infovista

KNOW YOUR NETWORK™

End-to-End Xhaul and C-RAN Service Assurance –Challenges, Requirements, Benefits and ROI

A guide for network operations and network engineering teams

Content

Introduction

Mobile Network Operators (MNOs) are under exceptional operational and financial pressure to manage the relentless growth of mobile data and video traffic. They must contain costs while providing the high-speed capacity and performance they need to satisfy demand. According to Ericsson's Mobility Report (2016), mobile broadband subscriptions are growing by around 25% year-on-year and mobile broadband will account for 90% of all subscriptions by 2022.

NFV/SDN-based virtualized networks and 5G access technologies are being introduced to help MNOs realize this goal. Virtual infrastructure provides greater flexibility and agility, while reducing costs, while 5G will, ultimately deliver the capacity and speed required to support the expected surge in traffic and devices. In addition, network slicing will provide a new means of allocating network resources, end-to-end across this infrastructure.

This transition is not without complexity, as it requires a hybrid of both legacy physical and new virtual infrastructure, but it will enable MNOs to offer their networks as a platform for connectivity and differentiated services – delivering the Network as a Service (NaaS).

Thanks to this new infrastructure and the emerging technology of network-slicing, MNOs will be able to offer corporates and industry-verticals entirely new, highly differentiated business services, with unprecedented performance. These will be backed by SLAs for enterprises and different industry-verticals, enabling them to deliver a growing range of always-available, high reliability, low latency IoT and connected device services.

To achieve these levels of performance, and to satisfy the differentiated service levels required, the radio access network (RAN) is undergoing a major transformation: centralization and cloudification, which are also bringing about significant changes in the network transport backbone. This will result in both a new fronthaul and backhaul network, an unprecedented leap in technology and performance. It will be essential for MNOs to assure QoS over this highly IP-ized fronthaul and backhaul (Xhaul) infrastructure in an integrated way.

The Xhaul transport network consists of high-capacity switches and heterogeneous transmission links (e.g., fiber, wireless optics, high-capacity copper, mmWave etc.); RRH (Remote Radio Heads); Baseband Units (BBU); PoAs (e.g., macro and small cells); cloud-processing units (mini data centers); and interconnections with the core networks of potentially multiple MNOs. This combination of assets will provide MNOs with the high capacity, efficiency and performance they require.

MNOs were able to manage and maintain the performance of their mobile backhaul networks as RAN technologies evolved from 2G to 4G and as transport technologies shifted from ATM, FR, and MPLS to Carrier Ethernet. However, the coming introduction of Xhaul presents new challenges.

We agree that, from a technical perspective, fronthaul, with its microwave, optical, and Ethernet technology options does not differ greatly from the backhaul. However, it must also be managed in parallel with the existing backhaul network - and the entire transport network must be treated as an end-to-end integrated whole. In this context, the increasingly important role that the integrated IP-ized Xhaul has on the success of the dynamic digital services that MNOs wish to deploy cannot be underestimated.

In addition to this, there are also new elements that have been added to the fronthaul domain, which require a different management approach. With the introduction of Mobile Edge Computing (MEC), the existing RAN of LTE is evolving into a more centralized and, ultimately, cloudified (C-RAN) to help increase network coverage, capacity and efficiency. C-RAN introduces new interfaces to the fronthaul, such as CPRI (Common Public Radio Interface), eCPRI (enhanced CPRI) and OBSAI (Open Base Station Architecture Initiative). It also introduces enhancements to the RRH (Remote Radio Head) and a new network node BBU (Base Band Unit), and enables the proliferation of macrocells and femtocells, which will be required to achieve 5G coverage.

As in the case of fronthaul assurance, the C-RAN is not expected to have significantly different assurance criteria from the traditional RAN. However, to ensure end-to-end QoS for current and future networks that are also intended to be offered as NaaS platforms for corporates and industry verticals, it's clear that the C-RAN will also need to be service-assured alongside the fronthaul and backhaul.

The objective of this whitepaper is to discuss in more detail the challenges that MNOs will face to assure end-to-end fronthaul and backhaul performance, in the light of the issues that the introduction of C-RAN technology is expected to bring. We will discuss several key points.

First, why extending service assurance to the transport network is as critical as service assurance for the RAN and Packet/Voice core networks. Second, how the QoS of an underlying IP/Ethernet transport network is paramount to the success of the high availability, low latency, and high reliability mobile networks of today and tomorrow.

Third, the paper also analyses the demands of new NFV/SDN and imminent 5G based networks, in which networks will be realized as multi-layered and complex hybrid (physical and virtualized) service platforms. Fourth, we explore how the concepts of network-slicing; the focus on enterprise and industry-vertical SLAs; and the always-available, high reliability, low latency IoT services, will require better performance from the underlying transport networks, whether microwave or optical.

Fifth, the paper discusses the specific requirements for the successful management of Xhaul performance, focusing on providing network operations team with the solutions they need to accelerate problem detection and resolution in the evolving hybrid networks, as well as enabling network engineering teams with the means to better plan and monitor network capacity.

Sixth, we examine a strategy that shows how to consolidate multiple performance data sources, through the use of open APIs in a complex service assurance ecosystem, in order to create a cost-efficient ecology and the dynamicity for rollout of the digital and IoT services that the virtualized and sliced networks are designed to deliver.

Finally, we consider the business benefits of adopting an integrated solution for Xhaul and C-RAN service assurance, with focus on churn reduction, mitigation of revenue loss, and CAPEX/OPEX optimization. We also discuss options to accelerate ROI, so that the solution may fit different MNO budgets.

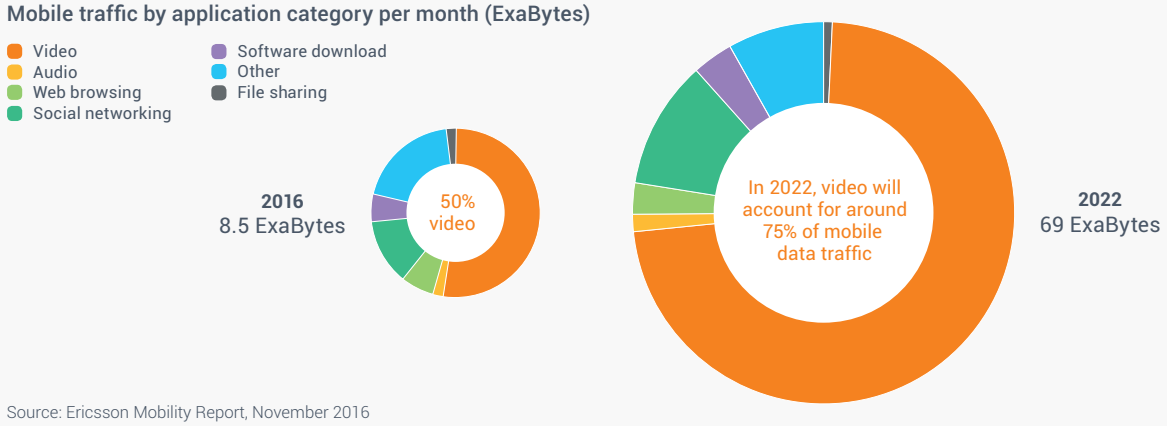
Mobile Networks are transforming at an alarming pace

With unabated demand for mobile video, the data tsunami from the use of smartphones and social media, and the impending onslaught of billions of interconnected devices, the mobile network is buckling under the pressure to deliver high capacity while maintaining consistent quality and to meet performance demands.

There are many reports that seek to quantify this deluge. For example, according to the Ericsson Mobility Report, by the end of 2022, there will be 8 billion mobile broadband users, of which 2.8 billion will be on 3G, 4.6 billion on LTE and 550 million on 5G. If MNOs cannot find ways to decentralize customer traffic, it will become unmanageable, suffer decreasing quality, and they will be unable to support the expected growth in the long-term. Let us examine in more detail the customer trends that are forcing the mobile network to make this rapid transformation.

Mobile Video growth:
As data traffic, especially mobile video, consumes capacity and bandwidth in mobile networks, it is imperative that MNOs adopt virtualization to deliver capacity on demand; discover unused capacity; and cost-effectively deliver digital video services.

While developments in live video streaming technology have raised customer consumption, this has also had the effect of increasing expectations of network performance. For example, over 20% of smartphone users face video streaming issues when outdoors (see Figure 1).



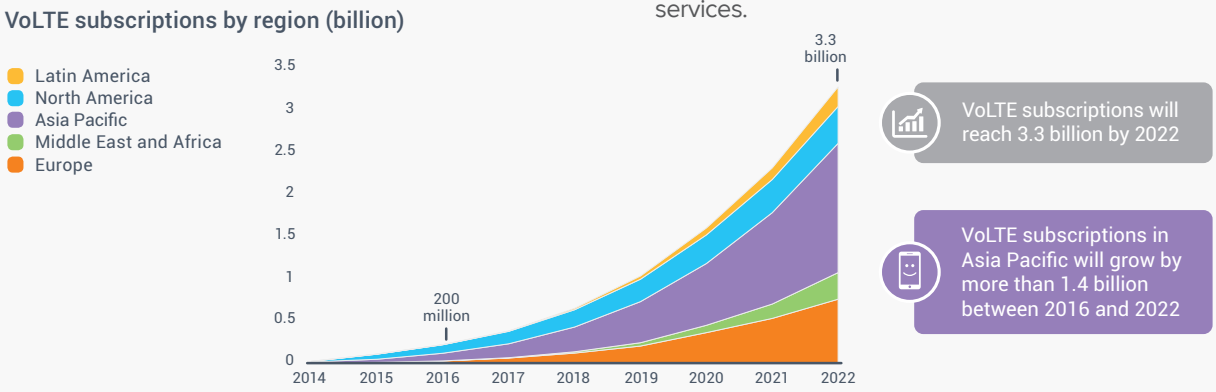
Source: Ericsson Mobility Report, November 2016

Figure 1. The growth of mobile video

With continuing growth in demand for video applications, which have high demands for latency, integrity, and bandwidth, MNOs need to invest in resilient, high capacity networks today.

The rise of VxLTE:

Growing deployment and adoption of VxLTE (Voice and Video over LTE) technology enables MNOs to offer high-quality services, including high definition voice and video communication, over the LTE network (see Figure 2). The current focus of MNOs is to launch and derive revenue from VxLTE services to regain their declining voice revenues, in the wake of competition posed by the OTT services.

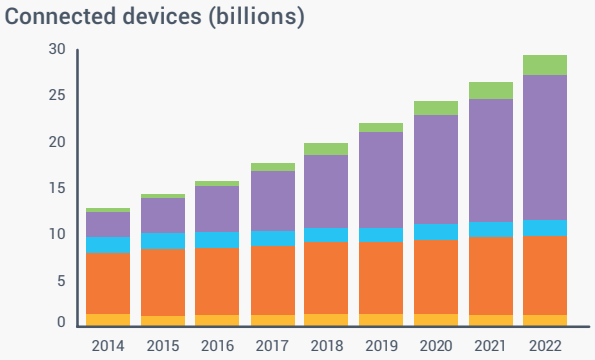


Source: Ericsson Mobility Report, November 2016

Figure 2. VoLTE growth

Growth of Mobile and IoT Devices

Around 29 billion devices are forecast to be connected and activated in the next 5 years, of which around 18 billion will service IoT applications. In 2018, mobile phones are expected to be surpassed in numbers by IoT devices, which include connected cars, remote machines, smart meters, wearables, and other consumer electronics. 70% of wide-area IoT devices will use mobile networks to transport data, which translates to about 1.5 billion IoT devices with mobile subscription (See Figure 3). This puts additional pressure on mobile networks to deliver high connectivity and, for some real-time applications (remote surgery, connected cars, and so on), a guarantee of high reliability and ultra-low latency is also expected.



	2016	2022	CAGR
Wide-area IoT	0.4	2.1	30%
Short-range IoT	5.2	16	20%
PC/laptop/tablet	1.6	1.7	0%
Mobile phones	7.3	8.6	3%
Fixed phones	1.4	1.3	0%
	16 billion	29 billion	10%

Source: Ericsson Mobility Report, November 2016

Figure 3. Growth of connected devices

Developments in 5G:

Research suggests that many MNOs will introduce 5G in their networks from 2020. With early deployments of C-RAN, NFV core and the build-up of IoT traffic in selected markets, rollouts of pre-5G services will begin even earlier. Globally, there are at least 30 MNOs that have publicly announced 5G plans, with many of them running 5G trials in 2017. Leaders in this space will need to rollout high-throughput (Gbps scale) services over high capacity networks, which will be a hybrid of 4G and 5G core and access technologies on virtualized and physical network nodes.

As a consequence, Mobile Transport is transforming too

MNOs are already taking steps to cope with the data deluge by introducing cost-efficient network technologies, such as LTE-Advanced, Small-Cells, and HetNet. However, it is with the introduction of C-RAN that MNOs will realize the boosts to network coverage, capacity and efficiency they need.

While 5G offers the long-term solution to the capacity problem by introducing high Gbps download speeds, together with a huge increase in the availability of bandwidth, it will be several years before its potential is realized and MNOs see the benefits. Therefore, to support current LTE-A and small cell traffic growth, MNOs are pre-empting the availability of C-RAN (Centralized RAN) solutions and deploying a new fronthaul with the backhaul between the RAN and the packet core to cater for this increased traffic.

The result is the transformation of transport networks to the new mobile Xhaul (fronthaul and backhaul), which will serve as the backbone for current and new access technologies for many years. This, however, requires re-design of base stations, separating radio- and base-band processing in different nodes that are separated geographically and connected through fiber or microwave and, collectively known as fronthaul.

Today, MNOs use a multitude of technologies, vendors and topologies to build their mobile backhaul. To increase capacity of the mobile backhaul, MNOs have already adopted cost-effective IP/ MPLS and Carrier Ethernet-based networks, which are 8 to 10 times cheaper when comparing cost per bps against TDM technologies. However, today, optical options such as Dedicated or Dark Fiber are also being considered by MNOs to cope with the additional traffic, in addition to GPON and other approaches.

The Xhaul must maintain support for all legacy 3G/LTE RAN networks, which will overlap with the introduction of new 5G RAN for the next few years. This means there will be a transition period during which new technologies are introduced alongside legacy solutions. As a result, the mobile Xhaul environment will become increasingly complex.

The Xhaul transport network under development consists of high-capacity switches and heterogeneous transmission links (for example, fiber or wireless optics, high-capacity copper, mmWave), interconnecting Remote Radio Heads, 5G Points of Attachment (Macro cells, Femtocells etc.), pooled-processing units (mini data centers), and points-of-presence at the core networks of several service providers.

The mobile transport network is evolving rapidly to meet challenging 4G/5G performance requirements. The Xhaul architecture uses a new, unified data plane protocol (CPRI/ eCPRI), which is capable of transporting both backhaul and fronthaul traffic. Integrated backhaul and fronthaul performance is therefore key to the success of mobile data and video services, with a high dependency on the CPRI/ eCPRI protocols.

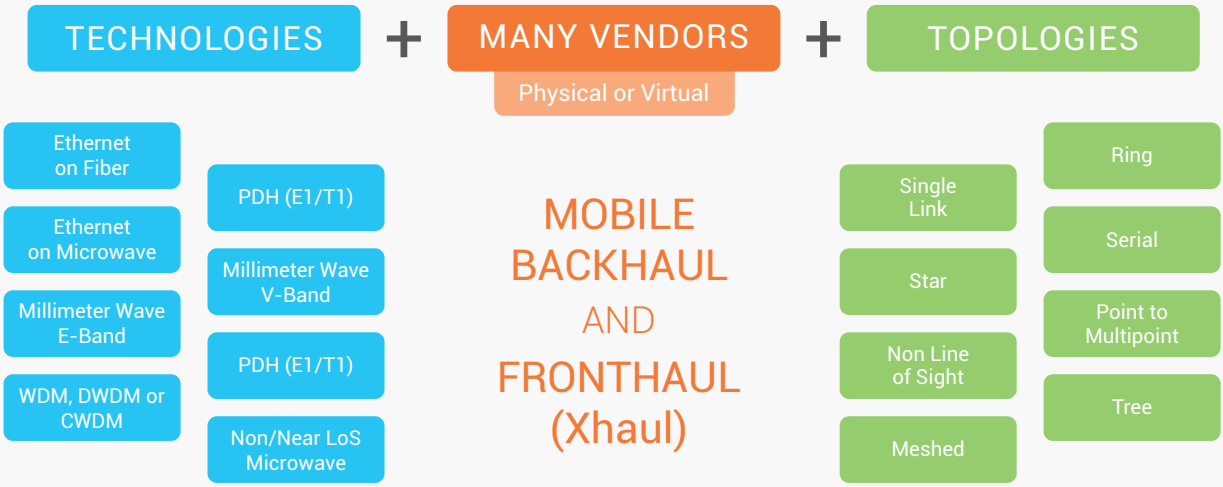


Figure 4. Complexity of the mobile network ecosystem

Implementing C-RAN with CPRI and eCPRI

As can be seen from the huge need for capacity, illustrated in the preceding sections, densification and virtualization of the RAN is a clear necessity. As intelligent data computing is brought to the mobile edge, realizing the concept of Centralized RAN, huge OPEX and CAPEX savings can be made by MNOs. In addition to fast processing, C-RAN also offers benefits such as resource pooling, increased virtualization, savings in energy and physical space, and more.

Heavy Reading cites CAPEX savings of 30% and OPEX savings of 53% at a large Asian MNO using the C-RAN concepts of RRH and a new BBU.

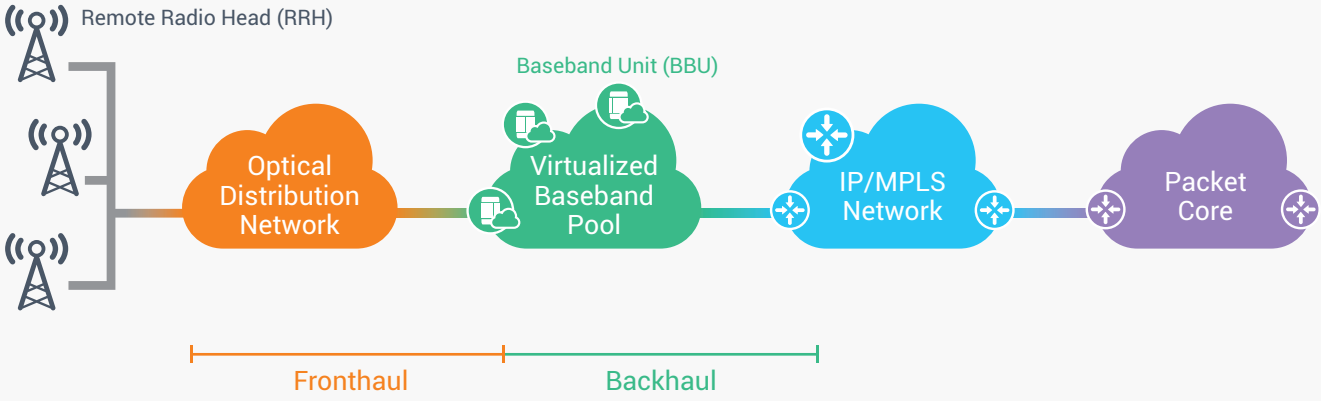


Figure 5. C-RAN, Fronthaul and Backhaul Topology

The next stage of RAN development - Cloud RAN – will deliver what can be defined as a RAN architecture with virtualized baseband functions (BBU), deployed on commodity servers. Some implementations of Cloud RAN could have virtual baseband functions physically centralized, however, Cloud RAN is also seen as a RAN network but with centralized and/or virtualized baseband units.

With C-RAN, new interfaces, such as CPRI, eCPRI or OBSAI, and several new nodes, such as the Remote Radio Head (RRH) and Base Band Unit (BBU) will be introduced.

Because C-RAN is at an early stage in the standardization process, definitions can vary. Most vendors define Cloud RAN as having some of the following features:

- Multi-technology support, spanning 2G to 5G, including macro cells and small cells;
- Capability to manage hybrid resources, both cloudified (virtualized) and physical;
- Dynamic, real-time RAN capacity scaling, dictated by customer behavior or need; and
- Support for 5G network slicing, allowing multiple digital services (such as connected cars, smart cities and IoT services) to be delivered over multi-technology layers for ultra-reliable, low latency or massive machine-type communications.

Since centralization involves moving Base Band Unit (BBU) from the mast to a common location that serves multiple masts, it provides immense economy of scale in terms of physical space, power and air-conditioning, thus significantly reducing OPEX. In addition, a pool of BBUs in a secure, centralized location also reduces truck roll and maintenance costs.

While CPRI is the interface of choice for carrying fronthaul traffic on fiber, eCPRI is being designed to support stringent 5G performance requirements (especially latency and jitter), and to offer Ethernet as a transport channel with the promise of a significant reduction in the required bandwidth. eCPRI also offers a real-time traffic interface, which supports the sophisticated coordination algorithms that guarantee the best possible radio performance. Analyst firm IHS Markit suggests the introduction of CPRI-based C-RAN technology will result in a 30% increase in bandwidth and potentially as much as 50% cost reduction when compared to LTE RAN.

Regardless of the transport technology adopted for the C-RAN fronthaul implementation, MNOs will gain significant benefits from processing the growing volume of traffic through minimized equipment. These benefits can be secured across different use cases, covering, for example, event venues, residential buildings, enterprise zones, or metropolitan areas.

- Resource pooling (BBU Pooling) for economies of space, energy, cooling, etc.;
- Greener infrastructure through a centralized location and re-direction of BBU for traffic loading and offloading;
- Base station virtualization (BBU), reducing CAPEX;
- Simplified management and operation over large RRH areas; and
- Reduced costs for deploying small cells.

However, while eager to benefit from C-RAN implementation, MNOs must also be aware of the challenges it can pose. For example, the new protocols (CPRI, eCPRI or OBSAI) will require careful monitoring and troubleshooting. As RAN fronthaul traffic throughput grows from current levels of between 1 and 2 Gbps to more than 20 Gbps on C-RAN infrastructure (with multiple Ethernet links, 100Gbps may be reached), careful and continuous monitoring will be required. Round-trip delays on the CPRI/eCPRI interface between RRH and BBU will also require monitoring and constant optimization. In addition, all RAN specific KPIs such as RF interference, utilization, mobility, and availability will also need to be assured, 24*7.

The Virtualization of RAN and Transport Networks as 5G Approaches

As Analysys Mason predicted in 2017, MNOs have begun to focus most of their 5G-related efforts on the non-radio aspects: C-RAN, increased fiber penetration and virtualized networks.

It is now clear that 5G also mandates a new transport system. This will be a hybrid of distributed RAN using Ethernet backhaul, a 4G C-RAN with a CPRI fronthaul, to be augmented with the new 5G C-RAN (virtualized RAN) using an eCPRI midhaul. These changes are geared towards delivering higher flexibility, more effective transport scalability, and better network performance.

When the RAN is fully virtualized, high spectrum efficiency will result and the network will offer extremely high levels of scalability. With virtualization /cloudification of the RAN, software-based BBUs will run on virtual off-the-shelf server machines. There is a clear trend for the virtualization and cloudification not just of networks, but also for all other associated products and services. According to Analysys Mason, network operator expenditure on cloud, network function virtualization (NFV) and SDN products and services will reach USD 11.9 billion by the end of 2017.

With cloudification of the RAN, proprietary, hardware-based BBUs will be replaced with software-based BBUs running on virtual machines. While some non-real-time BBU functions will continue to run as virtual network functions (VNFs) in the NFV cloud, others that are difficult to virtualize may continue to be deployed in physical infrastructure at the remote radio head (RRH). Surveys of MNOs (for example, from Heavy Reading) suggest that the number of C-RAN 'trailblazers' may reach 10% in 2017, as the benefits of flexible resource allocation, OPEX reduction and capacity improvement become more apparent to 5G aspirants. High bandwidth and low latency performance requirements between pooled BBUs and distributed RRHs have driven MNOs to build their first fronthaul networks using dedicated, direct fiber connectivity. Despite this, there will be challenges in maintaining performance

because of the stringent quality requirements of 5G services. Although C-RAN performance attributes that require service assurance are similar to those in the legacy LTE RAN (as defined by 3GPP), particular attention should be given to the following:

- VxLTE will be a key focus service running on C-RAN infrastructure from the outset. Sophisticated KPIs are needed for VxLTE accessibility, retainability, availability, and mobility. These KPIs are required for each network element supporting VxLTE. Special attention needs to be given to mobility metrics such as Inter-RAT handovers with co-existing RAN and C-RAN, and VxLTE roaming, due to non-standardized NFV adopted by different networks.
- Integration of RAN regional categories and groups, together with seamless drill down from higher levels for in-depth problem analysis. The assurance system should have the ability to view all sub-regional categories (such as RAN markets, RAN clusters and RAN super clusters) with similarly detailed analysis.
- BBU failures result in RRH cluster (area) outages, which means proactive monitoring and early detection are essential.
- Busy hour traffic reporting at the network element level (e.g., RRH, BBU) and service level (e.g., VoLTE, ViLTE etc.)
- Predictive network learning and alerting, using adaptive threshold capabilities to identify abnormal C-RAN performance. Usage forecasts over a period of time to help planning teams/orchestration systems plan scale-up or scale-down. Forecasting of traffic & services is vital for dynamic capacity handling (NB: every RRH addition means an additional fronthaul link)
- Utilization, uplink/downlink throughput, handover success rates, drop rates and other performance metrics for RRH groups and related BBUs.
- CPRI and eCPRI specific metrics: Ultra-low Bit Error Rates (10-12), low jitter and wander, and high data rates. Latency requirements are strict for CPRI (RTT of 5microsecs) and eCPRI, and require special attention.
- Identification of RAN versus Transport faults to reduce field truck rolls

As fronthaul traffic throughput grows from current levels of between 1 and 2 Gbps to more than 20 Gbps on C-RAN infrastructure, careful and continuous monitoring will be required.

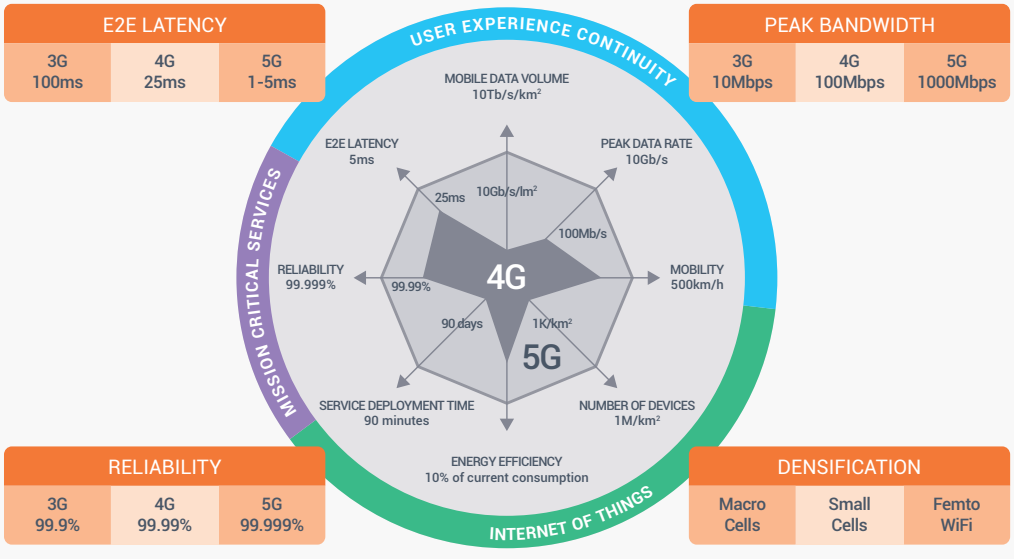


Figure 6. 5G RAN Performance Requirements

The build-up of 5G services

The increase in bandwidth requirements for current and future 5G services, means that an entirely separate fronthaul and backhaul will not cope with the new dynamic capacity and velocity requirements. However, considering the underlying transport network (Xhaul) as a single entity and utilizing its potential to deliver on the promise of service quality will not only offer the required resource optimization (and hence result in CAPEX optimization), but will also reduce the service rollout time (reducing OPEX).

Assuring 5G services such as Video-on-Demand (VoD), HD video-conferencing, TV broadcasting, IoT and other connectivity services, is critical as these services will increasingly depend on the delivery channels, i.e., the IP-ized Xhaul transport network. To meet 5G specific requirements (see Figure 6), it is imperative for the transport network to support high bandwidth, low latency, traffic aggregation, high resilience, and strict synchronization.

MNOs need to consider the multi-vendor, multi-technology transport network that is emerging and create a common data, control and management plane across all technologies to support pre-5G and 5G services.

A recent whitepaper from the European Commission shows that the next generation of 5G access networks will place higher demands on the mobile transport network. There are distinct MNO benefits in deploying cloud RAN in advance of the arrival of 5G as part of their preparation for the advent of new technologies and the services these will enable. The inherent capability of the cloud RAN to dynamically allocate resources as required will greatly facilitate 5G service deployment.

The new 5G radio access technology, C-RAN, is designed to fully support the service use cases illustrated in Figure 7 and to deliver the required QoS. However, what cannot be ignored is IP transport QoS which significantly contributes to the mobile backhaul and fronthaul supporting the C-RAN. Of key importance to maintaining IP QoS are several factors, such as assuring network latency (down to sub-microsecond), dynamic scalability, network timing, and clock synchronization.

It should also be noted that 5G network architecture is specified to leverage the principles of Software-Defined Networks (SDN) and Network Function Virtualization (NFV). Delivering high-QoS services over SDN and NFV will make transport network dependency higher, with virtual network devices dynamically provisioned in the network. For MNOs, this means that, while the pressure of implementing a Centralized/Cloud RAN is increasing, they also need to prepare themselves to assure voice and data quality of service over the C-RAN and new Xhaul network to support this complex transition.

To meet 5G specific requirements, it is imperative for the transport network to support high bandwidth, low latency, traffic aggregation, high resilience, and strict synchronization.

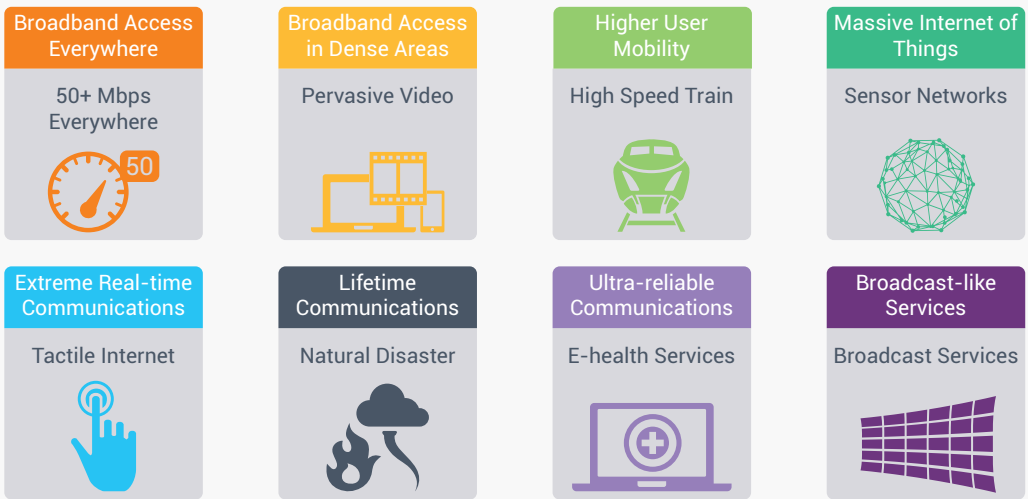


Figure 7. 5G Services

Assuring E2E Transport Performance as RAN centralizes and cloudifies

Legacy voice-oriented 2G (GSM) networks were deployed on extremely reliable, TDM/SDH backhaul. The deterministic nature of TDM/SDH meant that MNOs were able to easily manage the performance of their backhaul networks, using very simple fault management tools. With 3G (UMTS), MNOs adopted other technologies: hybrid deployments, in which TDM/SDH co-existed with IP/MPLS, ATM, and even Ethernet-based backhaul, as illustrated in Figure 8.

This transition required new, specialized performance management tools to manage the IP and Ethernet layers of mobile backhaul, since critical parameters such as bandwidth, delay, jitter and availability could not be guaranteed (and therefore needed close monitoring) in this environment. For other transport layers, MNOs continued to use basic tools alongside the element management systems (EMS) provided by vendors to monitor the backhaul. The arrival of LTE, LTE-A, and newer technologies such as VxLTE, have already forced MNOs to upgrade their mobile backhaul so that speeds up to 1Gbps per site can be supported. With speeds in tens of Gbps, this will need to change.

Additionally, many MNOs observed that the non-deterministic behavior of the lower microwave and optical layers of the network could also have a dramatic impact on overall service quality levels, especially with Xhaul capacity moving to tens of Gbps speeds. For example, the throughput of a microwave link can vary with weather conditions (modulation x throughput), which may result in

Near Real-Time Multi-Layer Troubleshooting

Analyze how the transport layer(microwave or fiber) is impacting the Xhaul IP/MPLS or Carrier Ethernet circuits and troubleshoot complex cross-layer issues, reducing MTTR and increasing network uptime.

Automated Topology Discovery

Support dynamic digital operations, which involve creation and teardown of services and dynamic orchestration of network elements and links, through auto-discovery of topology changes and its regular feed into network performance KPIs and dashboards.

Cross-Domain Visibility

A single pane of glass for integrated visualization of all Xhaul transport and RAN domains so that network issues and degradations can be easily identified across the multiple transport and RAN domains, and remediated using a top-bottom approach.

Accurate Capacity Planning

Proactive trending and forecasting capacity usage of fronthaul and backhaul networks for upscaling and downscaling of capacity so that network costs are optimized. This includes exporting traffic KPIs to planning tools.

C-RAN Service Assurance Features

Assure C-RAN QoS parameters and resource forecasting for BBUs, fronthaul links etc., based on an open data mediation system that covers all network devices in the access and core networks of a hybrid, multi-vendor ecosystem.

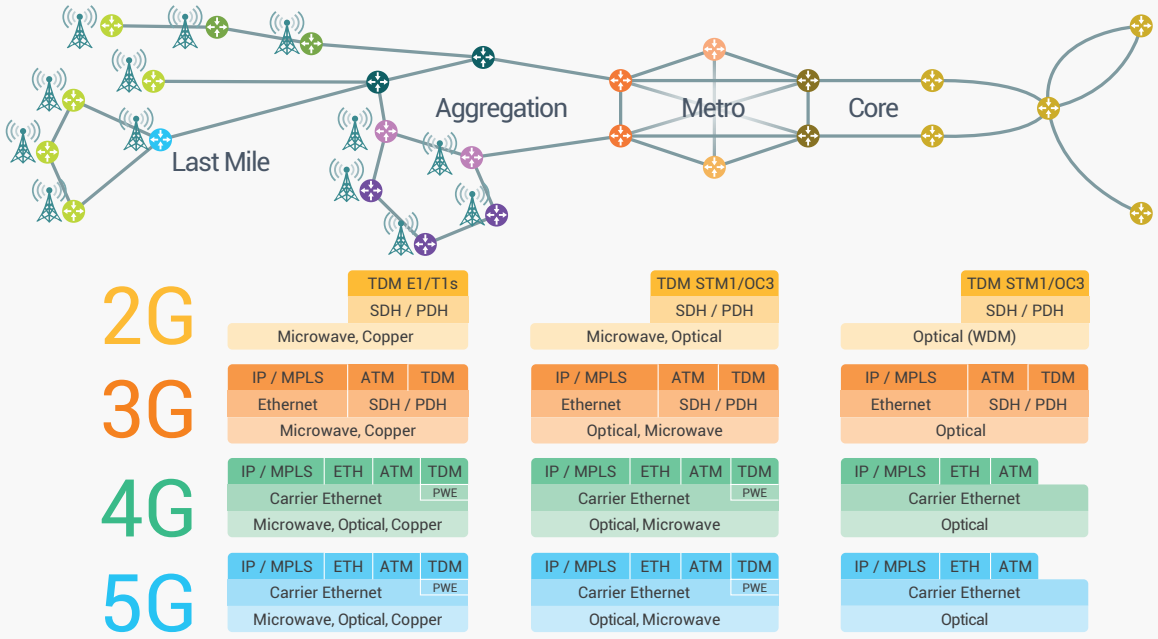


Figure 8. Evolution of Mobile Technologies

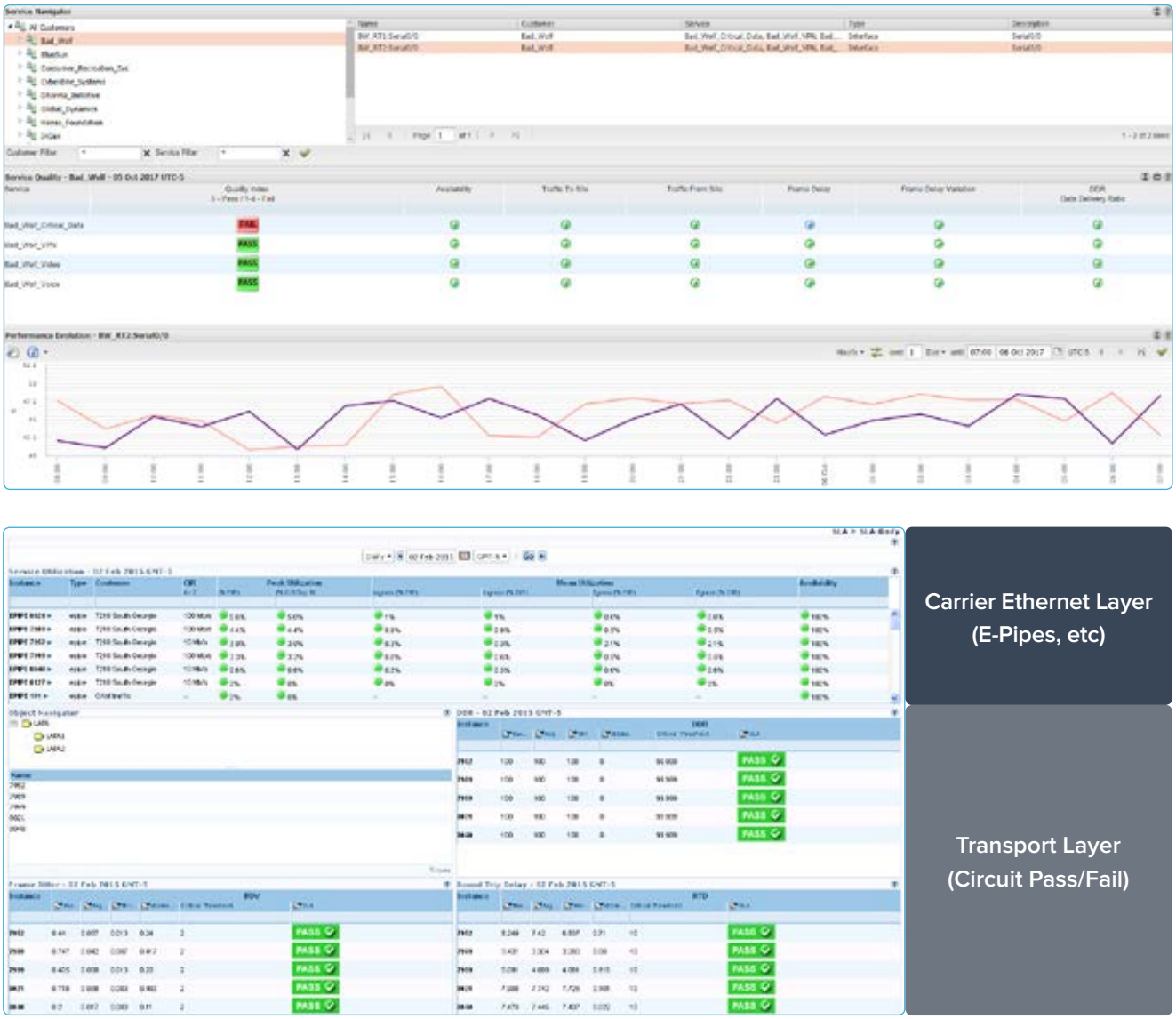


Figure 9. Visualization of Performance of Multiple Network Layers

sub-optimal performance, which, in turn, affects the upper IP/MPLS and Carrier Ethernet network layers. With a larger and less predictable backhaul to manage, the legacy approach of simpler tools to monitor backhaul performance using fault management and multiple vendor EMS tools, has already become inadequate.

Today, with the rollout of NFV, the advent of 5G, the introduction of C-RAN, and new nodes and interfaces, the need for a new, more stringent transport network service assurance has increased. As MNOs adopt C-RAN and fronthaul ahead of 5G introduction, they need a consolidated (and more advanced) end-to-end transport management solution that assures both fronthaul and backhaul (Xhaul) in a holistic way.

In a recent Heavy Reading survey, key MNOs ranked end-to-end service visualization and root cause analysis as their highest priority for service assurance in an NFV environment.

The solution should provide visibility of service quality using a configurable index based on negotiated customer SLAs. It should automate provisioning of customer and service data, based on the MNO operations (inventory manager, EMS, etc.) that are critical to achieve service level reporting, especially within an SDN context. One important measure that can be obtained is Network Quality Indicator (NQI), which provides an indication of end-to-end network health.

Monitoring and assuring the performance of the multi-technology backhaul and fronthaul networks has become a mission critical task for MNOs. It is necessary in order to protect and grow their revenues as they deploy next generation technologies. In order to be successful, they need to adopt more dynamic and real-time assurance systems to assure their networks and services. In particular, the following key requirements must be observed:

Near Real-Time Multi-Layer Troubleshooting

Often network operation teams (including the NOC and SOC) do not have a complete understanding of how each network layer is affecting the other. For example, whether the transport layer (either microwave or fiber) is affecting the Xhaul IP/MPLS or carrier Ethernet circuits. Root Cause Analysis can be conducted faster for performance degradation troubleshooting in cross-silo and cross layer networks.

For this, they need near real-time visibility into each individual network, as well as consolidated cross-layer performance reports, that will allow them quickly to detect which specific layer of the backhaul and fronthaul is causing a network outage or degradation.

Since many different vendors and different technologies co-exist in the network, the Xhaul service assurance solution must be able to collect raw network performance data from different sources and vendors, either from the network devices themselves or by integrating with their respective vendor EMS.

The solution must then be able to collect and process vast amounts of data (in other words, be scalable), leveraging automation to provide network operation teams with real-time reports and alarms to help detect and diagnose complex cross-layer issues, thus reducing time to repair and increasing network uptime.

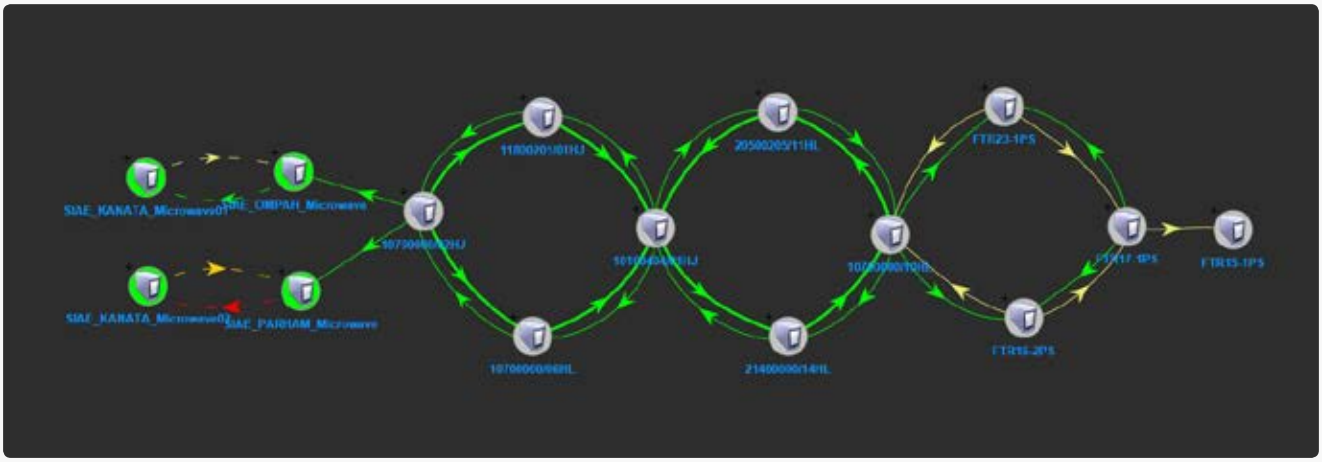


Figure 10. Multi-layer Troubleshooting

Automated Topology Discovery

The backhaul and fronthaul will both continue to grow and evolve. As the RAN becomes denser with deployment of more Small Cells, the integrated Xhaul will require dynamic management.

Today, mobile network devices are added, removed or relocated almost on a daily basis. Soon, network elements and links will also be dynamically configured (for L1, L2 and L3), to support digital operations and digital services. This presents a challenge on two fronts:

First, network performance dashboards must correctly indicate network changes, so that network operations team can be sure that they have a correct representation of the real network. Second, all network KPIs (key performance indicators) must also accurately reflect these changes.

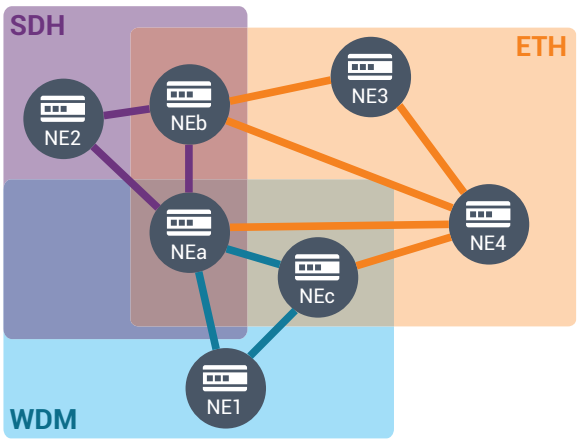


Figure 11. Overlapping Xhaul topologies

For instance, MNOs use aggregated KPIs to monitor performance quality at the cluster, city, regional and even, country-wide level. When a new device is added or removed, the solution must be able to automatically report changes in these grouped KPIs. Thus, if a site is added,

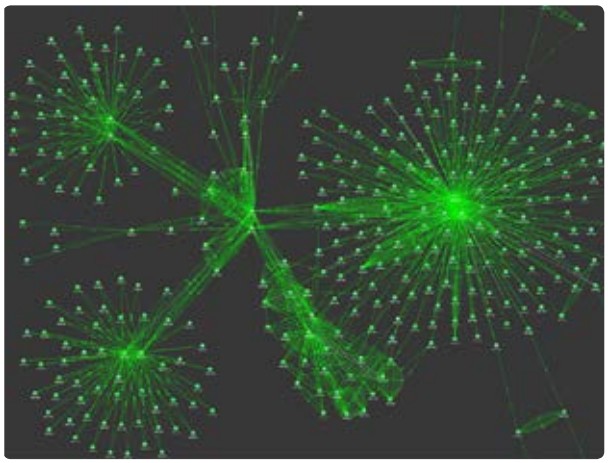


Figure 12. Managing complex Xhaul topologies

MNOs will need its status and traffic to be included in the calculation of the KPI of the respective cluster and to be located within the appropriate geographical hierarchy.

Legacy assurance tools often require MNOs to manually maintain the formula of higher-level group KPIs. With the expansion of backhaul into the Xhaul, capacity growth, increasing complexity and new dynamicity, this is no longer viable. A modern service assurance system must automatically handle these changes, so that the NOC and SOC can focus on monitoring the network, rather than expending time and energy manually cross-checking and correcting grouped KPIs.

As MNOs adopt C-RAN and fronthaul ahead of 5G introduction, they need a consolidated end-to-end transport management solution that assures both fronthaul and backhaul (Xhaul) in a holistic way.

Cross-Domain Visibility

The complete, integrated Xhaul transport network is composed of different network domains (access, aggregation, metro). It is essential that these domains be monitored as a cohesive service delivery chain, so that network operations can monitor performance parameters on an end-to-end basis, as well as be able to quickly detect which part of the Xhaul is responsible for causing a service outage or degradation.

However, while necessary, monitoring the Xhaul domains alone is not sufficient. For instance, a mobile subscriber who makes a phone call, relies on the fronthaul, backhaul and core networks working in synchronization. Problems with dropped calls in a region of the C-RAN may be caused by lost packets in a fronthaul link far away. Different network domains can also affect performance of others, making service quality issues much more difficult to isolate and diagnose.

With unconnected, siloed tools and only partial visibility into different domains, it is extremely difficult to measure end-to-end quality parameters, let alone quickly detect and solve quality problems that involve multiple networks. In this scenario, service outages and degradations are often detected only after customers complain. To avoid this, mobile operators need to consolidate their discrete service assurance systems into a single, unified platform that consolidates the assurance functions, using open APIs in an operator ecosystem. Such a solution can assure, not only the mobile fronthaul and backhaul, but also the C-RAN, the core and other relevant network domains, including those that have been virtualized or remain as physical entities.

Figure 13. Visualize Multiple Network Domains in a Single Pane of Glass

The system should be able to display the relevant performance of all domains in a single pane of glass. The reporting interface must be multi-tenant, graphical and easy-to-use so that one or multiple teams can work together and accelerate the time to resolution of these more complex cross-domain scenarios. Figure 13 illustrates such a solution.

Accurate Capacity Planning

The correct planning of backhaul and fronthaul channel capacity is critical for MNOs. Providing oversized channels may prevent capacity issues, but can result in significant additional costs in maintaining the transport network. On the other hand, under-sizing the Xhaul may result in the risk of creating performance bottlenecks in the network. Right-sizing the backhaul and fronthaul circuits, however challenging, needs to be performed on a continual basis to optimize network costs.

Right-sizing requires the monitoring of the evolution of traffic KPIs and trends, and the extrapolation of historical data to predict the network load in the future (for example, in 3 months' time). The data must be used to act pro-actively to adjust backhaul and fronthaul links, by either upgrading or downgrading their capacity as required.

Another key requirement for successful right-sizing is the ability to export live network traffic KPIs to external planning tools, thus enabling planning and engineering teams to increase accuracy when designing new parts of the network, or expanding existing sites.

Mobile operators need to consolidate their discrete Service Assurance systems into a single, unified platform that consolidates the assurance functions, using open APIs in an operator ecosystem.

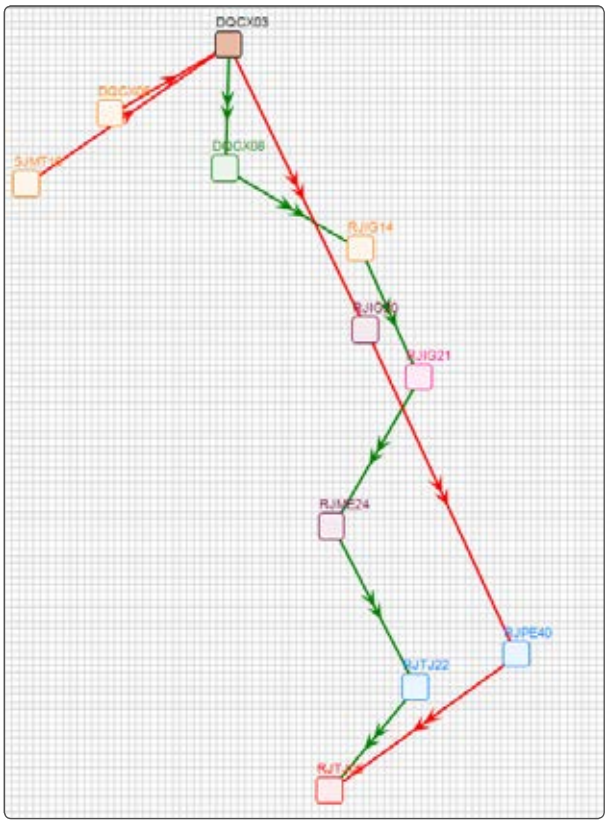


Figure 14. Right-sizing mobile backhaul circuits

C-RAN Service Assurance Features

There are 5 key C-RAN Assurance capabilities that need to be considered to assure high quality.
These are:

- Fronthaul Integrity: this translates into strict requirements for latency, jitter and synchronization, for which pro-active monitoring is necessary. If fronthaul data is collected from different EMS systems, then ensuring the integrity and normalization of the EMS and KPI data is also important.
- Resource forecasting: for events, venue and metropolitan deployments, there is a critical need for analysis of the usage, behavior and network retainability. This ensures that the resources within the BBU and core are capable of handling traffic during peak hours, special events, and for load steering. This data also enables engineers and automation systems to add or reduce network resources accordingly. It also helps to understand the impact to the network/ BBU/ RRH/ Link when the RRHs are dynamically switched.

- Cross-Domain Troubleshooting: when problems are detected in the network, engineers need to ensure fast MTTR by identifying and isolating the issue in a timely manner
- End to end quality/NQI/CQI: for indicators of high-level quality status of the entire network
- Open, flexible mediation: it is critical for the service assurance system to have a mediation layer that can monitor all network devices (legacy and future) for the access and core networks, in a multi-vendor ecosystem. This offers immense dynamic optimization/customization opportunities for adaptation to the changing network environment, especially in NFV/SDN domains. MNOs can benefit hugely from responding to customer service and network orchestration needs.

These mediation requirements were also noted in a 2017 survey conducted by Heavy Reading. The survey ranked service assurance challenges in NFV networks, and identified as being critical:

- Assuring performance over multi-vendor VNF chains;
- Delivering on-demand SLAs; and
- Dealing with poor/non-existent APIs between OSS and NFV Orchestrators

Business Benefits and ROI

In this paper, we have emphasized a number of key points. First, the growing importance for MNOs to assure mobile C-RAN based fronthaul and backhaul performance. Second, the essential need to treat them as a single entity for service assurance to protect the increasing data revenue along with voice. Third, how this is becoming ever more critical as networks grow and evolve to support advanced NFV-based digital services as well as future 5G services, which include IoT services that are dependent on network slicing.

Heavy Reading's survey, "Mobile Network Outages and Service Degradations", confirms that MNOs agree with this. They consider network performance (in particular network failure and congestion) to be the issue that affects consumers the most, with poor performance resulting in a bad experience and contributing to increased subscriber churn.

The adoption of a single service assurance system assures the IP QoS of the mobile fronthaul and backhaul, that is so critical to the success of NFV and 5G services, in a number of ways:

- Mitigation of network outages and service degradations, ensuring better customer quality of experience (QoE), and reducing subscriber churn;
- Prevention of direct revenue loss, due to an inability to capture revenue from billable minutes (lost voice minutes and data MB due to network unavailability); and
- Rationalization of costs via a number of direct and indirect CAPEX and OPEX gains, including:
- Reduction in the number of OSS tools and associated operational and maintenance costs
- Reduction of all direct and indirect costs associated with network troubleshooting, such as the reduction of field tests
- Reduction of regulatory intervention and fines; and other financial provisions reserved to deal with the fall out of more severe or widespread service outages and degradations
- Right-sizing the network for better allocation of CAPEX, which includes the ability to identify parts of the network that are – or will be – over- or underutilized
- Guarantees of capital protection by investing in a long-term strategic platform that evolves and supports all current and all future networks.

The Heavy Reading survey is also a good starting point to start to quantify the benefits of a unified performance solution for a ROI study. Specifically, the survey presents a list of the main causes of network outages and degradations, which a performance solution, such as that proposed in this paper, can help to mitigate.

Critical Service Assurance challenges in NFV networks include assuring performance over multi-vendor VNF chains, delivering on-demand SLAs, and dealing with poor/non-existent APIs between OSS and NFV Orchestrators.
(Source: Heavy Reading Survey, 2017)

Complaint/Tickets	Impact	Integrated Service Assurance
Related to Network Failures	Significant	Quicker detection and accelerated time-to-repair, especially when the solution monitor all layers of the network simultaneously. This enables the pro-active NOC, and allow the mobile operators to act before clients start calling to complain.
Related to Network Congestion	Significant	Quicker detection and congestion prevention. This is critical in IP convergent technologies when network resources are shared between voice and data. Trend analytics and abnormal behavior detection can prevent problems before they happen.
Related to Service Enablers/Activation	Moderate	The system can seamlessly integrate with other provisioning components of the BSS and OSS, so to automatically start monitoring the services once the network is provisioned.
Related to Network Configuration Issues	Moderate	Network performance KPIs often indirectly help diagnose this case, for instance, by correlating CPU overload with interface overload or increasing number of dropped packets.
Related to Application Server Issues	Moderate	A full end-to-end cross-domain solution can also monitor the datacenter and VAS infrastructure, allowing the mobile operator to isolate application caused problems from network problems.
Related to Customer Device Issues	Moderate	Modern solution can be integrated with other tools, for instance call-tracing tools, to enables correlation between network problems and type of customer device (requires integration)
Related to Malicious Damage	Low	Performance managements system cannot prevent this kind of problem

Figure 15. Impact of unified service assurance on network outages and degradations.

The “Significant” and “Moderate” qualitative assessment described in the table above could be converted into quantitative assessments and hence be made more useful through a ROI calculation.

For example, let us assume that an MNO knows, or can measure, the total number of trouble-tickets they receive for each kind of network performance issue (such as those detailed in the significant and moderate impact column in Figure 15). Let us further assume that the MNO could also estimate the potential reduction in numbers of tickets for each category by using a unified network performance monitoring tool. By doing so, the MNO could extrapolate the results to determine a reduction factor in churn rate, and from that, estimate associated protected revenues.

For example, a hypothetical MNO has 25 million subscribers, an ARPU of $15.00, and an average churn rate of 1.0%. Of these, 30% leave the operator specifically because of network quality problems, while the other 70% churn for other reasons, such as price.

Finally, let’s assume that – after giving proper weights and percentages in the survey list we discussed above, the mobile operator concludes that the new service assurance tool can help to reduce by 10% the number of cases in which trouble-tickets resulted in subscriber churn.

Using these parameters and some trivial calculations, we can then conclude that the solution could protect up to $112,500 of revenue per month, as illustrated in Figure 16, below.

Revenue Loss Due Poor Service Quality (Churn)	
Voice and data services	Mobile Pre-Paid
(A) Subscribers (Total)	25.000.000
(B) Average ARPU ($)	$15,00
(C) Total Churn Rate (%)	1,0%
(D) Churn Rate due Poor Service Quality = 30%*(C)	0,30%
(E) Reduction in tickets that result in Churn -> Survey Table Analysis	10%
(F) Churn Reduction w/ Unified Assurance = (D)*(E)	0,03%

Figure 16. Calculating the ROI – An Example

There is another important consideration. Modern service assurance solutions have evolved to support different business models, from the traditional licensed-based model, to managed service offers and fully cloud-hosted as-a-Service (aaS) models. The latter two models, in particular, can significantly reduce TCO and deployment times, thus accelerating ROI.

In some cases, these new business models are increasing the affordability of cutting-edge service assurance solutions – such as the ones we discuss here and are making them more accessible to smaller MNOs. They are also more appealing to MNOs of all sizes that may, perhaps, have postponed this necessary investment due restrictions in CAPEX allocation.

Conclusion

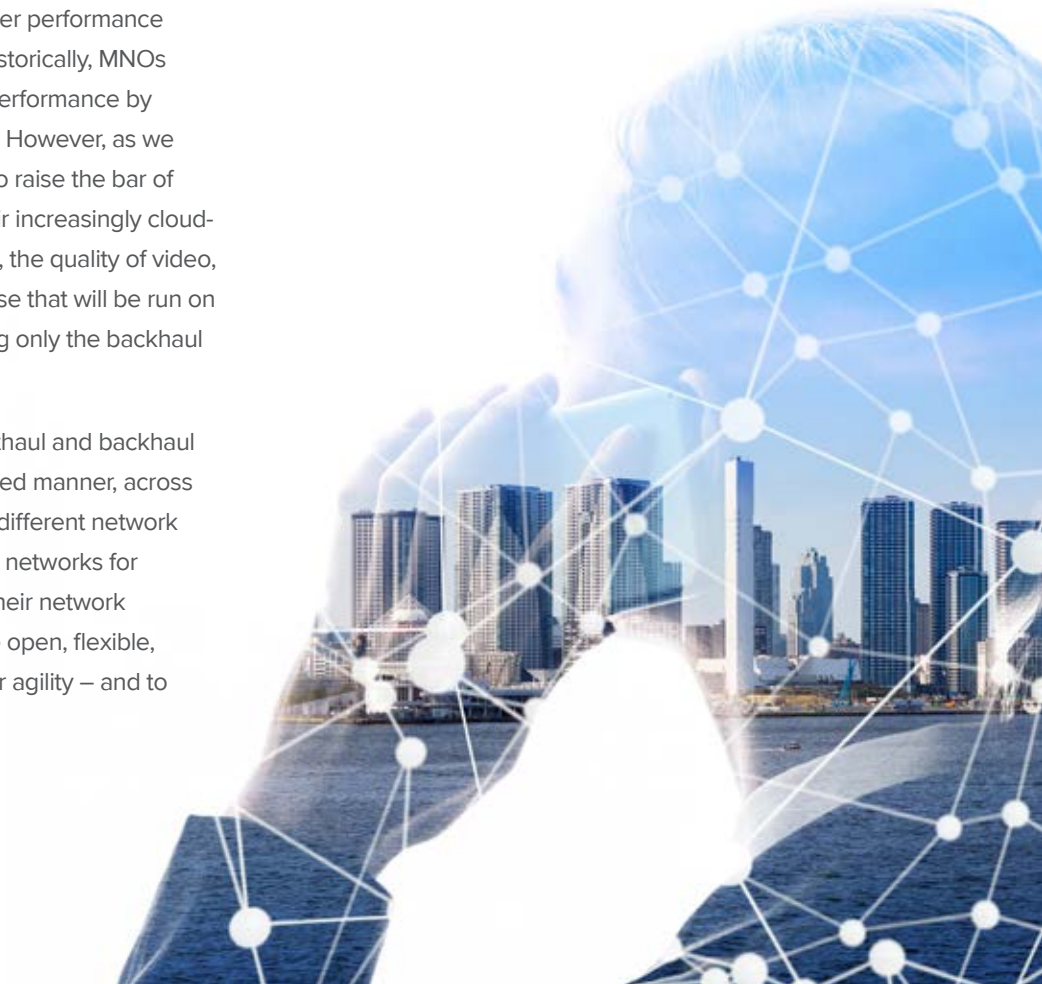
With continuing rollout of NFV and the imminent deployment of 5G technology, mobile networks are evolving to become dynamic, hybrid (physical and virtualized) networks, operating within a complex digital ecosystem. Their technical and commercial success is heavily dependent on the QoS delivered from increasingly IP-ized transport networks. The forthcoming technology of network-slicing that will support enterprise and industry-vertical SLAs, as well as always-available, high reliability, low latency IoT services, requires greater performance from underlying transport networks. Historically, MNOs have been able to manage backhaul performance by using a range of relatively simple tools. However, as we discussed in this paper, if MNOs wish to raise the bar of assurance to support the quality of their increasingly cloud-based, virtualized and hybrid networks, the quality of video, data and voice services, especially those that will be run on a Centralized/Cloud RAN, then assuring only the backhaul network is no longer sufficient.

MNOs need to assure end-to-end fronthaul and backhaul performance in real-time, in an integrated manner, across different network domains and across different network layers. MNOs also need to assure their networks for resilience, and scalability by evolving their network performance systems to become more open, flexible, ecosystem-friendly, and to offer greater agility – and to unlock the potential of the NaaS.

To realize the benefits of their existing backhaul and new fronthaul investments, MNOs should look for performance assurance solutions that offer real-time, multi-layer troubleshooting, automated topology discovery, cross domain visibility, accurate capacity planning, and more.

A service assurance system now needs to offer transport SLA capabilities, together with real-time analytics. As multiple sources of customer data flow through the hybrid NFV based network, it will be critical for MNOs to normalize and assess multi-technology and multi-vendor network performance in real-time. This requires a service assurance system that offers unique capabilities for data normalization and real-time service assurance in complex, hybrid ecosystems.

With a ready to deploy and easy to operate, cloud-based service assurance solution, realizing the benefits of such strategic investments is easy. Not only do such systems operate seamlessly, they enable the management of the QoS required to successfully rollout new services that demand high bandwidth, scalability and availability. In order to propel an existing 3G/4G MNO seamlessly into the emerging NFV and 5G network domains, assuring the C-RAN together with the underlying Xhaul in an integrated manner will deliver the desired high QoS and help to secure the anticipated higher revenue for MNOs and minimize revenue leakage from churn.



KNOW YOUR NETWORK™

About Infovista

Infovista, the leader in modern network performance, provides complete visibility and unprecedented control to deliver brilliant experiences and maximum value with your network and applications. At the core of our approach are data and analytics, to give you real-time insights and make critical business decisions. Infovista offers a comprehensive line of solutions from radio network to enterprise to device throughout the lifecycle of your network. No other provider has this completeness of vision. Network operators worldwide depend on Infovista to deliver on the potential of their networks and applications to exceed user expectations every day. Know your network with Infovista.