a much higher number of downloads. Figure 7 shows that the most preferred applications are the instant messengers, having in the first position the WhatsApp Messenger with over 88 million downloads per month in the US.

Due to the importance of the applications generating large revenues and using a large amount of resources from the network, it is quite important to ensure the correct operation. This will lead to a large **market in testing the performance of mobile applications** in the verification and validation phases of the development.

After the applications are launched in the market, the industry will require to control the performance in order to ensure the quality of service for the application subscribers. For this reason, the **certification testing of mobile applications performance** is another business opportunity.

Finally, network operators will require that all applications to be used within their network are correctly tested and their performance proved. Technical acceptance of network operators may be another business opportunity for the performance test systems.

4 Proposed Solution Description

The TRIANGLE Project is providing a testbed that addresses the performance testing gap in device and applications testing of technologies 4G and 5G market.

The TRIANGLE Project provides a testbed that facilitates the evaluation of the Quality of Experience (QoE) of new mobile applications, services and devices designed to operate in the current 4G and in the future 5G mobile broadband networks. The testbed is implementing identified reference deployment scenarios, has defined new KPIs and QoE metrics, developed new testing methodologies and tools, and has designed a complete evaluation scheme.

The TRIANGLE testbed ensures users' QoE in new challenging situations, especially those due to heterogeneous networks and considering the role software will have in the new 5G ecosystem. The testbed also provides the means to certify and obtain a quality mark for the applications, services and devices which are compliant with the requirements and test specifications developed in the TRIANGLE project.

The TRIANGLE testbed is intended to be used for the following purposes:

- Design verification for device manufacturers, network operators, researchers and application developers. This will allow vendors to fine tune their products as well as establish their differentiation in the current globalized and competitive market. The testbed focuses on providing mechanisms to incorporate new wireless technologies and topologies envisaged in 5G and contribute to the design verification within the new ecosystem.
- Certification of devices and applications according to industry accepted certifications schemes. The testbed will complement the certification test objects adding performance which is not included in the current schemes. This will provide consensus in the industry providing a way to assess the performance of devices and applications based on common accepted requirements and working scenarios. These requirements and scenarios can be agreed with the certification institutions in order to adapt them to their strategies.
- Private quality mark whose requirements have been established during the TRIANGLE project. This mark will define how well the product (application or device) behaves when used in a realistic network, including energy consumption and model-based runtime checking of the applications and devices. This mark will also allow to benchmark devices and applications according to their performance.

There are different business models to provide access to the product of TRIANGLE project for manufacturers, network operators, researchers, application developers and network operators. These models which will be considered in later sections of this document and will include the sale of hardware and software, rental of the testbed and delivery of services.

5 TRIANGLE Project Member Companies

There are six partners in the TRIANGLE project who have come together to collaborate on the testbed software, equipment, tools and features. In summary, Keysight brings the test automation platform (TAP), UMA pulls the testbed together from other FIRE testbeds and with new equipment offers a state-of-the-art 5G testbed. RedZinc brings a QoS engine allowing specified bandwidth in the control plane. UCL brings end users for testing and feedback and DEKRA provide the testing and certification. Quamotion devises and records user scenarios. Each company brings something different and all work together to provide the testbed services for testing and certification of applications, devices and services in 5G networks. This has the benefit for end testers of not having to have their own expensive testing equipment, getting ready for the 5G marketplace ahead of the network infrastructure and getting a certificate, which can eventually help them be competitive in a new 5G marketplace.

More details of the member companies participating in the TRIANGLE project are included in the paragraphs below indicating their specific contributions with a short description of the company and their contribution to the TRIANGLE project as included in the following tables.

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5.1 Keysight

Location: Belgium and Denmark.

Table 1 - Keysight Company Description and their Contribution to the TRIANGLE Project

Partner Equipment / Tools / Software	Function	Company Focus / Core Business
Test Automation Platform (TAP)	Orchestration/Test sequence and test plan creation.	The company core business focuses on test and measurement hardware and software equipment for the electronics market. Such global market includes several industries where the telecommunications and networking one plays a strong role.
UXM Wireless Test Set	Emulates a Radio access network (RAN - eNB).	
Power Analyser	Measures power consumption of end device.	

5.2 UMA

Location: Spain.

Table 2 - UMA Company Description and their Contribution to the TRIANGLE Project

Partner Equipment / Tools / Software	Function	Company Focus / Core Business
Testbed Deployment	Physical deployment of the testbed.	Education and Research.
Orchestration Framework	Testing lifecycle orchestration (Orcomposutor, TAP plugins)	
Portal	Testing campaign design and storage, reports storage.	
Testeldroid Probe	Measurement and Data Collection in the UE.	
Instrumentation Library	Android and iOS libraries for measurement collection inside apps.	
Model Based Testing	Automated generation of app user flows to drive Android applications.	
EPC And Control Server	Core Network functionality and server to trigger procedures/ configurations remotely.	
OML Server	Stores the measurements of the testbed.	
Transport Plane	Provide connectivity among the elements of the testbed and configurable impairments on any of the interfaces.	
LTE-Wi-Fi Aggregation	Support heterogeneous aggregation of traffic over Wi-Fi and LTE.	
GPS Emulation	GPS RF signal generation based on programmed route.	
Model Base Testing	Test cases automatic generation.	

5.3 RedZinc

Location: Ireland.

Table 3 - RedZinc Company Description and their Contribution to the TRIANGLE Project

Partner Equipment / Tools / Software	Function	Company Focus / Core Business
Velox Engine	Service with specific bandwidth request API on radio network.	Wearable video technology and R&D in 5G and future internet
SDN Deployment	Emulate the transport network between the eNodeB and the EPC.	
ONOS	ONOS, a network orchestrator or SDN controller	

5.4 UCL

Location: United Kingdom.

Table 4 - UCL Company Description and their Contribution to the TRIANGLE Project

Partner Equipment / Tools / Software	Function	Company Focus / Core Business
Applab	Provide end users for testing and getting quantitative and qualitative feedback. SME engagement and business model validation, entrepreneurial ecosystem support and sandbox creation	Education and Research

5.5 DEKRA

Location: Spain.

Table 5 - DEKRA Company Description and their Contribution to the TRIANGLE Project

Partner Equipment / Tools / Software	Function	Company Focus / Core Business
Dekra Performance Test Tool	Performance Measurement and Data Collection	Testing and Certification

5.6 Quamotion

Location: Belgium.

Table 6 - Quamotion Company Description and their Contribution to the TRIANGLE Project

Partner Equipment / Tools / Software	Function	Company Focus / Core Business
Web Driver	Automate user scenarios on application level (native or web) on iOS and Android devices. Does not require jailbreaking and is available on Windows, macOS, and Linux.	The core business of Quamotion focuses on test and monitoring solutions for mobile applications.
Record User Scenarios	Create application flows by operating a mobile device manually.	
Remote Device Control High Performance Screenshot Feed on Android and IOS	Operate a device remotely.	
Capture Instruments	Capture device information such as the device log, network statistics, running processes, CPU, memory and disk usage.	

6 Description of the TRIANGLE Testbed

The TRIANGLE testbed is a platform defined to provide a testing and certification framework that encompasses a wide range of use cases, network scenarios, and Key Performance Indicators (KPIs) that are able to cover not only the different traditional telco needs, but also the End-to-End (E2E) side, given the incredibly large variety of available and foreseen Apps and services.

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 type of user (application developer, device manufacturer, researcher, network operator). The main purpose of the testbed portal is preparing and running tests, and later reviewing the results.

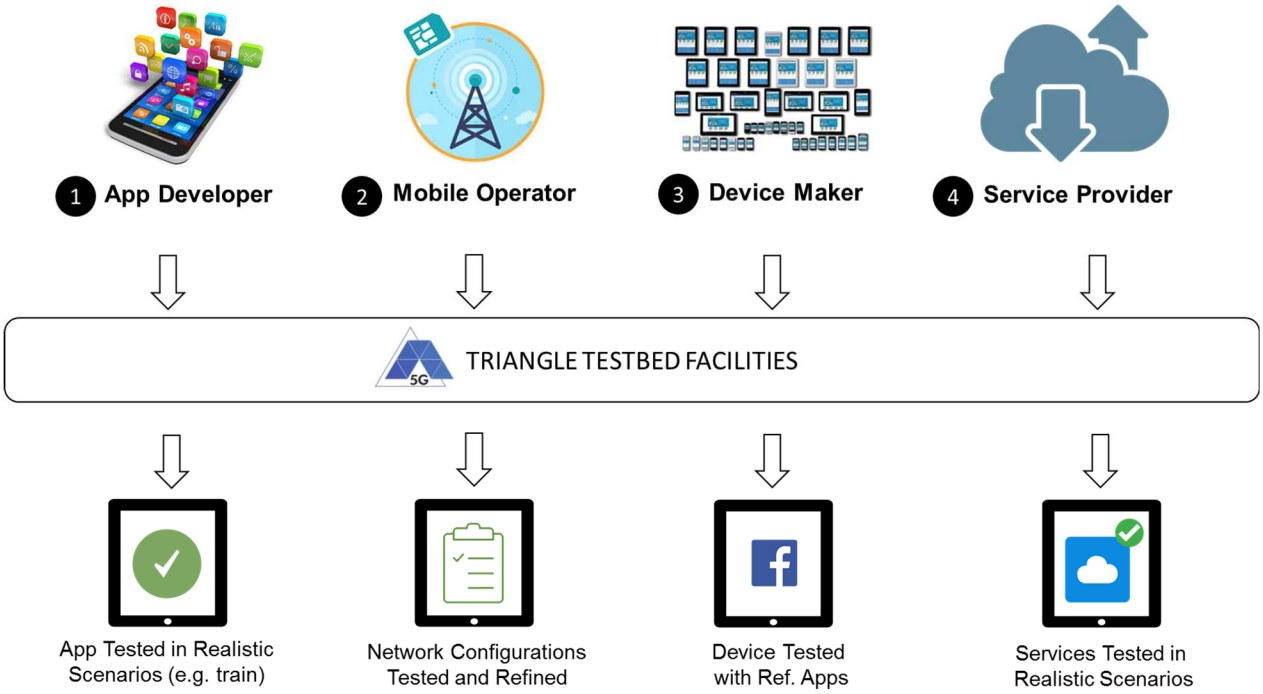

Figure 1 – Use of TRIANGLE testbed

To carry out a test, all components must be controllable by an orchestrator, which coordinates their configuration and execution. In the TRIANGLE testbed, the Test Automation Platform (TAP), coordinates the configuration and running of the tests.

In order to obtain measurements, to compute the TRIANGLE Mark and other reports, the testbed provides several probes (both software and hardware) which extract the required measurements.

These measurements are collected and analysed in order to calculate the key performance indicators (KPIs) associated with the features provided by the apps or devices, e.g. video streaming or VoIP calls. To facilitate their aggregation, all measurements are stored in a central OML server, which uses a PostgreSQL database server as backend.

Radio access emulation plays a key role in the TRIANGLE testbed. RAN is provided by a UXM Wireless Test Set from Keysight, a flagship mobile network emulator that provides state of the art test features.

This testbed is useful for application developers, device manufacturers, SMEs, network operators and/or research institutions who wish to test applications, services, or devices that could require high speed, low latency, or high reliability that would benefit from 5G and could benefit from benchmarking their apps, devices or services. The TRIANGLE testbed can measure many low-level aspects of mobile devices and applications including the impact of power drain, network latency and various types of network mobility. The testbed contains a number of powerful mobile testing and emulation devices to test different network conditions. The testbed features tools for automation of app deployment and configuration and includes the ability to execute automated test scripts. Experiments are expected to make use of the testbed functionality to test mobile apps and devices under different network conditions.

7 Market for the Solution

In this chapter, we explore the target market for the TRIANGLE testbed, analysing the possible type of customers such as researches, large and small device manufacturers, App developers, network operators, testing houses and equipment makers.

We also estimate how many of each customer exist in Europe to have a look at the market size from another perspective. There is a targetable number of each customer type across Europe to which 5G testing services could be marketed via selling, industry events, online marketing etc.

Finally, we provide some estimations, that can give an idea of the potential market size for the product of the TRIANGLE project, focusing on test equipment vendors and testing & certification service providers types of companies.

The full content of this chapter is **confidential**.

8 Competitive Analysis

In this chapter, we analyse some of the testing tools existing in the market that will be competitors of the TRIANGLE testbed. We examine the main characteristics of the tools and perform an exhaustive comparative among them.

The main performance testing mobile tools are also studied, highlighting the strengths of each tool and comparing the key functionalities required.

The comparatives show that TRIANGLE is providing a set of unique features that are expected to be well-received by the market.

The section also inspects the existing Test Lab competitors, defining its size and most relevant business. The wireless testing experience in general, and performance testing capabilities are analysed.

The full content of this chapter is **confidential**.

9 Business Scenarios

This section describes the different TRIANGLE business scenarios that have been considered in order to make the final choice of the business model selection for the consortium.

Initially, the business case is modelled defining key components such as possible type of business, type of customer, company leading the business or how the maintenance and the payment would be performed.

Business possibilities such as selling testbed individual components or selling the testbed as a whole solution, offering the testbed Infrastructure as a service or providing testing and certification service are developed.

These business scenarios are described taking into consideration their qualitative and non-quantitative component parts.

The full content of this chapter is **confidential**.

10 Business Model Selected

Taking in consideration several assumptions explained in the chapter and several business considerations the preferred business model is that a leading partner provides the 4G/5G testing service with TRIANGLE testbed. Other partner would be taking care of delivering, installing and commissioning the TRIANGLE testbed at the Test Lab facilities. In addition, other partner would coordinate the support, maintenance, repair, update and upgrade of the testbed in cooperation with the other members of the TRIANGLE consortium.

The main reasons for selecting this option are among others the expected testing services market, the complexity of the implementation and maintenance of the testbed itself and the consolidated market share of the leading partner that provides the testing services.

The full content of this chapter is **confidential**.

11 Conclusion

Performance of devices and applications working on 4G and 5G technologies becomes essential for the efficient use of the network resources and fulfilment of the expected requirements of the new technologies (use of ultra-broadband, low-latency and massive machine-type communications). None of the current coverage elements of verification and certification conveniently address the performance testing of devices and applications. Functional and field testing are not enough to show the real capabilities of a device or an application and the fulfilment of the expectations.

There is a clear business opportunity to introduce the performance testing in the certification schemes. To achieve this, it will be necessary to discuss with the certification institutions about the performance gap in the current certification scheme and the convenience of including performance testing for 4G and in the future 5G.

In addition to the adoption of the performance testing by certification institutions, the opportunity can be extended for the benefit of the network operators, as they might have the need to include the performance testing in their technical approval schemes. Network operators such as Telefónica, Vodafone, AT&T, T-Mobile, Verizon, etc. can be targeted for the adoption of performance testing.

The validation and authorization of the testbed for performing certification testing as well as device acceptance testing would be a big opportunity to move manufacturers (chipsets, modules and end devices), integrators and application developers to acquire the testbed or to request testing services with the testbed.

On the other hand, mobile applications are becoming more and more important as soon as the bandwidth increases. Applications are expanding to all ambits of activity. This is happening now with 4G and it is expected to exponentially grow with 5G.

The global growth of apps and app revenue is expected to continue due to worldwide expansion of smartphones and consumers interested in consuming and using mobile apps.

The increase of devices and applications forges a market need for 5G performance testing. It is expected that the market will spend around 21 Billion USD in the acquisition of test equipment for 4G and 5G testing from 2018 to 2025. And regarding test services for 4G and 5G, the expected expenditures from 2018 to 2025 are around 85 Billion USD.

We can estimate the market size for the two main business of the TRIANGLE testbed: testbed sale and testing services delivery. The estimated market size for the sale of the TRIANGLE testbed is around 738 million €. And the estimated market size for the delivery of services as the provided with the TRIANGLE testbed is around 1,5 billion €.

Since the market size for the delivery of 4G and 5G testing services is bigger than the market for the delivery of 4G and 5G test equipment, the complexity of the coordinated operations of support and maintenance of the TRIANGLE testbed and the situation of the competitors in both segments, the preferred business model is the delivery of test services with the TRIANGLE testbed. As stated previously, this business model would be implemented with DEKRA as the leading partner providing the 4G/5G testing services with TRIANGLE testbed. Keysight would be the leading partner taking care of the coordination for the delivery, installation and commissioning of the TRIANGLE testbed at DEKRAS' facilities. Keysight would also coordinate

the support, maintenance, repair, update and upgrade of the testbed in cooperation with the other members of the TRIANGLE consortium.

According to this decision, a projection of profit and loss for the delivery of testing services with the TRIANGLE testbed has been created for the years 2018 to 2026. This projection includes optimistic, realistic and pessimistic scenarios in order to identify the financial risk of the test services operation.

Considering the assumptions and the estimated profit and loss results of the business plan, it is possible to conclude that the market opportunity is significant due to the size of the market and the positive financial results. In the realistic case above, the results show moderate losses during the first year, a positive profit the subsequent years, enough to cover the testing services operations and the necessary contributions of the member companies providing a reasonable margin to all members. In the pessimistic case, there are greater losses in the first year, with positive results in subsequent years. In this case the results would cover the testing services operations and the necessary contributions of the member companies with a smaller profit.

Thus, TRIANGLE makes the happy conclusion that it is worth executing the project and implementing the testing operations with the TRIANGLE testbed, as the financial expectations are overall positive, with a limited amount of risk.

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13 Appendix 1: Mobile Apps Revenue Analysis and Forecast

According to the App Research Provider App Annie [1], the forecast for App Store Revenue is expected to reach US$ 139 Billion by 2021 (see Figure 2).

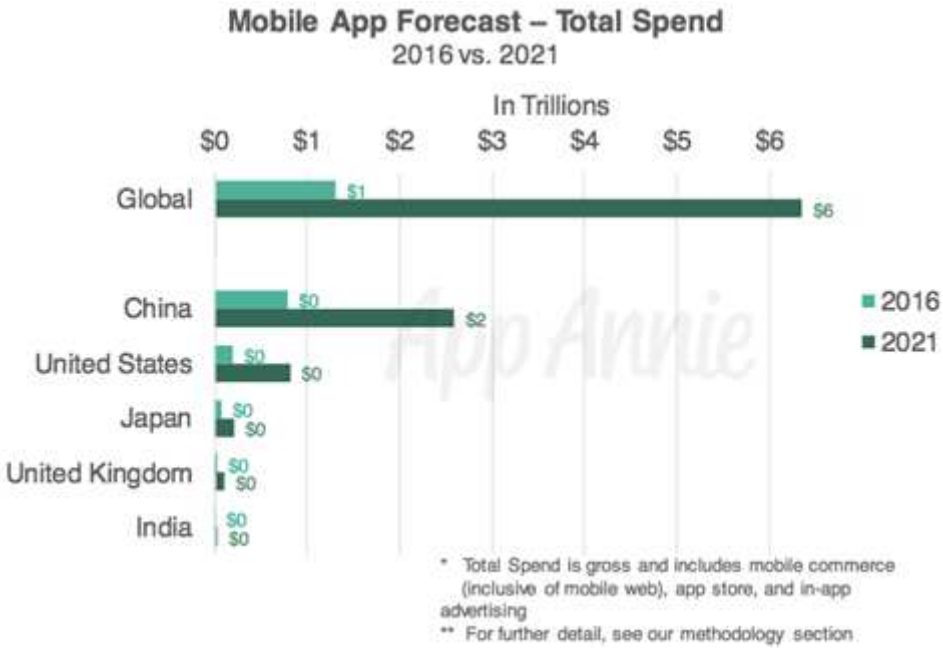

Figure 2 - Mobile Applications Spend for 2021 vs. 2016 (ref. App Annie)

The breakdown of the App Categories according to Digi-Capital [2] is shown in Figure 3.

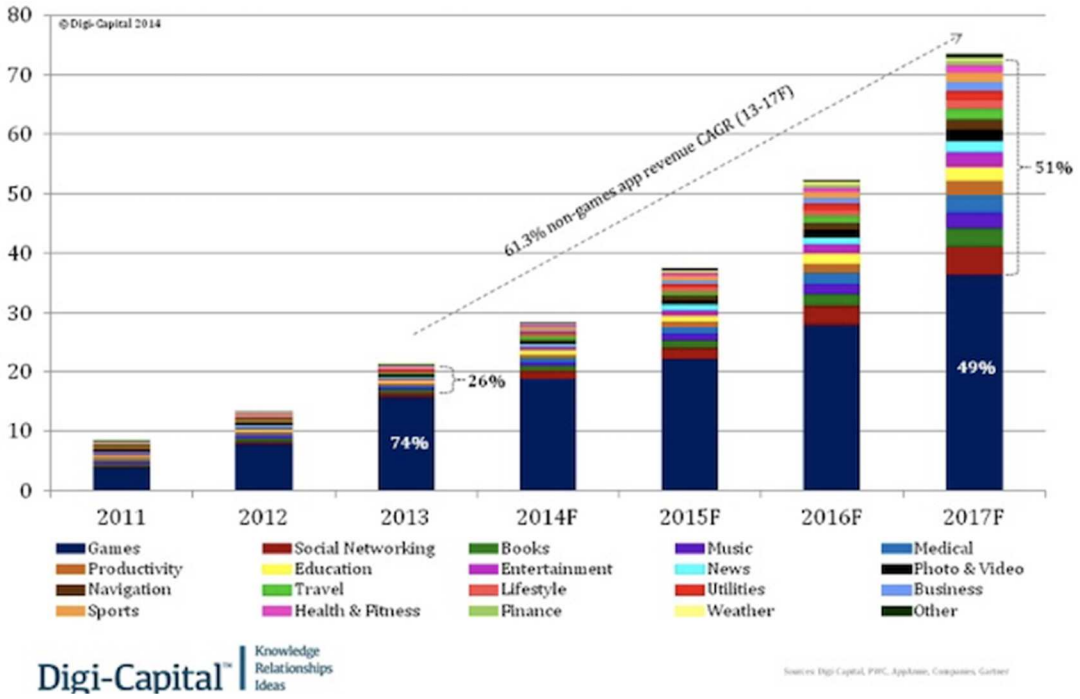

Figure 3 - Mobile Applications Categories from 2011 to 2017 (ref. Digi-Capital)

The following figures (compiled by Priori Data and Statista [3]) show the importance of mobile applications today.

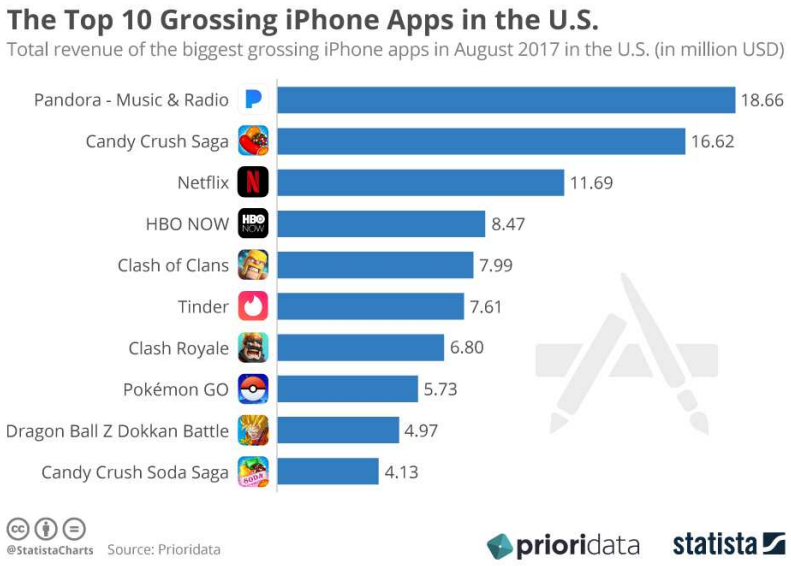

Figure 4 - Top 10 Grossing iPhone Applications in the US (ref. Priori Data and Statista)

According to Statista and Priori Data, the applications for iPhone are generating a large revenue in the US (see Figure 4). Audio & video streaming and games are the applications generating the most revenue. Pandora generates over US$ 18 million per month, US$ 2.04 Million more than the second most lucrative, Candy Crush Saga.

Figure 5 [4], shows the top 10 grossing Android applications with almost doubling the revenues of iPhone. For Android, the application generating the most revenue is the game Candy Crush Saga with over US$ 30 Million per month in the US.

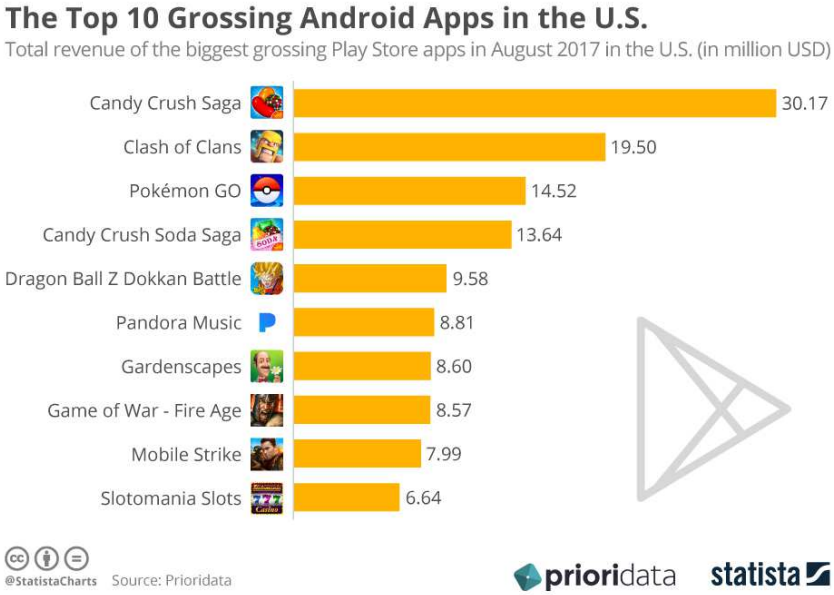

Figure 5 - Top 10 Grossing Android Applications in the US (ref. Priori Data and Statista)

Regarding the most used applications, they generate a huge number of downloads from the network according to Statista and Priori Data [5] and [6]. These applications are for e-mail, instant messaging, sharing experiences and audio & video streaming. The number of downloads of each application per month can be around a few millions per month for iPhone in the US (see Figure 6).

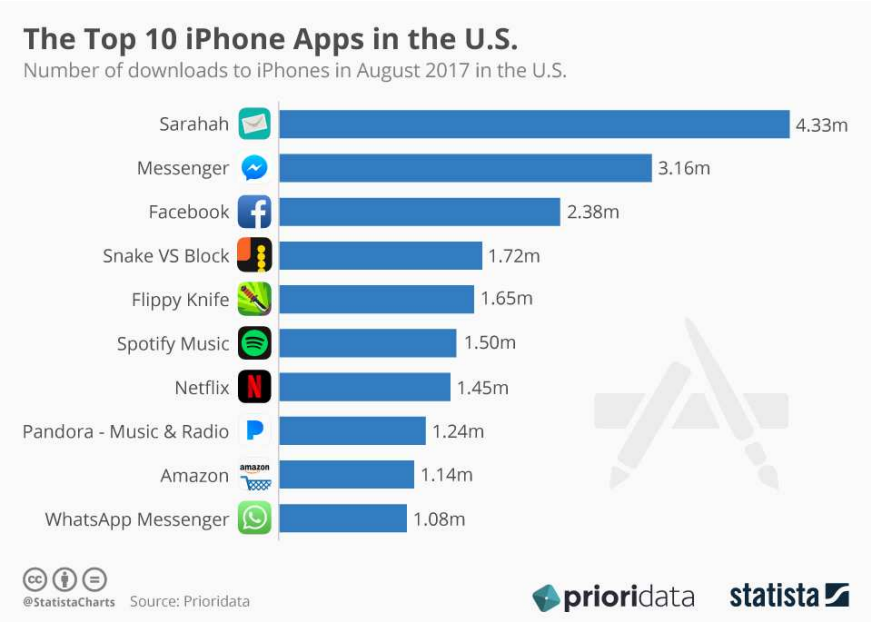

Figure 6 - Top 10 Most Used iPhone Applications in the US (ref. Priori Data and Statista)

In the case of Android and according to Statista and Priori Data, the applications for Android can generate a much higher number of downloads. Figure 7 shows that the most preferred applications are the instant messengers, having in the first position the WhatsApp Messenger with over 88 million downloads per month in the US.

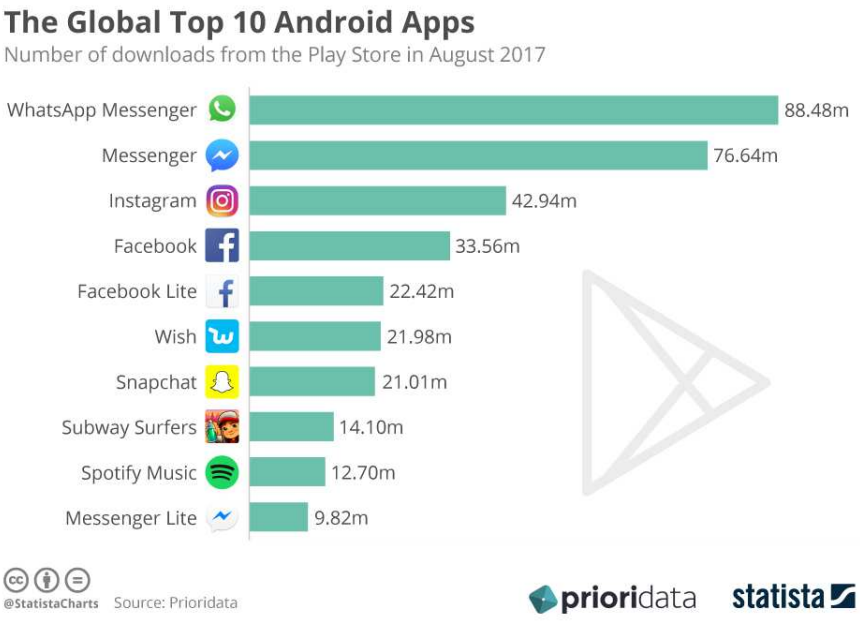

Figure 7 - Top 10 Most Used Android Applications in the US (ref. Priori Data and Statista)

14 Appendix 2: Detail of the TRIANGLE market to compete

The full content of this chapter is **confidential**.

15 Appendix 3: TRIANGLE Experiment Report

15.1 Business Impact

15.1.1 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?

15.1.2 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, etc.)?

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, etc.)?

15.2 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	Description	Used?	Please Indicate your Experience with the Tools. What were the Positive Aspects? What did not 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	No other tools were used		

15.3 Feedback Based on Design/Set-Up/Running your Experiment on TRIANGLE

15.3.1 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)?

15.3.2 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.)?

15.3.3 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?

15.3.4 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?

15.3.5 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?

15.3.6 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.

15.4 Why TRIANGLE was Useful to you?

15.4.1 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?

15.4.2 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?

15.4.3 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?

15.4.4 Other Feedback

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

15.4.5 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…

16 Appendix 4: Test Lab Competitors

The full content of this chapter is **confidential**.

17 Appendix 5: TRIANGLE Testbed Features

The table below lists the TRIANGLE testbed features.

Table 7 - TRIANGLE Testbed Features

Availability	Feature	Component	Benefit	Useful Domains
R2	Virtual Path Slicing	VELOX	Provides dedicated bandwidth allocation where possible	emergency services critical care media streaming
R2	GPS Emulation	USRP & GPS emulator software	Provides application location	Augmented Reality Travel logistics
R3	Gyroscope Movement	Robotic Arm	Allows mobile device to move in different directions	Augmented Reality Virtual Reality Games
R3	Screen Recording	video capture	Allows capture of what is happening on the screen during an experiment	Media streaming
R2	NB-IoT	NB-IoT component	Support for NB-IoT protocol	MMTC
R3	Edge-Side Computing	MEC Server	Support for processing in network	Media streaming Virtual Reality
R3	MPEG DASH Streaming	DANE Streaming Server	Video Streaming using MPEG DASH	Media streaming Virtual Reality
R3	SDN	Open Daylight	Configurable Network Routing and Load Balancing	Media streaming emergency services
R2	MANO	MANO Server (Openstack Tacker)	Network Function Virtualisation and Management	Media streaming emergency services
R3	VR support	Robotic Arm + tap controller + object recognition		Augmented Reality Virtual Reality

R2: TRIANGLE testbed release 2

R3: TRIANGLE testbed release 3