Visibility into VoLTE: Maximizing Quality After You Deploy
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Introduction: The Future of Profitable Voice

Nearly 200 LTE deployments have gone live worldwide, supporting some 160 million subscriptions. While early deployments were predominately data-only, voice-over-LTE, or VoLTE, is beginning to take hold as 4G network infrastructures evolve.

VoLTE stands to deliver a broad mix of technological and economic benefits, leveraging LTE and IMS (IP Multimedia Subsystem) infrastructures to improve quality, and in turn, profitability into the future. Compelling advantages include:

Protecting and growing voice revenues

According to Informa Telecoms & Media, voice accounted for $634 billion in mobile service revenues in 2013, more than 60% of the worldwide total. As data traffic continues to surge, voice revenues are expected to suffer attrition—Informa estimates a drop of roughly 9% by 2018—but will still represent a massive global market of $579B.

The evolution of voice traffic to LTE may even improve the quality of voice calls over 3G. With more bandwidth available, operators have greater flexibility to prioritize services to enhance the quality of voice calls without significantly compromising the performance of data applications.

Fast-tracking profitable new services

VoLTE is more than just voice. By leveraging the superior Quality of Service (QoS) capabilities inherent in IMS and LTE, operators are free to roll out a wide variety of innovative and compelling new services. For starters, coupling VoLTE with Rich Communications Services (RCS) supports real-time video chat and messaging. Customers may find it more convenient to subscribe to feature-rich applications and services offered by their trusted providers, but the real selling point is likely to be the higher quality 4G network operators can provide.

“HD voice could bring landline call quality to cell phones and could be offered as a premium service to those tired of repeating what they think they heard on the other end of the line.”

— Lars Johnsson, Sr. Dir. Product Marketing for LTE platforms at Broadcom

![Chart showing voice and data revenues from 2013 to 2018.](chart.png)
Deflecting threats from Over the Top (OTT) providers

VoLTE becomes one of first services to fully leverage the end-to-end quality of service (QoS) capabilities built into IMS-based networks. To offset revenue loss to OTT providers, operators have two viable options for monetizing quality: 1) they can launch their own compelling services that let customers do something more, better, or cheaper, or 2) partner with or sell to OTT players looking to differentiate on quality.

Either way, IMS and the QoS mechanisms inherent in LTE give mobile operators a clear advantage. Competitors that can’t guarantee quality on their own may in turn do well to pay to leverage these capabilities.

Improving the economics of service delivery

Voice calls consume less bandwidth on LTE than they do on legacy networks so that the same spectrum can be used to deliver nearly twice as many calls with VoLTE than using 3G services. And obviously, migrating a fair percentage of the voice load off of 2G/3G networks onto LTE frees up existing bandwidth. The migration to VoLTE in turn allows 2G/3G spectrum to be reused for LTE.

VoLTE also delivers sub-second call setup times, a major improvement upon 3G setups taking approximately 3 seconds. True VoLTE significantly improves upon interim LTE solutions using circuit-switched fallback (CSFB) where the latency resulting from handoffs to circuit-switched networks results in setup times exceeding 4 seconds.

How Much, How Soon?

With LTE deployments maturing and the benefits of voice-over-LTE becoming more compelling, Informa predicts 2014 will be the “breakthrough year” for VoLTE. Other estimates expect steadily accelerating deployments through 2018.

| North America VoLTE Subscribers, VoLTE Revenue and VoLTE POP Revenues US ($M) Subscribers and POP in Thousands, 2013-2018 |
|---|---|---|---|---|---|---|---|
| VoLTE Subscribers | 13 | 300 | 4,250 | 13,250 | 38,300 | 71,250 | 293% |
| VoLTE Revenues (US $M) | $2 | $29 | $467 | $2,199 | $7,140 | $15,595 | 383% |
| VoLTE POP | 300 | 30,000 | 120,000 | 210,000 | 300,00 | 350,000 | 85% |

Source: MindCommerce

To deliver on the promise of VoLTE, operators need proactive strategies for ensuring quality throughout the deployment lifecycle. This begins with proactive design and device validation in the lab, and continues as efficient, real-time monitoring of QoE in live networks and services.
Chapter 1. Validating VoLTE “Lab to Live”

Like LTE itself, VoLTE represents a whole new deal. Worldwide, and even regional implementations vary widely with many just now beginning to support voice and video traffic. Infrastructures include lots of new devices, from new and traditional manufacturers. This in turn introduces many new “unknowns,” before and after deployment.

What hasn't, and won't change with VoLTE are user expectations for “toll quality” voice. If anything, mobile user expectations continue to rise as voice traffic migrates off landlines onto cellular networks.

Subscribers to “VoIP” services once tolerated lower quality for the sake of lower cost, but this is changing. The migration of voice to LTE may not even be made known to users. Either way, VoLTE services leveraging IMS and IP-based infrastructures will now be expected to deliver the same reliable, rapid call setups and high-quality experience, or better.

To date, service providers worldwide have relied heavily upon equipment manufacturers to validate the performance both of their own devices and overall network designs. But with traffic volumes and expectations for quality both on the rise, this approach proves risky.

Each mobile network is unique, and they increasingly consist of equipment from multiple vendors. With so many new and moving pieces involved, operators must now model their own specific configurations, services, and traffic mixes in the lab, and continue to monitor and proactively resolve issues in the field.

End-to-end, life-cycle VoLTE validation must include:

- **Validating designs and devices.** Throughout deployment, operators need an efficient means of evaluating prospective equipment (performance, interoperability, mobility, etc.) and network configurations and capacity.

- **Prototyping services.** Before going live, new services should be modeled and tested against realistic scenarios, including high load and stress conditions, at scale.

- **Quality of Experience (QoE) monitoring.** Once things get up and running, operators need to maintain visibility into the network, making sure the tools and solutions used to monitor and optimize performance and security are functioning properly. This includes session-aware load balancing, and making sure each tool receives the data it needs automatically and efficiently.

- **Problem resolution.** Whether issues arise in the field or in the data center, operators must be able to take actionable data back to the test lab to devise ideal solutions. Visibility solutions gather data on key performance indicators (KPIs) and traffic patterns that can be used to inform further testing, and to replicate and resolve issues.

Throughout the process, the ultimate quality of voice, video, and other applications and services must be assessed, not with a focus on protocol testing, but on measuring QoE for voice, video, messaging, and other high-profile services.

**Critical Test Capabilities**

VoLTE testing should focus on end-to-end service validation versus individual device (node) testing. Network operators do not need to duplicate their vendors’ development testing, but rather measure the expected user experience.
Operators need to be able to evaluate the entire LTE/VoLTE network as a whole, and also isolate individual subsystems such as the RAN, EPC, and the IMS core. Validation strategies and test methodologies should include several critical components and capabilities:

**Subscriber Modeling**

Operators must be able to define subscriber types (residential, corporate, SMB, etc.) and correlating application profiles. By modeling the use and mobility patterns of actual subscribers in the lab prior to deployment, testers gain accurate insight into network capacity and the QoE achievable for each rich media or differentiated service.

**Load Testing**

Since most issues occur at high scale, operators can’t qualify performance, scalability, and resiliency just by using a handful of actual client devices as has been done in the past. Realistic traffic must be generated at realistic scale to simulate high-load or stress conditions where network and application performance might suffer. This means modeling peak usage and varying times throughout the day, simultaneously generating data, voice, and video protocols to emulate the respective multimedia traffic loads.

**QoS / Service Validation**

Policy management will play an increasingly integral role in enabling new services such as VoLTE as well as new business models to emerge. Operators must be able to assess and implement policies on multiple devices simultaneously, measuring the QoS capabilities of each along with the end-to-end performance achievable across the overall network.

**Live Network Monitoring**

LTE/VoLTE solutions require large, complex networks with many moving parts. Even with extensive planning and lab testing, the final network may bog down under load, or as a result of a failure.

For example, a software upgrade to one component in a chain might result in an incompatibility with neighboring components. Network monitoring allows issues to be identified before they become serious problems, allowing operators to troubleshoot proactively, before users are affected.

### General Requirements on Network-based VoLTE Measurements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete Monitoring of Network VoLTE traffic</td>
<td>24/7 Monitoring of every data flow with regard to SIP signaling and Voice Media</td>
</tr>
<tr>
<td>Network Visibility</td>
<td>Ability to filter KPI results with regard to mobile network elements (APNs, gateways, eNodeBs, Cells, P-CSCFs)</td>
</tr>
<tr>
<td>Device Visibility</td>
<td>Ability to filter KPI results with regard to the Individual Device and Device Models</td>
</tr>
<tr>
<td>Subscriber Visibility</td>
<td>Ability to filter KPI results with regard to the Individual subscriber</td>
</tr>
<tr>
<td>Near Real Time</td>
<td>Availability of results 10 minutes after capturing from network traffic</td>
</tr>
</tbody>
</table>

1 Velocent Systems, “VoLTE KPIs for Network-based Monitoring,” 2013
Chapter 2. VoLTE Visibility Monitoring: Challenges, Solutions, and Long-term Benefits

With network environments growing more complex, no network architect can anticipate every possible combination of uses, or how infrastructures will evolve long-term. And as we’ve seen, mobile operators can’t afford to let quality dip as implementations scale and usage soars.

“QoS” doesn’t guarantee “QoE.” Ensuring quality beyond deployment requires a cohesive and efficient strategy for monitoring and optimizing network and application performance in real time.

Maintaining visibility becomes increasingly valuable, and significantly more challenging, with VoLTE. To maximize performance, efficiency, and ROI, powerful new best practices are emerging to meet formidable new challenges.

VoLTE Monitoring Challenges

Sophisticated network monitoring strategies prove essential to troubleshooting, maintaining, and scaling mobile network infrastructures. Varying VoLTE implementation strategies, however, create new and diverse monitoring challenges.

For example, operators might wish to segregate or isolate the monitoring of VoLTE or voice services to different tools in the evolved packet core (EPC) portion of the LTE network, for use by specific teams or outsource providers. Certain groups may wish to only see VoLTE data, or to not see it all. A third “hybrid” scenario also exists whereby those monitoring performance will need to see everything.

Depending on the desired scenario, complex challenges may arise around filtering VoLTE monitoring traffic out from other data, and balancing the rapidly growing load of monitoring traffic among various probes and other tools. Specialized VoLTE monitoring tools and approaches are emerging within the EPC and IMS to provide enhanced performance analysis in all three scenarios.

Economics can also prove challenging as services scale. To avoid having to overinvest in costly probe deployments, operators need new ways of obtaining accurate, actionable data from their existing investments.

To this end, network packet brokers (NPBs) can be implemented as a cost-effective and strategic approach to ensuring the right tools receive and deliver data to the right team at the right time. Let’s take a look at advanced approaches.

Evolving Solutions for VoLTE Visibility

Monitoring tools have been evolving steadily since the 1990s, varying in usage and specialization. Among the more commonly deployed tools are:

- **Network performance monitors** that monitor network changes and provide alerts of major network events
- **Application performance monitors** that understand the protocols associated with particular interactions and deliver high-level statistics
• **Network analyzers** that capture raw network traffic for use in generating statistics or analyzing failed session

• **Network data recorders**: that capture data from critical network events

• **Security components** such as Intrusion prevention system (IPS), security forensics recorders, data loss prevention (DLP), and security information and event management (SIEM)

Special monitoring tools have also been developed to work with EPCs. One such tool is OneVu from Velocent, which monitors EPC health and can measure quality of experience (QoE) for subscribers. Subscriber sessions, encapsulated in GTP sessions, are automatically correlated for best results.

In addition to analyzing “good” network usage, monitoring solutions can be used to watch for overloads, faults, and inappropriate usage to spot “red flags” before serious problems occur. Monitoring tools highlight issues such as:

- Too little or too much traffic
- Dropped packets
- Excessive retransmissions
- Irrelevant traffic

Tools can also be directed to isolate particular problems with a specific service, user, interaction, event, or security violation. In all cases, effectiveness relies on receiving copies of traffic from locations throughout the network. As tools receive traffic from more places in the network, they’re increasingly able to perform monitoring, detection, and analysis.

Ultimately, this means problems can be identified and resolved more quickly. For example, Figure 1 shows a simplified network associated with a data center and associated monitoring tools.

![Figure 1: Simplified Data Center Network with Tools](image)
Challenges associated with maintaining visibility throughout the network can be overcome by deploying Network Packet Brokers (NPBs).

The red lines connecting the network switches to the tools indicate where information is collected from within the network, while the red bars show utilization of various tools. In this case, some are grossly underutilized while others are oversubscribed.

Information gathering relies on various network elements:

- **SPAN ports** – a term coined by Cisco. SPAN ports mirror the data being handled by a switch to the SPAN port. The mirrored data can be collected from an individual switch port, multiple switch ports, specific VLANs, or using other criteria.

- **Optical TAPs** – devices that passively collect data transmitted over a network connection. Data is collected from multiple optical Ethernet cables for forwarding to analysis tools.

- **Phantom TAPs** – With the combination of VoLTE and virtualization, a need arises to help find packets. Ixia’s Net Optics Phantom Virtualization Tap™ bridges the physical and virtual, monitoring the virtualized network with existing sets of tools. Phantom taps capture and send inter-VM traffic of interest to tools that are already monitoring in the physical network, providing 100% visibility of traffic passing between virtual machines (VMs) in virtualized computing environments and clouds.

In order for monitoring tools to have complete visibility throughout the network, they must be connected to the majority of network nodes. While directly connecting the tools to these nodes would provide strong coverage, doing so proves impractical for several reasons:

- A network connection would be required between every network location and every network tool. With a limited number of SPAN ports per switch (typically just one or two), TAPs, bypasses and switches would be required on a scale as large as the original network.

- Each tool would be very expensive, requiring a large number of input ports and a large degree of processing power to sort through vast amounts of network traffic. Ultimately, several copies of each tool would be required.

- Confidential data could be exposed in a massive way. Such data generally flows without encryption within a network and would be received by a number of the networking tools. Eventually, data might be exposed outside of the organization.

- Some tools would be overloaded with unnecessary traffic, while others are underutilized by monitoring smaller segments.

These challenges can be overcome by deploying a network packet broker such as Ixia’s Net Tool Optimizer (NTO). Network data is collected once from each significant network node and sent to the network visibility tool, which distributes the data to the network monitoring tools. Network visibility tools such as NPBs can perform several functions that make them especially valuable and allow them to operate at their intended capacity.
Maintaining quality as the network evolves is critical. Network packet brokers connect to essential components of both the RAN and EPC.

Network Packet Brokers (NPBs) Getting the Right Data to the Right Tools at the Right Time

Maintaining quality as the network evolves is key. This means monitoring LTE networks to ensure capacity, performance, and quality, as well as radio access networks (RANs). Network packet brokers, sometimes called monitoring switches, such as the Ixia Net Tool Optimizer connect to essential components in both portions of the network, as well as to network monitoring probes/tools, to efficiently provide data.

Monitored RAN and EPC Networks

EPCs may handle hundreds of RANs and millions of users. Analysis of countless VoLTE sessions requires the use of multiple tool instances. A network visibility switch such as the Ixia NTO can load balance multiple tool boxes, but special processing is needed to ensure that each monitoring probe receives all messages for particular GTP sessions.
For this purpose, Ixia offers the GTP Session Controller (GSC), which is connected as shown in the figure below.

**Filtering** enables only the desired packets to be forwarded to the appropriate tools so that tools are free to focus on their primary job, without having to wade through irrelevant data.

The GSC receives sessions from the NTO as shown in the figure, or directly from EPC network taps. It offloads session correlation from the monitoring tools, improving their performance. This is accomplished through:

- **GTP-session awareness** – groups together all messages for a session for forwarding to monitoring tools.
- **Filtering** – a session distiller samples and filters data to reduce traffic sent to tools to just the essential information. VoLTE traffic alone can be analyzed if desired.
- **Load balancing** – automatically load balances sessions across monitoring tools, distributing load according to tool capacity.
- **High capacity** – handling more than 25 million subscribers.
- **Robust/carrier-grade reliability**

The Ixia NTO performs several functions critical to optimizing VoLTE visibility and QoE:

- **Filtering.** Each type of tool may be interested only in particular protocols, port numbers, source or destination addresses, or source nodes in the network. The NTO filtering function enables only the desired packets to be forwarded to the appropriate tools. Tools are free to focus on their primary job, without having to wade through irrelevant data.

The filtering function can also be used to concentrate particular streams of data to specific tools. For example, a denial of service (DoS) attack on a network’s DMZ may require analysis. The NTO’s filter function can be used to quickly focus attention on the incoming port, filtering on particular ports and protocols. This data can then be forwarded to an IPS or other tool for real-time analysis.
• **Load balancing.** Data centers and wireless core networks are large entities that may require multiple copies of monitoring tools. The NTO can direct traffic to different tool instances in order to balance load and ensure against loss of data.

• **De-duplication.** With network feeds coming from multiple places in the network, duplicate packets are guaranteed. The de-duplication process removes the copies, allowing monitoring tools to concentrate on flow analysis.

• **Buffering.** Bursty traffic on data center and wireless core networks can easily overload monitoring tools if not buffered through the network visibility tool. This would result in the loss of data, perhaps at a critical time. The NTO maintains a substantial buffer to help handle bursty traffic.

• **Packet trimming.** Most monitoring tools are only interested in the first few packet headers. The NTO can trim the packet so that each monitoring tool receives only the information in which it is interested. This also helps with buffering, both in the tool and the NTO.

Packet trimming also plays an important role in maintaining data confidentiality. Packet payload data, which may contain user names, passwords, account numbers and other private data, can be removed before it is sent to monitoring tools or recorded.

• **Integration.** Growing networks tend to use network links that vary in technology and speed; for example, from 10/100 Fast Ethernet copper links to 10 Gbps fiber optic links. NTO offers plug-in options to receive data from each type and speed.

• **Automation.** Most monitoring tools are used to keep tabs on general network health, with alarms that go off when programmed limits are exceeded. Others, such as IPS systems, watch for security events. In either case, it may be important to gather additional information at the time of the alarm or event.

NTO provides this capability, for example by sending high resolution data from particular network nodes to a forensic recorder when an alarm or event occurs.

Ultimately, aggregation and load balancing, along with other features allow operators to efficiently scale their monitoring solutions, and in turn, their networks. Operators also save on CAPEX, by minimizing optical taps, bypasses, and analysis tools.
Chapter 3. VoLTE Monitoring KPIs

Most monitoring can be done in the EPC even though the connection between UEs and eNodeBs is external to the EPC. Visibility into the EPC network can be obtained through taps at critical EPC network connections.

**EPC Monitored Signals**

<table>
<thead>
<tr>
<th>Location</th>
<th>Signal(s)</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>eNodeB to S-GW</td>
<td>S1-U</td>
<td>Defines the user plane between eNodeB and serving gateway (S-GW). GTP-U is used for the per-bearer user plane tunneling and inter-eNodeB path switching during handover. It provides non-guaranteed delivery of user plane PDUs between the eNodeB and the S-GW.</td>
</tr>
<tr>
<td>MME to S-GW</td>
<td>S11</td>
<td>Controls the creation and modifications of tunnels using GTP-C. Used by the MME to control path switching and bearer establishment in the serving gateway and PDN gateway. Keeps control- and user-plane procedures in sync for a UE. For handover, it is used to relocate the SGW when appropriate, establish a direct or indirect forwarding tunnel for user-plane traffic, and manage the user data traffic flow.</td>
</tr>
</tbody>
</table>

Network taps can be placed throughout the EPC to monitor VoLTE performance, but the key locations are the S11 interface between the MME and the S-GW and the S1-U interface between the eNodeB and the S-GW.

Key performance indicators (KPIs) for VoLTE are defined for multiple protocol layers. The most important for estimating users’ QoE include

- Mean opinion score (MOS)
- Percentage of failed call attempts
- Percentage of dropped calls

Lower level KPIs are also critical to understanding VoLTE performance and quality. These are found in the several tables below:

**SIP Signaling Usage KPIs**

<table>
<thead>
<tr>
<th>KPI</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td># of successful Register transactions</td>
<td>Signaling rate per time interval</td>
</tr>
<tr>
<td># of successful Invite transactions</td>
<td>Signaling rate per time interval</td>
</tr>
<tr>
<td># of concurrent calls</td>
<td>Mean number of parallel SIP sessions</td>
</tr>
<tr>
<td>KPI</td>
<td>Units</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Mean Register durations</td>
<td>Mean duration of a successful Register transaction measured between Register to 200 Register OK messages</td>
</tr>
<tr>
<td>Mean Invite duration</td>
<td>Mean duration of a successful Register transaction measured between Invite to 200 Register OK messages</td>
</tr>
<tr>
<td>Register success ratio</td>
<td>(# of successful Register transactions) divided by the (# of all Register transactions)</td>
</tr>
<tr>
<td>Invite success ratio</td>
<td>(# of successful Invite transactions) divided by the (# of all Invite transactions)</td>
</tr>
<tr>
<td>Register failure status code ratio</td>
<td>(# of Register transactions with failure status codes) divided by the (# of all Register transactions), per status code (3xx, 4xx, 5xx and 6xx)</td>
</tr>
<tr>
<td>Invite failure status code ratio</td>
<td>(# of Invite transactions with failure status codes) divided by the (# of all Invite transactions), per status code (3xx, 4xx, 5xx and 6xx)</td>
</tr>
<tr>
<td>Invite cancel ratio</td>
<td>(# of cancelled Invite transactions) divided by the (# of all Invite transactions)</td>
</tr>
</tbody>
</table>
## Voice Media Usage KPIs

<table>
<thead>
<tr>
<th>KPI</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td># of voice media connections</td>
<td>Number of dedicated bearers for VoLTE audio</td>
</tr>
<tr>
<td>Mean voice media call duration</td>
<td>Mean duration of dedicated bearer</td>
</tr>
<tr>
<td>Mean throughput per call</td>
<td>Mean data throughput within dedicated bearers, per direction</td>
</tr>
<tr>
<td>Total aggregated throughput</td>
<td>Total data throughput over all dedicated bearers, per direction</td>
</tr>
<tr>
<td># of concurrent calls</td>
<td>Mean number of parallel RTP connections</td>
</tr>
<tr>
<td>Time per CODEC operation mode</td>
<td>Total call time per CODEC operational bitrate</td>
</tr>
</tbody>
</table>
## Voice Media Quality KPIs

<table>
<thead>
<tr>
<th>KPI</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean fraction of packets lost</td>
<td>Mean packet loss as obtained from RTCP receiver report per direction</td>
</tr>
<tr>
<td>Mean jitter</td>
<td>Mean jitter as obtained from RTCP receiver report per direction</td>
</tr>
<tr>
<td>Mean delay</td>
<td>Mean delay as obtained from RTCP receiver report per direction</td>
</tr>
<tr>
<td>Mean MOS</td>
<td>Mean opinion score calculated from packet loss, jitter, and delay according to ITU-T G107 and G107-1.</td>
</tr>
<tr>
<td>Mean MOS critical</td>
<td>Mean opinion score calculated as above during QoE monitoring intervals where jitter, delay, or packet loss indicate considerable QoE impairment.</td>
</tr>
<tr>
<td>Time fraction with MOS critical</td>
<td>Percentage of time when MOS critical is in effect</td>
</tr>
<tr>
<td>Mean fraction of packets lost during MOS critical</td>
<td>Mean percentage of packets lost during MOS critical times</td>
</tr>
<tr>
<td>Mean jitter during MOS critical</td>
<td>Mean jitter during MOS critical times</td>
</tr>
<tr>
<td>Mean delay during</td>
<td>Mean delay during MOS critical times</td>
</tr>
</tbody>
</table>
VoLTE by the Book

To benefit fully from investments in VoLTE, and LTE in general, operators need to get deployments right the first time, and maintain satisfaction as services evolve. To that end, a first-of-its-kind book by Ixia wireless test experts presents a step-by-step guide for validating VoLTE implementations cost-effectively in the lab prior to deployment.

This includes evaluating:

- Device and network performance
- Interoperability
- Quality of service and quality of experience
- Network visibility and monitoring

About Ixia

The most trusted names in networking trust Ixia solutions to optimize equipment, networks, services, and applications. We help deliver innovative, differentiated offerings, improve management and visibility, and ensure a high-quality, always-on user experience.

Leading mobile operators worldwide use Ixia’s award-winning LTE solutions to accelerate and optimize 4G deployments and speed new services to market. A comprehensive suite of products and services are used to test, assess, and optimize key technology initiatives:

- Network performance, compliance, and security
- Visibility into applications and services that accelerates troubleshooting and enhances monitoring performance
- Securing mission-critical networks and services against attack
- Cloud /virtualization and data center initiatives

For more information about Ixia, visit www.ixiacom.com. Also check out our other groundbreaking ebook, Small Cells, Big Challenge: A Definitive Guide to Designing and Deploying HetNets.