VIAVI Solutions

Application Note

Test Suite for O-RAN Specifications

Updated for 2021 to include learnings from 2020 plugfest

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, measurement, assurance and optimization, VIAVI Solutions has developed a comprehensive test suite with modules for lab validation, field deployment and service assurance. This guide provides descriptions of use cases, and instrument and system recommendations to support a robust and efficient test environment.

Based on its leading position validating network products for operators and manufacturers worldwide – including all Tier-1 network equipment manufacturers – VIAVI has the most comprehensive O-RAN test platform on the market, with CUSM-plane parameters used by more vendors than any other solution. The company is also active in specifications development, as the editor of interoperability test specifications in the open fronthaul (WG4) and open interfaces (WG5) working groups, and the only test and measurement vendor to chair multiple working groups at the O-RAN ALLIANCE. VIAVI participated in the 2020 global O-RAN plugfest across five countries. This experience has enabled VIAVI to develop partnerships with complementary solutions from best-of-breed vendors.

Use Cases for Enabling the O-RAN Ecosystem

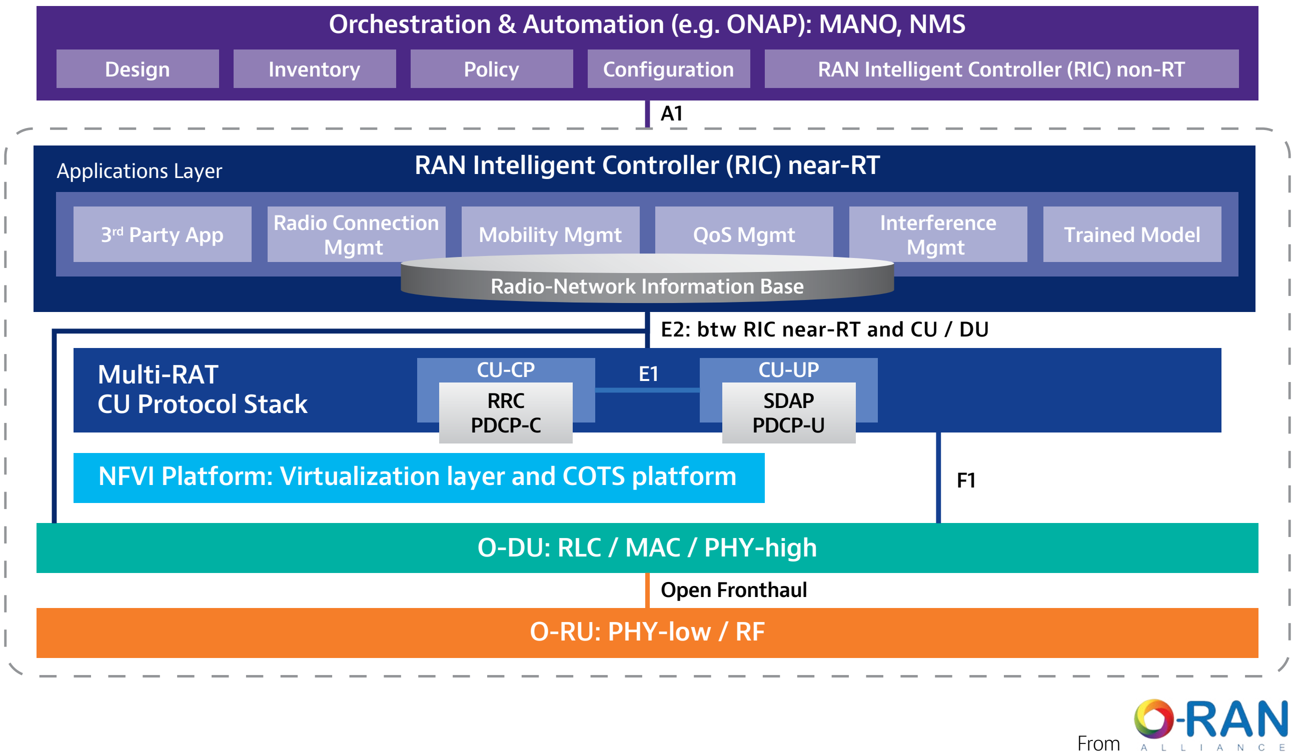

Figure 1. O-RAN Architecture

In an open multi-vendor scenario, it is essential to ensure disaggregated RAN components (O-CU, O-DU, and O-RU) are not impacting network performance. This can be achieved by validating them in the lab environment to make sure the nodes are designed and functioning per O-RAN specifications, and are interacting with each other without causing performance issues. Scaling the validation to a real network environment under heavy traffic with different traffic and application mix also needs to be performed to discover and address failures to meet KPI targets under real-world heavily loaded network conditions.

Today, VIAVI TeraVM and TM500 are the de facto solutions used by almost all network vendors in the lab to make sure their products will meet the performance requirements of wireless service providers. Building on that experience, VIAVI solutions now support O-RAN specifications to ensure the same level of precision testing at the O-RAN interfaces can be performed in the lab. Once network components are deployed, our field solutions such as T-BERD®/MTS-5800 and CellAdvisor® 5G help service providers troubleshoot and isolate problems quickly and efficiently.

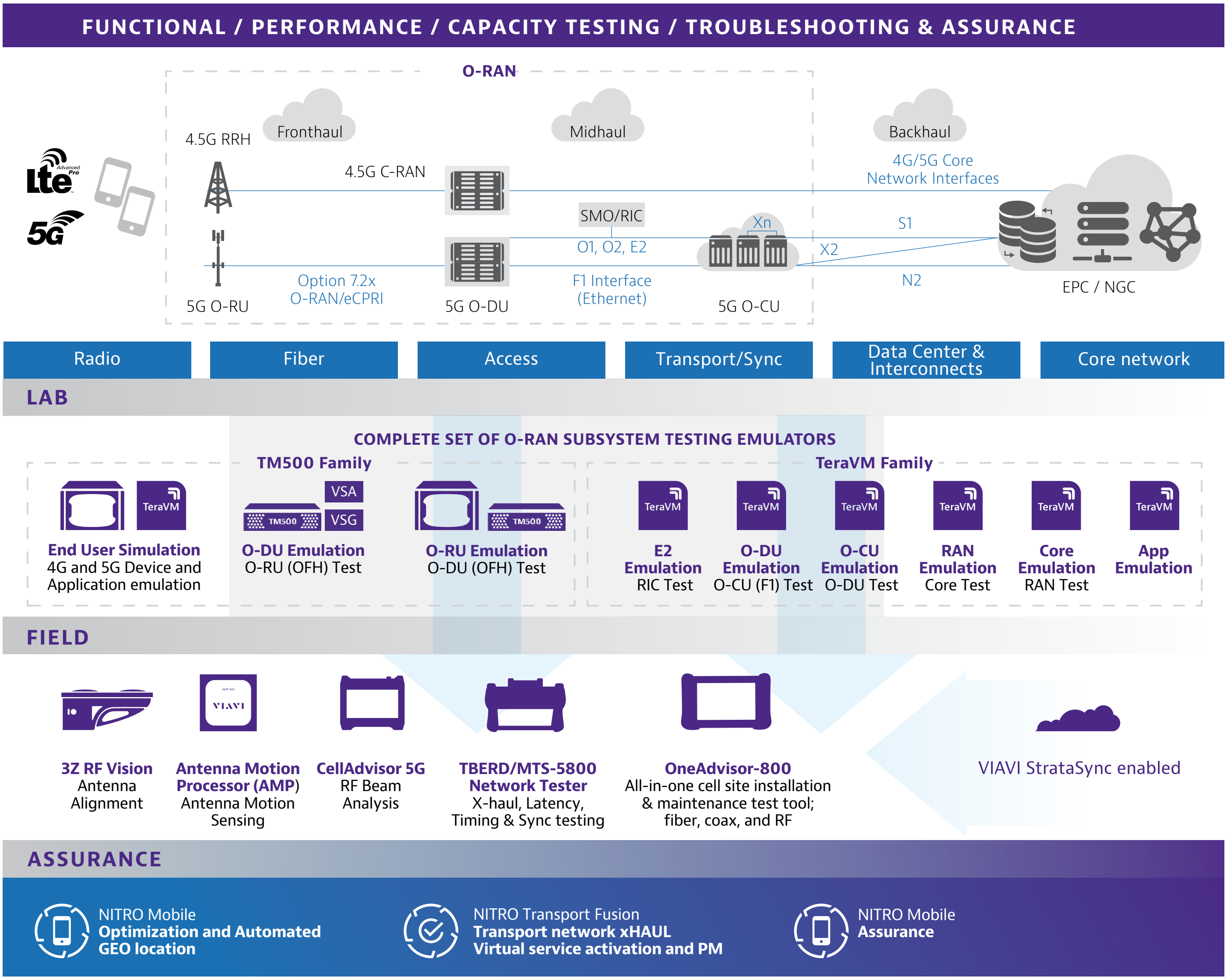

Figure 2. VIAVI 5G and O-RAN Test Portfolio

Now, let's discuss some of these lab and field challenges and how VIAVI can help both vendors and operators overcome them efficiently, through the following use cases:

A. O-RAN Subsystem and End-to-End Testing

A1. O-RU: Proving O-RU Interoperability and Performance to Network Operators

A2. Open Fronthaul: Performance and Interoperability Validation in the Lab and Field

A3. O-DU: Validating O-DU in a Multi-Vendor O-RU Environment

A4. O-CU: Validating F1 Interface Performance Using an O-DU Emulator

A5. RAN Intelligent Controller: RIC and xApp Mixed Vendor Ecosystem Assurance

A6. End-to-End Network Performance, Mobility and Capacity Test

B.Transport Network Testing

B1. Verification of 4G and 5G FH Transport and Synchronization Networks

C.Network Assurance

C1. Operational Assurance, Troubleshooting and Optimization

A. O-RAN Subsystem and End-to-End Testing

A1. O-RU: Proving O-RU Interoperability and Performance to Network Operators

Historically operators have purchased RAN network equipment from a very small set of vendors. As such, it has been easier to achieve performance objectives, liaising with very few vendors for support and optimization to provide a good user QoE in the end. With O-RAN, a concern that operators may face is obtaining the same or better level of performance from the individual O-RAN network components and more crucially when they are all inter-operating End-to-End. This is why it is crucial to address these concerns when testing the O-RU in steps, i.e. from functional, conformance, interoperability, capacity and performance testing, all of which VIAVI addresses.

Operators need to be convinced by the vendors that interoperability and high performance can be achieved with other components of the O-RAN network. To this end, the following tests stand out:

1) Functional, conformance and performance tests at the sub-system level where the C, U, S and M planes are validated to ensure the protocols work as they should, but also that performance metrics such as achieving the maximum data rates are achieved for different frequency bands and antenna configurations to name a few examples. This helps to avoid uncertainties when inter-operating with an O-DU.

2) The second set of tests are to do with End-to-End testing while inter-operating with the O-DU, O-CU and the Core Network. This is key in addressing concerns on performance by operators. Functional and conformance testing alone cannot provide the level of confidence operators need. This means a comprehensive test coverage is required that addresses interoperability, capacity, performance and optimization when new features are added. The scope of testing can include but is not limited to, increasing the number of UEs and 5G carriers, testing different frequency bands and MIMO antenna configurations in different and realistic traffic, fading and mobility scenarios, all with the same test tools.

It is important that during the evolution of testing, the same test tools are used for a smooth test progression, facilitating the means to identify issues early, open opportunities to do optimizations to achieve the maximum throughput e.g. in the event of new added features, software and maintenance upgrades. The other benefit of maintaining the same test tools, is providing opportunities to do other types of testing to maximize 3GPP channel performance.

In summary, testing the O-RU goes far beyond conformance and interoperability testing, with the aim to give both vendors and operators the confidence that from a system and End-to-End viewpoint, their objectives are being met, in spite of the multi-vendor nature of O-RAN.

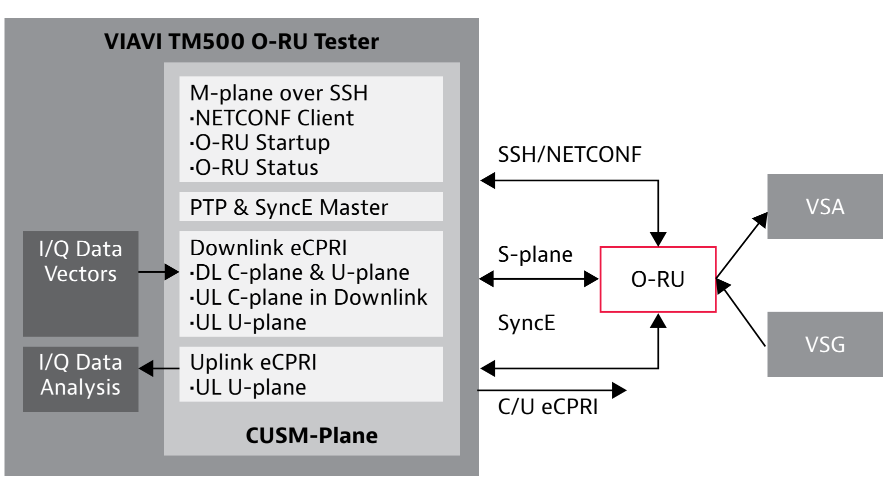

Figure 3. Testing of the O-RU

A2. Open Fronthaul: Performance and Interoperability Validation in the Lab and Field

eCPRI-based O-RAN technology relies on transmission of control plane (CP) and user plane (UP) packets between the O-DU and the O-RU. In an O-RAN environment with O-DU and O-RU potentially from different vendors, any anomaly in transmission of control and user plane packets can lead to problems in O-RU or O-DU. The VIAVI T-BERD/MTS-5800 with O-RAN support not only can check the health of the open fronthaul, but it also can capture O-RAN CP and UP packets and filter those packets to validate if the packet transmission is compliant with the O-RAN fronthaul protocol specification. Operators can view the captured and filtered packets in Wireshark expediting the analysis and allowing faster troubleshooting and a successful on-time network launch.

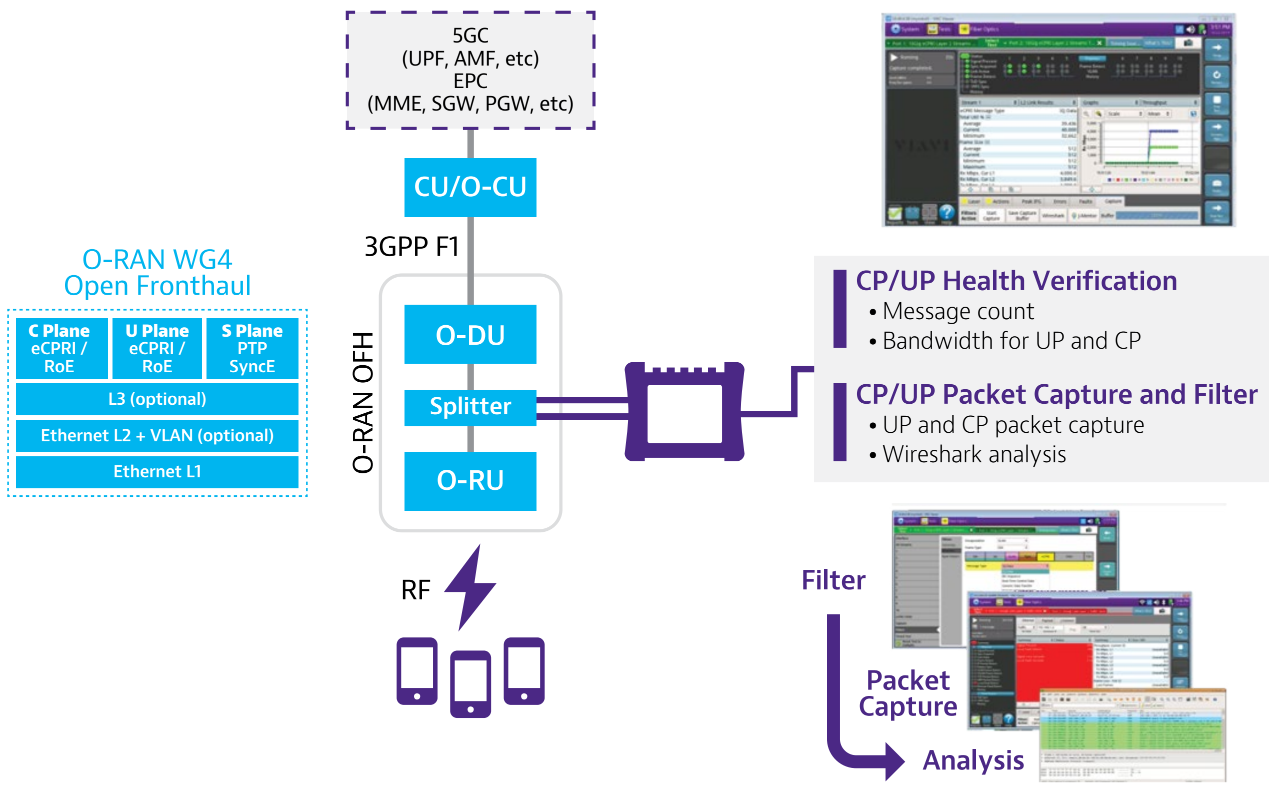

Figure 4. CP/UP Analysis using a VIAVI T-BERD/MTS-5800

In O-RAN specifications, open fronthaul is defined as the link between the O-DU and O-RU. Mobile broadband services that are expected to take advantage of advanced mobility applications will require coordination of multiple radios driving a lower layer functional split of the baseband function. The lower layer functional split was primarily implemented in 4G using CPRI as the interface between 4G BBU and RRH. While simple in design, it requires significant transport bandwidth proportional to the bandwidth of the baseband signal and the number of antennas. This disadvantage poses a significant challenge to the introduction of 5G services that rely on much larger bandwidths and antenna ports. The challenge has been addressed with the introduction of a new lower layer functional split. Known as enhanced-CPRI (eCPRI), this packet-based transport technology significantly reduces the fronthaul bandwidth, but it also presents some new challenges. It exposes some of the disadvantages of packet-based technology such as its inherent packet delay variation. Furthermore, eCPRI is not a synchronous technology and relies on synchronization technologies such as Precision Time Protocol (PTP) and optionally synchronous Ethernet (SyncE).

Open fronthaul facilitates the use of standardized multi-vendor interfaces which paves the path to successful interoperability between O-DU and O-RU, but performance validation of the open fronthaul and interoperability of the O-DU and O-RU over the open fronthaul will be necessary to ensure field deployments do not result in catastrophic failures.

T-BERD/MTS-5800 can be used to validate the performance of the open fronthaul in the lab and in the field. Network vendors can quickly validate the health of the transport and synchronization performance. T-BERD/MTS-5800 allows lab engineers and field technicians to perform this validation in the live mode giving them visibility into the protocol messages between the O-DU and O-RU. The following verification can be performed in the live mode:

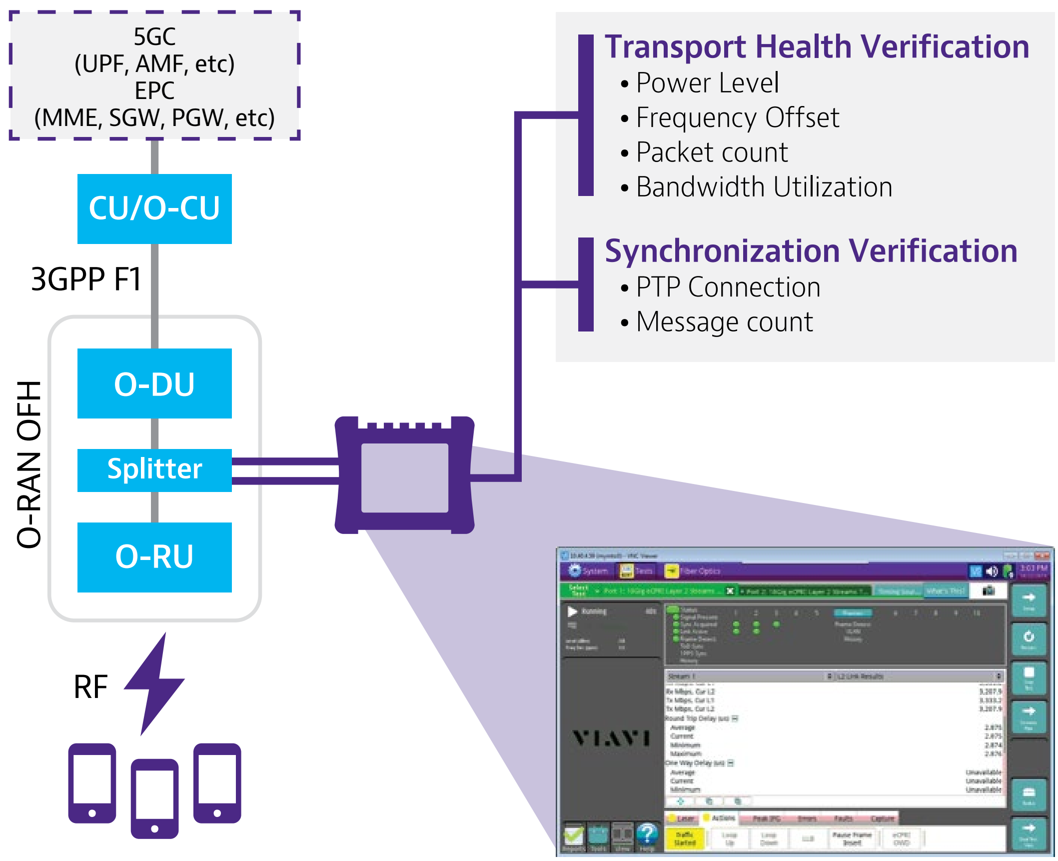

Figure 5. Fronthaul Analyzer – Transport and Synchronization Network Test

A3. O-DU: Validating O-DU in a Multi-Vendor O-RU Environment

In a multi-vendor O-RAN environment, network vendors and service providers will face situations where they must support a varied set of O-RU configurations, potentially supporting O-RUs from multiple vendors simultaneously in the same network. Having different O-RU configurations can add complexity in terms of interoperability. This is compounded by the fact that compared to testing over RF of single vendor networks, the O-DU and standardized O-RAN Fronthaul interface are new entities, which introduces a new risk. O-DU focused testing is used to minimize this risk to the 3GPP features and interactions the network must support, which requires all disaggregated nodes to perform well. O-DU vendors therefore need to ensure that O-DUs can handle multi-vendor O-RUs without introducing performance compromises and avoid the addition of new risks from a 3GPP feature interaction point of view.

Extensive experience and VIAVI leadership in validation of 3GPP features and interactions over RF is leveraged (as shown in Figure 6) in the VIAVI TM500 O-RU Emulator solution to validate the capability of an O-DU to handle multi-vendor O-RUs without unexpected performance compromises.

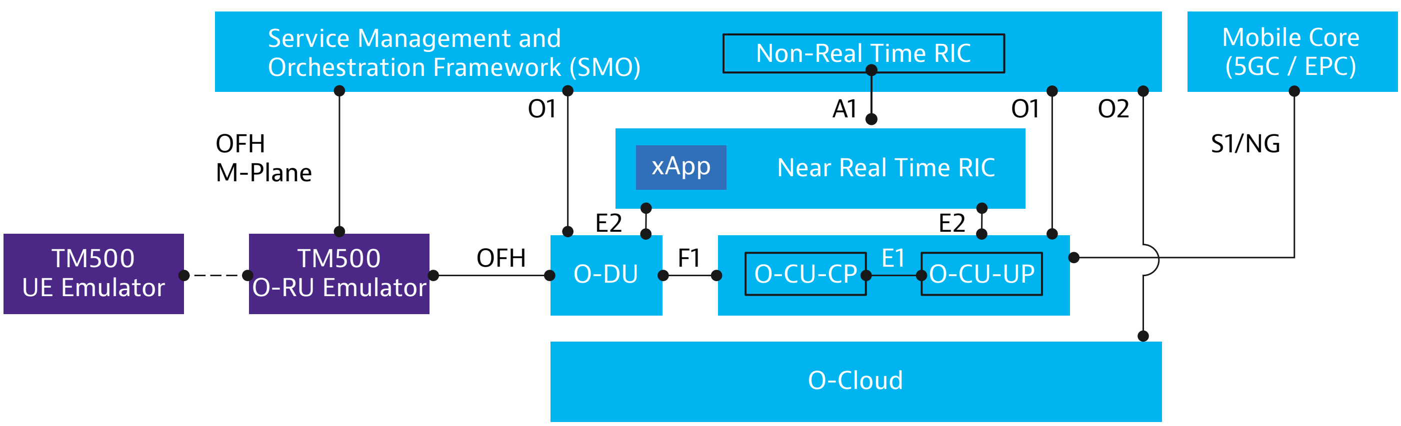

Figure 6. Validating O-DU in a Multi-Vendor O-RU Environment

A4. O-CU: Validating F1 Interface Performance Using an O-DU Emulator

3GPP F1 interface connects multiple O-DU nodes back to the central unit (O-CU) for both the control plane (CU-CP) and user plane (CU-UP) . Ensuring the performance of the F1 interface and ability of the O-CU to handle many O-DUs while supporting different traffic profiles with large numbers of UEs is important to quantify overall network performance. With the VIAVI DU/RAN Emulation solution, network vendors and service providers can emulate many O-DU nodes with a realistic traffic mix generated by a large number of emulated UEs. The X2 interface used between eNBs in LTE is reused between the Master eNB and the Secondary en-gNB for non-standalone (NSA) operation and is supported with VIAVI virtual RAN emulation functionality. The DU/RAN Emulation solution enables validation of the performance of the O-CU F1 interface, realistically mimicking how individual UEs are successfully managed in a multi-vendor environment. This solution efficiently adds hundreds of O-DUs worth of traffic applied to the O-CU under test without the cost or complexity associated with many real O-DUs (and even more O-RUs). UE stack integration allows realistic modeling of very high load traffic scenarios with dynamic F1 traffic emulation.

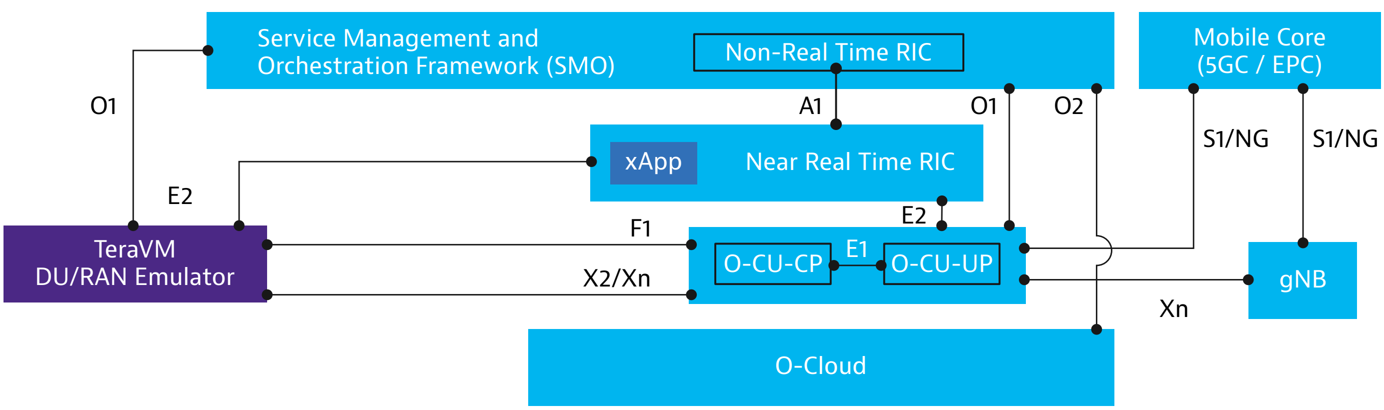

Figure 7. Validating F1 Interface Performance Using an O-DU Emulator

A5. RAN Intelligent Controller: RIC and xApp Mixed Vendor Ecosystem Assurance

The O-RAN ALLIANCE is currently defining the RAN Intelligent Controller (RIC) which has two principal logical components. The non-real-time RIC (non-RT RIC) forms part of the vendor's service management and orchestration (SMO) framework and may implicitly use the SMO's O1/O2 interface (O2 connects to the RAN virtualization platform) for collecting data from the RAN and for making configuration changes. Additionally, the non-RT RIC may use the A1 interface, defined by O-RAN, for disseminating policy and enrichment information to the near-RT RIC. The near-RT RIC is located with the O-CU network element of the vendor's gNB. It connects to the RAN via the O-RAN ALLIANCE defined E2 interface which gives the near-RT RIC access to information exposed by the RAN and permits modification of RAN operation to execute policies passed down by the non-RT RIC.

The RIC and RAN together operate as a set of nested control loops. The O-DU operates in "real-time" with a sub 10 ms response time; the near-RT RIC operates in the 10 ms to 1 second range; and the non-RT RIC operates with response times of 1 second and greater. The response time associated with each element is indicative of where the decision functionality of use cases with that response time would be expected to be located.

The inputs and outputs of the near-RT RIC are defined by open interfaces. The O1/O2 interface is defined by 3GPP, augmented as required by O-RAN, and together with the fronthaul M-Plane interface, provides OAM functionality. The A1 and E2 interfaces are standardized by the O-RAN ALLIANCE. The platform-independent functionality of the near-RT RIC will be performed by a mix of xApps. These xApps will likely be from a variety of suppliers including the RIC vendor, in-house developments from the operator, and third parties. The xApps are expected to ingest RAN data from various sources including over E2, performance management (PM) data over O1, enriched data that may mash up internal data and external data over O1, as well as data from other xApps. The xApps will process this data and ultimately implement A1 policies over the E2 interface. Additionally, rApps are being introduced to the non-RT RIC to support platform-independent functionality in a similar manner to xApps. The O-RAN ALLIANCE is defining an R1 interface to support exchange of information between the rApps and the non-RT RIC fabric.

The O-RAN ecosystem needs assurance across all stages of the product life cycle from sandbox development through to assurance of network operation. It is essential to ensure that once xApps from disparate sources are available, they operate in a coherent and compatible manner—either when operating independently or chained together—and produce the required objectives. This includes validation that the heterogeneous xApps in combination are able to implement the policies of the operator across a mix of subscribers consuming the range of services envisaged for the network across multiple network slices and in an appropriate set of mobility profiles. Furthermore, conflict can arise between xApps from different vendors, performing disparate functions or striving for varying objectives. Conflict management is complex and unlikely to be fully standardized so will rely on testing to determine compatibility over a range of scenarios. These use cases for validating the compatibility and conflict management of an ecosystem of xApps must be validated at scale, making them well suited to VIAVI End-To-End Wireless Network Test.

A6. End-to-End Network Performance, Mobility and Capacity Test

With the TM500 Network Tester emulating multiple UEs, tests over RF can be done to assess the end-to-end performance of a real O-RU upwards to a real O-DU, O-CU and the core network. With the TM500 supporting real data applications e.g. HTTP, FTP, and streaming/UDP traffic, performance validation can be done to ensure that KPIs such as throughput, latency, and round trip times (RTT) meet customer requirements even though the O-DU and the O-CU may come from different vendors.

The introduction of 5G adds new fading profiles and handover scenarios which must be tested for low, medium, and high UE capacity test scenarios. In NSA mode for instance, multiple types of handovers can occur between 4G and 5G carriers depending upon the deployment scenario and UE distance from the base-stations. For example, a handover can occur from 5G to 4G , 4G to 5G, 4G to 4G or 5G to 5G. Additional fading and channel profiles introduced by new deployment scenarios and frequencies above 6 GHz defined in 3GPP TR 38.901 contribute to complexity in terms of the different test scenarios that must be validated.

The TM500 emulator, with the support of real data applications, can execute high capacity end-to-end performance tests in simulated real-world environments facilitating validation of the different mobility, traffic and handover scenarios for 4G and 5G. Such end-to-end validations continue to be vitally important when testing disaggregated RAN networks leveraging O-RAN based components.

B. Transport Network Testing

B1. Verification of 4G and 5G FH Transport and Synchronization Networks

Fronthaul transport nodes (FTN) aggregate and transport traffic between CPRI/eCPRI-based RRH/O-RU and BBU/O-DUs. While they simplify the fronthaul topology, they can introduce transport and synchronization issues. Validating FTN-based networks is essential to minimizing any issues caused by excessive packet loss, delays, jitter and poor QoS. In a multivendor O-DU/O-RU deployment, these FTN challenges can create more complexity in the validation, verification and troubleshooting of the open fronthaul, and other O-RAN components. Verifying FTN readiness for O-RAN is necessary for a smooth O-RAN deployment.

The VIAVI T-BERD/MTS-5800-100G performs eCPRI tests including throughput, delay, and packet jitter. Engineers can configure eCPRI message types according to eCPRI specification, measure bandwidth for each message type, and measure Round Trip Delay (RTD) with sub 5ns accuracy. CPRI BERT verifies 4G BBU to RRU transport quality. By performing FTN tests, engineers can validate the transport requirements of the FTN and can ensure they are within the designed network specifications.

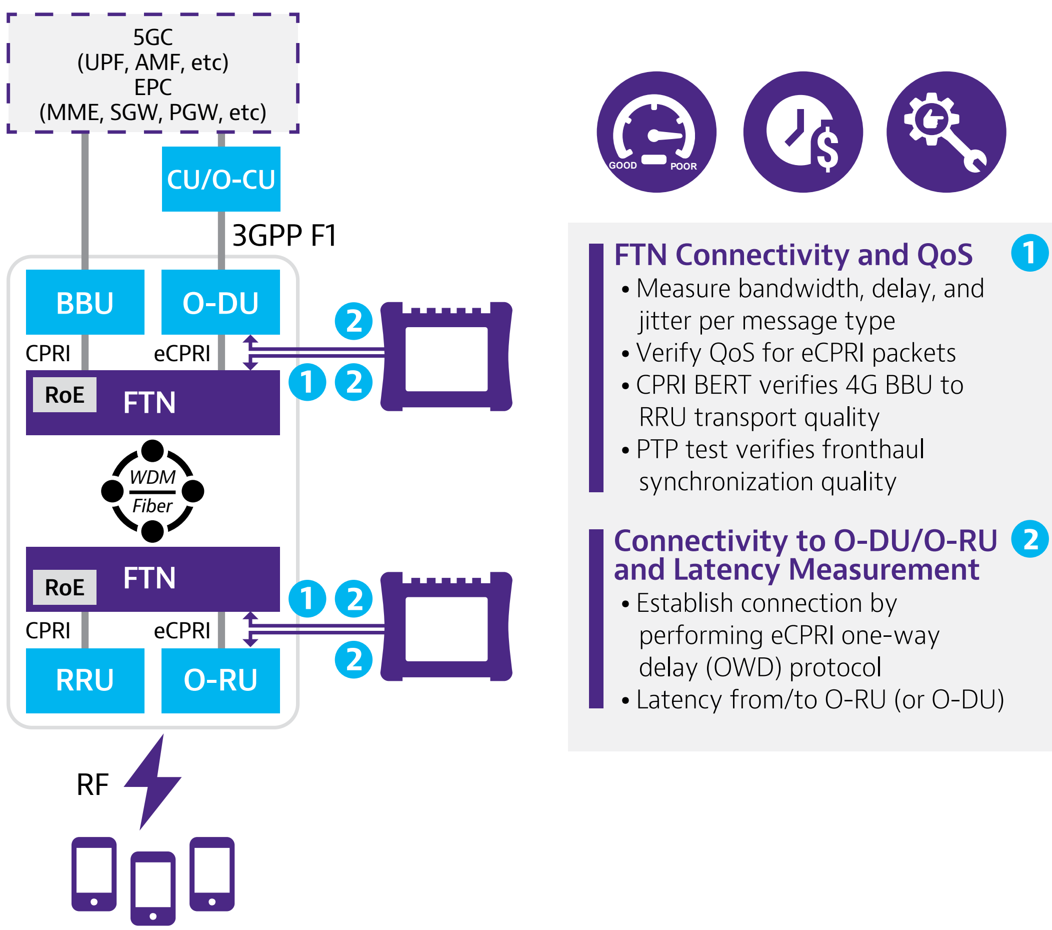

Figure 8. Fronthaul Analyzer – 4G /5G FTN test

O-RAN open fronthaul networks can be synchronized in several modes as depicted in Figure 8 and as described in the O-RAN WG4 CUS specification. Where LLS-C1 through LLS-C3 modes rely on PTP/SyncE for O-RU synchronization, LLS-C4 works based on a local GNSS-based timing source. The LLS-C1 mode obtains its source from the O-DU, whereas LLS-C2 and LLS-C3 deploy one or several fronthaul transport nodes between the O-DU and O-RU. In LLS-C2, the Telecom Grandmaster (T-GM) resides in the O-DU; in LLS-C3, that function is assigned to the fronthaul network, and both O-DU and O-RU play the role of a telecom time slave clock (T-TSC).

The PTP networks can support an ITU-T G.8275.1 (Full Timing Support) profile, or ITU-T G.8275.2 (Partial/Assisted Partial Timing Support) profile. The former profile is expected to be the main one to be deployed in future fronthaul networks. It is characterized by one or several Telecom Boundary Clock (T-BC) functions resident in the fronthaul transport nodes. They ensure the proper function and performance of the synchronization plane in line with network limits provided in standards such as ITU-T G.8271.1. Timing error constitutes one of the most important parameters for the proper operation of the radio network. The T-BERD/MTS-5800-100G delivers the complete set of testing parameters, thresholds/masks and profiles for verification of synchronization standards. The measurements can be performed at the output of any T-BC as provided in the example of LLS-C3 mode below.

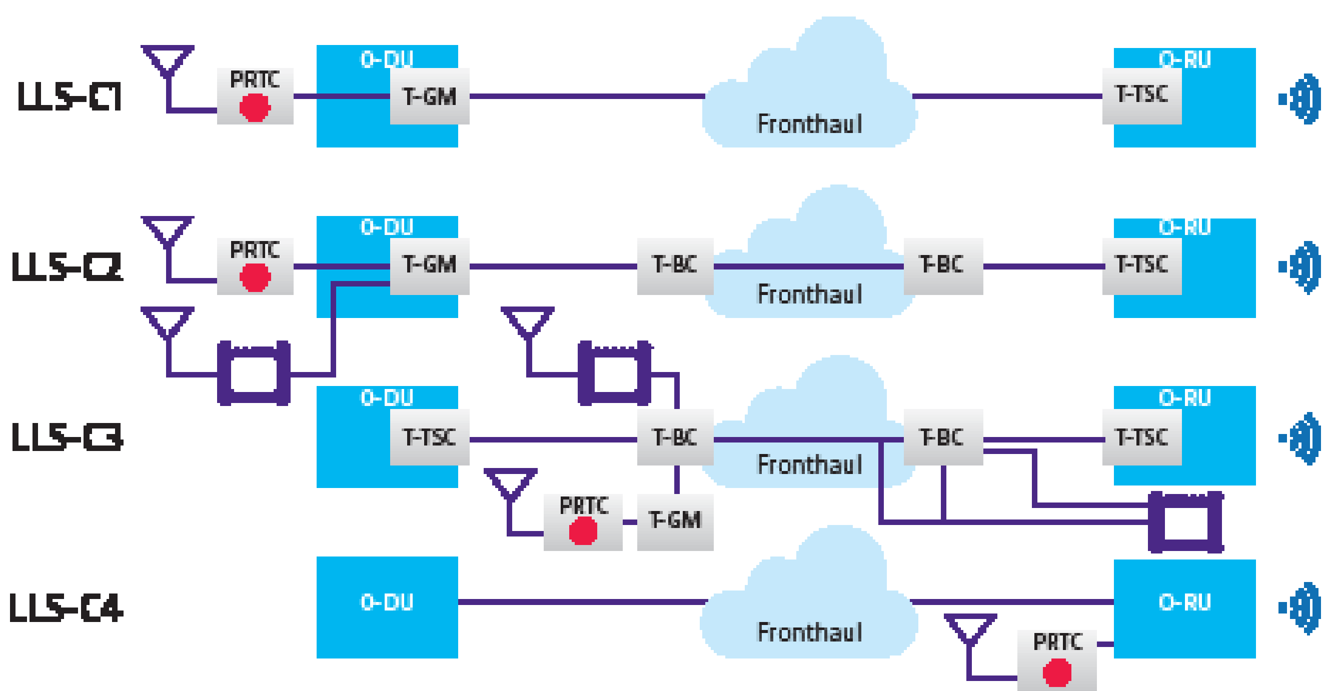

Figure 9. O-RAN WG4 S-Plane Topologies

T-BERD/MTS-5800-100G can also be used to monitor the fronthaul link for PTP or SyncE messages by delivering message counts and decodes. The messages can also be recorded for offline analysis with Wireshark. Furthermore, it can be used to characterize the performance of a T-BC or a T-TSC by conducing 1PPS wander measurements.

Finally, T-BERD/MTS-5800-100G can be used to emulate a PTP/SyncE Grandmaster or a Primary Reference Time Clock (PRTC) by connecting its Timing Expansion Module (TEM) to a GNSS antenna. TEM provides stable reference synchronization signals such as 1PPS and 10MHz. TEM can be placed into a holdover mode in case of lack of access to a GNSS antenna.

C. Network Assurance

C1. Operational Assurance, Troubleshooting and Optimization

As described above, there are profound benefits of disaggregation of the network into multiple discrete components with a decoupled control system in the form of the RIC. And with more components comes more complexity and an increased number of ways for the network to experience impairments. Impairments in a more complex network can be harder to detect, diagnose and resolve than they would be in a simpler network with fewer components.

Considering the many and varied potential ways that the operational network can experience degraded performance, the network may suffer from impairment or failure in the transport network (fronthaul, mid-haul, backhaul). This may range from congestion leading to latencies or packet loss out of acceptable ranges, to complete loss of a fiber link through breakage or physical disconnection. The disaggregated RAN or core network functions may become impaired, for example, through overload or software quality issues. The SMO system may experience impairment or the physical infrastructure on which the logical functions are hosted may degrade. Also, the non-RT RIC or near-RT RIC may experience conflict or confusion between rApps or xApps from different vendors respectively. The 5G New Radio (5GNR) is a shared resource in a harsh environment and can sometimes be poorly tuned to the demands placed on it by the subscribers. Concentrations of increasing demand for 5G services can lead to congestion on the radio resources. Poor coverage or interference can impact the accessibility of the network services. These phenomena will vary as the spatial dynamics of demand for services around the network changes. This is compounded by the fact that 5G will generally be deployed on top of a mix of legacy 4G, 3G and 2G systems so creation of a consolidated view of system performance and of fault-finding will also be critical to effective management of the operational network. And as the demand for different mixes of services with novel mobility profiles pushes the resource management capability to the limit, new edge failure cases beyond what was tested at the pre-deployment stage can be exposed and manifest as degraded performance.

Each of these phenomena will manifest in the complex system in different ways, not necessarily associated with the network component directly suffering the impairment. For example, a loss of a radio unit through hardware failure will mean that nearby O-RUs, O-DUs, and O-CUs will pick up more traffic along with subjecting the X-haul links to more load and potentially congestion. This challenges the network monitoring and assurance system to provide a more complete view of the network, with richer analytics to detect problems, isolate the cause and provide the most appropriate mitigation.

The VIAVI NITRO™ platform provides the visibility of the network across the breadth of the radio, RAN, transport and core. This unprecedented visibility brings with it the ability to detect instances of issues such as congestion of spectrum or transport assets, or impairment of physical or logical infrastructure. The intimate view on the network means that the location of the problem can be quickly isolated and the root cause identified. Thus, with the richest information on the network performance, the autonomic network control systems will be most effective and where intervention by the operational network management engineers is required, resolutions can be implemented within the shortest timeframes.

Conclusion

O-RAN brings many benefits for operators such as an open ecosystem that removes vendor lock, lays down the foundation for virtualized network elements, and introduces white-box hardware that can be quickly scaled up through software-based nodes. At the same time, it also creates significant challenges in terms of test and integration. Having the right test and network management strategy and the right partner during the development, deployment and operation of an O-RAN network can help operators overcome those challenges.

VIAVI has the expertise, legacy and vision to help operators validate open RAN components, both hardware and software in the lab. And with our integrated lab, field and assurance solutions, operators can be certain network performance issues will be isolated and rectified quickly to meet their KPI goals.

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