SUPPLEMENT TO
UNDERSTANDING 5G

VIAVI Solutions

Testing 5G:

Tools and Techniques for Successful Implementation, Maintenance and Monetization

Contents

The Case for 5G Testing

As 5G moves from a concept in the lab to service deployment in the field, engineers, technicians and installers are grappling with the myriad of challenges of ensuring that rollouts meet both the profitability use case for the service provider and the staggering advances in service levels expected by the end customer.

Validating 5G in the controlled environment of the lab takes one school of expertise, supplemented by specialized systems and instrumentation, while moving 5G into the field and delivering service at scale, requires another. 5G technology cuts across all aspects of the network—core, transport, radio access network (RAN), and the underlying fiber infrastructure that connects it, necessitating field validation and assurance solutions that are efficient, multi-functional, easy to use, and automated. This right combination of features and functionality enables service providers to successfully launch 5G technology while maintaining existing 4G infrastructure. Let's analyze some of the network changes introduced in 5G, the implications and the tools you can rely on to address the challenges.

A primary use case for 5G is enhanced mobile broadband (eMBB), where tens of Gbps will be offered over the air interface. This high throughput requires network infrastructure to evolve from today's service level. In response, service providers worldwide are upgrading fiber infrastructure to support 5G traffic requirements.

A key characteristic of 5G is the same network that will deliver eMBB service also must be nimble enough to offer ultra-reliable low latency communications (uRLLC). This means some of the transport and User Planefunctions may be located at different locations, and possibly be virtual. Network function virtualization and network slicing enables operators to offer different applications and services on the same network, helping them deliver on the diverse use cases of 5G. However, this technology shift adds to the complexity of network deployment and management.

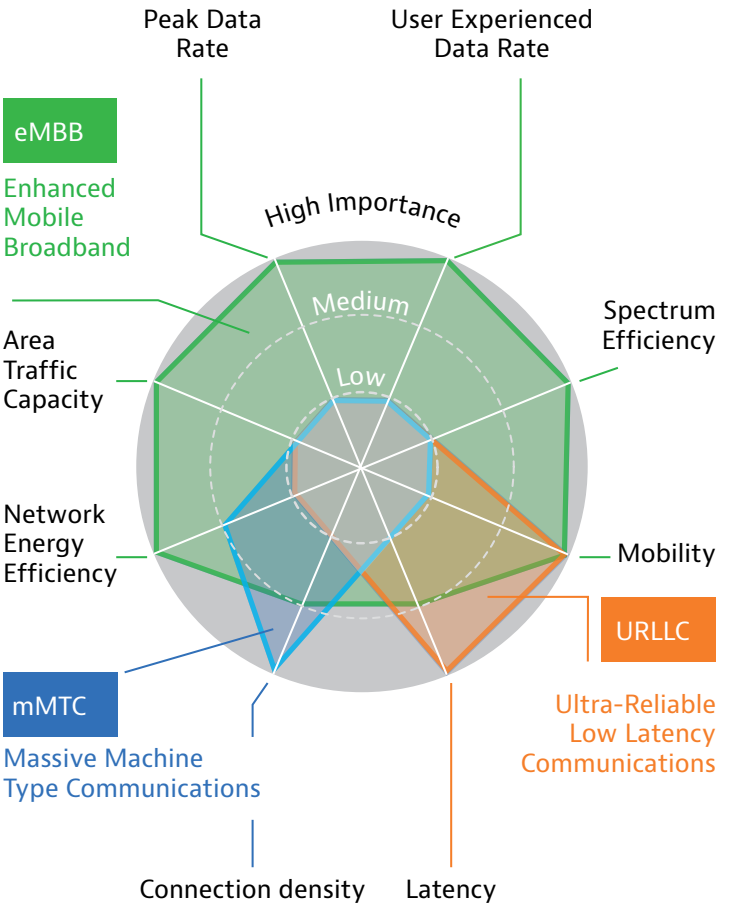
5G Deployment Challenges

1. New complex technologies (mmWave, next generation passive optical network (NGPON), adaptive antenna system, fronthaul functional splits, latency-optimized frame structure, virtualization and network slicing etc.)
2. Fiber and bearer infrastructure upgrade
3. Scale of upgrade (20 to 30 times the number of small cells)
4. Managing multiple RAN technologies
5. Skills gap to manage complex workflows
6. Managing CapEx and OpEx

As with every 3GPP technology, 5G will be spread over multiple releases. In the first phase, release 15, the non-standalone (NSA) option will be supported, allowing early adopters to use their 4G core with 3GPP NR radio to offer 5G service. The first phase of release 15 will be mostly about eMBB, and massive MIMO. Phase 2 of release 15 will enable standalone (SA) operation which will enable 5G services on the next generation core.

Although network function virtualization and network slicing will be supported in phase 2 of release 15, it will be some time before we will see them implemented in the field. In release 16 and beyond, we will see enhancements to support industrial IoT, vehicle to everything (V2X), unlicensed bands, and higher spectrum (>52.6GHz), which will probably be commercially deployed at a later stage (beyond 2020).

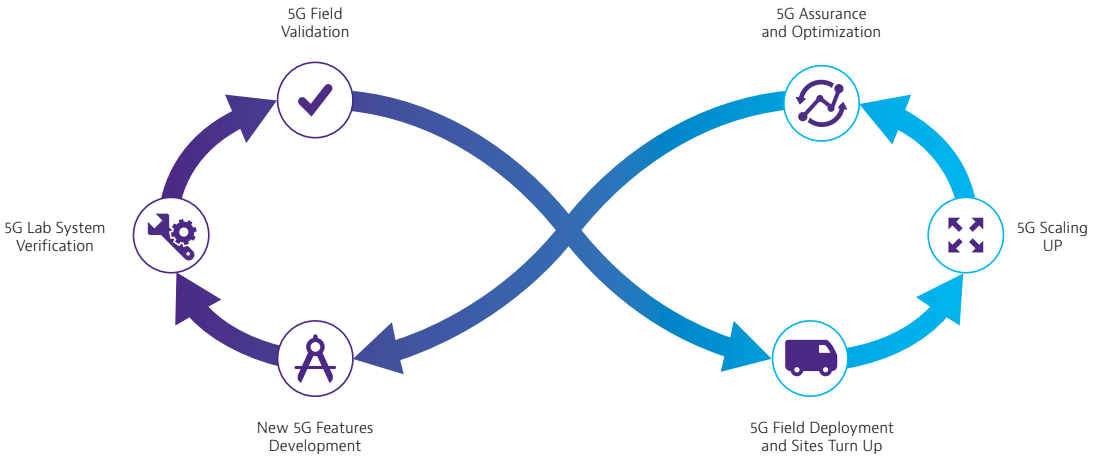
This pace of technology evolution and the exacting demands 5G will place on networks requires a thorough testing strategy from lab to field to assurance, RAN to core. In addition, Open Radio Access Network (O-RAN) is being adopted by operators and equipment vendors to reduce infrastructure deployment cost and lower the barrier to entry for new product innovation.



VIAVI Solutions for Network Validation, Verification and Visibility

At VIAVI, we help test networks before deployment, then we verify networks at turn-up to ensure they meet subscriber needs. Finally, we assure and optimize the in-service network to deliver high levels of service quality so that the customer—whether business or consumer—receives the enhanced experience they expect. Our customers rely on VIAVI equipment, systems and software solutions in three key phases of 5G:

1. Validation of technology and experience in the lab
2. Verification of service in the field through field trial, network activation, and maintenance efforts
3. Visibility to assure, optimize, and monetize the network



THE THREE PHASES OF TEST, MEASUREMENT AND ASSURANCE

Validation

Validation

The success of 5G depends upon multiple pieces of the puzzle simultaneously falling into place. With new services and a complex architecture, service providers and NEMs need products that go beyond standards compliance to optimize performance end-to-end. Whether deploying 5G non standalone (NSA) or standalone (SA), handling multiple frequencies and connectivity or minimizing security risk, you need to be able to rely on trusted test equipment to know your customers will receive the quality of experience (QoE) they expect.

The 5G NR (new radio), O-RAN architectures and SA core network create three significant areas of challenge that require comprehensive lab testing during R&D and then prior to deployment:

- The complexity of requirements (eMBB, URLLC, Massive IoT, SA/NSA), and balancing these in a lab environment.
- Cost: e.g. the use of new frequency bands such as millimeter wave (mmWave) spectrum, larger carrier bandwidths, and beamforming, are complex and costly to validate.
- Time to market: 3GPP is rapidly evolving standards; the time-to-market window is far shorter for 5G than that for 4G; upgrades to testing equipment must keep pace with change.

VIAVI solutions for lab testing are designed to cover the complete set of 3GPP capabilities. VIAVI holds an unrivaled market-leading position and has developed a roadmap to support customers working on the cutting edge of 5G while continuing to develop a leading 4G roadmap.

Network Equipment Manufacturers

5G networks introduce testing and validation challenges for NEMs, including:

- Functional testing of individual new 3GPP capabilities
- System integration as components in either the gNB or core are integrated
- Capacity testing to ensure that the networks can handle real world traffic at scale
- Regression and stability testing to ensure that each new software release meets the required quality

Service Providers

Networks are going through a rapid architectural change with the introduction of 5G technology in order to improve network performance and deliver new 5G applications.

Supporting these new applications requires service providers to optimize their networks prior to deployment:

- Pre-deployment testing prior to service launch to enable evaluation of technologies, expected performance and potential impact on other service users.
- Scenario planning such as evaluating how the network will perform in extreme situations such as a major event, pressure points in the network, or a disaster when both emergency responders and the general public are placing extreme load on the network.
- End to end performance testing to address the increasingly interconnected nature of network architectures.

It is vital to ensure the complete network infrastructure performs under loaded conditions, delivering an optimum experience to the end-user, resulting in an excellent Quality of Experience for the wireless subscriber. Service providers therefore require a testing product that manages:

- Maximum throughput
- True Visibility
- Optimization
- Testing at scale
- Interactions between 4G and 5G
- Multiple frequencies
- Mobility
- Low latency
- Massive IoT – 1000's of UEs and millions of connections

5GNR – the challenges of beamforming and Massive MIMO

Integral to the success of 5G, beamforming involves the use of multiple-input, multiple-output (MIMO) arrays. These feature dozens of small antennas combined in a single formation, meaning signal processing algorithms can be used to determine the most efficient transmission path from the base station to each user. Individual packets can be sent in multiple directions then choreographed to reach the end user in a predetermined sequence.

Beamforming and Massive Multiple Input Multiple Output (M-MIMO) will deliver capacities that are many multiples of what is achievable in older generations of mobile communication, with more resilience. Utilization of millimeter wave, which is essential for massive MIMO and beamforming, involves frequencies that are much more susceptible to propagation loss from environmental conditions. Validating over-the-air (OTA) performance

is extremely important to ensure the UE can perform beam tracking and switching. This is a challenge for service providers who need to perform beam-centric radio planning and optimization and need to quickly troubleshoot and identify the root cause of poor massive MIMO and beamforming performance.

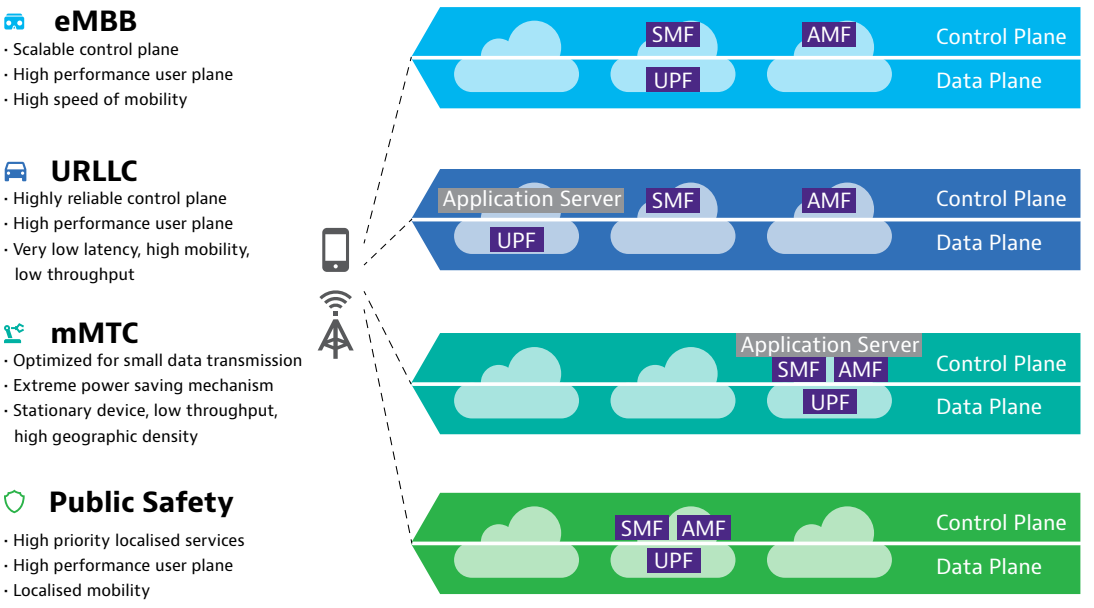
Network disaggregation and O-RAN

5G network dis-aggregation allows components of the network to be virtualized, providing a means to scale and improve user experience as capacity grows. The benefits of virtualizing components of the RAN provide a means to be more cost-effective from a hardware and software viewpoint especially for IoT applications where the number of devices is in the millions.

The introduction of eCPRI interfaces presents a more cost-effective solution as fewer interfaces can be used to test multiple 5G carriers. The eCPRI interface for 5G is used in the O-RAN fronthaul interface such as the O-DU. This new interface and virtualized function add a layer of complexity to testing.

Network slicing

Network slicing adds an extra dimension to the NFV domain by allowing multiple logical networks to simultaneously run on top of a shared physical network infrastructure. Each 5G vertical will have its own requirements, so network slicing becomes an important design consideration for 5G network architecture. Testing network slicing within real-world infrastructure with millions of physical devices is near-impossible. As a result, lab testing is vital.



MEC Testing

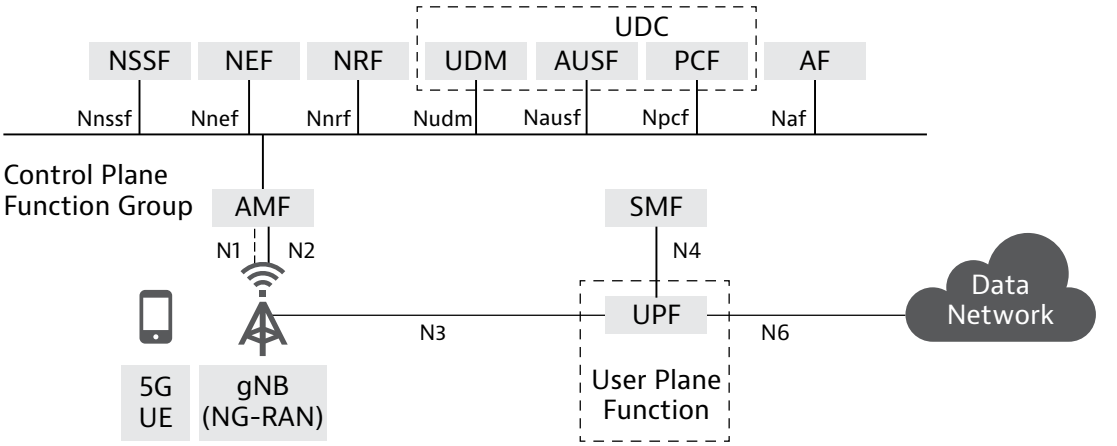
Multi-Access Edge Computing (MEC) is an important element of 5G architecture. MEC is an evolution in cloud computing that brings the applications from centralized data centers to the network edge, and therefore closer to the end users and their devices. 5G networks based on the 3GPP 5G specifications are an ideal environment for MEC deployment. The 5G specifications define the enablers for edge computing, allowing MEC and 5G to collaboratively route traffic.

In addition to the latency and bandwidth benefits of the MEC architecture, the distribution of computing power will better enable the high volume of connected devices inherent to 5G deployment and the rise of the Internet of Things (IoT).

Core Network Testing

The 4G Evolved Packet Core (EPC) is significantly different from the 5G core, with the 5G core leveraging virtualization and cloud native software design at unprecedented levels.

The new 5G core, as defined by 3GPP, utilizes cloud-aligned, service-based architecture (SBA) that spans across all 5G functions and interactions including authentication, security, session management and aggregation of traffic from end devices. The 5G core further emphasizes NFV as an integral design concept with virtualized software functions capable of being deployed using the MEC infrastructure that is central to 5G architectural principles.



Test tools are required that support the development of virtualized functions in mobile edge architecture; offer an end-to-end testing solution from RAN through the EDGE to the Mobile Core; and stress tests the impact of RAN traffic on the core network. Service providers need to prepare their networks for the demands of a massive number of connections through the IoT, whilst also coping with bandwidth hungry, delay sensitive edge applications such as AR.

Security Performance Testing

The performance benefits and diversity of applications 5G will bring will also introduce new security risks and expose additional "attack surfaces" within the 5G security architecture.

The trust model has expanded, with more players involved in the service delivery process than with previous generations of mobile technology. The IoT and user propagation create an exponentially higher number of endpoints with many of these traffic inputs no longer supervised by human hands.

Among the improved 5G security features detailed by the 3GPP standards are unified authentication to decouple authentication from access points, extensible authentication protocols to accommodate secure transactions, flexible security policies to address more use cases and subscriber permanent identifiers (SUPI) to ensure privacy on the network.

As 5G deployment continues and critical performance nodes become increasingly virtualized, service providers will need to continually monitor and assess security performance. Adherence to best practices means end-to-end network security monitoring throughout the system architecture, devices and apps.

5G Lab Testing Solutions from VIAVI

It is only through the use of complete, RANtoCore™ lab testing and validation solutions that service providers will be able to gain a complete view of their network, Whether you are testing MEC latency, end-to-end network slicing reliability or developing a 5G Core you can determine how it performs under the demands of real-world traffic scenarios.

TM500

The TM500 is a highly scalable network performance and capacity test product that validates networks by simulating mobile devices connecting to the network under test. It tests the network performance as experienced by end users. By continuing to innovate when it comes to new features, the TM500 continues to stay ahead of market need, empowering network service providers to prove network performance under real life usage conditions before the availability of actual handsets, with the ability to test independent complex services at scale with vendor agnostic performance testing.

This powerful product delivers 5G first while continuing to support the latest 4.5G specifications, allowing simultaneous capacity testing with a combination of 4G and 5G scenarios such as VoLTE, Video users and IoT devices, enabling the assessment of how new 4G services are impacted with the introduction of different 5G requirements. The TM500 is the de facto solution in ensuring Quality of Service to all types of devices and users at

scale, ensuring the network delivers without compromise and so helping to maintain brand reputation.

TeraVM

The TeraVM virtualized platform makes it an ideal solution for validating the 5G SBA (Service Based Architecture) virtual mobile core and its components. The 5G Core Tester provides a full wraparound test of a 5G Standalone Core Network and gives Core Network engineers a controllable and repeatable test environment that helps implement 3GPP standards rapidly. It also simplifies the development lifecycle of the 5G SA Core Network and the introduction of 5G services to the market. The TeraVM Core Tester provides fully configurable emulation of thousands of base stations, millions of UE's and user applications to create the most realistic 5G SA RAN environment to stress the core. Full support for 3GPP interfaces enabling the tester to accurately emulate UE applications and mobility behavior for inter-5G and inter-RAT scenarios.

TeraVM Can also emulate the 5G core network as a whole, individual nodes such as the UPF, SMF, AMF as well as SBA functions. This allows engineers to fully wrap around the base station and ensure that signals are handled in the correct way and meet quality of service expectations.

With the VIAVI TeraVM F1 Load Generator/O-DU Simulator solution, network vendors and service providers can emulate many O-DUs and UEs to generate 5G control plane and/or user plane traffic to test the O-CU. TeraVM supports both 5G SA and NSA scenario, complemented with VIAVI virtual RAN emulation functionality.

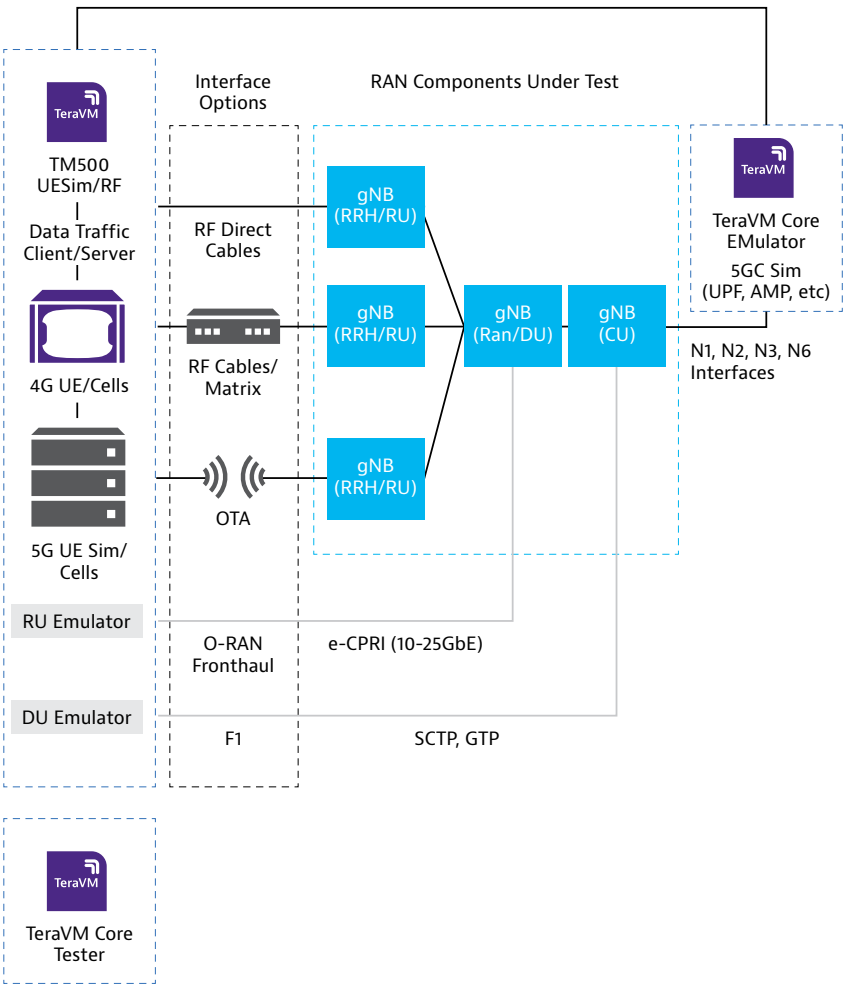
When developing a 5G core network, engineers must also ensure that the RAN sends and receives the correct signals and responses, which can be validated using our Core Tester. When used with the VIAVI TM500 emulating hundreds of thousands of UEs, service providers can measure latency and round-trip time of a 3GPP-compliant 5G core network in a virtualized, lab environment. This enables the user to test the UPF function in V2X signaling, for example, to ensure that data is transmitted from one car to another through the network within the required parameters of URLLC. Users can therefore ensure that, with the UPF positioned at the edge of the network, they can deliver on that particular Service Level Agreement. By combining TM500 and TeraVM VIAVI provides a comprehensive means of testing end-to-end network slicing.

TeraVM for security testing

TeraVM can demonstrate test scenarios by replicating cyber-attacks involving hundreds of thousands of IoT devices attached to a network. By validating networks against hacks by simulating genuine device traffic and throughput, network service providers

can understand which areas of their networks require more stringent security measures. TeraVM offers an elastic test bed which can be used to deliver software defined testing with reliable and repeatable results. Network validation is a crucial component to reduce the damage of attacks, which are increasing due to the huge influx of IoT devices, and high-bandwidth connectivity, such as 5G.

Focusing on field trials, turn-up, and activating and scaling the network, verification testing is a key element of the lifecycle. It covers planning, installation and Commissioning, acceptance, and maintenance. 5G technology cuts across all aspects of the network, namely core, transport, RAN, and the underlying fiber network. In addition (and this is true for all the life-cycle phases), maintaining, for example, 4G infrastructure while deploying 5G technology is crucial for any Mobile Operator. Whether SPs are deploying new technology or launching a greenfield network, all components, connections and the overall network needs to be tested. In this section we will talk about some of the key fiber, ethernet and RF tests that are essential for a successful and timely 5G launch, especially in regard to components and technologies that are either being upgraded or deployed for 5G.



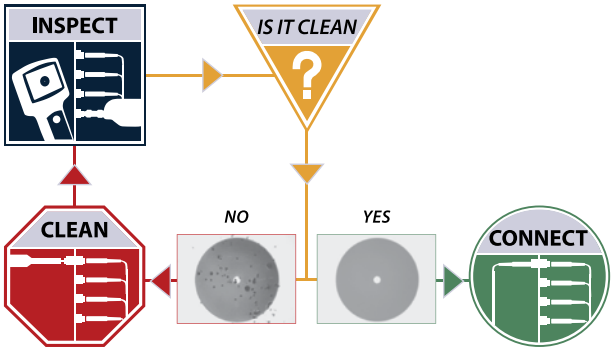
THE THREE PHASES OF TEST, MEASUREMENT AND ASSURANCE

Verification

Verification

Fiber Inspection

Contaminated connectors are a leading cause of problems in fiber optic networks. A single particle mated into the core of a fiber can cause significant back reflection, insertion loss, and even equipment damage. Operators should follow the "Inspect Before You Connect" process to ensure fiber end faces are clean prior to mating connectors.



OTDR Test

An optical time-domain reflectometer (OTDR) allows technicians to detect, locate, and measure events on fiber links such as mated connectors, splices, bends, ends and breaks, and the following properties can be measured by having access to only one end of the fiber (unidirectional testing):

- Attenuation – The optical power or signal loss or the rate of loss between two points along the fiber span.
- Event Loss – The difference in the optical power level before and after an event.
- Reflectance – The ratio of reflected power to incident power of an event.
- Optical Return Loss (ORL) – The ratio of the reflected power to the incident power for an optical link.

The VIAVI SmartOTDR allows technicians at any skill level to perform all essential fiber tests. The Smart Link Mapper (SLM) application displays each event as an icon, giving technicians a schematic view of the entire link, helping them use an OTDR more effectively, without the need to be able to interpret and understand OTDR trace based results.

In order to more accurately characterize fiber links and individual events, and to try to uncover additional events that may have been concealed by an OTDR's own dead zone performance when testing unidirectionally, dark fiber providers or the fiber owner/operator can perform bi-directional tests. This allows for more accurate measurement of events (losses and reflections, etc.), and to confirm they are the same in both directions, there are situations due to fiber tolerances, mismatches or splicing that can result in excessive or differing optical losses (or apparent gains) when viewed from different directions.

Keep in mind you can never be 100% sure what direction of service a fiber will be used for when it is installed. A lot of applications are dual fiber with one Tx and one Rx fiber, but there are also single fiber implementations with different wavelengths being used for Tx and Rx on the same fiber in opposite directions.

VIAVI FiberComplete™ is an all-in-one, automated and single test port solution that tests bi-directional insertion loss (IL), optical return loss (ORL), and OTDR.

Wavelength Division Multiplexing (WDM)

It is expected that most of the fiber network infrastructure will be upgraded to take advantage of higher multiplexing technologies to offer higher throughput. Solutions from VIAVI that address this area include:

- Channel Check: OCC-55 and OCC-65 can be used to validate transmitted wavelength, shift and output power level per wavelength
- OTDR Test: 4100 Series modules can be used to detect any fiber anomalies
- PON OTDR: OLP-87 PON power meter and FiberComplete for T-BERD/MTS

Fiber Monitoring

PON and its variations will be used in fiber infrastructure for 5G, and as the scale of PON network will increase so will the demand for troubleshooting and maintenance. Automating physical layer tests of a PON system from a centralized location such as a mobile telephone switching office (MTSO) can reduce provisioning time and maintenance cost and can improve network quality of service. As discussed earlier, an OTDR can pinpoint the location of faults in a fiber link and certify the workmanship involved in an installation. VIAVI ONMSi (Optical Network Monitoring System) can test and certify PON during the build and construction phase and then switch to on-going monitoring for multiple PON networks during their operational phase. ONMSi allows a single technician to test the network

during installation. After service activation, the system accurately detects and locates fiber infrastructure degradation, alerting operators and managers with the details of faults.

Automating physical layer tests from a centralized location can reduce provisioning time and maintenance costs while improving the overall service quality. ONMSi (Optical Network Monitoring System) can test and certify during the build and construction phase and then switch to on-going monitoring.

Timing and Synchronization Test

Timing and synchronization play a vital role in the performance of a wireless network. In 5G, those requirements are further enhanced due to phase and timing demands on networks based on time division duplex (TDD) and coordinated radio techniques. Whether we are using a physical layer based or packet-based synchronization architecture, the requirements essential for synchronization network must be met, these requirements differ based on the use case, with Category A+ demanding the most stringent synchronization requirements. The T-BERD/MTS-5800 along with the TEM module can test PTP/SyncE/GPS based networks for synchronization.

Fronthaul Network Test

In 5G, a fronthaul transport network node (FTN) is introduced to manage the Ethernet access ring that can deliver a converged fronthaul supporting legacy CPRI and 5G eCPRI. It is essential to validate FTN networks to make sure they are not creating any excessive delays and are meeting the delay and synchronization budgets for the access network. The T-BERD/MTS-5800 can perform CPRI and eCPRI tests, measuring throughput, delay and jitter.

Ethernet Test

Validate performance of the backhaul network from the core to the virtual central unit (vCU) to ensure correct configuration and high-quality transport of data-plane and control-plane. RFC 2544 and Y.1564 test methodologies validate end-to-end configuration at either the Ethernet or IP level and ensure that the key performance objectives such as committed burst size (CBS), committed information rate (CIR), latency, packet jitter, and frame loss are met. Network operators can select either RFC 2544 or Y.1564 to test a single service or select Y.1564 to test multiple classes of service.

Tests can be performed in a single-ended or dual-ended test topology. The latter requires two test units but can ensure proper characterization of network in both directions and can detect potential asymmetries between the two directions. One-way delay measurement can also be performed to identify asymmetries caused by network equipment, components or fiber lengths. VIAVI T-BERD/MTS-5800-100G provides the following 2-port testing up to 100G:

- Throughput/one-way and loopback latency/frame loss/jitter
- RFC2544 testing
- Y.1564 testing

With network function virtualization (NFV), the network is moving away from a hardware-centric, proprietary network infrastructure toward an open, standards-based, software model that is revolutionizing the way networks will be designed, implemented and operated.

VIAVI NITRO vNet Fusion combines software-based agents with standards-based (RFC7594) data collection methodologies to enable operators to leverage the non-proprietary compute platforms they're already deploying (for virtual network functions).

Radio Access Network (RAN)

Where 5G radio enhancements will deliver a flexible tactile network, they will also create significant challenges for service providers to manage a wide array of complex technologies such as mmWave, massive MIMO, beam forming, and dual connectivity along with multiple applications with varying performance demands. We can all agree that the scale of the network will be much larger. From a service provider perspective, it will be essential to be able to scale resources to this ever-evolving network of networks. The traditional methods of service activation and network maintenance will not scale. Verifying all these technologies with the right solutions during the installation and acceptance stages will be the key to successful and efficient network deployment.

The 5G NR (new radio) is highly complex with new frequencies such as mmWave, MIMO and massive MIMO and beamforming. Indeed, the focus on 5G moves away from being cell site centric to being beam centric. The CellAdvisor 5G (CA5G) was the first to market Base Station Analyzer for 5G. With CA5G technicians can quickly verify radio performance, perform real-time spectrum analysis (RTSA), interference analysis, beam analysis and capture RF coverage map. In addition to being used by deployment teams and RAN experts in the field, CA5G can also be used in the lab to support pre-deployment testing.

RF characterization and conformance testing are the key to successful 5G network deployments. Ensuring 5GNR radios are behaving in accordance to 3GPP performance recommendations will help eliminate RF interference and radio performance issues. By validating the channel power, occupied bandwidth, adjacent channel leakage ratio, and spurious emission mask using a VIAVI CellAdvisor™ 5G, technicians can quickly validate radio performance

5G Beam Analysis

Massive MIMO and antenna beamforming are the key technologies enabling 5G, which will change from static cell-centric coverage to dynamic user-based coverage for 5G radio access networks. Beamforming is the ability to generate and shape multiple beams using a much larger antenna array by manipulating the phase and amplitude of the arrays, thereby directing energy to a user's specific service area. At higher frequencies, millimeter wave (small wavelength) makes it easy to integrate a larger array into a relatively smaller form factor. Utilization of millimeter wave, which is essential for massive MIMO and beamforming, presents additional obstacles, as these frequencies are much more susceptible to propagation loss from environmental conditions. Validating over-the-air (OTA) performance is extremely important to ensure UE can perform beam tracking and switching in this challenging RF environment.

Validating beam performance is a challenge for operators who need to perform beam-centric radio planning and optimization and need to quickly troubleshoot and identify the root cause of poor massive MIMO and beamforming performance. CellAdvisor 5G allows engineers to easily validate beam performance and ensure that they are taking advantage of massive MIMO and beamforming.

Antenna Alignment

To maximize the use of high-band mmW frequencies and Massive MIMO beamforming antenna performance, precise antenna alignment and a line-of-sight survey are critical during installation. Failure to install per planned specification will lead to sub-optimal 5G network performance. Similarly, failure to identify near-field RF obstacles (not identified by 5G modeling software) may render the cell unusable. 3Z RF Vision antenna alignment tool allows technicians to quickly perform accurate alignment on 3 dimensions: azimuth, tilt, and roll. With a built-in camera and augmented reality, the tool provides a visual guide that helps identify near-field obstacles. Dual frequency GNSS technology is implemented to measure each satellite twice and deliver more accurate and faster readings, even in high density areas. Once alignment is achieved, a comprehensive antenna alignment and line-of-sight report is automatically created per site and can be easily shared using RF Vision's Bluetooth app, while still on site.

THE THREE PHASES OF TEST, MEASUREMENT AND ASSURANCE

Visibility

Visibility

Phase 3 of the 5G lifecycle focuses on Visibility for Assurance, Analytics and Optimization. The disaggregated 5G RAN provides new interfaces and new ways of capturing the crucial data required. With Mobile Edge Computing and the need for the User Plan Function (UPF) to move to the network edge to support the latency requirements of URLLC applications, the RAN is the new Core.

The 5G concept of Beam Forming has a significant effect on managing the network. Where in previous mobile architectures the cell was the key atomic element, in 5G, Beams are the key element - both coverage and user beams. We move from cell-centric to beam-centric radio. With beams:

- Elevation becomes an important dimension in coverage and optimization
- Geo Location accuracy requirements are much higher than 2G/3G/4G
- Real-time analytics are needed to enable more automation and root cause prediction

The UPF can be distributed depending on the application, which means that access to the User Plane may be at the network edge - requiring a RAN-based methodology for access.

In addition, being able to analyze data across multi-RAN technologies is crucial to getting an overall view of the service. As the 5G network layer is expected to support ever-increasing numbers of connected devices, in diverse new use cases, a mobile assurance, geolocation and optimization solution must be able to scale up. Not only must it incorporate a new radio technology alongside older installed infrastructure, it must be able to scale its data collection and analysis components to deal with the increased ingress of heterogeneous data.

The VIAVI GEO Location solution now integrates subscriber-centric 5G NR measurements along with current technologies allowing operators to plan, assure and optimize multi-technology networks as they build out 5G. The #1 GEO Location solution in the market, transforms performance engineering, creates a true understanding of customer experience and enables monetization of unique insights.

Coverage Assurance 5G delivers an integrated RAN to Core 360o QoE view, with simplified automated workflows. Using the only 5G 3D GEO Location patented technology,

Coverage Assurance provides a truly unique view of the subscribers, network, services and applications.

- Enhanced 2G, 3G, 4G, 5G multi-technology network performance
- Automated workflow simplification
- RAN to Core Analytics delivering business value for 5G

Network Slicing

Another important component of 5G is Network Slicing. This is a network architecture that enables multiple logical networks to run on top of a shared physical network infrastructure. It uses virtual network architecture capabilities to essentially partition a network to meet a specific service class need. So, for example, an URLLC application (e.g. autonomous vehicles) would have a different slice to that of mMTC, because of its latency requirements.

With NITRO Mobile, we are building on a leadership position in GEO location providing unprecedented insight into what is happening on the network and where with high levels of granularity. Having visibility into not only 5G but also correlated with previous versions of mobile technology in one integrated platform is crucial to delivering on the value and business benefits of 5G while optimizing the network for consumers and enterprise.

Monetization

At the end of the day Operators need to make money from 5G and drive new revenue streams. They don't need more data but rather insights into services, applications, locations and the network to drive monetization opportunities with detailed analytics. The rich insight VIAVI provides through NITRO Mobile transforms the operators' business to leverage the intelligence we provide to monetize the 5G network.

O-RAN

O-RAN

Open Radio Access Network (O-RAN) is being adopted by operators and equipment manufacturers worldwide to reduce infrastructure deployment cost and lower the barrier to entry for new product innovation. As a leader in 5G test and measurement, VIAVI Solutions has developed a comprehensive test suite with modules for lab validation, field deployment and service assurance. This guide provides an overview of O-RAN, descriptions of use cases, and instrument and system recommendations to support a robust and efficient test environment

The expectations of 5G will place enormous demands on the network infrastructure to deliver massive volumes of data over swathes of spectrum to multitudes of users at challenging latencies. To meet this challenge necessitates the possibility for the different logical functions of the network to be flexibly placed at different physical locations and the network must be disaggregated into more components than has been seen before.

Traditionally, RAN components such as radio and digital base band have been built on proprietary hardware, and these components typically use vendor-specific protocols for communications. Software functions and interfaces between the different RAN components are designed for optimal performance for that proprietary hardware. For example, Common Public Radio Interface (CPRI) is commonly used for LTE fronthaul (link between radio unit and baseband unit), however, vendor specific implementation often restricts multi-vendor operability.

For the introduction of RAN functions disaggregation and open interfaces in 5G, 3GPP has in Release 15 specified a Higher Layer Split (HLS) option of the gNB which is known as well as the Option 2 NR-PDCP split option. In this option, the gNB may consist of a Central Unit (gNB-CU) and one or more gNB Distributed Unit (gNB-DU) connected through the F1 interface. 3GPP has delivered a set of specifications for the F1 interface, however realizing multi-vendors interoperability over the F1 interface can be very challenging as these specifications have been defined with options which can be used in different manners depending on vendors' implementation.

3GPP has started a study on Lower Layer Split (LLS) in Release 15 during which multiple lower layer split options were identified but it has proven to be difficult for the 3GPP community to converge on specifying a single split option in 3GPP. Many vendor specific implementations of lower layer splits exist in the market today which even though have been optimized to take advantage of the benefits of lower layer split such as improved

radio performance due to coordination gains, these closed systems do not support multi-vendors interoperability.

O-RAN sets out to deliver well defined specifications to the industry aiming to enable deployments of O-RAN based programmable networks consisting of fully disaggregated modular O-RAN network functions which are designed to be multi-vendor interoperable over open interfaces running on cloud-based virtual systems. This allows operators to design and deploy mixed-vendor network and network slices which is key to delivering mixes of use cases in the same O-RAN infrastructure.

Challenges of Deploying and Managing O-RAN based networks

Interoperability and end-to-end performance will be by far the biggest concerns on the minds of vendors and operators in an O-RAN environment. Imagine all the advanced coordination features, power control algorithms and intra-technology interactions in a multi-vendor RAN. Today, having one vendor simplifies all that. And, when product related network performance issues arise, which is inevitable, service providers work with only one vendor to resolve them. Now imagine a network where RAN components such as central unit, distributed unit, and radio unit are supplied and supported by multiple vendors – operators and vendors will face greater challenges in both identifying and isolating issues as well as ensuring that performance/cost compares favorably to that of an optimized single vendor solution. Another key challenge of an O-RAN based multi-vendor network will be network management and resource management. Management of multi-vendor spares and training resources to maintain a multi-vendor network will be a learning curve for service providers' operations team. Not to forget, integrating new functions and orchestration of new services in an O-RAN based network will be another key challenge.

VIAVI has introduced the industry's first comprehensive test suite for O-RAN specifications. Open Radio Access Network (O-RAN) is being adopted by operators and equipment manufacturers worldwide, to reduce infrastructure procurement, deployment and operational costs and lower the barrier to entry for new product innovation. As a leader in 5G test and measurement and contributor to the O-RAN Alliance, VIAVI has developed a comprehensive test suite with modules for lab validation, field deployment and network assurance.

VIAVI has been working closely with operators and vendors around the globe to help them address these challenges. The company has identified various use cases which can

help identify, isolate and resolve any network performance issues before and after a multi-vendor based O-RAN network is launched. Following are key areas of focus in lab validation, field deployment and network assurance:

- Multi-vendor interoperability test (MV-IOT) for functionality, performance, reliability, robustness, and resilience
- Subsystem (wrap-around) test
- System level test

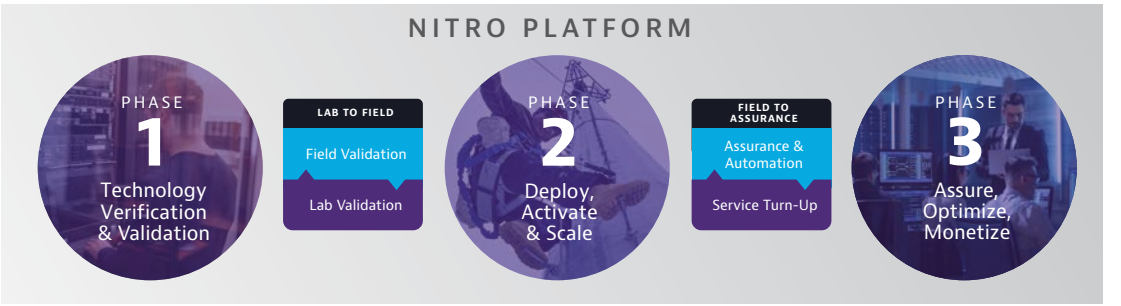
Vendors-pairing evaluation

- Protocol compliance for open interfaces and protocols
- Continuous integration (CI) and Continuous Delivery (CD) test automation
- Continuous test process throughout the entire lifecycle
- Holistic evaluation of multiple RAN deployment options (RAN dis-aggregation, spectrum bands, delay management, features, vendors, etc.)
- Performance monitoring of open interfaces and protocols to ensure optimum operation

5G Products and Solutions

VIAVI 5G Products and Solutions

These products comprise the VIAVI 5G lab to field test and assurance portfolio:



Research Institutions

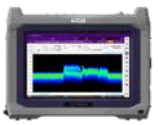
Network Equipment Manufacturers

Service Providers

Solutions for 5G Technology Verification and Validation in the Lab

		
TM500 Wireless Network Tester	**TeraVM** Application Emulation and Security Validation	**ONT-600** Multiport Test Module

Solutions to Deploy, Activate and Scale 5G in the Field

		
CellAdvisor5G Cell Site Test Solution	**OneAdvisor** Cell Site Installation Tool	**T-BERD/MTS-5800** Handheld Services Tester

3Z RF Vision
Antenna Alignment Tool

Fiber Test Tools

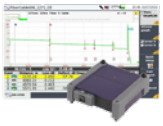
FiberChek Probe and Sidewinder
Fiber Inspection Tools

SmartOTDR
Handheld Fiber Tester

FiberComplete for T-BERD/MTS
Automatic bi-directional IL, ORL and OTDR test solution

WDM

OCC-55 and OCC-65
Optical Channel Checker



4100 Series modules
CWDM OTDR Test Solution

OLP-87 PON
PON Power Meter

Solutions to Assure, Optimize and Monetize 5G Services

NITRO Mobile
Converged Assurance & Analytics

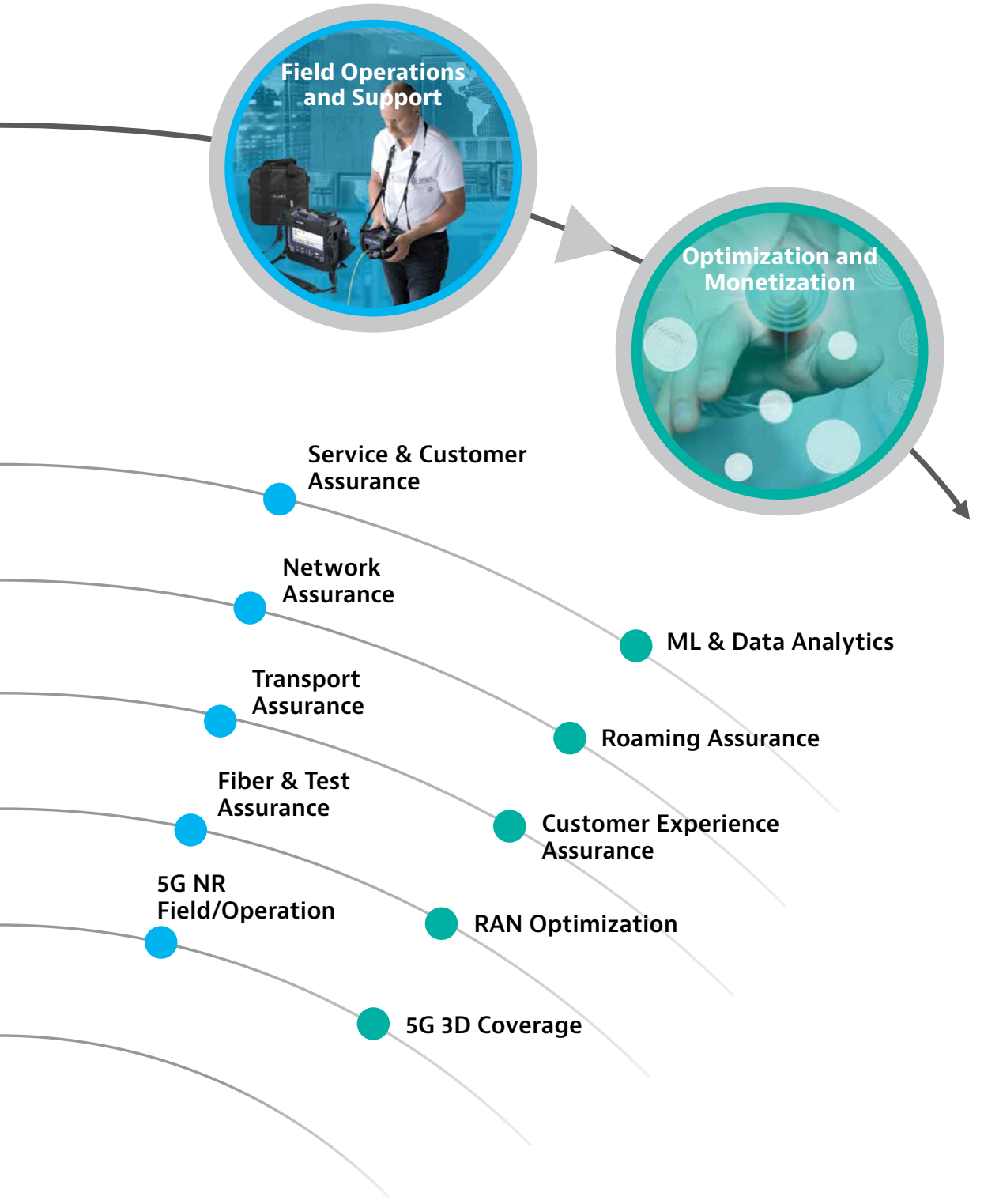
NITRO GEO
Location Intelligence Solution

NITRO vNet Fusion
Virtual Test and Activation

ONMSi
Optical Network Management System

VIAVI 5G Life Cycle Solutions

- 3D Coverage & Site Certifications
- Beam Verification
- Core & Services Emulation
- Lab2Field
- Protocol Verification
- Beam Scanning
- Transport Verification
- Antenna Alignment & LOS
- RF Lab Emulations
- Layer 0-4 Testing
- Devices Load Emulations


Field Operations and Support
Optimization and Monetization
Service & Customer Assurance
Network Assurance
Transport Assurance
Fiber & Test Assurance
5G NR Field/Operation
ML & Data Analytics
Roaming Assurance
Customer Experience Assurance
RAN Optimization
5G 3D Coverage

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