White paper

5G RAN: Ensuring KPIs from Metro Edge To End User

Introduction

The 5G rollout – currently with 5G New Radio (5G NR) non-standalone (NSA) as specified in 3rd Generation Partnership Project (3GPP) Release 15 and subsequently with future versions that will utilize standalone (SA) technologies – is changing the way mobile networks are designed, deployed, operated, and maintained. To achieve the low latency, high speeds, and large capacity that will significantly improve existing wireless applications while creating new ones, networks must evolve.

Among the issues that mobile operators, as well as system developers, need to consider are:

- Complex technologies (i.e. millimeter wave [mmWave], passive optical networks [PON], adaptive antenna systems [AAS], network slicing, network timing and synchronization)
- Infrastructure enhancements, particularly fiber technologies
- Significantly denser networks, due in large part to small cells
- Multiple Radio Access Network (RAN) technologies

A new generation of test instruments are necessary to meet these changes, especially when it comes to RAN. Using the proper solutions during deployment, installation and maintenance of new networks will ensure key performance indicators (KPIs) are met from the Metro edge to the end user.

5G NETWORK SLICING

To determine the proper test solutions and their capabilities, it's important to understand how the evolving 5G architecture is affecting network operation. A major design element to enable 5G is network slicing, which allows mobile operators to divide a single physical network into multiple virtual networks that perform on an as-a-service-needed basis. This approach enhances operational efficiency and reduces time-to-market for new services. Benefits of network slicing can be seen in figure 1.

Key Benefits of Network Slicing
• Robust, secure and stable operations via network compartmentalization
• Customizable slices optimized for the needs of defined services or segments
• Built-in flexibility and efficiency with AI-powered automated service orchestration

Figure 1: *Network Slicing Benefits*

Network slices are based on various service characteristics, such as bandwidth and latency demands (figure 2). It spreads across all 5G use cases, from entertainment (i.e. Augmented Reality) and Massive IoT (connectivity for smart meters, electrical grid, etc.), to mission critical (capacity and/or coverage on demand).

Another benefit of 5G network slicing is the ability for mobile operators to deploy only those services that support particular customers and market segments, creating cost efficiencies. Limiting functionality also allows for faster deployment of 5G systems.

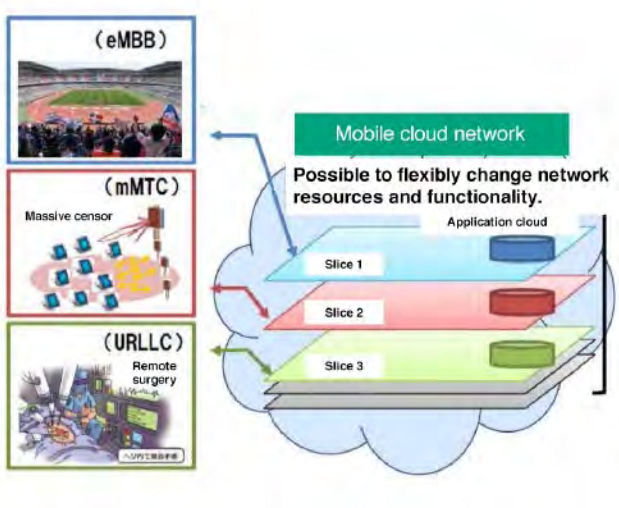


Figure 2: *5G Network Slices*

PHYSICAL INFRASTRUCTURE CHALLENGES

Network slicing enables operators to offer a myriad of applications and services on one network. While this technology helps satisfy the needs of diverse 5G use cases, it adds to the complexity of network deployment and management.

Due to network slicing, a flexible fronthaul network that supports multiple traffic types with different latency requirements and protocol functions must be deployed. The topology of the network where Central Unit (CU) and Distributed Unit (DU) functions reside will vary by application but the premise remains the same. Typically, the User Equipment (UE) sends its traffic to the Radio Unit (RU), which forwards the traffic to the DU that manages the UE's RF time critical areas. Traffic is then sent to the CU, which performs the heavy data processing. Data is given priority across the CU to RU network over different network slices based upon use case and its mission-critical nature.

Speaking of use cases (figure 3), enhanced mobile broadband (eMBB) is a major one for the first phase of 5G. Network infrastructure must evolve to meet the high throughput of eMBB. The same 5G network that will deliver eMBB service must further evolve and be robust enough to also accommodate ultra-reliable low latency communications (URLLC). There is also Massive Machine Type Communications (mMTC), which will add millions of devices to the network. All this means that the transport elements connecting and including CU, DU and RU may be at different locations, possibly in a virtual or combined fashion.

5G Requirement	Target	Against 4G
eMBB (Enhanced Mobile Broadband)	Up to 20 Gbps	10x ~ 100x
URLLC (Ultra-reliable & low-latency Communications)	< 1 ms	1/10
eMTC Massive Machine Type Communications)	1 Million devices / km^2	10x ~ 100x

Figure 3: *Major 5G Use Cases*

The physical layer becomes daunting because URLLC must satisfy more stringent requirements for low latency and ultra-high reliability than eMBB. This combination creates a considerably different level of quality of service (QoS) compared to traditional mobile broadband applications. Therefore, eMBB services, while utilizing the same physical network, must allow URLLC priority, including across the 5G air interface.

From a radio access standpoint, traditional RF spectrum is no longer sufficient. It has become extremely overcrowded and it can't support the 5G bandwidth and speed specifications. mmWave solves this dilemma but not without its own set of considerations. Since 5G mmWave band waveforms are more easily obstructed than LTE, each base station only covers a narrow area. That means more small 5G base stations are necessary to achieve the same coverage as LTE. Small 5G mmWave base stations use highly directional active antennas arrays, which coupled with the higher frequencies, makes transmissions more susceptible to interference and signal drops.

Legacy technologies, such as common public radio interface (CPRI), cannot scale to the throughput demands of 5G. Ethernet has become a viable choice because with new standards CPRI can be carried over Ethernet and can be used alongside emerging packet technologies, including Radio of Ethernet (RoE), eCPRI, and Open Radio Access Network Alliance (O-RAN).

SETTING 5G STANDARDS

Synchronization is a major consideration with 5G infrastructure. Among the options are GPS, precision time protocol (PTP), and/or synchronous Ethernet. Standards bodies are working to deliver new requirements to address this condition, as well as overall network performance.

Legacy mobile networks primarily required frequency synchronization to align signals but that will not suffice for 5G. Synchronization requirements are derived from several bodies. 3GPP technical specifications 36.104/38.104 describe base station radio transmission and reception requirements. Section 6.5 focuses on transmit signal quality and specifies essential requirements for network synchronization. One is time alignment error (TAE), which is the timing difference between any two signals belonging to different antennas or antenna arrays.

O-RAN is gaining momentum, as it is an open standard being developed with direct involvement by the major mobile operators. Figure 4 shows the O-RAN architecture. It includes Open Fronthaul Specifications with control, user, synchronization and management plane protocols. Most operators and OEMs are committed to adopting the fronthaul specifications and are introducing O-RAN-compliant products in commercial 5G networks. O-RAN is able to be transported over RoE (IEEE 1914.3), also an open standard, or eCPRI.

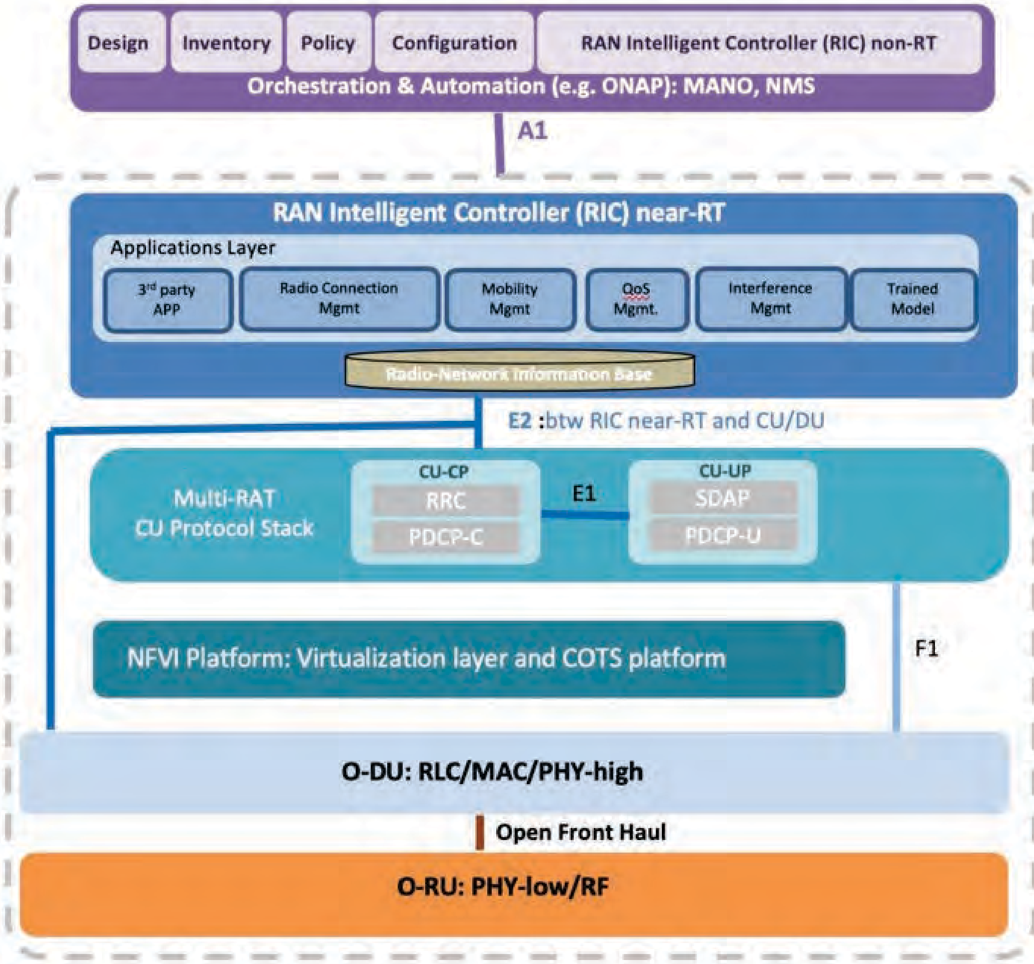


Figure 4: *O-RAN open system architecture*

IEEE also developed two transport network standards for 5G networks. 1914.1 is for architecture and divides the fronthaul into two Next Generation Fronthaul Interface (NGFI), aka xhaul, elements to prioritize traffic. The standard outlines the priority groups for traffic across the CU, DU and RU allowing network operators to design the network and use network slicing to manage latency across the different traffic types.

IEEE 1914.3 establishes the RoE standard that specifies a transport protocol and encapsulation format for transporting time-sensitive wireless data between two endpoints over Ethernet-based transport networks. It is preferred over eCPRI, even though the latter could provide a faster path for 5G deployment and utilization. eCPRI, however, has the same concerns as CPRI in that it is a specification developed by equipment manufacturers, not an open industry standard. IEEE 1914.3 is now compliant with the open O-RAN standard and able to carry O-RAN traffic the same as eCPRI.

KEY ELEMENTS SHAPING 5G

Similar to many technologies, 5G will evolve. Initial rollouts of 5G NR utilizing NSA technology delivers vastly superior performance to LTE, specifically in latency, power, bandwidth, and speed. Future versions featuring SA technologies will provide greater benefits in these critical areas.

Latency

5G significantly reduces latency requirements, which is the transmission time for a data packet. One-way latency, shown in figure 5, is the time between when a packet is sent and when it's received by the recipient; roundtrip latency refers to the period between the transmission of a packet and the receipt of acknowledgement.

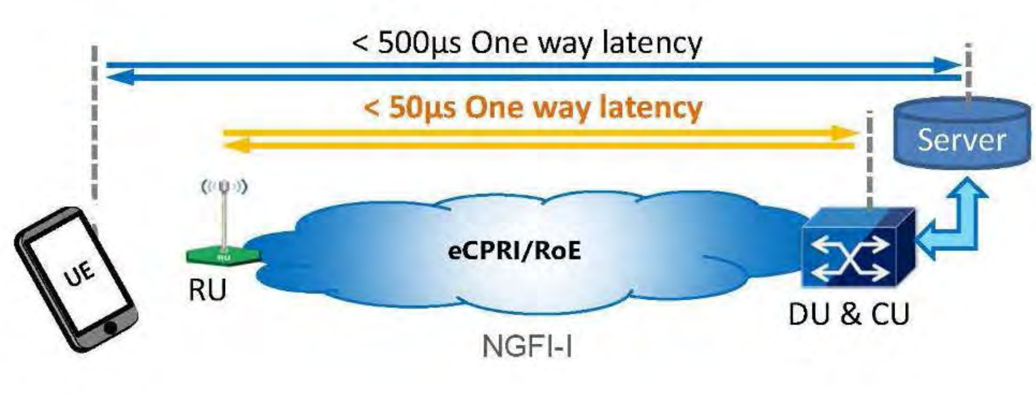


Figure 5: *One-way latency example.*

5G will be required to achieve round trip latency of 1ms or less – a 10X improvement compared to 4G. This will dramatically enhance user experiences and create new applications. For example, low latency is what provides real-time interactivity for cloud services, a key element for the success of autonomous vehicles. Additionally, it is particularly advantageous in mission-critical cases where response time can literally be the difference between life or death.

Bandwidth

4G channels have 20 MHz bandwidth, with a maximum of 160 MHz when channels are combined. That pales in comparison to the 100 MHz single-channel bandwidth of 5G, which is achieved by extending into the higher mmWave spectrum. The result is a 100x increase in traffic capacity and network efficiency to satisfy the needs of emerging applications such as augmented reality (AR) and virtual reality (VR). This increase in RF bandwidth requires a much higher throughput between CU and RU of 25G or larger per antenna, requiring large changes in optical network design.

Speed
Initial 5G networks are experiencing typical download speeds of 450 Mbps, with a peak of nearly 1 Gbps, which enables a full HD movie to be downloaded in less than one second. Uploads on a 5G networks are estimated to be as much as 130 Mbps. As 5G evolves and no longer requires an LTE anchor, future generations will be even faster to satisfy the needs of ever-expanding use cases.

Multiple Connections
5G will use Massive MIMO antennas that have numerous connections to transmit and receive more data simultaneously. The benefit is that more people can simultaneously connect to the network and maintain high throughput. As a comparison, 5G networks can handle 20 times more conversations than 4G networks.

ALL-ENCOMPASSING 5G NETWORK TESTING

5G technology impacts all aspects of the network – core, transport, RAN, and fiber. It also changes the way network testing is conducted, as well as the instruments that must be used by those deploying, installing, and maintaining the 5G infrastructure. The test tool box must consist of solutions that can perform transport, fiber, and RF measurements.

TRANSPORT MEASUREMENTS

eCPRI/RoE
Communications and latency tests measuring eCPRI/RoE frame bit errors and latency with high accuracy are required to maintain fronthaul communications quality. Because RoE and eCPRI frame formats use Ethernet in their lower layers, timing areas can be tested using standard Ethernet analysis methods. Areas such as routing and BER over the 1914.3 and eCPRI frame formats must also be tested.

Latency Measurements
Network latency is critical in the NGFI network segment and ensuring that it is within required limits must be confirmed during network installation. URLLC networks have strict requirements on the NGFI segments and a delay of microseconds is significant. Both the 1914.1 and eCPRI standards require a known network latency, ensuring delivery of the frame payload to the RF interface accurately and reliably.

Service type	Source	BBU–UE	NGFI-I	NGFI-II	Comment
URLLC/ cM2M	1914.1	-	50 µs	50 or 100 µs	NGFI-II segment possible if total latency ≤100 µs
4G/eMBB/M2M	1914.1	-	100 µs	1 or 3 ms	NGFI-II depends on operator assigned priority level
URLLC	802.3CM	-	100 µs		From RU to CU or CU to RU
E2E URLLC	3GPP	0.5 ms	-	-	From UE to BBU or BBU to UE
E2E eMBB	3GPP	4 ms	-	-	From UE to BBU or BBU to UE

Figure 6: *5G network requirements.*

Different standards offer insight into network latency requirements. 3GPP specifies latency from the base band unit (BBU) to UE and back the RTT must be within 1 ms for URLLC, while IEEE 802.1CM requires a latency of 100 µs across the transport network between the CU and RU. IEEE 1914.1 focuses on the transport network, dividing it into sub-classes based on network segments and traffic types. Network requirements vary, some of which are listed in Figure 6.

Time Synchronization Measurements

Use of the 5G mmWave band requires numerous small base stations because the high radio-wave frequency only propagates over short distances. As a result, PTP aligns the intervals between base stations and RUs. Time synchronization using PTP demands strict evaluation of the entire network to maintain time differences within the permissible range.

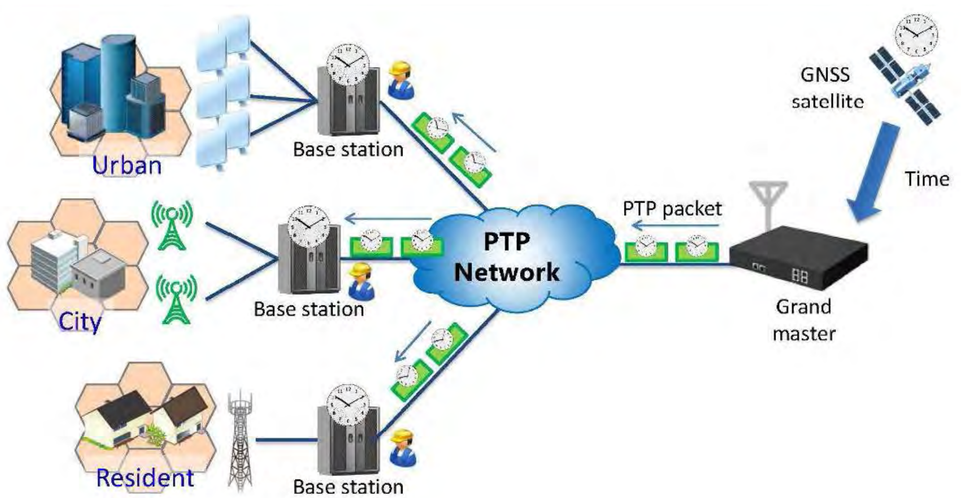


Figure 7: *PTP network configuration.*

All connections between the next generation core (NGC) at the data center to the 5G NR-capable AAS involve a fiber physical interface. Technologies employed include NGPON, CWDM, DWDM, RoE and eCPRI. The fundamental requirement to validate every fiber connection remains consistent and requires test tools that perform measurements based on the respective standards.

OPTICAL FIBER NETWORKS

PON (Passive Optical Network) Measurements

5G mobile fronthaul networks require extensive testing between the numerous locations with multiple RUs and a CU. A PON uses an optical fiber splitter to connect the RUs with a single CU, serving as an effective way for efficient 5G base station deployment.

Sharing an optical fiber by using a PON reduces costs, making it a preferred option for some operators. A high-precision OTDR that can analyze a PON optical splitter with up to 128 branches is necessary to measure optical fiber transmission losses, as well as fiber fault location and distance.

Overall Network (Core, Metro, 5G Fronthaul/Backhaul) Optical Line Measurements

Optical fiber installation and maintenance requires detection and measurement of fiber breaks at trunk-cable installation and maintenance, including the access drop cable. An OTDR must have sufficient performance to detect events, such as loss and reflections, with high accuracy in fibers ranging from a few meters to 200+ km in length. Additionally, the OTDR should have functions for simple display of measurement results highlighting areas outside configured thresholds. Results identified outside thresholds should include indicative possible cause and suggest possible resolution.

RF MEASUREMENTS

Over-The-Air (OTA) Measurements

The ability to view the RF spectrum and measure transmissions is critical to avoid interference and achieve 5G KPIs. LTE networks have test ports to validate RF characterization of the radio. Because 5G has AASs, test ports are likely unavailable, making over-the-air (OTA) tests a necessity. OTA measurements are an essential part of the performance evaluation and certification of 5G networks. Figure 8 lists key measurements that should be conducted. Among the key measurements that must be conducted are:

• **Adjacent Channel Leakage Ratio (ACLR)**	• **Modulation Quality**
• **Beam Strength and Quality**	• **Occupied Bandwidth (OBW)**
• **Cell/Sector ID**	• **Spurious Noise**
• **Equivalent Isotropic Radiated Power (EIRP)**	• **Multi-PCI Coverage Mapping**
• **Frequency Error**	• **Time Offset**

Figure 8: *Key 5G OTA RF measurements.*

5G RAN TEST SOLUTIONS

Conducting transport, optical fiber, and RF measurements to ensure 5G networks comply with industry standards and meet the KPIs means test instruments must reach a new level of capability, performance, and flexibility. Additionally, instruments need to be durable enough to withstand the rigors of field use while also being portable, lightweight, and easy to use.

There are three main classification of test instruments to meet the fronthaul, midhaul and backhaul requirements of 5G networks – optical transport testers, OTDRs, and RF spectrum analyzers.

Optical Transport Testers

For transport and optical fiber testing, optical transport testers such as the Network Master™ Pro MT1000A are necessary. This portable, all-in-one, expandable tester enables eCPRI/RoE and precision Ethernet latency and time synchronization measurements, as well as BER communications tests and latency measurements using eCPRI and RoE frames.

In addition, the high-resolution and high-accuracy latency measurements required by 5G standards are supported by the MT1000A. One-way latency can be measured based on the time stamp in the IEEE1588 packet using the time synchronization data from the GPS. This supports the Time Transfer Error measurement specified by ITU-T G.8273.

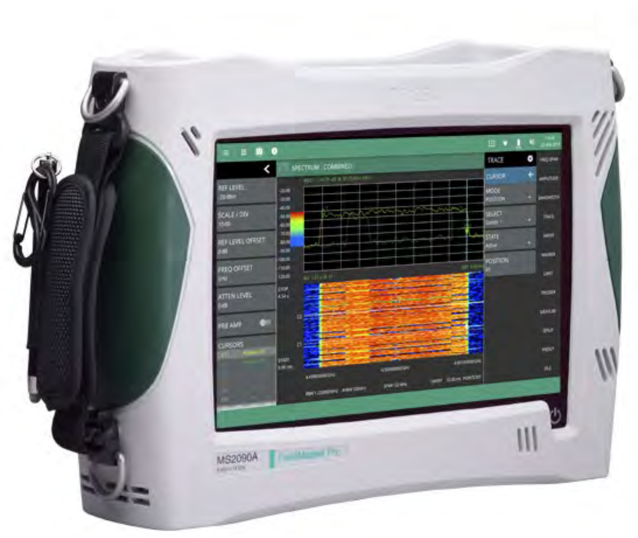
Network Master™ Pro MT1000A
Optical Fiber/Transport Tester

OTDRs

Fiber serves as the underpinning of a 5G network, which makes a full-featured OTDR necessary to ensure performance. The ACCESS Master MT9085 or Network Master™ Pro OTDR supports deployment of large-capacity 5G networks with functions to measure PON optical splitters for mobile fronthaul applications. It can detect fiber events, such as optical fiber loss and reflections, in 5G networks with high accuracy and displays easy-to-understand measurement results.

RF Spectrum Analyzer

With continuous frequency coverage from 9 kHz to 54 GHz, the Field Master Pro™ MS2090A spectrum analyzer with 110 MHz real-time analysis is specifically designed to meet the challenges of 5G test. Necessary measurements, such as spectrum clearing, radio alignment, harmonics, distortion, and coverage mapping, can be made with a high degree of accuracy. A 100 MHz modulation bandwidth coupled with best-in-class phase noise performance maximizes measurement accuracy and 0.5 dB typical amplitude accuracy provides confidence when testing transmitter power and spurious.



Field Master Pro™ MS2090A
Spectrum Analyzer

OTA measurements are supported by standing in front of the 5G NR and AAS, ideally in the far field, and using a wave guide horn or broadband antenna to make measurements on the beams formed. The Field Master Pro™ MS2090A spectrum analyzer 5G NR demod mode facilitates a full range of RF measurements by decoding the synchronization signal blocks (SSB) and displaying values of RSRP, channel power, EVM, and other parameters of each beam.

Conclusion

The 5G network architecture poses many design and test complexities that must be addressed to achieve specified performance metrics. Understanding the RAN topology and using the proper test solutions will ensure proper deployment, installation, and maintenance to achieve KPIs and ensure end user satisfaction.

Anritsu envision : ensure

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