Small Cell Backhaul Performance Assurance

From install to ongoing operation & optimization

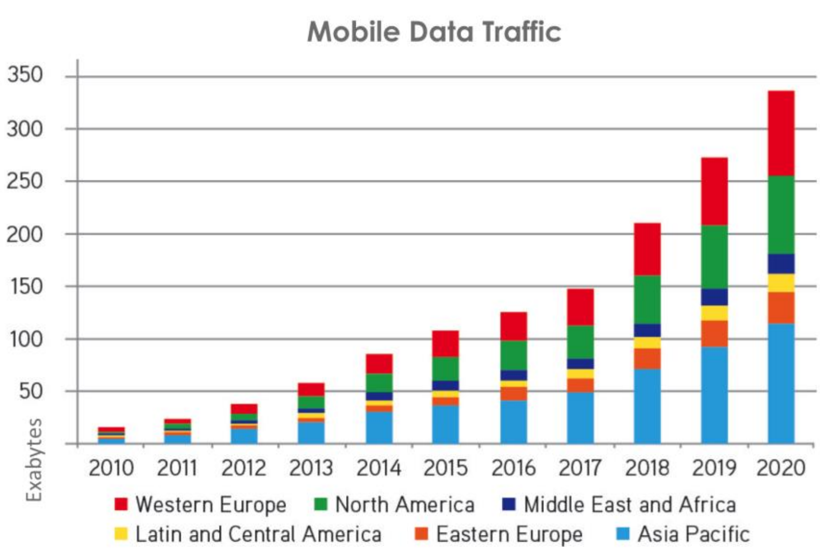
Small Cells – Big Impact

There is no doubt we are attached to our mobile devices, to the point where they now outnumber the global human population. Mobile data will increase 1000-fold between 2014 and 2020[1], with users expecting service quality to keep in step. RF capacity has its limits, and is unable to keep up with demand unless a new radio access model emerges.

Mobile access networks are strained to maintain quality as more subscribers run bandwidth-intensive applications from a variety of devices. With the annual throughput of mobile traffic expected to increase from 58 Exabytes in 2013 to roughly 335 Exabytes by 2020[2], brute-force over-provisioning of bandwidth is no longer an economically feasible solution. Operators must implement strategies to meet growing quality of experience (QoE) expectations even in the face of finite spectrum.

Mobile Data Reality

- **Spectrum is finite:** increasing macro cell capacity is not a scalable option.
- **Smartphones = 70%** of mobile traffic[1].
- **80%** of mobile traffic **originates indoors**.
- The femtocell market is expected to grow from $304.8m in 2013 to **$3.7bn by 2020**[3]
- QoE expectations increasing - **5 bars**: **everywhere**, every time, every device.



Annual Global Throughput of Mobile Network Data Traffic by Region 2010 – 2020 (Exabytes)[2]

Sources: (1) Nokia Solutions and Networks 2013, (2) SNS Research, The HetNet Bible (Small Cells and Carrier WiFi) – Opportunities, Challenges, Strategies and Forecasts: 2013 – 2020, (3) Femtocell Market (Types, Technology, Applications and Geography) – Global Analysis, Trends & Forecast through 2020

May 2014

Small Cell Reality

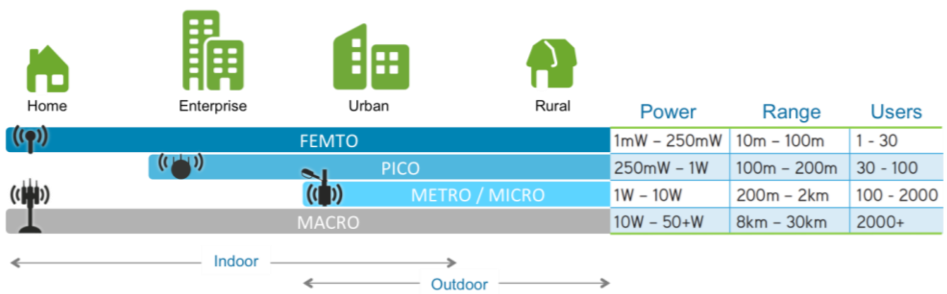
- The small cell backhaul market is expected to **grow to over $5 billion** in 2018 (ABI Research)
- Infonetics expects a cumulative **$3.6 billion** will be spent worldwide on outdoor small cell backhaul equipment between 2013 and 2017[7]
- **$43 billion** will be spent on macrocell backhaul equipment between 2013 and 2015 (Infonetics[7])

Small cells are the answer to dramatic mobile traffic growth, but new challenges in the backhaul accompany them. Small cells allow operators to spatially share precious spectrum, operating inside the macro cell footprint and effectively bringing the network closer to the majority of users indoors and in highly dense urban areas. Unlicensed spectrum, including WiFi, also relieves licensed-band saturation, and small cells typically employ multiple technologies to scale their capacity.

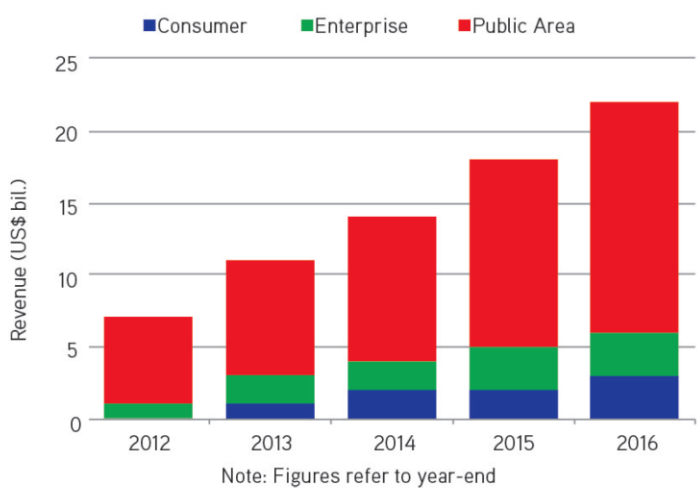
The solution is as effective as it is necessary. Mobile operators will deploy 5 million small cells annually by 2017[3], where over half of mobile traffic will be carried by more than 62 million small cells worldwide[4,5]. ABI Research forecasts 125% year-on-year growth of units shipped in roughly the same timeframe for a $3.6 billion market[6].

HetNet Composition

Heterogeneous mobile networks, or HetNets, are the combination of many types of small cells, including femto, pico, metro cells and WiFi access points. Each cell type is characterized by the number of users supported in a given range with a specific power level. By pushing network access closer to customers, small cells offload traffic from traditional base stations and deliver right-sized coverage from the home, enterprise and metro area to remote locations underserved by macro cells.



With coverage and increased access speeds comes revenue, largely driven by enterprise and high-traffic public areas, where mobile utilization is on the rise. Indoor femto cells, a common practice, will see slower growth as neighborhood pico cells find wider deployment.



Sources: (3) HetNet Forum 2014, (4) Informa 2013, (5) Ibtd 2013, (6) http://www.rcrwireless.com/article/20130722/wireless/hetnet-news-abi-sees-small-cell-market-rebound, (7) Infonetics Research, Small Cell Mobile Backhaul Equipment Bi-Annual Market Size and Forecasts 2013

New business models are also emerging. Small Cells as a Service (SCaaS) and host-neutral distributed antenna systems (DAS) can increase revenue for Alternate Access Vendors (AAVs) and fixed-line ISPs traditionally providing last-mile backhaul access to mobile operators.

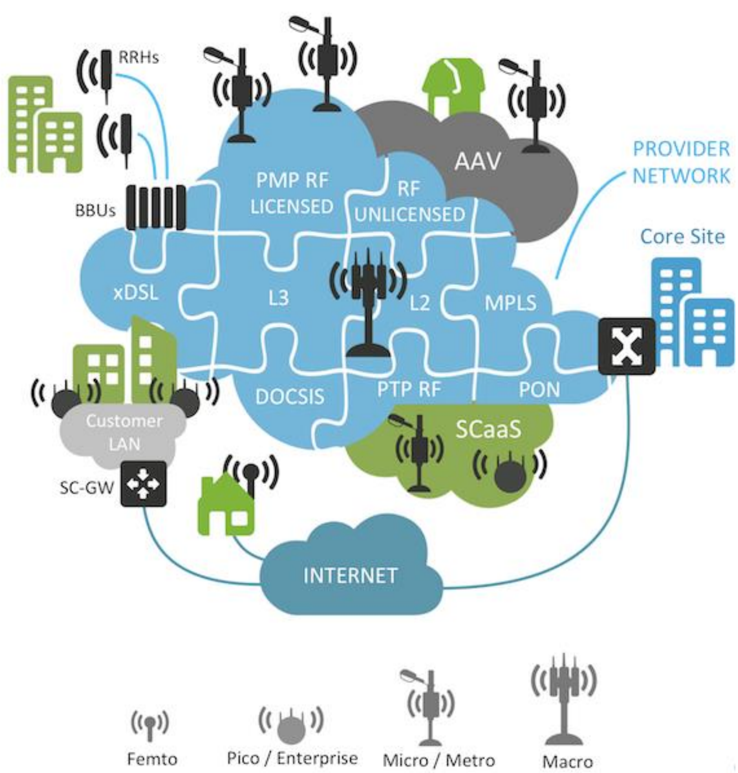
It's clear small cells increase Quality of Service (QoS), customer retention and utilization by ensuring customers have the signal strength necessary to continue a call or load a video. Ensuring customer QoE is an operator's key differentiator, and so accelerating time to market is critical.

Performance assurance solutions, right-sized to fit the demanding business model of small cells, can accelerate deployment, assure quality and optimize performance in the highly dynamic world of HetNets and self-organized networks (SON).

Diverse Backhaul Architectures: It's all about data traffic offload

The ongoing proliferation of LTE and small cell solutions is transforming the architecture of backhaul networks. Offloading large amounts of mobile traffic is the key when it comes to backhaul efficiency and performance. As the backhaul chain reaches further out to the service edge, simple hub-and-spoke models can no longer keep up with today's stricter latency requirements and more frequent roaming between cells covering ever-smaller areas.

Meshed architecture models, such as Enhanced Packet Core (EPC), move backhaul to layer 3 and enable inter-cell communication to more efficiently handle data and signaling traffic. Up to 80% of traffic can be offloaded during peak usage periods[8], more than doubling macro cell and backhaul capacity[9]. Macro cells need to retain capacity for mobile users in transit (to minimize handoffs) and to serve areas where small cells aren't installed.



Example of HetNet Backhaul Diversity

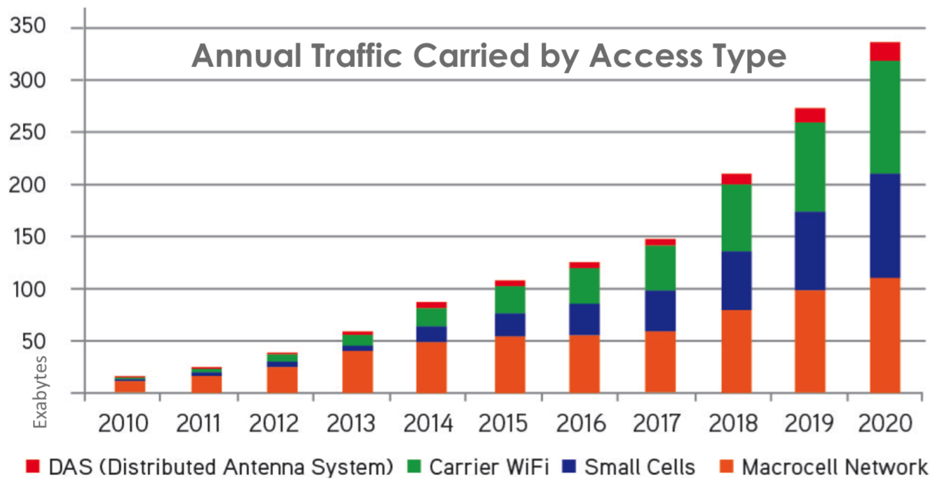
Sources: (8) Alcatel-Lucent 2014, (9) Huawei Field Studies, 2014

Offloading to small cells also means offloading to new backhaul networks – either extensions of the macro backhaul, or new ways of reaching the small cell altogether. A diverse range of technologies are being put to use to meet cost objectives and coverage, including licensed and unlicenced point-to-point (PTP) and point-to-multipoint (PMP) microwave links, FTTx, xDSL and DOCSIS, and even customer owned LANs and internet connections.

All of these new backhaul technologies are required to meet the growing demand for data hungry devices. They also introduce new challenges to maintaining the QoS required to provide a seamless user experience.

Small Cell Backhaul Performance Matters

The Majority of traffic will be carried by small cells by 2016



SNS Research, 2013

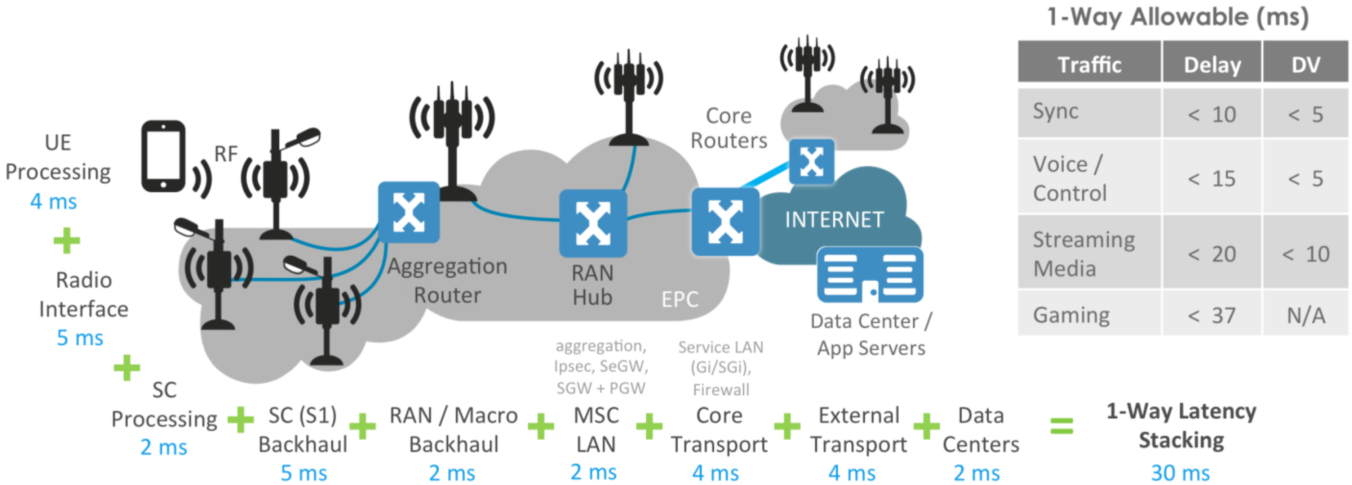
While DAS solutions are currently used to provide wireless coverage for fixed applications (such as office buildings, convention centers, train stations, etc.), they require the installation of heavy RF cabling to connect all the antennas – increasing the cost and complexity of the installation and on-going maintenance.

Small cell solutions, on the other hand, can leverage a Cloud RAN (C-RAN) architecture that centralizes the processing of mobile Remote Radio Heads (RRH) across cloud-based data centers using the common public radio interface (CPRI) protocol.

This approach is quickly becoming the defacto approach to areas where high antenna density is required (e.g. office towers, stadiums), as it allows for the efficient coordination of handoffs, and results in compact macro cells that are easier and less expensive to install and maintain. As a downside, fiber links are required to handle capacity requirements of the CPRI-encoded signals.

Small Cell Backhaul: Diminishing Performance Margins

Small cells come with significantly different deployment challenges than macro cells, but require the same or tighter performance. The added backhaul transport and processing latency introduced by further hops to user equipment (UE) can easily exceed allowable delays for cell timing sync, voice and control plane traffic if the backhaul is not carefully designed and monitored.



1-Way Allowable (ms)

Traffic	Delay	DV
Sync	< 10	< 5
Voice / Control	< 15	< 5
Streaming Media	< 20	< 10
Gaming	< 37	N/A

With this tighter operating envelop comes the shear volume of small cells that must be deployed, and the fractional contribution each makes to revenue. Installation, configuration, service activation and optimization need to be nearly zero-touch, and need to be done right the first time. CapEx and OpEx pressures on small cell deployments demand it.

A typical 1-way delay can amount to 30 ms under high-use conditions, negatively impacting sync, voice, control plane and media streaming – ultimately impacting QoS and customers' QoE.

Dynamic Threats to QoS

Shared Interference

It's not just longer backhaul chains that threaten the QoS of small cells. The very nature of installing a small cell within the coverage of the macro leads to a variety of dynamics based on shared resources: shared spectrum, shared backhaul, shared infrastructure in the case of multi-operator installations, and cells fending off interference in unlicenced, public WiFi bands. And there is also interference from the macro cells themselves – a common issue when transmissions from two cells terminate on closely located UEs.

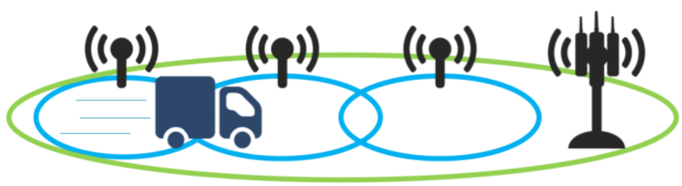
Multi-Radio Small Cells

Backhaul utilization is highly dynamic – not just by time of day, week or year, but also from UEs switching from a lower-capacity carrier to a faster one in multi-band cells and roaming between them. Each transition can create a step in bandwidth demand at any one location, compounded by bursting traffic as TCP negotiates increased transmission rates in backhaul networks with varying capacity and utilization.

- 66% of small cells will combine 3G, LTE-FDD / TDD & WiFi carriers by 2017 (Infonetics, 2013)
- backhaul utilization 'step' disruption with intra-cell hand-off:

Increased Hand-Offs

QoS is also threatened by frequent handoffs between neighboring small cells or from small cell to macro, even potential ping-pong scenarios. UEs in transit through a cell field, for example from a train or elevator in an office tower, can generate significant signaling messages as handoffs are negotiated inter-cell over the X2 interface or by the Mobility Management Entity (MME) at the mobile switching center (MSC), disrupting QoE or even dropping sessions entirely.



Network Access Closer to Customers

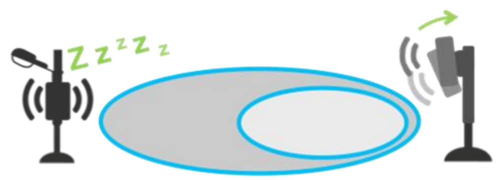
As networks move closer to the users, and backhaul fans out deeper to support many more endpoints, operators lose the performance monitoring visibility they rely on to support macro cell QoS and ultimately, the customer experience. The shear number of inter-connecting cells – and 15 small cells per macro is typical – means more subtle traffic pattern shifts and less visibility.

Diverse Last-Mile Connections

Backhaul performance is comparably reliable in the fiber-rich and licensed backhaul connections feeding macro sites. The wide range of alternate access methods, from inexpensive RF to copper and even customer Internet connection backhauling, is accompanied by variability in latency, capacity, stability and reliability.

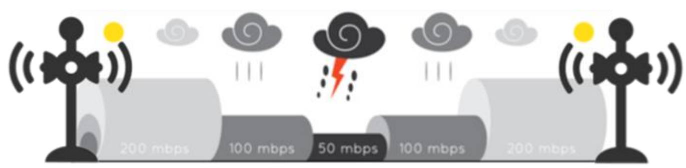
Dynamic RF Optimization

Small cells, and LTE in general, are dynamic by design: from self-optimizing networks (SON) of cells that can tilt antennas, adjust transmission power and receiver gain, or even hibernate in sleep mode to conserve power during times of low utilization. The network is alive – constantly adjusting to optimize its own performance. This should be a good thing, but considering standards for SON are only now emerging, and each vendor has a different approach to optimization, this could be more of a problem than a solution. Multi-vendor SON interoperability is years away, if it will ever be achieved.

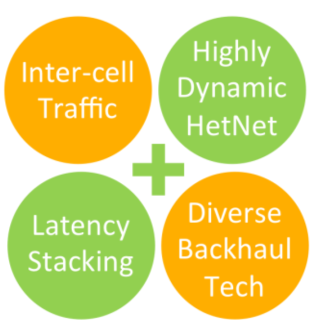


Dynamic Configuration: SON

Multi-vendor overlay solutions may be the answer, however these methods will require performance data from the multi-vendor, multi-technology backhaul to be effective – a challenge in itself. Variations across vendor Policy & Charge Control (PCC) implementations, coupled with multi-tiered QoS implementations, shifting traffic patterns and capacity (not to mention weather conditions), all converge to challenge accurate performance tuning.



Weather fades also introduce a significant dynamic into backhaul QoS employing RF links



Interoperability

Like in SON, interoperability concerns also arise in the backhaul. Carrying traffic from small cells – not necessarily carrier-grade – through other network elements and technologies can affect end-to-end preservation of multiple Service Data Flow (SDF) tiers – critical to ensuring bandwidth is properly allocated to signaling and real-time traffic before filling the backhaul with general data flows.

With small cells contributing to a highly dynamic environment, it's clear that real-time backhaul performance monitoring is required to maintain visibility and QoS. There are too many moving parts in these networks to leave performance to chance.

SDF Bearer Model

A bearer is a virtual transport tunnel from the user equipment (UE) to the packet data network gateway (PDN-GW). It contains a set of either 2 or 4 QoS parameters, depending on whether it is for real-time or best-effort traffic:

Quality Class Indicator (QCI) – specifies the treatment of IP packets

Allocation / Retention Priority (ARP) – used primarily in hand-over situations to determine if new dedicated bearers can be established through the radio base station.

Guaranteed & Non-Guaranteed Bit Rates (GBR, Non-GBR) – a GBR bearer reserves (and uses) a minimum amount of bandwidth on radio base stations. Non-GBR bearers do not reserve bandwidth and are used for best-effort services.

Service Data Flows (SDF) – SDFs represent the IP packets related to a service and are linked to specific bearers at the PDN-GW and UE using traffic flow templates (TFT).

Traffic Flow Templates (TFT) – define packet filtering information and map packets to specific bearers using a minimum of five parameters:

- source IP address
- destination IP address
- source port
- destination port
- protocol identification (i.e., TCP or UDP)

Backhaul Performance Assurance Challenges

In addition to low-touch deployment requirements, the low cost of small cells constrains the technology choices for assuring their performance. Traditionally, macro cell backhaul is monitored by Network Interface Devices (NIDs) – Accedian Networks' performance elements now monitor over 100,000 cell sites in the U.S. alone. These devices, which can also be used to condition traffic, terminate Ethernet services and more, are the perfect complement to 3G and 4G base stations.

But small cells have different performance monitoring needs: footprint, power and cost also need to be "small", without sacrificing the ability to precisely measure critical KPIs such as latency, delay variation, utilization, packet loss and availability. Installation and on-going maintenance also need to be minimized, ideally eliminating the need for truck rolls entirely in favour of embedded, virtual instrumentation.

The introduction of "Smart SFPs" – pluggable modules with integrated Flow Performance Assurance (FPA) processors and similarly low-cost GbE modules for copper connections – address the requirements of both indoor and outdoor small cells, from the enterprise cells connected to GbE LAN switches and Small Cell Gateways (SCGWs) to micro and pico cells on lamp posts fed by PONs, DOCSIS, RF or xDSL access links.

Testing methods need to support the all-IP layer-3 backhaul of the evolved packet core (EPC). The Y.1731 OAM standard, widely used to monitor the QoS of Ethernet backhaul to macro sites, can't span IP domains. The layer 3 Two-Way Active Measurement Protocol (TWAMP, RFC-5357) can be used to achieve a similar result where the standard is supported.

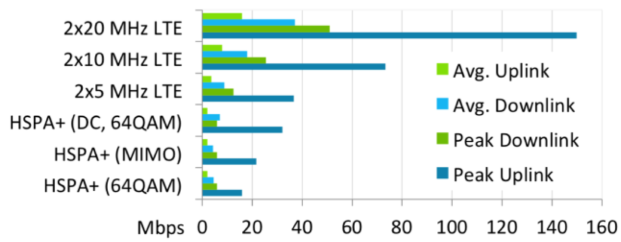
The luxury of overprovisioning backhaul bandwidth to assure QoS is impractical in 4G networks, where traffic demands and spectrum constraints clash, and bursts of TCP traffic can easily result in high packet loss in the backhaul during peak periods. Yet it is critical to achieve a single view of backhaul performance across the entire HetNet, including macro and small cells from multiple vendors, in order to tune traffic distribution and conditions.

3GPP addresses this requirement through the standardization of multi-tiered Service Data Flows (SDFs), governed by Quality Class Indicator-tagged traffic (QCI), and the concept of end-to-end bearers for each type of flow. A typical LTE deployment would implement at least 3 SDF classes: for signaling, for real-time traffic, and for everything else. Each tier needs to be monitored independently to ensure QoS is maintained under real-world conditions. Tiered SDFs are not only critical to maintain network performance, but also allow operators to increase revenue by tiering QoS by type of customer, and to introduce new services and applications.

ACCEDIAN NETWORKS

With streaming video and the emergence of LTE-broadcast video, the asymmetrical nature of up-link / down-link bandwidth will remain significant. The clear implication is that QoS monitoring must be directional. It's common that phone calls, as an example, are clear from one caller's perspective, but unusable at the other end.

Asymmetrical Capacity



Backhaul Performance Assurance Fundamentals

Establishing and maintaining performance in small cell backhaul networks means addressing the full service lifecycle. Service activation must be validated and benchmarked, QoS must be monitored from core-to-cell as well as inter-cell, and ongoing performance optimization must have access to current performance data from all corners and layers of the network.

The fundamental requirements to any such solution will include:

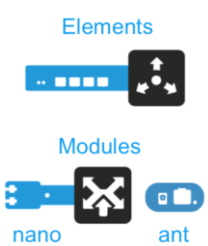
- **Standards-Based**
- **Ubiquitous**
- **Accurate & Precise**
- **Continuous**
- **Programmable**
- **Interoperable**
- **One-Way Metrics**
- **Granular**
- **Real-Time**
- **Open**

- Standards-based test methods to ensure interoperability with the greatest range of networking and test platforms, and to take advantage of performance monitoring functionality already available in many network elements.
- Ubiquitous coverage: from MSC to macro and small cells, from layers 1-4.
- The ability to conduct one-way measurements – round-trip metrics are not sufficient in highly asymmetrical networks. One-way delay measurements are critical to verify PTP timing & sync when running LTE-TDD.
- High accuracy and precision: when millisecond latency is required, performance assurance solutions need *microsecond-level* resolution for results to be meaningful.
- Granular performance visibility: micro-bursts, the intermittent nature of TCP packets and quickly shifting traffic trends means sub-second measurement frequency can make the difference between detecting issues or missing them between samples.
- Continuous, real-time results reporting, providing immediate feedback for network optimization and proactive QoS-degradation mitigation.
- All solution components must be structured within an open, programmable architecture that can integrate with existing and emerging network management, SON, SDN and other platforms, as well as support feature upgrades as new standards and test methods emerge.

Smart SFPs

Small cells are an ideal candidate for pluggable Smart SFPs, like the Accedian Nano Module, which can maintain performance monitoring streams (e.g. Y.1731 at layer 2, and TWAMP, RFC-5357 at layer 3) in addition to generating full line-rate, multi-flow traffic for turn-up tests and on-demand troubleshooting.

The pluggable form factor is ideal not only because of its attractive cost, but also because of minimal power and zero footprint attributes.



Typical Service Activation Testing (SAT) Workflows for Small Cell Backhaul

The dynamic nature of HetNets demand test strategies that are flexible and scalable, incorporating inter-cell and cell-to-core connections. Passive reflectors and centralized testing is not enough. Small cells are more self-directed, forming more intelligent and complex mesh architectures that require new validation strategies.

Automated Service Activation Testing (SAT) is the first step towards establishing a performance-assured backhaul network. Standards-based Y.1564 (layer 3) and RFC-2544 (layer 2) turn up testing are the trusted approaches to establishing a performance baseline and activation "birth certificate":

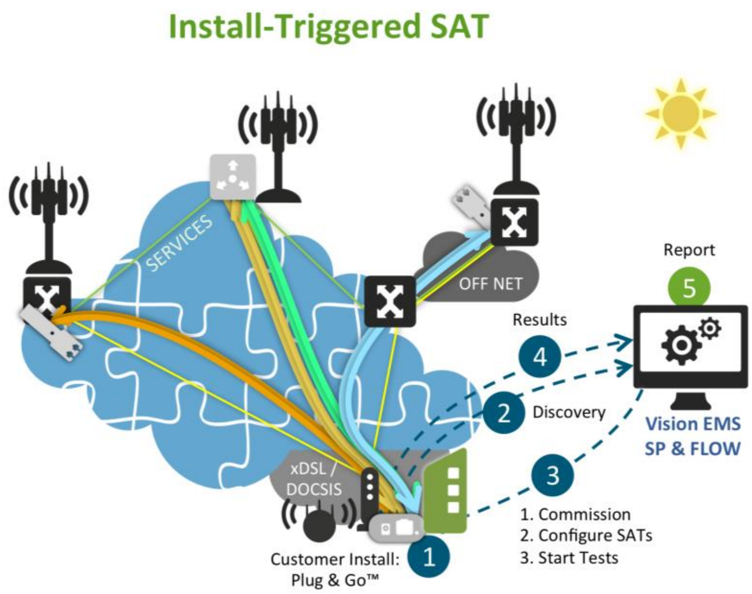
- **Multi-stream** Y.1564 & RFC-2544, Layers 2 & 3
- **Every Site:** low-cost pluggable test modules
- **Every Path:** Inter-Cell, Core-to-Cell, Multi-Segment, Multi-Site
- **1-Way** or round trip
- **Distributed,** scalable traffic generation
- **Workflow-Automation**: Small Cell Discovered, SAT Test Sequence Executed
- **Centralized Control**: Immediate or Scheduled, Single Site or Batch
- **Real-Time** results & baseline reports: Open API / NBI

To be useful in small cell deployments, these tests must be conducted between neighboring cells, as well as to centralized resources at the MSC and at BTS-"hotels" (e.g. where C-RAN may be hosted). Tests need to be conducted to every service delivery endpoint.

To ensure small cells can be deployed by untrained technicians, or even the customer themselves in the case of enterprise femto cells, the service activation process needs to be supported by workflow automation. Let's examine two common deployment scenarios.

The first example demonstrates an **install-triggered SAT** used by an operator deploying an enterprise femto cell with three neighboring macro sites. The backhaul is a DOCSIS 3.0 cable access link. The Accedian antMODULE™ is connected by the customer between their modem and small cell. Other sites are instrumented with the Nano smart SFP module or network performance elements like the Accedian GT.

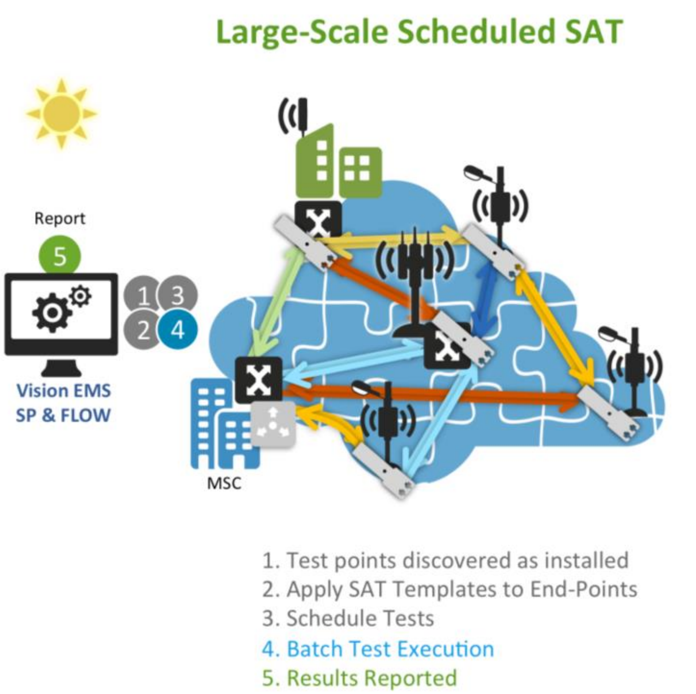
Once installed, the module is discovered by Vision EMS, which then starts three layer 2 & 3 RFC-2544 service activation tests with multiple service flows to the other customer locations – all without any operator or technician intervention. Once the tests complete, the results and reports are available from the Vision Suite dashboard at the NOC. Since traffic is generated directly at customer sites, just like the real service, turn-up tests can be conducted immediately upon install – no waiting for maintenance windows.



Example: extending cell coverage with an enterprise small cell. Site activated & SAT started within 20 minutes of install.

The second example demonstrates **large-scale, scheduled Service Activation Testing**. This solution is well suited to applications like small-cell backhaul, where each small cell needs to be tested to its peers as well as the MSC during turn-up. Scheduling allows a full sector of small cells to be tested simultaneously once they are all installed and added to inventory. Since neighboring cells also need to be online for tests to be conducted, batch execution is the preferred automation approach. In the case of small cells, tests would be configured to concurrently validate IP service data flows (SDFs) with different quality classes using the Y.1564 standard. Again, since traffic generation is distributed, tests can be scheduled to execute during the day for the most realistic results.

With Accedian Networks' Vision EMS platform, turn up testing sequences can be scheduled in a batch, or triggered by the discovery of a new small cell coming online, with results centrally stored and subject to test templates and acceptance criteria specific to the location, type of cell, or application. With test traffic generated from the site itself, tests can be conducted immediately upon install, without the congestion concerns that come with large-scale, centralized test heads. Distributed traffic generation also permits site-to-multisite concurrent testing, including inter-cell performance validation. With a capable northbound interface and API, test results are openly available to NMS and 3rd party performance platforms. Accedian provides this capability through its SkyLIGHT™ interface, used by the SevOne performance reporting platform at leading operators, for example.



1. Test points discovered as installed
2. Apply SAT Templates to End-Points
3. Schedule Tests
4. Batch Test Execution
5. Results Reported

Example: deploying dozens of Small Cells in 1 Day. Testing inter-cell: all units must be installed to start testing.

The combination of centralized test control with distributed test traffic generation brings the best of each approach together, eliminating the shortcomings of scalability, while providing full network coverage from core to service-edge, and any point in between. Right-sized performance elements cost-effectively match the business case demands of large-scale, small endpoint service deployments. Distributed test-traffic generation and analysis means tests follow the actual service path, and can run during peak hours just like the real service.

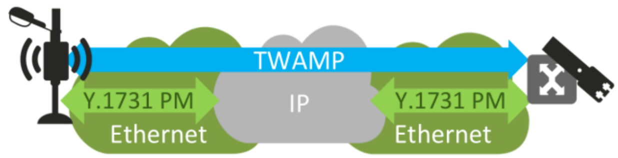
Workflow automation consistently executes template-based service activation test procedures on demand, when triggered by an install, or scheduled for batch execution. The result is a complete solution that makes turn up testing simple, efficient, and realistic. It's a solution that keeps operational expenses and investment to a minimum, while paving the way for best-in-class service QoS, every time.

Concurrent Performance Monitoring

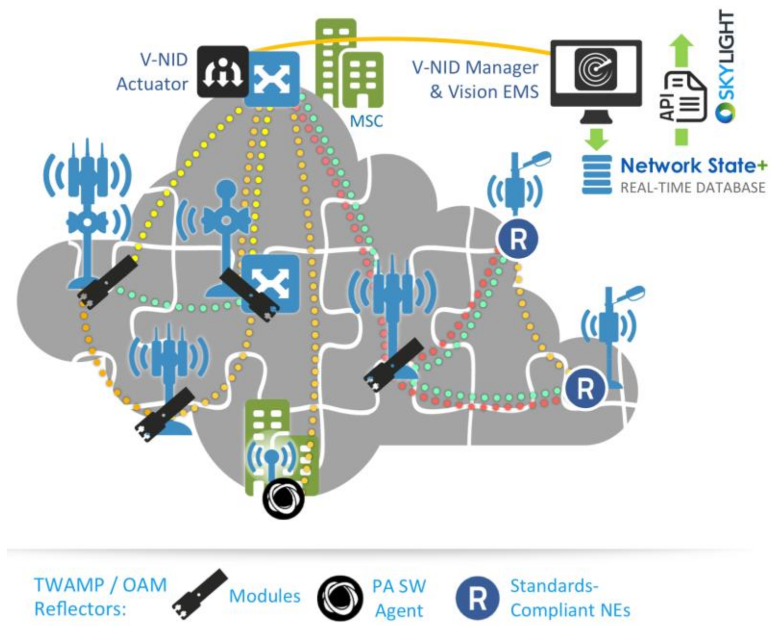
The Accedian V-NID™ platform can conduct thousands of concurrent performance monitoring (PM) sessions to diverse endpoints at the service edge and at key locations along the service delivery path: to network performance elements such as Accedian's GX unit, to smart SFPs and copper GbE modules like the Nano and antMODULEs, to TWAMP and Y.1731 reflectors in network elements and small cells, and to software agents that can be embedded into nodes, virtual machines in datacenters and even handsets.

Backhaul Performance Monitoring

The NGMN Alliance considers delay, delay variation, packet loss and availability the key backhaul QoS KPIs for small cell monitoring. The combination of ITU-T Y.1731 (L2) & TWAMP RFC 5357 (L3) are their suggested methods because of the wide deployment of these industry standards in elements ranging from core-routers to macro base stations and a growing number of small cells.



In addition to the metrics these standards support, bandwidth utilization by port and Service Data Flow (SDF) is key to capacity management and planning. Port level utilization is required in addition to the utilization of each service flow, as up to 30% of total backhaul traffic is overhead above and beyond the service data. As an example, IPsec overhead consumes an additional 14% bandwidth, signaling can total up to 4%, and 10% more can be attributed to transport protocols.



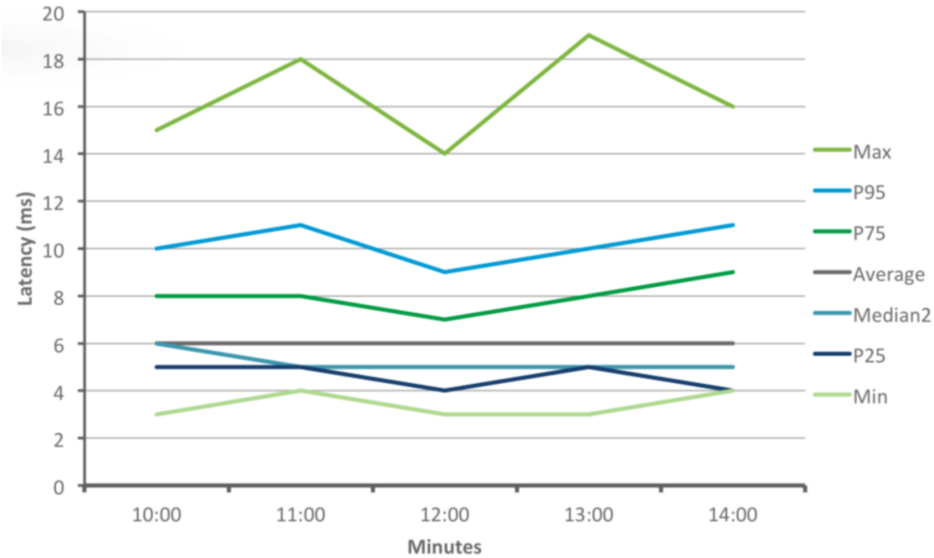
With so many service endpoints and flows, relying on simple thresholds for fault detection and management can result in a "sea of red" on NMS and fault management dashboards. Actionable, compound metrics based on derived performance statistics can cut through the noise and provide insightful alerts to operators. Using stats calculated on-the fly as measurements are conducted, the Accedian V-NID platform provides percentile-based fault mediation, allowing meaningful alerts to be triggered using compound criteria, for example, "provide a warning when one-way latency on the signaling SDF is higher than 5ms, 95% of the time".

Percentiles are useful for network engineering and planning in cases where it is impossible to dimension a network to take care of all possible scenarios. Percentiles validate SLAs towards a high percentile as opposed to only minimum / maximum/ average values, delivering a high number of samples for calculating metrics. For example, in the diagram below, delay percentile 95 (P95) shows the delay line at which 95% of frames fall below. Another way to think of it is the max delay if you disregard the 5% worst.

+ Derived Stats

- percentiles, mean, min/max
- MOS, R for VoLTE
- forest vs. trees

Statistical 1-Way Latency Metrics vs. Time



The combination of right-sized instrumentation and accurate measurements with statistics calculated on-the-fly results in total network coverage, both end-to-end, inter-cell and segmented along traffic paths, with the most comprehensive set of metrics. Accedian' Network State+ is a real-time flow of over 50 real-time KPIs open to integrate into fault management, reporting, QoS visualization and performance optimization applications via the SkyLIGHT™ API.

Backhaul Bandwidth is Precious

- SON optimizes RF and performance between cells…Backhaul also benefits from dynamic optimization
- Pushing data down-link without Network State knowledge means loss, retransmission, and poor QoS
- DPO eliminates RF-link loss & congestion
- Retransmits moved out of backhaul to head-end where bandwidth is less scarce and expensive.

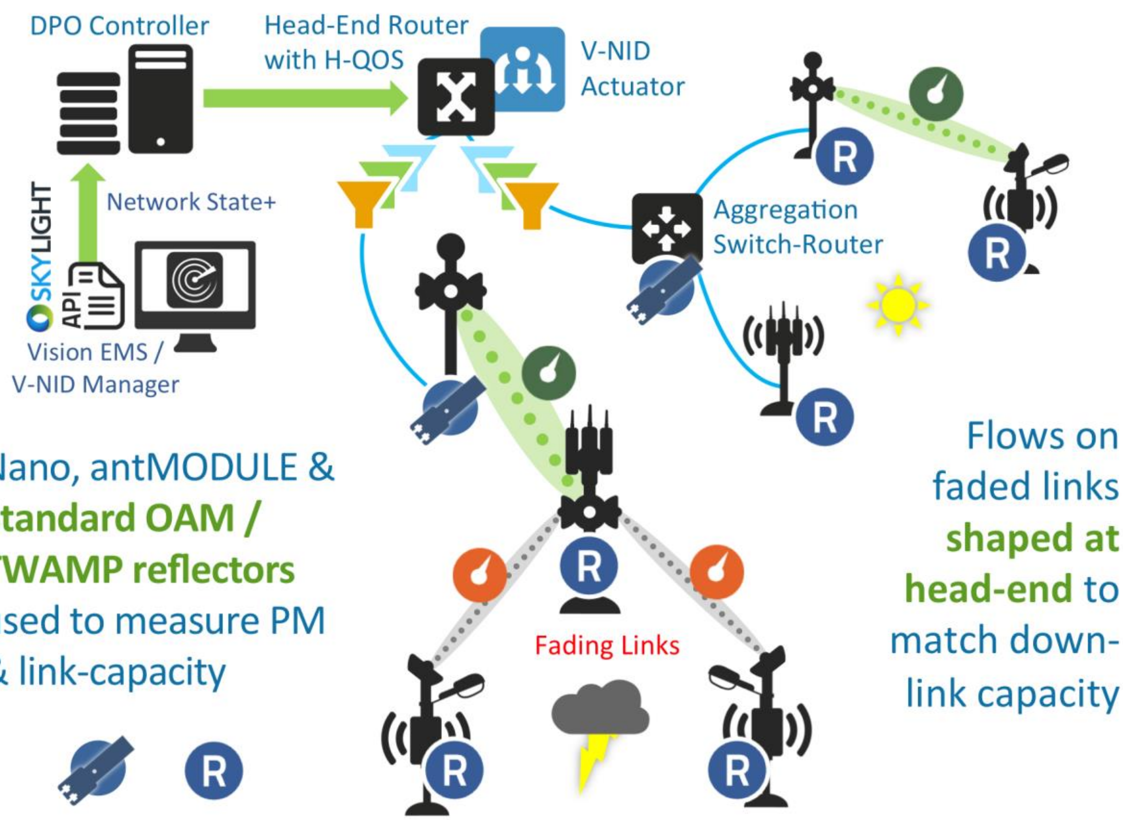
Dynamic Performance Optimization (DPO)

Running the most efficient backhaul makes good economic sense, as well as a foundation for exceptional QoS that only the best use of all resources can provide. Microwave backhaul links can vary in capacity with changing weather, seasonal temperature swings, interference and multi-path, and countless other factors. Running a “blind” backhaul, where data is pushed down-link when capacity is not available to carry it can result in over 30% lost capacity due to packet loss and retransmission.

Dynamic Performance Optimization (DPO) is the insightful orchestration of link capacity awareness with real-time H-QoS enforcement and traffic conditioning. Just like SON aims to optimize the performance of LTE macro and small cells, DPO can optimize distribution of backhaul bandwidth where it’s needed, and groom data to fit links current capacity. This results in a congestion-free, lossless RF backhaul, as retransmission of packets is pushed uplink where bandwidth is less scarce.

Accedian solutions provide the real-time, per-second, network-wide QoS KPIs needed by performance management systems and SDN or SON controllers implementing DPO.

Real-time link capacity information is measured by network performance elements such as the GT, GX, or 10GbE LT series, or small form-factor units like the Nano and antMODULEs – without any need to query or embed software on PTP radios. This per-link capacity information is combined with Network State+ metrics to provide a complete, segmented and per-flow view of current performance via the SkyLIGHT™ API to optimization systems or applications.



Reflecting the immediate state of the network, per-flow, hierarchical shaping and traffic conditioning policies can then be pushed to head-end and selected aggregation routers to control traffic as it distributes into the backhaul. The net benefit is drastically improved QoS and lower bandwidth utilization from MSC to small cell, extended radio infrastructure lifespan and maximized use of scarce spectrum.

Future Performance Considerations

We are now seeing the impact small cells have on mobile network capacity, QoS and the ability for mobile network operators to scale with the 1000-fold traffic growth expected over the next several years. LTE Advanced, including the timing-critical LTE-FDD / TDD standards, will further tighten performance requirements over the coming few years, extending LTE network capacity further where required.

As fast as they can be deployed, however, industry experts still expect 4G networks will reach their limits within five years. 5G networks and standards are the inevitable answer, taking bandwidth another order of magnitude forward, supporting 1000% device densification and the "Internet of things."

5G will come with a further tightening of performance requirements, approaching 1 ms latency bounds, tighter packet loss and higher availability limits. By the time first deployments of 5G networks begin, Cloud RAN (C-RAN) and virtualization of network functions, and even the networks themselves in the case datacenters and backhaul. The SDN approach of separating control and data planes will also be required, allowing multiple frequency bands (e.g. millimeter wave combined with 4G spectrum) to be implemented without requiring changes to the control infrastructure. All of this virtualization will require monitoring to extend into the virtual fabric, with software agents installed on virtual machines (VMs), for example.

Accedian's current solution portfolio is ready for the future: the required precision, granularity and scale exist today, and the SkyLIGHT™ VCX Network Function Virtualization (NFV) platform introduces a new level of programmability and feature extension to Nano and antMODULEs. NFV means these cost-efficient units can extend into virtual CPEs, fully featured test heads with virtualized results calculation and reporting. NFV also offers the ability to roll in new standards and test methods for TCP traffic assessment, microburst detection, application specific QoE metrics and more, all without any need to upgrade units in the field. Software agents are also being tested on handsets and other mobile endpoints as well as on VMs and V-Switches, to address the lack of end-to-end visibility SDN and cloud computing shifts introduce.

5G Performance

- LTE-A, LTE-FDD / TDD, VoLTE require tighter specs
- 5G about 5 years away
- Migration to Cloud RAN (monitor to VMs with SW Agents)
- NFV will supplement modules' capabilities

5G @ Year 2020 vs. 2014

- 10,000x more traffic
- 100x more devices
- sub-ms latency limits
- 10 Gbps+ data rates on premium 5G download
- Low-end 100 Mbps access rates

5G competing demands include **capacity, energy consumption, cost and coverage**, all at lower latency.

Stats as projected by NSN

Conclusions: Performance Assured Small Cell Backhaul

It’s clear small cells make a big difference, and are the next important step in increasing capacity, coverage and QoS in mobile 3G, 4G and the 5G networks of the future. And the future is close, with 62 million small cells expected to carry half of mobile traffic by 2016.

Despite the need to keep CapEx and OpEx within strict limits imposed by the small cell business case, backhaul performance will need to meet new levels of precision – all this in a HetNet that’s more dynamic, diverse and interactive than traditional macro-cell backhaul. Without performance assurance solutions as flexible as the HetNets themselves, operators will lose QoS visibility as endpoints rapidly increase in numbers and move closer to the customer.

Backhaul Performance Assurance needs to be as **Flexible as HetNets** themselves

Automation is required to ensure complete service assurance is conducted in a uniform, near zero-touch manner over the full service lifecycle: from service activate testing to ongoing monitoring and dynamic performance optimization. By deploying a standards-based, ubiquitous, real-time, open and programmable performance assurance solution, service providers are in the position to drive the growth of their network and their revenue base with eyes wide open.