5G competitive advantage through customer centric service assurance automation

Enabling enterprises and service operators to rapidly prototype and innovate ahead of 5G networks

A Research White Paper

Vodafone

Version 1, May 2019

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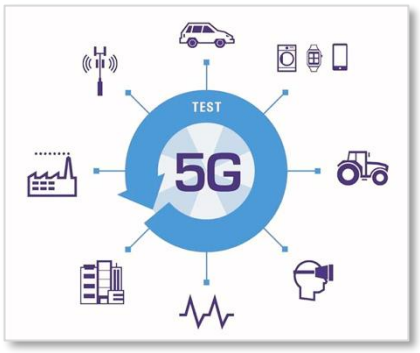
Executive Summary

This white paper details how Vodafone and similar service providers can work with innovative customers to leverage latest telco technologies for their application development, new products and service innovations, and at the same time increase the service providers' addressable market.

As an example of a potential completely new market, later in this document, we discuss a recent Vodafone project with technology company Continental, using AI and edge computing to provide a value added enhancement for road safety.

Enterprise customers and verticals represent a huge opportunity for the mobile industry in the journey to 5G. Associated with 5G are new and innovative solutions made possible by the faster, lower-latency connectivity available, thanks to emerging technologies like edge computing and cloud-native functions. Future use cases, like assisted autonomous driving and other safety critical applications, need to be thoroughly tested before coming to the market.

By making available comprehensive and highly flexible, 5G-ready indoor and outdoor labs and test zones, Vodafone and similar companies can quickly work with innovative partners to test and bring new solutions to market and increase confidence in new telco technologies with enterprise customers. This ability will be key in building a pipeline of new offerings for telco service providers. However, such labs and live network test zones for enterprise customers must be equipped with state-of-the-art, flexible service monitoring solutions, like the one introduced in this paper.



Another important consequence of developing partnerships rapidly is the ability to grow the global addressable market. Whole new markets will be opened up in security, safety and other verticals. Only by using automation to enable quick and efficient work processes will telco service providers be able to help create new products in a shorter time and enable customers to swiftly introduce them in the market.

If telco service providers cannot support enterprise customers well, especially during the feasibility and prototyping phases, these customers will go elsewhere: OTT and non-telco providers already offer tailored services at a fast pace and an easy way to do testing and business.

Recommendations for telco service providers

1. Build up the ability to **rapidly prototype solutions** for and with enterprise customers, and provide the tools for the service provider as well as the enterprise customers to effectively research and examine operational aspects of such new solutions. This data-driven approach increases effectiveness in the R&D phase. Being easy and fast to operate and work with will also be a differentiator.
2. Build an ecosystem of **innovation partners** who add value to the core connectivity and testing offering, open up new opportunities and help in expanding the global addressable market.
3. Explore **cross-service provider proofs of concept and testing projects** in particular for use cases that need interworking between operators. Again, right from the start, provide assurance tools with having the enterprise customer's needs in mind.

The rest of the paper analyses the three imperatives for the transformation of a telco service provider's network into a digital infrastructure platform, on the basis of a joint research project, presented at MWC 2019 in Barcelona, that Vodafone has undertaken with an enterprise customer.

Imperatives for a digital infrastructure platform

Network Cloudification Enablers: NFV, SDN	**What**: Network as a cloud. **Why**: To compete against OTT and cloud-native players with more efficient, flexible and dynamic networking that drives lower cost-per-bit and opens new business models. **Challenge**: Mission-critical services requiring carrier-grade SLA with guaranteed QoS, dynamically and end-to-end across multi-cloud environments.
Edge Computing Enablers: MEC	**What**: Move the cloud to the edge. **Why**: Latency is the new killer app that allows to differentiate versus cloud players today. **Challenge**: Ultra-reliable low latency services demanding accurate and reliable measurement data for instantaneous corrective action.
Programmable Networking Enablers: DevOps, CI/CD	**What**: Service automation driving agility and faster time-to-market. **Why**: To unfold (and embrace) Industry 4.0 service verticals and others. **Challenge**: Close-loop orchestration with continuous service performance validation.

1. Network Cloudification

5G introduces a new architecture that comprehensively cloudifies access, transport, and core networks. More specifically, it replaces the traditional physical networks with flexible, dynamic, programmable and highly automated cloud-native networks built upon principles of Software Defined Networking (SDN) and cloudification.

Some of the most innovative concepts introduced with 5G are network slicing and service chaining, which will let telecom operators provide portions of its networks for specific vertical use cases (e.g. connected car, Internet of Things (IoT) factory, smart energy grid) coupled with dynamic interlinking of network functions in the form of so-called service chains. Network slicing enables a smart way to segment the network to support particular services or business segments by providing customised connectivity in a highly programmable and dynamic manner. Network slices are defined by a number of customisable software-defined functions, in the form of coverage area, duration, capacity, speed, latency, robustness, security, and availability. Key benefits of 5G slices and service chains are rapid service innovation and faster time-to-market, along with significant savings compared to deploying full functionality to support devices that will use only a part of that functionality.

On the flip side, telecom operators must ensure that network slices and service chains deliver the guaranteed Quality of Service (QoS) as stipulated in carrier-grade Service Level Agreements (SLAs) for specific types of users and devices (in the form of bandwidth, latency, jitter and quality of service profiles). This is particularly challenging to achieve due to the complex distribution of network functions and application components across service providers' network segments (physical and virtual), virtual network slices (potentially multi-tenant), and the simultaneous use of multiple (hybrid and public) clouds. A proactive approach to visibility is needed: Active service assurance must become an essential part of the service, rather than a part of the network as it used to be in the past. It must be an embedded function of every service, where active test agents form part of a network slice as a wider service chain.

The good news is that network cloudification enables augmented active testing capabilities to address those challenges. Telco service providers can take advantage of the inherent capabilities of the network cloudification features to dynamically implement test agents end-to-end across the network in a cost-effective manner, deployed as part of network slices and service chains during the development, pre-staging and provisioning processes.

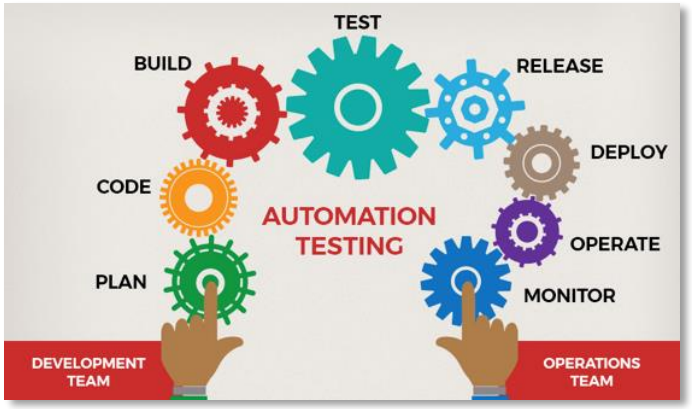
1.1 Assessment of Customers' Solutions in Modern Test Environments

Modern communication use cases for enterprise customers are becoming increasingly complex. With the advent of 5G, targets will include more and more industrial and machine-to-machine communication as opposed to largely human communication that dominated the previous generations.

Different enterprise domains or verticals (e.g. automotive, Industry 4.0, energy, healthcare) look for different end-to-end solutions, each with a distinctive set of requirements and validation tests to be executed. Enterprise customers are becoming more knowledgeable in wireless/radio technologies and networking, due to the need for always-connected applications and services, thus requesting solutions for complex environments and expecting accurate assessments from telecommunication service providers. They ask for:

- End-to-end, fine-grained evidence of how their application performance relates and maps to the underlying network infrastructure
- Guaranteed Quality of Experience (QoE) provided to their final end users, to be derived from network characteristics like latency, jitter, cloud infrastructure performance, Radio Access Network (RAN) performance and traffic load, etc.
- Capabilities that enable them to clearly separate the application and network realms in order to attribute performance issues either to their own application or to network- and telco cloud-related aspects.

The above requirements are relevant for enterprise customers already during the crucial R&D phase of their products as well as in closed-loop feedback during commercial operation and consumption of their products by end users (e.g. as elements of a bigger end-to-end vertical industry solution). Being able to quickly respond to such enterprise requirements is an important success factor for telco service providers.



Service providers worldwide have been building new laboratories for testing proofs of concept or early prototypes of verticals solutions, employing the latest virtualised and cloud-native technologies (e.g. SDN, containers, service mesh) and generated by an unprecedented disruption driven by innovative startups and IT companies. Those facilities, which often include vertical-oriented components like automotive tracks or smart meter grids, are rarely provided entirely by one vendor. Instead, a set of different hardware and, more and more prominently, software components makes up the full environment. Software from open-source projects (e.g. ONAP, Kubernetes) and software following modern IT standards/paradigms (e.g. REST APIs) need to interact with more traditional telco products (e.g. physical and virtualised network functions), making the monitoring and assurance of such deployments a hard yet imperative task.

2. Edge Computing

By running applications and performing high-demanding processing tasks close to the end user, Multi-access Edge Computing (MEC) enables real-time processing and guaranteed bandwidth, whilst reducing latency and lowering ineffective use of communication capacity in comparison to centralised cloud. MEC is a key enabler for emerging scenarios such as Industry 4.0 (control and monitoring of industrial machinery), connected and autonomous vehicles, Augmented Reality (AR) and Virtual Reality (VR), to name a few. Such scenarios have two characteristics in common: low latency and the need for continuous corrective action, which combined demand very accurate and reliable measurements in real time.

Latency requirements are becoming more and more stringent as we transition from 4G to 5G networks. A critical requirement is an accurate timestamp in the order of microseconds, and this is optimally addressed by active testing.

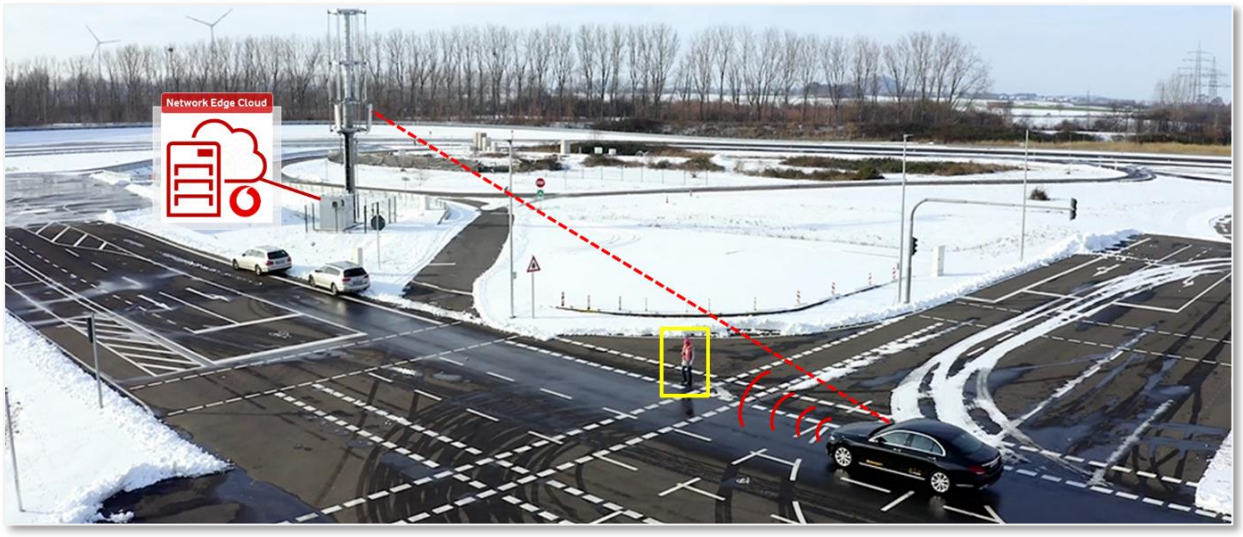
Active testing involves injecting traffic at one end and then measuring the impact at the other end. In contrast to passive probing, active testing provides a real-time view of the service with very high accuracy and across a wide range of measurement capabilities all the way from Layer 2 up to the application layer.

However, accurate measurements are not enough. They must be combined with other assurance data sources (such as passive telemetry data) to create a richer data set for developing corrective actions in real-time with continuous contextual insights and predictive analytics. This is particularly true for Ultra-Reliable Low Latency Communications (URLLC) services:

Vodafone and Continental pioneered research on this topic by realising a Proof of Concept on the use of MEC for a new type of automotive application, powered by Artificial Intelligence (AI)[1].

2.1 Proof of Concept: "Edge Computing Enabled Pedestrian Safety Shield"

The project originated from the desire to reduce the number of accidents that involve pedestrians, cyclists and vulnerable road users (like children or elderly people). An AI application, hosted at a GPU-powered MEC location, analyses in near real time a pre-processed video stream from a front-facing video camera in a vehicle and detects whether a hazardous situation is likely to occur.



Continental approached Vodafone with a well-defined list of network measurement requirements. In order to evaluate the feasibility of the joint proposition, the customer needed to get access to an accurate picture of the underlying network conditions.

For automotive enterprise customers (car and OEM manufacturers), guaranteed end-to-end performance from the underlying network (whether 4G or 5G, physical or virtualised) is the key to offering a reliable service to their end users and, in the near future, directly to autonomous cars. With the goal of finding an optimal balance (both technical and economic) for the distribution of application components (i.e. microservices hosted within the car, at the edge of the network or in the cloud), technology companies and automotive players wish to understand the performance of ideally every segment in the end-to-end service delivery chain (including the service provider network and hybrid/public clouds). They can then establish an automated Continuous Integration/Continuous Deployment (CI/CD) framework that can drive application optimisation in real-time.

The project was split in two phases:

1. A set of preliminary tests in a controlled, indoor lab in the UK
2. A set of driving runs on an outdoor test track in Germany at the Aldenhoven Testing Center, the home of Vodafone's 5G Mobility lab.

In both facilities the project team deployed full LTE coverage and the necessary MEC virtualised infrastructure to host the AI application. However, for legacy reasons, the two deployments were slightly different in terms of vendors and platforms. Hence the main challenge was to provide all the required measurements quickly, efficiently and in a comparable way in two different virtualised deployments.

[1] https://www.vodafone.com/content/index/what/technology-blog/multi-access-edge-computing-to-power-artificial-intelligence-for-automotive.html

3. Programmable Networking

In order to deliver on the promise of digital transformation and 5G, telco service providers need to embrace extreme automation in their network operation and look at every opportunity to reduce human intervention to support dynamic services and capitalise on new business models. SDN and cloudification make it possible to provide more dynamic and programmable services as they enable the automation of many of the operational processes, including scaling and healing of services based on capacity demand, performance degradation, etc. The secret to achieve these goals is service and application orchestration.

Orchestration entails the full lifecycle automation of service activations and changes in the network, and it is founded on CI/CD and DevOps principles throughout all stages of the development and fulfilment of any service. In this context, service assurance must no longer be an afterthought. Telecom operators need to take advantage of the inherent capabilities of the programmable networking features to automate service testing by integrating virtual test agents into the orchestration layer to drive closed-loop automation with actionable insights.

End-to-end service validation and assurance are important during network service design, during initial activation testing and service operation, as well as in connection with each update or change during the service lifecycle. This is where CI/CD and DevOps approaches to network management become instrumental in maintaining dynamic network services with high customer QoE. The ability to orchestrate and automate active testing makes assurance of service quality possible in complex, virtual environments, while at the same time saving operational costs and optimising resources. Service providers need the right management, orchestration and test solutions to ensure carrier-grade service levels are achieved throughout the service lifecycle.

3.1 The Lack of Measurement Tools

The lack of versatile and affordable measurement tools in the current era of virtualised network infrastructure is one of the most prevalent challenges for enterprise customer solutions. This is particularly acute for testbeds and proofs of concept, as often the necessary investment planning has not been carried out sufficiently and projects (e.g. for co-creation with enterprise customers) need to progress fast. Even lean environments like laboratories and test centres struggle to cope with the pace at which modern networking technologies and use cases are advancing (e.g. cloud-native applications, containerised VNFs).

Enterprise customers demand fast iterations in both research and commercial projects, supported by the pillars of modern agile development: DevOps and Continuous Integration/Continuous Delivery (CI/CD). Every iteration must be driven by the outcomes of well-specified tests; therefore, a set of measurement tools must be always available. Such tools should preferably be accessible by the enterprise customers themselves as a service (which can be a tenant on the same underlying test infrastructure) and be customised according to their goals. Traditional telco vendors cannot always meet the needs of such an agile, CI/CD compliant process for every different vertical. They may have good generic products, but they sometimes lack specific solutions addressing the peculiar problems of an enterprise customer, even within a vertical sector they cover well.

Startups and new innovative companies, often coming from the IT and cloud world, can help fill these gaps in the end-to-end toolchain. Their solutions are often very specific and specialised in scope, and thus well aligned with certain requirements. They can quickly solve a problem (like network measurement/assurance) with a small footprint (e.g. a light, loosely coupled framework which is easy to integrate with the surrounding environment), and their highly customisable solutions can be reused for the next customer or project. Testbeds and trial environments targeting vertical industries should look at the opportunities offered by such agile companies on the market and find sustainable business models to enable investment in relevant measurement technologies.

4. Netrounds

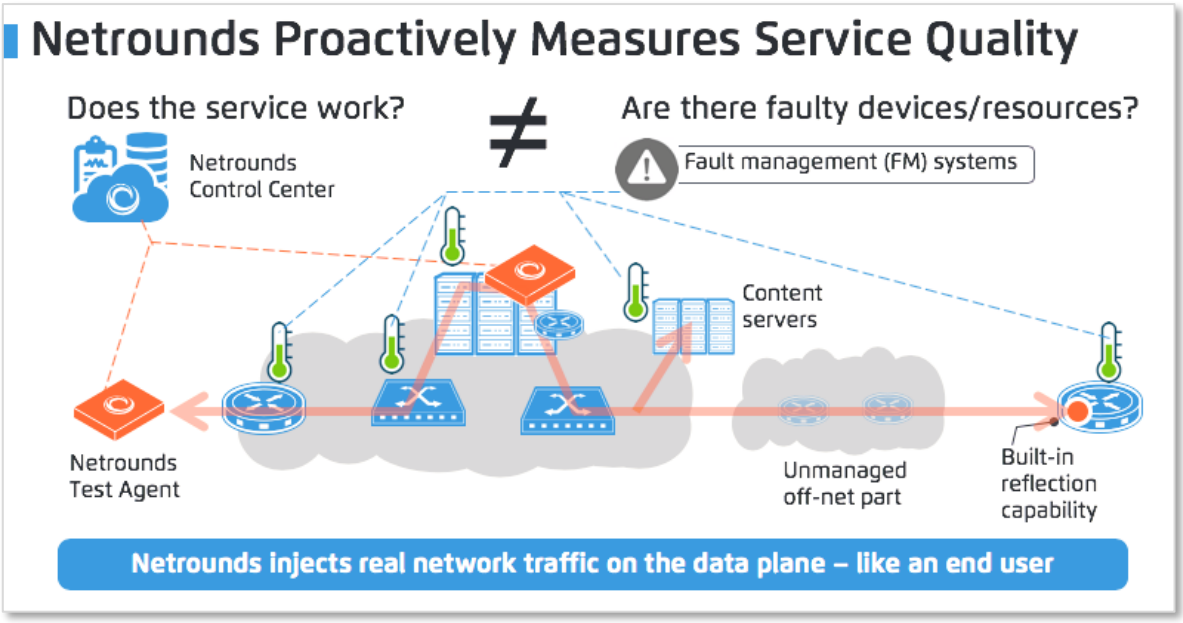
Netrounds is a Swedish company, founded in 2007 to address the problem of how complex and time-consuming it is to roll out new revenue-generating network services that result in an excellent experience for end users.

Most of the existing fault and performance monitoring solutions today are reactive. This means that they wait to see a fault and then report it. There are two main issues with this:

1. Customers/applications see issues and are impacted by them
2. For innovative 5G use cases, customers/applications can be critically impacted (e.g. real-time, latency sensitive scenarios).

Netrounds takes a different approach, by injecting traffic into the data plane and continuously monitoring a multitude of KPIs. Netrounds can proactively find issues and:

- Allow self-healing and other interventions to reduce restore time.
- Inform critical applications of network limitations so that they can adjust.



This active testing and monitoring approach enables service providers such as Vodafone to offer an enhanced network assurance service that will open up new opportunities. By making available highly accurate KPIs, such as latency, packet loss and jitter, proactively and in real-time, Netrounds enables applications to consider real-world network conditions and optimise their behaviour based on this data.

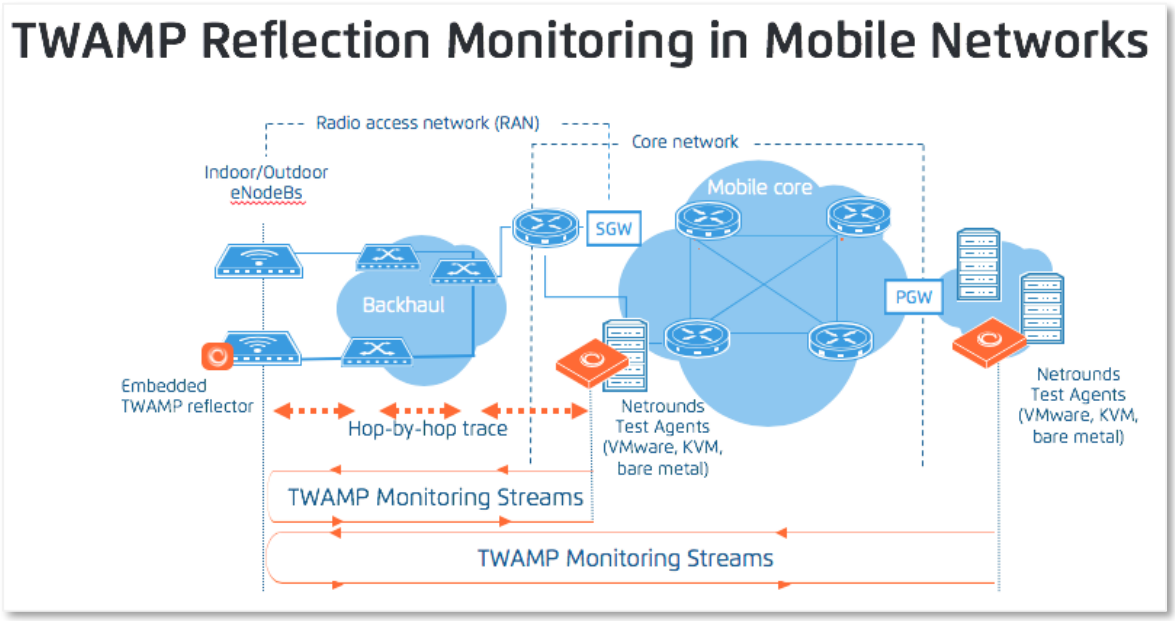
In the proof of concept in Section 4.1, if Netrounds signals that the network is of sufficient quality, data can be sent for processing at the edge compute and returned to the car in time. If the car moves to an area of congestion, or poorer coverage, Netrounds will proactively see this and signal feedback, so the application can adjust its behaviour if it is designed to receive such network feedback. Many similar applications will require knowing KPIs for critical parameters in real-time in order to deliver a meaningful service. Netrounds can provide such information and enhance service providers' offering to industrial partners, opening up new markets and opportunities.

4.1 Proof of Concept: Netrounds in Action

The project team leveraged Netrounds' fully virtualised probes to deploy the same set of measurement points in the network infrastructure in both UK and Germany. The deployment process was extremely quick and, at the end, the two environments were equivalent with regard to network measurement.

The project team decided to use active testing instead of passive testing for the following reasons:

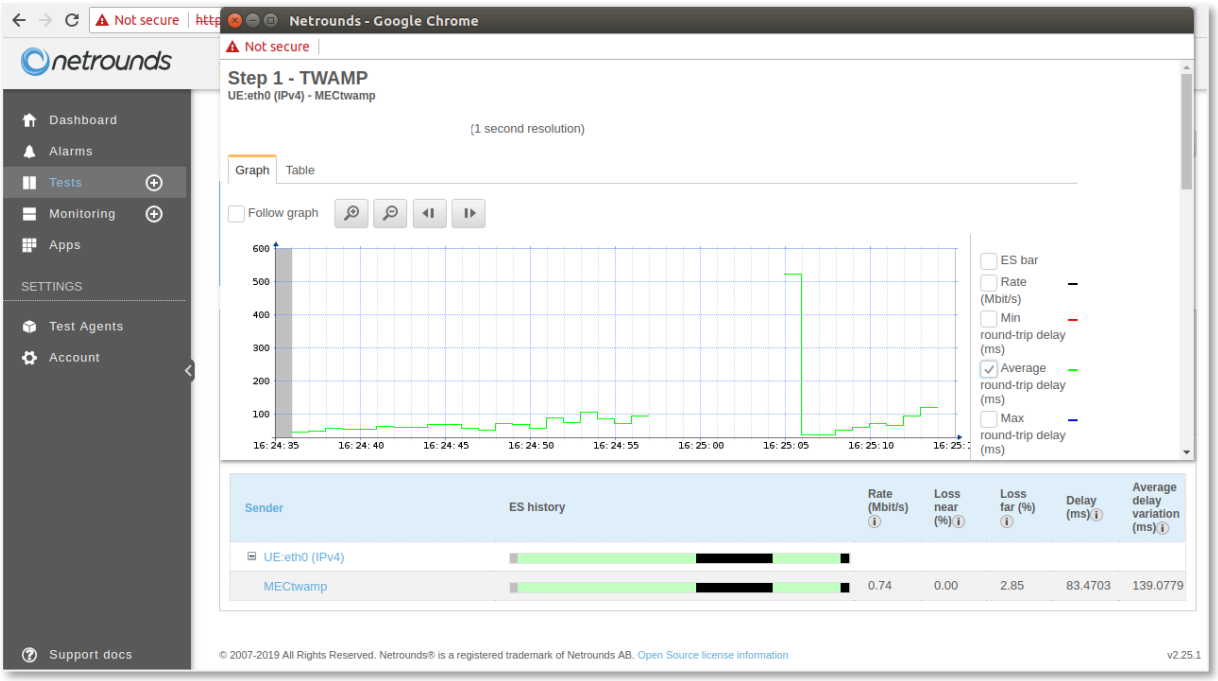
- Netrounds supports it natively and offers powerful, easy to use customisation of injected traffic. Therefore active testing was easy to deploy and faster to set up.
- It required no new development from either the network operator or the enterprise customer, while the passive testing would have required processing and tracking application traffic, adding a burden to the project partners.
- Although passive testing may provide a more accurate measurement for the given application traffic, active testing is much more flexible and plays a key role in what-if testing scenarios.
- Active testing allows generating data on the same network path as used by the customer's application to load network elements with customised, monitored traffic tailored to the current specific use case and customer requirements.
- Passive testing may be considered too intrusive by an enterprise customer developing an innovative, differentiating application in a competitive vertical industry.
- The extra traffic generated by active testing is negligible in terms of volume in comparison to the native traffic created by an enterprise customer, and therefore, doesn't impact the customer's application itself.



The Netrounds solution also includes a way to create test templates and a REST API to consume them, which dramatically facilitates the definition of end-to-end tests and their repeatable execution, potentially done and managed by the enterprise customer themselves through APIs.

5. Learnings and Opportunities

Netrounds has been a key factor to the success of the "Edge Computing Enabled Pedestrian Safety Shield" project as reported at MWC 2019 in Barcelona. Their virtual setup allowed the team to reuse test templates and learnings from the UK deployment in the German environment. Results from the probes were accurate enough to satisfy the enterprise customer and helped them understand how the network environment performed and where the application itself could be further improved. As an example, TWAMP measurements in the figure below reported outliers for network latency in certain situations. The customer could easily see that behaviour and take it into account, in addition to storing test data and analysing it further offline on their own and together with the service provider.



From a Vodafone perspective, working with Netrounds was a very smooth process, as the company is a perfect example of an innovative startup providing the following benefits: a well-designed user interface for the monitoring system; complete, readily available documentation; prompt and precise technical support; informal, fast communication; and agile development/deployment iterations.

Real-time network intelligence and performance measurements open up new opportunities for the future. Two areas can be distinguished:

- Enabling a CI/CD pipeline for corrective actions within the telecoms network itself. Based on real-time measurement information about the performance of certain network segments, decisions can be made to optimise network connectivity. For example, in an automotive scenario, the network segment between the IoT endpoint in a connected vehicle and the cloud instance hosting an application can be tightly monitored and temporarily switched from 4G/5G radio connectivity to satellite connectivity in case coverage through cellular radio decreases in an area the vehicle is driving through.
- Enabling a true DevOps practice for corrective actions within the 3rd party application. Assume a real-time sensitive application consisting of multiple application components: one deployed at an IoT device, another one deployed for reasons of latency-sensitive, computational offload at a telecoms network-based edge cloud, and yet another in a public cloud. The application itself could use insight generated about its (current and potentially predicted) network connectivity to optimise its performance. For example, if the network segment between connected IoT device and the telecoms edge cloud suffers from increasing latency, continued offloading of latency-sensitive computing tasks from the IoT device to the network edge cloud would not make sense. The application itself could adjust to this, temporarily stop offloading computation to the edge cloud and during this time continue in a minimal "safe mode" which purely relies on the capabilities deployed at the IoT device. Other control software could be informed about this temporary adjustment and may operate on different components (e.g. lower the speed of an autonomous vehicle, or slow down the movements of robots).

In both the above cases, enabling such network-aware cloud applications (inside or outside the service provider realm) requires the exposure of network insight to applications through appropriate APIs.

6. Summary and Conclusions

This paper motivates the need for telco service providers to work and co-create with innovative customers in order to help them explore new products, services and solutions. This also prepares the ground for new markets, enables the service providers to increase the addressable market and stay competitive in the advent of 5G. The paper appeals for developing a data-driven ability to assist in rapid-prototyping enterprise customers' solutions and for building an ecosystem of innovation partners to increase responsiveness to enterprise customers with different needs.

On the basis of a joint research project with an enterprise customer, successfully presented at MWC 2019, this paper appeals for the transformation of a telco service provider's network into a digital infrastructure platform across three imperatives: Network Cloudification, Edge Computing and Programmable Networking.

Whilst such a digital transformation will enable companies like Vodafone to address new service verticals and unlock new business models, it poses key challenges that demand adopting a holistic active assurance approach, where accurate measurements drive corrective actions in real-time with continuous contextual insights and predictive analytics. This is particularly true for Ultra-Reliable Low Latency Communications (URLLC) services and solutions of vertical industries: in a Proof of Concept for a new type of automotive application using Multi-access Edge Computing (MEC) with Artificial Intelligence (AI), covered in this report, the role of Netrounds' programmable active assurance solution was deemed critical for enabling dynamic, closed-loop assurance (to both customer applications and service provider network operations) reliably with accurate measurement data and analytics.

In order for service providers like Vodafone to build a pipeline of new offerings rapidly as new opportunities emerge, real-time network intelligence and performance measurements must be in place both during the crucial R&D phase that enterprise applications usually go through and during commercial operations for closed-loop feedback. Service providers need to take advantage of the inherent capabilities of the network cloudification features to dynamically implement test agents end-to-end across the network in a cost-effective manner during the development, pre-staging and provisioning processes following CI/CD and DevOps methodologies. Only by using closed-loop automation to be able to work quickly and efficiently will telco service providers be able to help enterprise customers create new products and do well in a very competitive market.