TELECOM INFRA PROJECT

Multi-Operator Radio Access Network (MORAN) Testing for NaaS (Network as a Service) Environments White Paper

Network as a Service (NaaS) Solution Group

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Executive Summary

1. Executive Summary

This white paper presents a vendor-agnostic approach for testing and deploying Multi-Operator Radio Access Network (MORAN) solutions in rural and urban Network-as-a-Service (NaaS) environments. For the purposes of this paper, NaaS is defined as an open access network where a neutral host (NaaSCo) operates a shared Radio Access Network (RAN) that is connected to multiple Mobile Network Operator (MNO) Core Networks.

MORAN is a well-suited form of RAN Sharing for the NaaS use case as it is widely supported by RAN equipment vendors, allows for independent network configuration and control for each MNO partner and, does not require sharing or pooling of spectrum, which requires a more complex regulatory framework. However, because the RAN is connected to multiple MNO Core Networks and RAN equipment vendors can implement MORAN features and functionality slightly differently, it is critical that NaaSCos fully test and validate the MORAN solution in representative lab and/or field environments before commercial deployment. It is also critical that NaaSCos understand key MORAN-related deployment considerations prior to commercial deployment to ensure proper agreements and processes are in place.

This white paper addresses these topics in detail following the structure below:

- Introduction: Definition of NaaS requirements and challenges, overview of RAN Sharing options and a detailed description of MORAN architecture.
- Testing: Description of why testing MORAN is critical, development of a baseline test plan, guidelines for testing, expected results and best practices.
- Commercial Deployment Considerations: Definition of key considerations, such as required commercial agreements and coordination of RAN design, network interconnection, integration, and acceptance. Links are also provided to more detailed information contained in the TIP NaaS Solutions Group Playbook.

2

Introduction

2. Introduction

The TIP NaaS Solution Group seeks the continued development of an innovative business model designed to enable the expansion of mobile coverage into rural and peri-urban areas and the addition of network capacity into Urban Areas through a third-party neutral host known as a NaaSCo. The NaaSCo strategy is to invest in shared network infrastructure enabling MNOs to utilize this shared infrastructure to provide greater network coverage and capacity for their customers.

The NaaS business model and its relation to RAN Sharing is addressed in this section. First, the NaaS requirements and challenges are defined, then the RAN Sharing solutions are presented and finally, the MORAN solution architecture is detailed.

2.1 NaaS Requirements & Challenges

NaaSCos own and operate a RAN that can be shared with multiple operators. In rural areas, this model enables the expansion of mobile connectivity to remote locations that are typically not deemed economically viable using traditional models due to the lack of infrastructure, low population density, and high deployment/operational costs.

Furthermore, for urban locations where network densification is sometimes economically unviable with capital investment from a single MNO, the NaaSCos are uniquely positioned to create a positive business case by leveraging RAN Sharing architectures.

This innovative business model requires RAN Sharing solutions and low-cost transport for capital efficiency and interoperability with multiple network cores. Furthermore, the NaaSCo must have full control of their network while allowing some visibility and management functionality to the MNOs utilizing their network.

In addition, the NaaSCo must interact with several stakeholders to enable the deployment and operation of the network. Main aspects include coordinating with transport providers to get backhaul connectivity and establishing agreements with MNOs for commercial and technical aspects including spectrum management and utilization.

2.2 RAN Sharing Concept & Solutions

RAN Sharing consists of two or more network operators sharing active and/or passive RAN infrastructure to improve efficiency of network deployments while reducing capital expenditures (CAPEX) and operating expenses (OPEX). In the NaaS model, RAN Sharing is required to achieve a sustainable business case by leveraging the same infrastructure to provide service to multiple MNOs.

RAN Sharing schemes will vary based on the portion of the network that is shared. These may include passive and active elements as shown in

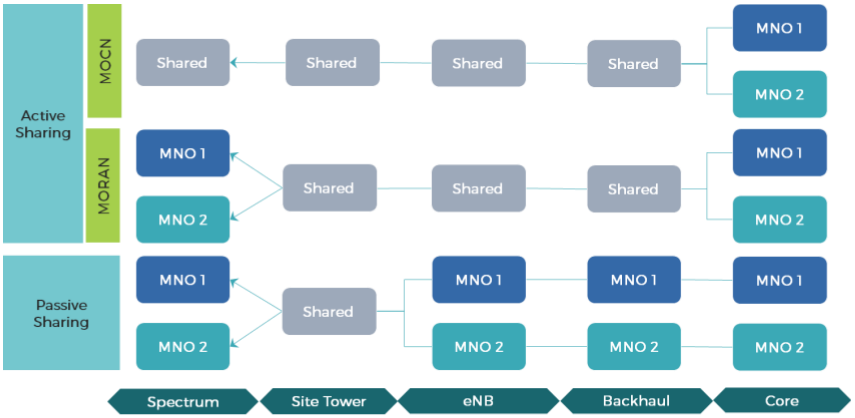


Figure 1, ranging from towers, poles, and equipment rooms, to antennas, spectrum, remote radio units (RRUs) and base band units (BBUs):

Passive Solutions:

- Site Sharing. This is the simplest sharing solution, where separate RAN equipment is installed for each MNO at the shared site with the option to share supporting infrastructure such as power, air conditioning, and cabinets.

- Antenna Sharing. In addition to supporting infrastructure, the antenna is shared. This can be done through distributed antenna systems, multiport antennas, and radio frequency (RF) couplers to inject multiple carriers into a single antenna.

Active Solutions:

- MORAN. RAN equipment, site infrastructure and backhaul can be shared through MORAN while maintaining independent cells and spectrum frequencies for each MNO.
- MOCN (Multi-Operator Core Network): Like MORAN, MOCN enables sharing of RAN equipment, site infrastructure and backhaul; however, in MOCN the spectrum is also shared, supporting one or more public land mobile network (PLMNs) per cell or carrier.
- Roaming: Roaming solutions allow users from MNO A to transit services through the network of another operator (MNO B) in places where MNO A has no coverage. For the NaaS model, this would require the NaaSCo to own the spectrum and offers roaming services to other MNOs, or to have multiparty agreements for roaming between the spectrum owner, the NaaSCo and other MNOs.

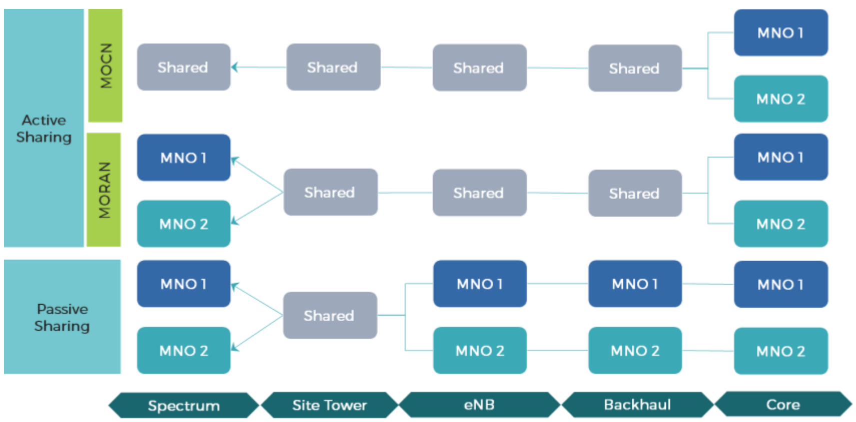


Figure 1:RAN Sharing Solutions

Passive sharing techniques are simpler to implement but are not suitable for a NaaS business model because redundant equipment for each MNO increases costs.

Regarding active sharing solutions, Roaming is usually not feasible since it requires the NaaSCo to own spectrum and a mobile core or to negotiate a multiparty agreement between MNOs and the NaaSCo. This leaves MORAN and MOCN as the main RAN sharing solutions for NaaSCos. Main features of these two solutions are presented in Table 1.

Concept	MORAN	MOCN
RAN Equipment (RRU & BBU)	Shared	Shared
Carriers (Spectrum)	Independent	Shared
Cell Management & Licensing	Independent	Shared
Backhaul	Shared	Shared
Configuration Management (CM)	Independent	Shared
Fault Management (FM)	Independent	Shared
Performance Management (PM)	Independent	Partially Independent
User Equipment (UE) Requirements	No	MOCN Compliant

Table 1: MORAN & MOCN Comparison

The selection between MORAN and MOCN should be considered on a case-by-case basis. At a high-level, it is important to consider the level of independence required, equipment compliance and country-specific spectrum regulation. The rest of the document focuses on MORAN since it provides more independence and is generally more widely support from a regulatory perspective.

2.3 MORAN Architecture

When NaaSCos implement MORAN, the evolved NodeB (eNB) hardware is shared by multiple MNOs. The eNB assigns each MNO their own radio resources with independent cells and frequencies, broadcasts the operator's PLMN and routes the traffic to the corresponding core network. The high-level view of the MORAN architecture is illustrated in Figure 2.

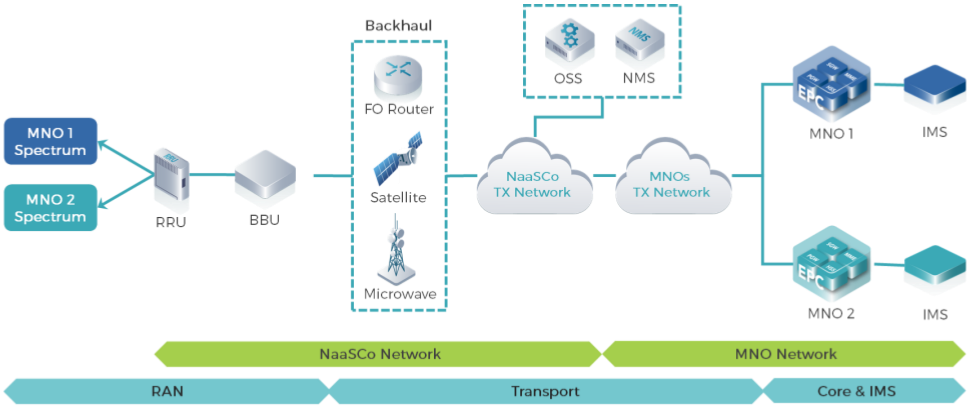


Figure 2: MORAN Architecture

The role of the NaaSCo in the MORAN architecture is to provide MNOs with the required infrastructure and resources to deliver their network services to users leveraging their own spectrum resources. Furthermore, since MORAN is a solution that impacts only the eNB level, no special configuration or feature is required for the evolved packet core (EPC).

The MORAN architecture allows Long Term Evolution (LTE) cells to be configured and managed independently for each MNO, including fault and performance management.

3

MORAN Solution Testing

3. MORAN Solution Testing

This section addresses aspects to be considered for MORAN solution testing before scale deployment takes place, including lab requirements, test cases, and best practices.

3.1 The Need for MORAN Testing

It is important to fully test MORAN before deploying commercially because not all RAN OEMs implement MORAN features in the same manner and MORAN requires interaction with multiple MNO Core Networks. Testing will allow detection of potential technical issues and build confidence that the solution will gain acceptance from MNOs for implementation.

Two types of environments can be considered for testing:

- Laboratory: Controlled environment where live network conditions are replicated, creating a propitious scenario to validate configuration, characterize performance, solve potential issues, and determine viability of the solution.
- Field Trial: Validating the solution in the field can be seen as an alternative to lab testing or as a second phase of the testing process where basic functional and performance validations can be performed. This type of environment allows confirmation of lab results with real propagation conditions and real user traffic.

Whether lab or field testing is considered, the test plan for MORAN must include functional and performance test cases. Functional testing aims to validate signaling procedures and basic End-to-End (E2E) services (e.g., TCP/UDP data, video streaming, web browsing, voice). Outcomes from functional tests include reference configurations and collection of logs that will improve and streamline troubleshooting.

eNodeB capacity is typically based on one MNO's traffic, so in MORAN testing it is critical that capacity is considered for multiple MNOs. Performance testing is critical to evaluate the capacity, performance, and quality of service (QoS) provided by the MORAN solution under varying load conditions. This type of testing provides a performance benchmark that can help validate live network performance and perform accurate network capacity planning.

3.2 Testbed Architecture & Requirements

Lab testbed for MORAN solutions should allow replication of the urban/rural environment while isolating the components of the solution. A high-level view of the recommended testbed architecture is shown in Figure 3.

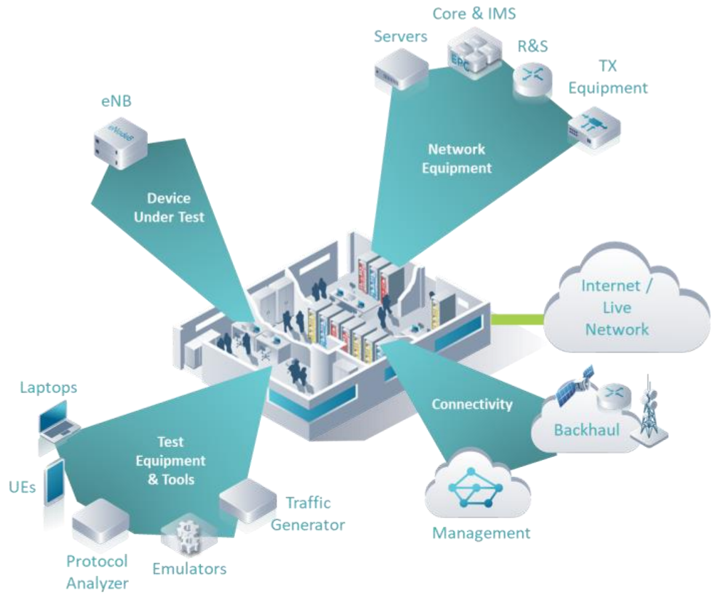


Figure 3: High-level view of Testbed Architecture

Requirements for the MORAN testbed can be grouped into network equipment, test equipment & tools, and connectivity, as described in the following sections.

3.2.1 Network Equipment

The testbed should incorporate the required network equipment to replicate the production network scenario, including the device or system under test which is the RAN equipment that implements the MORAN solution. If the equipment utilized in the live network is not available, it can be substituted with equivalent equipment or emulators.

Network equipment to be considered includes:

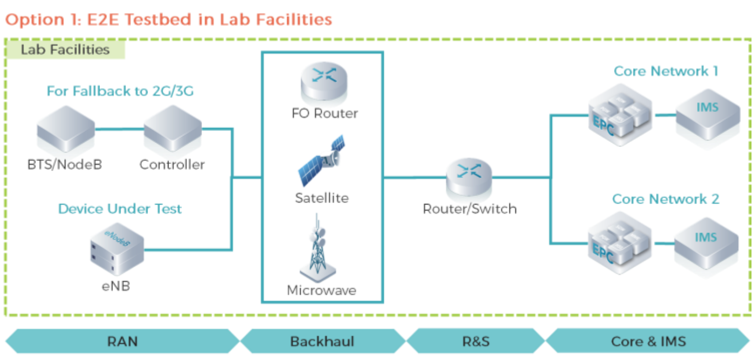
- RAN. Consists of the base station which can be an all-integrated or split solution. In addition, if fallback to 2G/3G will be tested for voice services, then the base transceiver station (BTS), NodeB and controllers (BSC and RNC) should be considered in the architecture.

- Backhaul. According to NaaSCo requirements, the test bed should include microwave (IDU + ODU), satellite (VSAT antenna + modem) or fiber optic (switch/router) backhaul equipment.

- Routing & Switching (R&S). Required equipment to interconnect all the network segments.

- Core & IP multimedia subsystem (IMS): Baseline architecture only considers the EPC. However, if 2G/3G voice services will be tested then packet switched (PS) and circuit-switched (CS) Core are also required. Finally, if voice over LTE (VoLTE) service is part of the test plan, an IMS will be required.

Alternatively, the live network elements can be shared with the lab setup through external connectivity. For instance, the production mobile core could serve the lab testbed for MORAN E2E testing. In any case, it is important to highlight that the RAN and backhaul equipment must be dedicated instances to avoid any bottlenecks. Figure 4 shows the two alternatives to build the testbed.



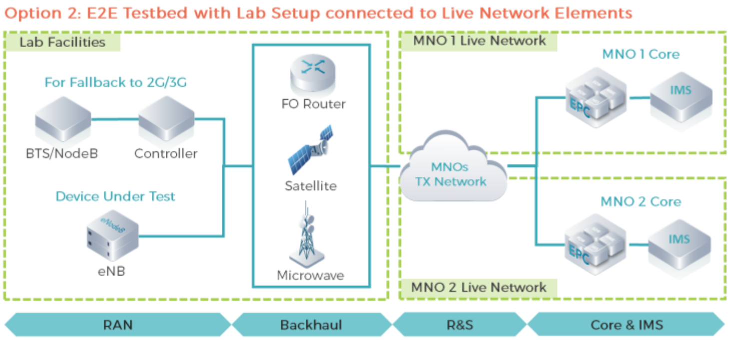


Figure 4: Testbed Network Equipment Alternatives

3.2.2 Test Equipment & Tools

Availability and measurement capabilities of test equipment and tools determine the range of tests that can be executed. Some test tools/software are free to download, which allows the collection of the minimum required measurements to validate MORAN.

Broadly speaking, the test equipment and tools include analyzers, emulators, and generators. Table 2 lists the required test equipment along with the associated description and existing alternatives to expensive equipment.

Test Equipment/Tool	Description
RF Vector Signal Analyzer	• Measures the LTE carrier magnitude and phase. • Spectrum Analyzer can be considered as a lower-cost alternative to perform magnitude measurements only.
Test UEs	• Handsets/mobile phones that comply with the network and service technical specifications (e.g., UE category, frequency bands, VoLTE support).
Test/Logging Applications	• Real-time diagnostic monitoring of UEs to capture radio stack logs, events and signaling messages (e.g., QXDM). • Free smartphone apps can be utilized for basic RF parameterization (e.g., PLMN ID, Cell ID, EARFCN), RF conditions (e.g., RSRP) and RF events (e.g., handover).

	Signaling messages cannot be captured with these apps.
Programmable SIMs	• SIM cards which configuration can be modified according to the network to be tested.
Traffic Generator/Servers	• Creates different types of traffic flows to emulate actual traffic in the mobile network. • Alternative is to use iPerf and file transfer protocol (FTP) servers in conjunction with mobile apps that act as clients. Automation and scalability are reduced with this solution.
Protocol Analyzer	• Application to capture packets and monitor network traffic including decoding and analysis of received protocol messages. (e.g., Wireshark)
UE Emulator	• Robust equipment to emulate one or more UEs to generate specific actions and traffic flows to perform functional, performance and load testing. • The alternative is to use multiple real UEs, making it unviable to execute tests that require certain number of UEs.
Network Taps	• Device that duplicates the physical signal on an interface to provide traffic monitoring and packet capture. • Tap can be substituted utilizing mirror ports in the network equipment. This option consumes resources of the network equipment.

Table 2: Test Equipment and Tools

Cost of test equipment and tools may drive the utilization of some of the alternatives mentioned above, which may or may not have an impact on the executable tests. Thus, further analysis of testing priorities and available equipment must be performed while defining the test plan for MORAN solutions.

Additionally, test laptops and applications should be considered together with various miscellaneous elements such as optical, unshielded twisted pair (UTP) and RF cables, RF shielded boxes, RF attenuators, and power adaptors and converters.

Figure 5 illustrates test equipment as part of the Lab Architecture.

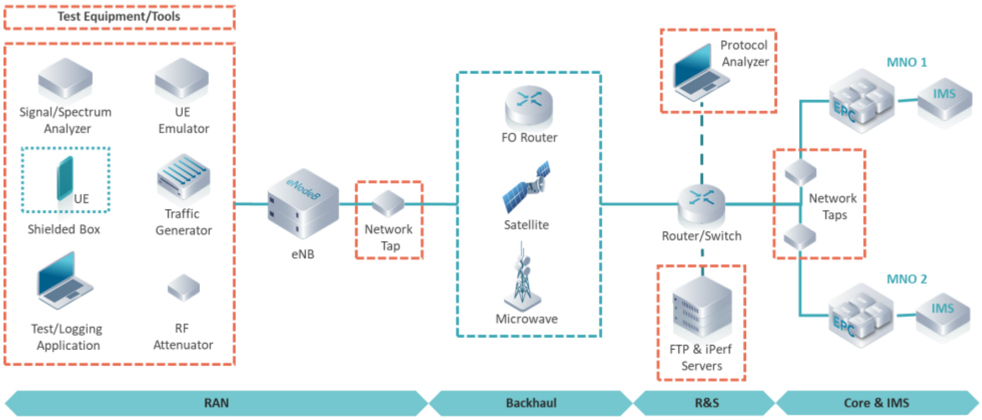


Figure 5: Testbed Test Equipment

3.2.3 Connectivity

In order to enable E2E testing, the lab infrastructure should meet the following connectivity requirements:

- Internet: Network equipment and UEs must be able to reach the internet to validate 4G data services. Additionally, laptops and other lab devices should be able to access to the internet.
- Live network: Lab infrastructure should have connectivity to the production network in cases where live network elements are used for the E2E scenario.
- Backhaul: Connectivity to an external backhaul network is required to test actual delays of transport equipment including satellite and microwave.
- Management: Implementation of a virtual private network (VPN) is required to provide secure and remote access to the lab network, test equipment and management systems.

Figure 6 illustrates connectivity requirements for the lab testbed architecture.

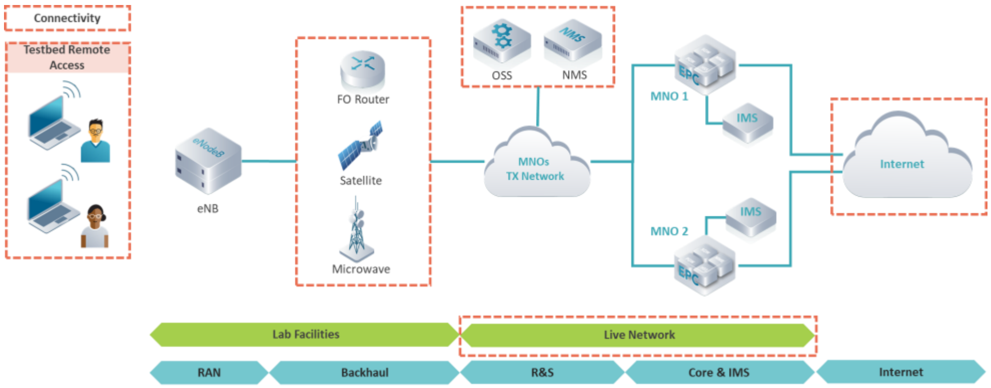


Figure 6: Testbed Connectivity Requirements

Considering the testbed requirements presented in this section, each NaaSCo will need to develop a test strategy based on their capabilities and available budget to perform MORAN solution testing. The following facilities can be considered to perform lab testing:

- NaaSCo Lab. NaaSCos utilizing their own lab have more flexibility and can control all the testing processes.
- MNO Lab. One of the MNOs that will share the NaaSCo network assigns resources to test MORAN in their own lab, making it easier to replicate the production network scenario. This may require additional personnel and requires intensive coordination.
- TIP Community Lab. NaaSCo collaborating with TIP can get support from a TIP community Lab to validate MORAN based on a specific scope of work. For more information visit https://telecominfraproject.com/test-and-integration/.

3.3 Test Plan Overview

NaaSCos must define a test plan that guarantees the correct and complete evaluation of the MORAN solution in terms of functionality and performance. This section presents the recommended MORAN solution test plan considering the following test case categories:

- Provisioning. Verification that eNB supports MORAN and successfully activates independent LTE cells for each MNO.

- **Signal Procedure Validation.** Validation of elementary signaling procedures (e.g., UE attach/detach) between the UE, eNB and EPC to ensure connectivity and compliance with 3rd Generation Partnership Project (3GPP) standards.

- **E2E Service Testing.** Evaluation of UEs correct LTE network attachment to successfully establish data/internet and voice sessions and benchmark performance for these services.

- **Operation and Maintenance (O&M):** Verification of the main O&M functionalities including the reporting of basic eNB alarms, counters, and key performance indicators (KPIs) at operations support system (OSS)/network management system (NMS).

For each category, related test cases are described below, exposing their objective, procedures, expected results, pass criteria, and required testbed.

3.3.1 Provisioning

Provisioning contemplates test cases to validate:

- Independent cell configuration
- Software/Firmware upgrades
- Cell visibility at OSS/NMS
- RF configuration validation through spectrum measurements.

These test cases are critical to ensure that the eNB supports the cell configuration required in the field. Additionally, they allow for streamlining the deployment process by identifying constraints and considerations for the provisioning process.

The testbed for provisioning test cases is shown in Figure 7.

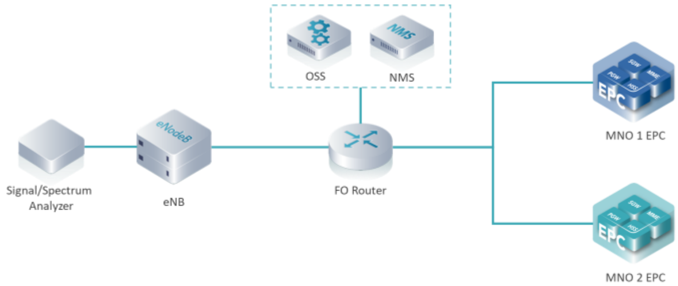


Figure 7: Lab Testbed for MORAN Provisioning Testing

3.3.1.1 LTE Cell Provisioning

Objective of this test case is to verify that the eNB allows provisioning of LTE cells when the 4G MORAN feature is active, with each cell supporting separate parameterization.

Procedure

MORAN Provisioning

- Confirm that the eNB is visible in the OSS/NMS
- Configure the eNB logical entity, LTE Cell, 4G Baseline and licenses
- Enable the LTE Cells and verify that they're active through a UE

Cell Visibility at OSS/NMS

- At OSS/NMS validate that LTE Cells are visible for Fault, Configuration and Performance Management

Software and Firmware Upgrade

- Through OSS/NMS, upgrade the software and firmware
- Verify the eNB inventory to confirm the software and firmware upgrade

Independent Radio Parameters per Cell

- Through OSS/NMS, validate the LTE Cells parametrization (PLMN ID, Cell ID, Cell Name, PCI, RSI, TAC, Band, EARFCN, Carrier Bandwidth)
- Verify that the eNB rejects invalid configuration by configuring invalid Cell ID and PCI, and by configuring the same EARFCN for both cells.
- Verify that eNB allows to configure each cell with different bandwidth

Expected Results / Pass Criteria

- The eNB allows independent provisioning of LTE cells for each MNO
- LTE cell radio parameters are within valid range
- The eNB software and firmware are successfully upgraded through OSS/NMS

3.3.1.2 Carrier Frequency Validation

Using a spectrum analyzer, verify that the signal transmitted by the eNB complies with frequency and bandwidth for each MNO.

Procedure

For each LTE Cell:

- Adjust the frequency range in the spectrum analyzer to visualize the carrier
- Verify that the carrier is centered in the expected frequency and occupies the configured bandwidth.

Expected Results/Pass Criteria

- The eNB transmits with the frequency (EARFCN) and bandwidth configured for each cell.

3.3.2 Signaling Procedure Validation

Signaling Procedure Validation contemplates test cases to validate S1 setup, attach/detach, default bearer setup/release, paging and handover. Additionally, call flows for voice services should be validated. Considering the trend towards VoLTE, the test cases presented herein only address VoLTE, however, similar test cases can be considered for circuit switched fallback (CSFB) and single radio voice call continuity (SRVCC).

These test cases aim to guarantee proper integration of the MORAN solution with the live network and identify any potential issues. Results will also provide a baseline for comparison that will ultimately streamline O&M troubleshooting tasks.

3.3.2.1 Basic LTE Procedures

Verify that the signaling messages between the UE, eNB and EPC follow the proper signaling flow for each MORAN cell.

To validate signaling flows it is recommended to trace packets at the air interface and S1 interface as shown in Figure 8.

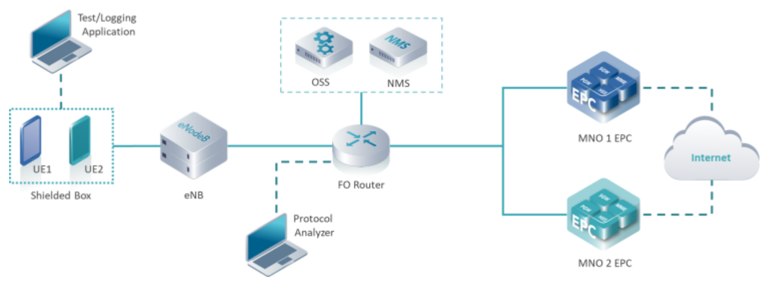


Figure 8: Lab Testbed for Basic LTE Procedures Validation

Procedure

For each MORAN cell apply the following steps:

S1 Link Setup

- Reboot the eNB
- Validate if the signaling procedure follow the LTE S1 setup signaling flow

Attach & Default Bearer Setup

- Power on/reset or turn-off airplane mode in the UE to initiate an attach procedure and verify that the UE has 4G service.
- Validate if the signaling procedures follow the LTE attachment signaling flow

Detach & Default Bearer Release

- Power off or turn-on airplane mode in the UE to initiate a detach procedure
- Validate if the signaling procedures follow the LTE detachment signaling flow

Paging

- Keep the target UE in idle mode
- Trigger a notification to the UE through an instant messaging application
- Verify that the UE received the notification.
- Validate if the signaling procedure follows the LTE paging signaling flow

Expected Results / Pass Criteria

- S1 link setup signaling flows captured at the S1 interface comply with the procedure established in 3GPP TS 36.413.
- Attach, detach and paging signaling flows captured at the S1 interface and the LTE Uu interface comply with the associated procedures in 3GPP TS 23.401 and TS 23.272.

3.3.2.2 Handover

Verify that the signaling messages between the UEs, target eNB, source eNB and EPC follow the proper signaling flow when handover is triggered in a 4G MORAN scenario.

To validate handover signaling procedure, the testbed requires a second eNB commissioned with the MORAN solution. The required testbed to validate handover is shown in Figure 9.

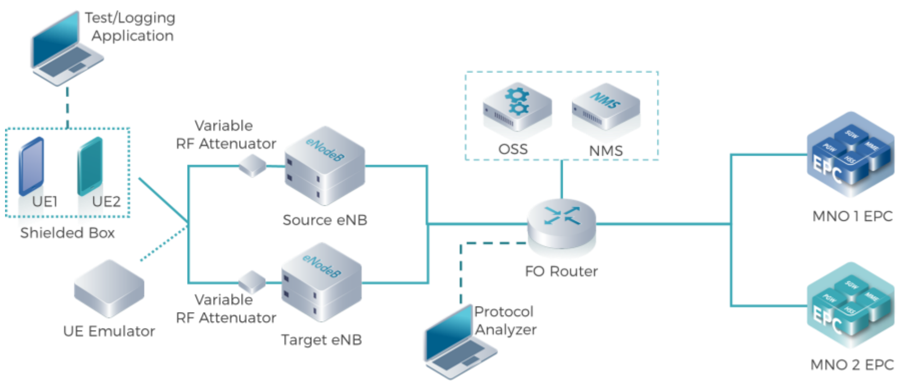


Figure 9: Lab Testbed for Handover Procedures Validation

Procedure

For each MORAN cell apply the following steps:

- Trigger a handover through the UE emulator or utilizing variable RF attenuators to reduce received power from the source eNB and increase power from the target eNB.
- Verify the UE handover from source eNB to target eNB
- Validate if the signaling procedure follow the LTE handover flow

Expected Results / Pass Criteria

- Handover signaling flows captured at the S1/X2 interface and the LTE Uu interface comply with the associated procedures in 3GPP TS 23.401.

3.3.2.3 VoLTE Call Flows

A VoLTE call is monitored to verify that the signaling procedures for IMS registration, call setup and call termination follow the proper signaling flow. Importantly other variations of the procedures can be considered depending on the NaaSCo expected scenarios.

Figure 10 depicts the associated testbed for VoLTE call flows.

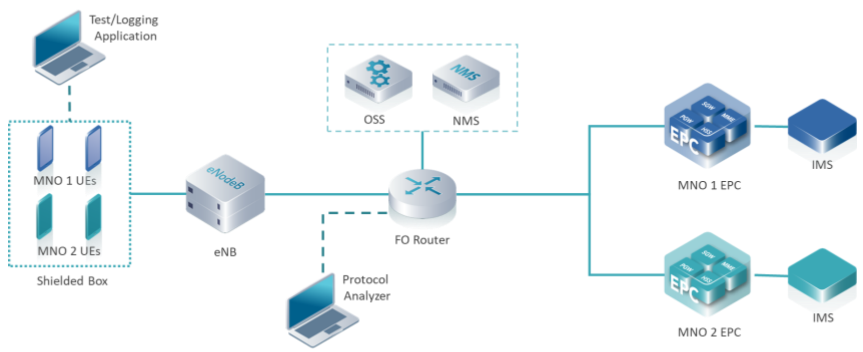


Figure 10: Lab Testbed for VoLTE Call Flows Validation

Procedure

For each MORAN MNO apply the following steps:

- Power on/reset or turn-off airplane mode in the UEs (UE1 and UE2) to initiate an attach procedure and IMS registration.
- Initiate a VoLTE call from UE1 to UE2 (Both attached to the same LTE network)
- Terminate the call from UE1
- Validate if the IMS Registration, Call Setup and Call Termination signaling procedures follow the expected signaling flows.

Expected Results / Pass Criteria

- Successful establishment of VoLTE Call between UE1 and UE2
- Expected call flow for IMS Registration, Call Setup MO/MT and Call Termination Initiated/Received is observed.

3.3.3 E2E Service Testing

E2E Service Testing contemplates test cases to validate basic services functionality, data service performance with single/multiple users, and QoS mechanisms testing; all with the objective to identify any potential issues that could compromise end user service and provide a performance benchmark for network capacity planning and optimization.

3.3.3.1 Service Functionality

Verify that internet protocol (IP) connectivity and associated data services are appropriately delivered in a MORAN configuration, including TCP/UDP data transmission, FTP data transmission, web browsing, video streaming, and VoIP calls.

To execute the tests above, connectivity toward the internet and availability of FTP and iPerf servers is required, as shown in Figure 11.

Figure 11: Lab Testbed for Service Functionality Validation

Procedure

Apply the following procedure for each cell and then simultaneously:

Ping

- Verify that the UE is attached to the network
- Execute a ping from UE to the FTP server
- Execute a ping from UE to the TCP/UDP (iPerf) server

Web Browsing

- Visit 5 websites using any Internet Browser on the UE and browse the web pages

Video Streaming

- Start and maintain a video call during 5 min to test uplink (UL) video streaming
- Play different HD videos on a video streaming application to test downlink (DL) video streaming

TCP/UDP Data

- Start DL data transfer and register the throughput reported by the UE. Maintain the traffic for at least 2 min.
- Then, start UL data transfer and register the throughput reported by the UE. Maintain the traffic for at least 2 min.
- Finally, start DL+UL data transfer and register the throughput reported by the UE. Maintain the traffic for at least 2 min.

FTP Traffic

- Start DL FTP data transfer and register the throughput reported by UE. Maintain the traffic for at least 2 min.
- Then, start UL FTP data transfer and register the throughput reported by UE. Maintain the traffic for at least 2 min.
- Finally, start DL+UL FTP data transfer and register the throughput reported by

UE. Maintain the traffic for at least 2 min.

Expected Results / Pass Criteria

- UE successfully pings FTP and iPerf servers
- Successful web page load and browsing without glitches
- Successful UL/DL video streaming without glitches on LTE cells
- Successful UDP/TCP data transmission for UL, DL and simultaneous DL+UL on LTE cells
- Successful downloading/uploading of file(s) utilizing FTP without interruptions for UL, DL and simultaneous DL+UL

3.3.3.2 Data Service Performance for Single User

Validate simultaneous maximum DL and UL Throughput for one active UE per carrier attached to the eNB under test.

The testbed required to validate max cell throughput for a single user is shown in Figure 12.

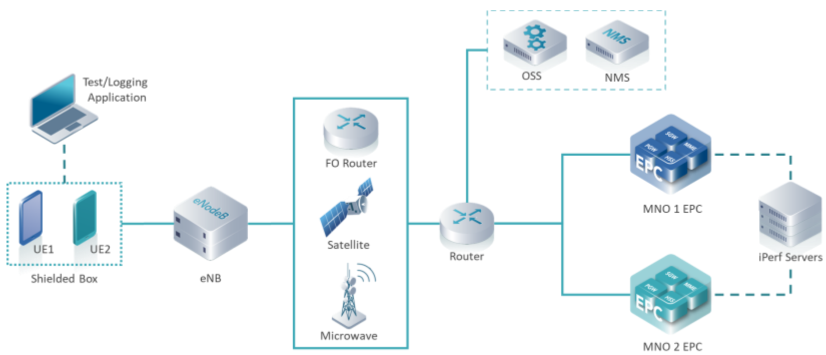


Figure 12: Lab Testbed for Single User Data Service Performance Evaluation

Procedure

Execute the following steps with simultaneous data traffic for both cells:

- Verify that the UEs have 4G service from the correspondent PLMN
- Start DL/ UL TCP data transfer for each UE through the iPerf client in the UEs. Maintain the simultaneous traffic for 15 min.
- Start DL/UL UDP data transfer for each UE through the iPerf client configuring the maximum throughput expected. Maintain the simultaneous traffic for 15 min.
- Register the throughput reported by UEs for TCP and UDP data traffic.

Expected Results / Pass Criteria

- Validation of data service (TCP/UDP) delivery to both UEs.
- Average cell DL and UL throughput is close to the max throughput expected.

3.3.3.3 Data Service Performance for Multiple Users

Multiple user performance evaluation contemplates test cases to validate:

- Max Cell Throughput
- Multiuser Attach/Detach
- Multiuser Data Call Setup
- Multiple VoLTE calls

UE Emulator is implemented to validate multiuser test cases, considering a gradual increase in active UEs.

To execute the above tests, the testbed shown in Figure 13 is required.

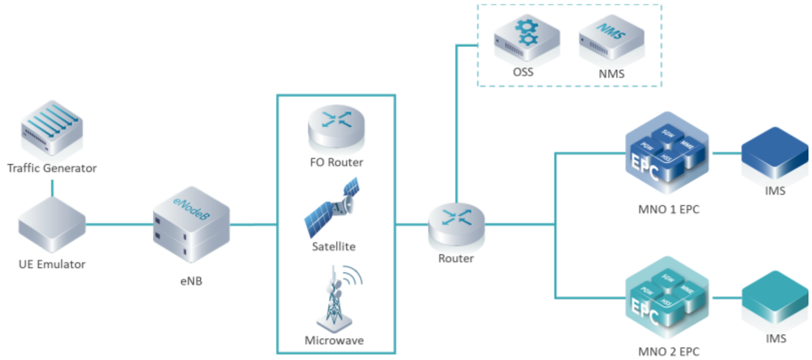


Figure 13: Lab Testbed for Multiple User Data Service Performance Evaluation

Procedure

Multiuser Attach/Detach

- At the UE Emulator configure a test with 25% of the UEs supported per cell.
- Trigger UE attachment
- Gradually detach all the UEs
- Validate the correct UE attach/detach
- Repeat the previous steps with the 50%, 75% and 100% of supported UEs

Multiuser Data Call Setup

- At the UE Emulator configure a test with 25% of the UEs supported per cell
- Trigger UE attachment
- Start the DL/UL FTP data transfer for all UEs and maintain the service at least 5

min

- Validate the correct UE data session establishment
- Repeat the previous steps with the 50%, 75% and 100% of supported UEs

Multiuser Max DL/UL Cell Throughput

- At the UE Emulator configure a test with 25% of the UEs supported per cell
- Trigger UE attachment
- Start the DL/UL data traffic for all UEs and maintain the service at least 10 min. Max supported data rate should be distributed among UEs
- Monitor the average cell DL/UL throughput
- Repeat the previous steps with the 50%, 75% and 100% of supported UEs

Note: It is recommended that TCP/UDP data proportion used during testing corresponds to actual MNO traffic profiles.

VoLTE Quality

- Trigger a VoLTE Call for each MNO and maintain the call for 10 min
- Verify that the calls were successfully established
- Repeat the previous steps until the max number of supported VoLTE Calls per cell is reached
- Monitor Call Setup Time, packet loss ratio (PLR), Jitter and mean opinion score (MOS)

Expected Results / Pass Criteria

- Successful UE attach/detach procedure and data call setup for incremental number of active UEs for both cells.
- Validation of maximum cell throughput with incremental number of active users. The average cell DL/UL throughput is close to the reference (maximum expected).
- Successful establishment of VoLTE Calls with the following KPIs:
    - Call Setup Time < 10 s
    - PLR < 1 %
    - Jitter < 20 ms
    - MOS > 3.5

3.3.3.4 QoS Testing

QoS testing consists of verifying that the QoS class identifier (QCI) mapping to differentiated services code point (DSCP) is working correctly at the eNB and that QoS mechanisms are prioritizing voice and signaling traffic over best effort (data) traffic.

The lab testbed should include network taps to verify QoS marking as illustrated in Figure 14.

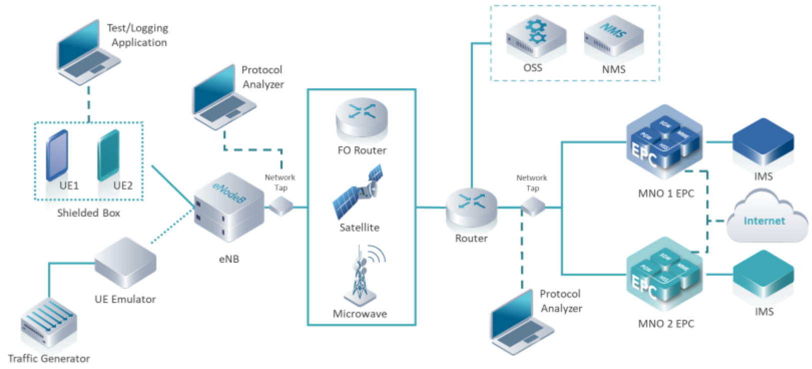


Figure 14: Lab Testbed for QoS Testing

Procedure

QCI Mapping & DSCP Marking

For each cell, validate QCI to DSCP mapping for S1 signaling, TCP/UDP data, VoLTE data, and IMS signaling and management traffic according to the MNO profile.

- Power on/reset the UE to initiate an attach procedure and validate if S1 signaling traffic flow is marked as expected
- Generate TCP/UDP DL and UL traffic, a VoLTE call and management traffic to the OSS/NMS and validate if each type of traffic is marked as expected.

QoS Traffic Prioritization

Execute the following steps for each MNO:

- Trigger DL/UL data traffic from real UE with the UDP data at 50% of transport guaranteed bit rate and maintain the traffic for 1 min
- Repeat the previous step with 75%, 90% and 100% of transport guaranteed bit rate and verify if packet loss is present
- Maintain the UE simultaneous DL/UL data traffic for the rest of the test using the whole available backhaul bandwidth
- Execute 15 times a command directed to eNB and validate if they were successfully executed
- Gradually, trigger VoLTE calls (15s of delay between each VoLTE call) until the maximum supported calls per cell is reached and maintain the voice service for

10 min

- Verify VoLTE calls were correctly established and maintained

Expected Results / Pass Criteria

- Consistent E2E QCI Mapping and DSCP Marking according to MNO requirements
- Stable UE DL/UL throughput for MNOs with data traffic at 50%, 75%, 90% and 100% of transport guaranteed bit rate
- eNB commands successfully executed even when data traffic is congesting the backhaul link.
- Signaling and VoLTE traffic is preserved even when data traffic is congesting the backhaul link.
- No call drops for the simultaneous VoLTE calls while maintaining acceptable voice quality (PLR below 1 % and MOS above 3.5)

3.3.4 Operation & Maintenance

Operation & Maintenance contemplates test cases to validate independent alarm and counters for each cell and failure independence by simulating S1 link connectivity loss with one of the MNOs, and then verifying that the active user of the other MNO maintains the service without any kind of interruption.

These test cases aim to validate O&M functionality for the MORAN cells, ensuring adequate monitoring and fault and performance management.

The required lab testbed is shown in Figure 15.

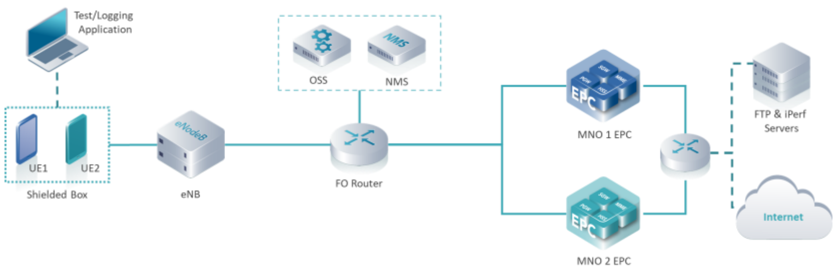


Figure 15: Lab Testbed for O&M Testing

3.3.4.1 Cell Monitoring & Isolation

Procedure

LTE Cell Alarms

- Generate exception conditions by rebooting the eNB, performing a power cycle and disconnecting transport link from eNB and verify alarms that are triggered.
- Verify that alarms are cleared after eNB power and connectivity is restored.
- For each LTE cell, change the LTE cell administrative status to disabled and verify that critical alarms are reported at OSS/NMS
- Enable the LTE cell and verify that alarms are cleared

eNB Counters

Execute the following steps for each cell:

- Power on/reset the UE to initiate an attach procedure
- Verify that accessibility counters registered the attachment event
- Start DL/UL TCP data transfer and verify that traffic (traffic volume), integrity (cell avg throughput) and capacity (PRB usage) counters augmented due to the generated data traffic

Cell Failure Isolation

- Power on the UEs to initiate an attach procedure and verify that the UEs have 4G service from the correspondent cell
- Start separate data sessions for each UE
- Block S1 traffic for cell 1 through configuration of the router between the eNB and the EPC
- Verify that the UE attached to cell 1 loses 4G service
- Verify that the UE of cell 2 keeps 4G service (uninterrupted data sessions) and maintain the service by 2 min.
- Restore S1 traffic from cell 1
- Repeat the previous steps, by blocking S1 traffic from cell 2.

Expected Results / Pass Criteria

- Correct reporting of status alarms at OSS/NMS
- Correct reporting of different counters and alarms categories
- The DL/UL data traffic is one cell is not affected by failures in the other cell

3.4 Testing Best Practices

Best practices for MORAN testing during test planning, test design and implementation, test execution and test completion are provided in this section to improve testing efficiency and quality and minimize the impact of potential issues during testing.

3.4.1 Test Planning

In this stage, the NaaSCo defines the lab testing scope, estimates timelines, and assesses potential risks for equipment procurement, equipment installation, test plan development, test execution and results reporting. Best practices for this stage are listed below:

- **RAN vendor support.** Ask for support from the RAN vendor to rapidly resolve queries about the solution configuration/integration, hardware/software characteristics and test results feedback.
- **Lab Inventory.** Generate a detailed lab inventory with information of network/test equipment, available connectivity, and ancillary equipment (e.g., cables and power supplies). This will contribute to identify the lab scenarios that can be built and determine the missing lab items for the full execution of the Test Plan.

3.4.2 Test Design and Implementation

In this stage detailed test cases are developed, including test objectives, conditions, procedures and expected result; then, the test bed is integrated, and configuration scripts are developed. Best practices in this stage are summarized below:

- **Get MNO network configuration, traffic profiles and specifications.** Request MNO data to improve accuracy of the test plan and the test bed.
    - User traffic profiles are useful to obtain a better characterization of the multi-user performance. Lacking this information, a 50% TCP/ 50% UDP traffic profile can be utilized.

- MNO network configuration data helps to faithfully replicate the conditions of the production network. If this information is not provided, use standard configurations.

- Test case review. Ask for feedback on the detailed test plan from RAN vendor and MNOs to identify potential issues.

- Single EPC. To simplifying testbed setup, evaluate the option to use the same EPC to configure the two PLMNs, avoiding the need to utilize two different EPCs. Support for this feature must be confirmed with the EPC vendor.

- Intermodulation Distortion Analysis. Before establishing carrier frequencies and bandwidths for testing, make sure to perform an analysis for intermodulation distortion identifying frequencies that will introduce significant 3rd and 5th order intermodulation products interfering with the desired signals.

  This is an important step since intermodulation interference reduces signal-to-interference-plus-noise ratio (SINR) and thus, achievable throughput. For a quick estimation of this phenomenon use a passive intermodulation (PIM) calculator to find the number of hits for intermodulation products of 3rd and 5th order. The greater the number of hits, the greater the interference.

3.4.3 Test Execution

This is an iterative process, that applies for all the test cases of the Test Plan. The process includes the following steps:

1. Creation, configuration, and maintenance of the test scenario.
2. Validation of testbed integrity.
3. Execution of the test procedure.
4. Collection and registration of the results.
5. Post-processing of test case results.

Best practices for test execution are listed below:

- RF Setup validation. In advance to test commencement, perform the following verifications:
  - RF ports and cables do not present any physical defects and are tightly

connected

- Verify received power to ensure adequate power levels are received at the UE and the radio unit. Attenuators can be used to adjust the received power on the radio unit; however, it is important to verify that identical attenuators are utilized in all the transmit (TX)/receive (RX) ports.

- **Network taps.** Use network taps directly connected to the network ports of the eNB and EPC to validate QCI mapping and DSCP marking. This will guarantee that the measurements correspond to the actual packets being sent over the interfaces as opposed to those regenerated in a mirror port.

- **Multiuser traffic profiles.** When testing multi-user throughput, traffic profiles in terms of TCP/UDP distribution, traffic load, and number of UEs, may need to be adjusted to obtain maximum throughput.

- **Reporting.** Generate periodic test status reports to register the actual Test Plan progress, factors that delay or block the progress, and results summary.

3.4.4 Test Completion

At this point, all the lab project participants provide their expert opinion about the test results, lessons learned, insights and recommendations. Finally, the test plan, scripts, execution logs and status reports are stored for future reference.

Best practices include documentation of lessons learned and organizing all testing materials into a single folder that includes description of the materials and main findings.

3.5 Field Testing

As stated before, field testing should be included as a second phase (after lab testing) or an alternative to validate performance and ensure readiness for the live production network. Furthermore, field trials can be leveraged to validate overall deployment and operational expenses in a scalable way.

With a Field Trial, NaaSCos will evaluate the MORAN solution on their production network. Therefore, the results obtained under this scenario will reflect the actual network conditions helping to identify potential issues that could hinder the scale implementation of MORAN. However, some tests cannot be done due to their disruptive nature or because specific conditions cannot be controlled.

Importantly, the knowledge acquired during the lab testing phase will be useful to speed up the configuration, commissioning, and installation of the E2E network elements.

To define the field-testing scenario, NaaSCos should consider the following cell site characteristics:

- Site Infrastructure: Try to select sites with existing tower, power, and core connectivity to minimize the required time for installation and integration.
- Number of Sectors: Consider the most common configuration that will be used during deployment to define the number of sectors.
- Number of Sites: Select contiguous sites if the scenario requires a cluster, otherwise select separated sites, where each of them replicate a specific scenario of the MORAN deployment (e.g., urban, rural and peri-urban areas).
- Transport Topology: Determine the type of backhaul to be tested.

Test equipment for field testing consists of the UEs and associated monitoring applications that will generate traffic to validate cell performance. These UEs are handed to friendly users that can be coordinated to perform tests with specific traffic conditions. In addition, a protocol analyzer may be included to monitor signaling at the S1 interface. Test Plan for field testing should include the following validations:

- LTE Cell Parametrization. Using mobile applications, the LTE Cell parametrization (e.g., PLMN ID, Cell ID, EARFCN) is validated.

- Basic Services Validation and multiuser performance. Web Browsing, Video Streaming and TCP/UDP data traffic are directed validated through the normal use of the network or by coordinating friendly users to generate this kind of traffic.

- **Counters and KPIs Monitoring.** The friendly users use the network as if they were real subscribers for a period of one or two weeks. The objective is to validate cell performance under a realistic traffic scenario, and gather the following KPIs: LTE Cell Availability, LTE radio resource control (RRC) Setup Success Rate, LTE DL/UL Avg User Throughput and LTE DL/UL PRB Utilization, among others.

The field trial results obtained from the above test cases are used by the NaaSCo to compare them against the lab results and verify consistency. Finally, lab and field-testing results determine if the MORAN solution complies with the minimum requirements to be commercially deployed.

4

MORAN Deployment Considerations

4. MORAN Deployment Considerations

This section captures the aspects that require special consideration from NaaSCos for a successful MORAN implementation, including relevant elements for commercial agreements with MNOs, technical aspects for site design and deployment and network interconnection. Further elaboration of these issues can be found in the NaaS Playbook and proper reference is made in each of the subsections below.

4.1 Commercial Agreement

Before a NaaSCo implements MORAN or any other RAN Sharing solution, several discussions with the MNOs are required to onboard them and define technical and commercial aspects of the network operation.

After initial engagement, both parties start assessing potential areas and/or sites for MORAN implementation based on MNO current coverage and business targets, and NaaSCo operation areas. Once the attractive areas or sites are agreed upon, negotiations for a long-term commercial agreement should take place to establish the sites to be shared and billing, reconciliation, service level agreements (SLAs), and operating model aspects.

The following presents a summary of the most relevant items to be considered for the MNO-NaaSCo commercial agreement:

- Technical solution description. Commercial agreements with MNOs should include a sufficiently detailed description of the technical solution and the network infrastructure to be provided by the NaaSCo, including demarcation points and the expected role of the MNO for successful interconnection.
- Sites/Areas included in the Agreement. Include the initial set of sites or areas where the NaaSCo will provide its services to the MNO, with options to add areas or scope in the future.
- SLA. The SLA should be specified as part of the commercial agreement, including service level objectives and compensation measures when the NaaSCo fails to meet such objectives. Service level objectives should include network availability, throughput for DL/UL and other relevant KPIs.

- Operating Model. The agreement should specify the split of roles and responsibilities between the MNO and the NaaSCo for network design, deployment, service provisioning and O&M. This is also an important issue to be considered for NaaSCo service pricing.
- Billing: Billing mechanisms in the commercial agreement should include how the NaaSCo collects revenue from the MNO. This can be done on a per-site basis, based on traffic, or through a revenue sharing agreement. The three options must be assessed from a business and implementation perspective.
- Conflict Resolution: Another important consideration in the commercial agreement between the MNO and the NaaSCo is the way that discrepancies in terms of billing, or compliance to SLAs are resolved. Thus, a set of clauses should be stipulated in the agreement specifying procedures and guidelines for conflict resolution.

NaaSCos must have experienced personnel to estimate the impact, pros and cons of the different alternatives of the above aspects and to manage negotiations with MNOs. This will save NaaSCos from being in a disadvantageous position from a legal and commercial perspective.

For further reference visit the NaaS Playbook modules Strategy & Scope Fundamentals and High-Level Project Plan which provides more details for MNO-NaaSCo commercial agreements.

4.2 RAN Design Coordination

To perform a successful integration of the MORAN sites with the MNO network, NaaSCos must coordinate with the MNOs regarding RAN design tasks. The MORAN architecture allows NaaSCos to coordinate the high-level design (HLD) and low-level design (LLD) tasks with each MNO independently. The expected role of NaaSCos and MNOs during RAN design and relevant items for consideration are detailed below.

4.2.1 RAN HLD

In the HLD stage, the NaaSCo oversees the coverage and capacity analysis of each site to determine the RF configuration for each site. To accomplish this task, the NaaSCo requires the MNO to provide a subscriber forecast and subscriber traffic profile for the target areas.

Information provided by the MNO must be evaluated and factored into the design process to generate the HLD outputs which include the RAN site configuration (radio equipment, number of sectors, transmit power, antenna gain) and the related bill of quantities (BoQ).

Further guidance in RAN Network HLD module in NaaS Playbook with E2E descriptions.

4.2.2 RAN LLD

Once the HLD is accepted based on commercial and technical feasibility, the low-level design takes place to generate the required outputs to perform the deployment and integration of each site. These outputs include the Datafill with RF parametrization, the RF baseline, equipment licenses and equipment configuration scripts.

Depending on the operating model, the way that these tasks are distributed between the NaaSCo and the MNO will vary. In any case, the NaaSCo and the MNO must establish the following aspects to ensure successful integration of the sites into the MNO network:

- Network Element Naming Conventions. MNOs must provide naming nomenclature to the NaaSCo to homologate with non-RAN Sharing sites. If the naming convention changes, then site traceability and identification will be difficult.
- RF Planning. PCI, TAC and mobility management entity (MMEs) assignation have a geographic dependency. If the NaaSCo is responsible for this task, the MNO must provide the design rules and visibility of neighbor sites since an ill-informed PCI allocation may cause a collision with nearby sites.
- Neighbor Strategy. The NaaSCo needs visibility of the sites owned by the MNO to determine the neighbors of the MORAN sites. Otherwise, the network mobility

capabilities will be compromised.

- **Network Parametrization.** This task consists of the configuration of features and mobility parameters based on MNO requirements. If the NaaSCo is responsible for this task, some guidance from the MNO will be required to ensure consistency across the MNO network.

Finding the best strategy to distribute the LLD tasks and tight coordination between NaaSCo and MNOs to validate designs is crucial to reduce the risks during deployment and malfunctions during the site operation.

Further guidance in RAN Network LLD module in NaaS Playbook with E2E descriptions.

4.3 TX Network & Mobile Core Interconnection

The NaaSCo network must be connected to the MNO network to provide connectivity between the eNBs operated by the NaaSCo and the EPC, OSS and other eNBs operating by the MNOs in their own networks.

To this extent, the NaaSCo and the MNO must coordinate certain aspects and parameters of the transport network and to understand how the mobile core in the MNO network has been deployed and how to access it. Other EPC configurations are not required under the MORAN architecture.

Importantly, the transport network configuration can be done in an independent way for each MNO by assigning each MNO its own logical resources on the NaaSCo network.

The following subsections provide an overview of the transport network aspects to be considered by the NaaSCo for MORAN implementation.

4.3.1 IP Planning

The NaaSCo and the MNO must define the IP segments for interconnection interfaces. In addition, depending on the level of integration between the NaaSCo and the MNO, IP pools for the eNBs may also be defined.

The IP plan to be developed must consider the following interfaces:

- S1 control plane (CP) & user plane (UP)

- X2 CP & UP
- O&M
- Sync Plane

The IP plan must be validated by the NaaSCo and the MNO, to prevent any potential IP address conflicts between the plans. If an issue is detected, the NaaSCo must coordinate and discuss with the involved MNO to resolve and update the IP Plan.

In addition, the MNOs must provide the IP addresses and assignation rules for MMEs, serving gateways (S-GWs) and precision time protocol (PTP) master clocks.

Further guidance for Tx and IP architecture in Tx Network HLD and Mobile Core HLD modules in NaaS Playbook with E2E descriptions.

4.3.2 VLANs Management

The NaaSCo should coordinate with the MNOs to establish the virtual local area network (VLAN) configuration based on the current allocation in MNO networks. It is recommended to assign different VLANs for the following traffic flows on a per-MNO basis:

- S1 CP
- S1 UP
- X2 CP
- X2 UP
- O&M and Sync

4.3.3 Sharing of Backhaul Bandwidth

Since multiple MNOs will be sharing the backhaul in the NaaSCo network, the NaaSCo must provision adequate QoS mechanisms that respond to the SLAs and commercial agreements with the MNOs. In particular, it's important to prioritize time-sensitive traffic such as voice and perform adequate handling of critical data traffic.

4.4 MORAN Site Integration & Acceptance

The NaaSCo will be responsible for coordinating site integration and acceptance tasks which include on-site and remote activities. While the on-site activities are performed by the NaaSCo field personnel, the remote activities can be split between the NaaSCo and the MNO which requires coordination between the MNO and NaaSCo network operations centers (NOCs).

Once the equipment has been installed, the integration process begins by setting up the eNB management interface. From this point, the NaaSCo, the MNO or both can perform the integration tasks. The most common approach is for the MNO to perform configuration of the EPC elements and interfaces, while the NaaSCo performs configuration of the backhaul and the eNB. However, both parties should be informed of the progress and ideally participating on a voice bridge to resolve any issues during the process.

Importantly, MNOs that are already active in the sites should be informed of the activity that will take place, since any unexpected issue may affect the service of the whole eNB.

Once the configuration is done, the MNO and the NaaSCo should perform remote test and execute troubleshooting as required. Then, the NaaSCo's on-site personnel validates that no alarms are present and performs a set of pre-agreed tests utilizing test UEs to verify cell parametrization, basic services, throughput, and coverage.

Based on test results and visibility of the new eNB on management systems, the MNO accepts the new site and the NaaSCo provides a close-out package or folder with all the details of the site and the tests that were performed which serve as a reference for the O&M teams.

As reference several NaaS Playbook modules for deployment aspects from Deployment Planning and Management to I&C and Site Acceptance.

Glossary

3GPP	3rd Generation Partnership Project
BBU	Baseband Unit
BoQ	Bill of Quantities
BSC	Base Station Controller
BTS	Base Transceiver Stations
CAPEX	Capital Expenditures
CLI	Command Line Interface
CM	Configuration Management
CP	Control Plane
CS	Circuit-Switched
CSFB	Circuit Switched Fallback
DL	Downlink
DSCP	Differentiated Services Code Point
E2E	End-to-End
EARFCN	E-UTRA Absolute Radio Frequency Channel Number
eNB	Evolved NodeB
EPC	Evolved Packet Core
FM	Fault Management
FTP	File Transfer Protocol
HLD	High-Level Design
IDU	Indoor Unit
IMS	IP Multimedia Subsystem
IP	Internet Protocol
KPI	Key Performance Indicator
LLD	Low-Level Design
LTE	Long Term Evolution
MME	Mobility Management Entity
MNO	Mobile Network Operator
MO	Mobile Originating
MOCN	Multi-Operator Core Networks
MORAN	Multi-Operator Radio Access Network
MOS	Mean Opinion Score
MT	Mobile Terminating
NaaS	Network as a Service
NaaSCo	Network as a Service Company
NMS	Network Management System

NOC	Network Operations Center
O&M	Operations & Maintenance
ODU	Outdoor Unit
OEM	Original Equipment Manufacturer
OPEX	Operating Expenses
OSS	Operations Support System
PCI	Physical Cell Identity
PIM	Passive Intermodulation
PLMN	Public Land Mobile Network
PLR	Packet Loss Ratio
PM	Performance Management
PRB	Physical Resource Block
PS	Packet Switched
PTP	Precision Time Protocol
QCI	QoS Class Identifier
QoS	Quality of Service
QXDM	Qualcomm Extensible Diagnostic Monitor
R&S	Routing & Switching
RAN	Radio Access Network
RF	Radio Frequency
RNC	Radio Network Controller
RRC	Radio Resource Control
RRU	Remote Radio Unit
RSI	Root Sequence Index
RSRP	Reference Signal Received Power
RX	Receive
S1	S1 LTE interface
S-GW	Serving Gateway
SIM	Subscriber Identity Module
SINR	Signal to Interference & Noise Ratio
SLA	Service Level Agreement
SRVCC	Single Radio Voice Call Continuity
SSH	Secure Shell Protocol
TAC	Tracking Area Code
TCP	Transmission Control Protocol
TIP	Telecom Infra Project
TX	Transmit
UDP	User Datagram Protocol
UE	User Equipment
UL	Uplink
UP	User Plane

UTP	Unshielded Twisted Pair
VLAN	Virtual Local Area Network
VoLTE	Voice over Long-Term Evolution
VPN	Virtual Private Network
VSAT	Very Small Aperture Terminal
X2	X2 LTE Interface