Assuring QoE on Next Generation Networks

Whitepaper

Introduction

As recently as three years ago, VoIP was a dream. So were Napster downloads, streaming media, and intelligent content servers. Gateways were hard-pressed to handle ten simultaneous calls, and there was no such thing as a Softswitch. (Actually, there was something called a "gatekeeper," but few people understood exactly what that was.) H.323 looked like the de facto winner, and SIP and H.248 were unheard of. Virtually no one had a cable modem, and OC-3 seemed fast for the network core.

The industry has come a long way, as have the demands being placed on it. An emerging generation of equipment, based on a convergence of network technologies, is being deployed to carry voice, data, Web and video traffic. But, it is important for the creators and deployers of these new networks not to lose sight of the reason for this new gear and infrastructure: To deliver applications that people want to use. Accomplishing this means ensuring that consumers have a positive experience using new networks and applications. We call this Quality of Experience, or QoE.

A convergence of network technologies has been driven by the converging needs of network users. However, most labs continue to test the components of converged networks with tools and methodologies conceived when telephone and data networks were completely separate entities. Test equipment plays a critical role in helping to meet the challenge of assuring QoE on converged networks. A next generation of converged test systems is emerging to help empower providers of new services and equipment to assure *QoE*.

QoE: The only metric that matters

The quality bar is set high

Carriers and equipment manufactures trying to deploy new technology face the challenge of an extremely well-entrenched standard. Circuit switch telephony is being phased out not because anyone is complaining about the "five 9s" quality of service it delivers, but rather because the next generation of equipment offers economic benefits as well as the promise of future enhancements. Next generation network equipment is expected to meet the quality and performance levels of the established PSTN. So, the bar is set extremely high for new technology.

According to the Gartner Group:

> "The real challenge is shifting significant volumes of voice traffic from the traditional connection-oriented public switched telephone network (PSTN) to the packet network environment quickly and cost-effectively (with the same or a better level of quality than the PSTN)."

Hours spent in the lab measuring connect latency, packet loss, or call completion rates are justified by the high-stakes nature of the game and the importance of quality. Evidence of this is in a recent lawsuit in which a large CLEC is refusing to pay for over $60 million worth of equipment from a major manufacturer, essentially on the basis that the next generation equipment doesn't work as well as the PSTN. The delinquent CLEC cites everything from poor voice quality to the non functioning 911 service as deficiencies that justify its position. This stringency of carrier requirements reflects the expectations and intolerance of the end users of the networks into which new equipment is being deployed.

Defining QoE

Quality of Experience (QoE) is a new term describing the emerging reality that what ultimately matters in moving to the next generation network is how users think it performs. QoE is not a metric per se, but rather a concept comprising all elements of a subscriber's perception of the network and performance relative to expectations. The concept applies to any kind of network interaction. The following table describes the elements of the experience of a user of telephony services and the level of quality expectations for those elements.

Element of User's Experience	Expectations for Level of Quality
Reliability	Works every time
Availability	Always available
Call Completion	Calls always completed as dialed
Connect Latency	Rings in seconds
Voice Quality	At least as good as the PSTN
Speech Latency	Imperceptible
Services	All available, all functioning properly
Billing	Completely accurate

QoE is similar in concept to some of the original intent of the term Quality of Service (QoS); however, QoS in data networks has really evolved to focus on packet delivery statistics. These measures can often correlate with end-user system performance and from them one can draw inferences about the user's experience. However, focusing only on packet statistics is one step removed from the actual traffic carried across the network. It is possible to have excellent QoS and poor QoE. Flawless transmission of garbled packets does not make for happy users.

QoE can mean different things for different applications. For a telephony user, positive QoE means the call will go through quickly and sound as good as the existing PSTN. A Web surfer cares that graphics download before they get bored enough to click to the next site. For an IT department it means that the new routers they install can seamlessly process their unique blend of voice, data, and video traffic.

For next generation networks, the most important initial focus for QoE is the ability to handle telephone calls. This is because real-time streaming applications are the greatest QoE challenge for packet networks (where best-efforts delivery has been the standard). According to Dataquest:

> "IP economics dictate the use of IP networks for data applications when compared with circuit-switched and TDM networking or other packet protocols. However, choosing economic solutions at the expense of quality for time-sensitive and delay-intolerant applications (such as voice and video) would be detrimental in the long term for carriers."

For carriers to enjoy the economic benefits of carrying voice-over-packet networks, they must ensure QoE. Equipment manufacturers and carriers alike must assess voice QoE in the lab prior before they deploy next generation network equipment. As other real-time applications become more available and in demand, lab gear must evolve to meet those needs as well.

Assessing QoE in the Lab

The testing game has gotten tougher

In some ways testing requirements took a giant step backward with the advent of voice-over-packet technology. Early gateway developers were as thrilled as Bell and Watson, when a colleague was able to pick up a handset and receive a single, audible IP telephone call. Similarly, voice quality, long taken for granted in the circuit switch world, soon became the big challenge for the new equipment.

But if testing needs initially took a step backward, they have rapidly caught up. Engineers have come quickly to the sober realization that the thrill of new technology does not manifest in the end user's appreciation of a converged network. Network users are essentially oblivious to the technology behind the telephone.

The PSTN evolved over decades, and subscribers' expectations evolved in tandem. Over time, the network and its components were tested and retested, and consequently engineered and reengineered to a highly evolved state. Users' expectations for quality and new functionality moved at the same conservative pace.

The converged network is being deployed into a very different environment. The fiercely competitive, deregulated market applies severe time-to-market pressure. The enormous business opportunity of replacing the PSTN has drawn a multitude of sophisticated investors. The consequent level of attention to what is happening in the lab is something that the Bell Labs engineers of yore would have found unimaginable. These pressures leave little time for testing in the lab.

At the same time, the ultimate end users of the network, while they may enjoy the performance cutting-edge telecom stocks in their portfolios, have no patience or sympathy for network shortcomings when they pick up the phone to call their brokers. So labs are squeezed between the rock of getting the new technology deployed and the hard place of guaranteeing that it will support a positive user experience.

New capabilities needed

As a result of the expectation of PSTN-level quality, equipment manufacturers and service providers need to accurately assess QoE in the lab in conditions that mirror the richness and variability of real networks. Doing so goes well beyond making a few measurements of technical specifications. Understanding the experience of end users is a multifaceted problem. It requires emulating the users and gauging the performance they will experience. Further, the test environments set up in labs must subject the equipment under test to real-world conditions: High volumes of mixed-media traffic from endpoints and network emulation to recreate the way packets are handled in between. Finally, when problems occur, developers and deployers of next generation gear must be able to locate and solve problems that they discover as a result of using real-world testing scenarios.

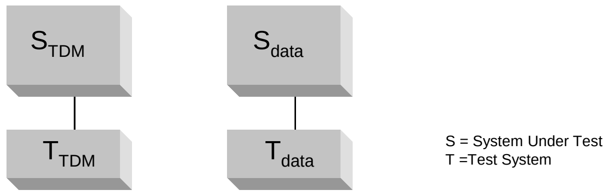
Test bed requirements

To meet these needs requires test equipment capable of:

- Measuring performance from the QoE perspective
- Emulating real-world conditions
- Aiding engineers in isolating and diagnosing problems.

Traditional testing solutions

Traditional testing solutions have been designed to function within their respective networks—TDM tester connecting to TDM Systems Under Test (SUTs) and data testers connecting to data SUTs. (Time Division Multiplex is the technique by which voice, modem, and facsimile traffic are carried in the



Traditional Domain-specific Testing Solutions

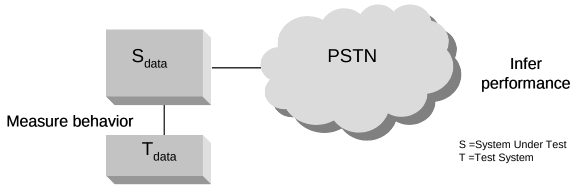
PSTN.) Although each class of test solutions met the above requirements well within their respective domains, each has limitations with respect to a converged network.

Limitations of Traditional Testing Approaches for Testing Converged Networks

Similar to those who are developing the next generation network infrastructure, test equipment suppliers are converging from two different camps: Some have historically developed instruments for testing data networks and devices (for example, routers, data switches, and VPNs); others have in the past developed test equipment for TDM network equipment and applications. Each group brings strengths to the test challenge and has evolved testing solutions and approaches with converged networks in mind. But at the same time, the inherent homogeneous nature of the approaches means that each has limitations when it comes to testing converged networks.

Data-side solution strengths

In general, a data-side approach to testing converged networks is to make measurements on the data-side and to infer performance at the other end of the PSTN cloud:



Traditional Data-side Testing Approach to Converged Network Testing

Data-side test solutions bring some strengths to testing converged networks. They generally support high data rates, which are critical to stressing data networks. They are also capable of detailed protocol analysis to ensure proper data handling.

Data test equipment providers have evolved strengths in protocol analysis to apply to a new set of protocols. Recognizing a heightened need for management of QoS in converged networks, they have offered packet-level QoS monitoring tools. Generally, data solutions offer good analysis of activity points in the network. A new level of difficulty arises in converged networks due to the increased number of handoffs from signaling protocol to signaling protocol. To track down handoff problems requires assembling point solutions and piecing together diagnostics from the different sources.

Data-side solution limitations

Data-oriented products have been deficient in taking the user perspective when testing converged network components. By monitoring the data-side, one can only infer the impact on the user, not directly assess it. For example, one approach is to inject RTP packets into a network and measure packet loss. From that, based on some empirically observed correlations, tools draw an inference about the voice quality that might result at the end of the line.

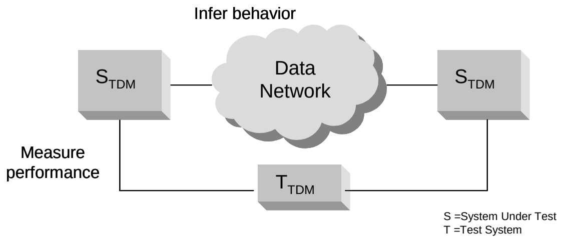
While there is some value in such analysis, a measurement based on inference is, by its nature, limited. The approach, for example, implicitly assumes that poorly transmitted packets will score poorly, and packets transmitted within tolerance will score well. While this may, for the most part, be true, it can certainly break down under real network conditions. For example, if the payload of a packet was corrupted by a codec and then traversed the network within tolerance, this type of data testing would predict a good score when, in actuality, the voice quality would be unacceptable.

Conversely, the approach would predict that a certain level of jitter would adversely affect voice quality; however, an adaptive jitter buffer on the far end gateway could correct the deviation in packet spacing and thus preserve voice quality.

Finally, data test approaches tend to assume that all packets are created equal. Generic packet blasting test approaches, which may work well for testing a router's ability to support best-effort IP delivery, do not uncover the issues that arise when RTP packets need to arrive on time.

TDM-side solution strengths

Generally, a TDM-side approach to converged network testing is to take measurements from either end of the TDM side and to infer the behavior of the data network in between.



Traditional Voice-side Approach to Converged Network Testing

Coming from the other side of the gateway, TDM test equipment makers also evolved existing solutions in the face of voice-over-packet equipment development. In 1998, the industry's first VoIP test system became available. The centerpiece functionality of the tester was voice quality measurement with PSQM, as well as some other measurements of user perception.

Some TDM-side test solutions have advanced capabilities in being able to stress SUTs with real-world traffic from the edge. There are a number of dimensions to this capability. The most effective TDM test solutions can:

· Deliver volumes of traffic at multiple DS3 levels from a single control point.
· Vary traffic volume patterns to emulate different times of day or extreme network conditions.
· Deliver different mixes of TDM media: Tones, real-voice, fax and modem traffic.

All of these capabilities are essential to emulating real-world scenarios.

The best TDM-side solutions can combine the ability to assess QoE from the edge with the ability to deliver realistic traffic, two extremely important capabilities with respect to testing converged network elements.

TDM-side solution limitations

However, while all of the capabilities mentioned above are necessary, they are not sufficient to ensure the QoE of converged networks. There are a number of limitations to a TDM-centric approach.

The challenge arises when trying to test a converged edge device, that is any device that takes information (call signaling or bearer load) and translates or transforms it into some other form, for example, PCM to RTP or SS7 to SIP. The traditional approach is a back-to-back test that uses a complementary device to revert the information to its original format and then testing from the ends.

This kind of testing requires at least two devices to test, which may be difficult early in the design cycle. Also, like-devices may mask violations in protocols by mirroring the same mistake and therefore not manifest the problem. There is a need for an unbiased opinion to ensure compliance and interoperability.

Further, the tendency is to assume that if the system performs in the lab network (sometimes only a wire) it will work when deployed. Typically, however, gateways tested back-to-back in the lab will not exhibit the same performance when deployed in a real network.

Recognizing this limitation of a TDM-side test solution, developers may build up expensive real networks in the lab. Networks in labs are not only expensive to put together, but are also difficult to tune to represent different types of network configurations and problems. Because it is difficult to modify the behavior of the lab network, it is impractical to employ the technique of assessing how close it is to the bounds of its tolerance range, by tweaking the network parameters until there is a breakdown.

Additionally, when there is a problem, TDM-side solutions (similar to data-side test solutions) can only infer what is occurring on the other side of the gateway. Some tools, for example, send tones at specific intervals and attempt to correlate any deviation in spacing as being jitter. Latency variations based on varying network traffic or a malfunctioning codec could also account for the change; however, jitter is blamed. Other tools predict, based on voice quality scores, that packets are being lost somewhere on the line. But the voice quality may be corrupted by another non-packet related source. There are numerous opportunities in a converged network for a call to go awry—codecs, protocol handoffs, and buffering. Inferring which could be the problem is only minimally helpful in diagnosing problems in the equipment being tested.

For the most part, test equipment manufacturers have played to their strengths, still offering solutions that primarily focus on one side of the gateway or the other. One vendor provides a system that begins to cross over to the other side of the gateway. The system uses an Ethernet connection in addition to TDM port to generate RTP traffic on the data side, thus achieving more of the real world on the network. The system also uses the network connection to monitor QoS statistics, such as jitter, packet loss, and bandwidth utilization on the network. Although this has been a great step forward, the inherent performance limitations of a PC NIC card limit the capabilities.

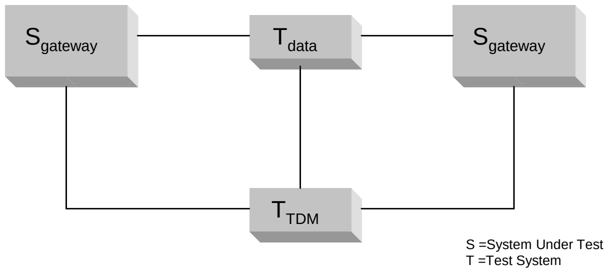
The real answer to meeting the requirements of assuring QoE in converged networks lies in *converged* testing solutions.

Converged Testing Approaches

The concept of converged testing is straightforward at one level. It simply means integrating TDM- and data-side testing solutions and allowing the tester to tweak either side to understand the impact on the other. The benefits of a converged solution are fewer problems in the field, faster diagnostics in the lab and reduced testing time and cost. Today, engineers must cobble together pieces of traditional solutions, and attempt to synthesize the results back into a coherent understanding of what the problems are and how to fix them. Converged testing solutions take that burden off of developers and test engineers and provide a step increase in ability to ensure QoE in next generation networks. Converged testing approaches can provide the best of both, and make it easier to create real world conditions in test labs and to isolate and diagnose problems in systems under test.

Converged Network Emulation

The first step in enhancing next generation network testing is Converged Network Emulation testing. It exceeds what has been possible before for testing systems under real-world conditions. This approach merges the real-world traffic generation and measurement capabilities of TDM-side solutions with the real-world data network emulation capabilities of data-side solutions. The TDM tester initiates calls while controlling how the data test platform functions as a network emulator, delaying and modifying packets as they pass through to emulate actual network impairments.



Converged Network Emulation Approach

From a single logical test system (physically one or multiple boxes), the user may set test parameters, monitor on-going results, and review integrated reports documenting corresponding events on both sides of the gateway. This test approach involves a test bed that truly replicates real-world conditions and thresholds and avoids the cost of placing the actual components in the lab. It also avoids time-consuming configuration and reconfiguration of each individual component in order to mimic parameters of implemented networks. This approach monitors QoE from an end-to-end perspective, while also validating that QoE will hold up under real-world network conditions.

Users determine the profile by which TDM-based calls are generated (media type, call frequency and duration, off-set) and, at the same time, define the network packet-handling behavior (jitter, packet loss, duplication, re-order, corruption) for a particular test. Running a test with no impairment, and then running that same test with different network degradation scenarios (all operating at wire speed), while observing the effect on voice quality and latency gives a clear picture of how an integrated solution will behave when deployed.

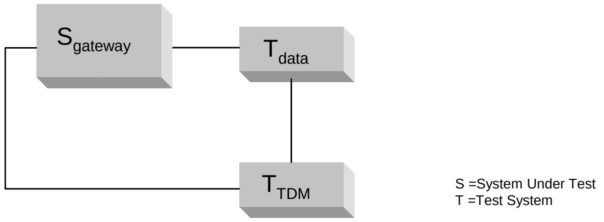
This test methodology is particularly useful for uncovering defects that may not show up in traditional homogeneous approaches. For example, by applying step changes in a particular network condition (impairment), users can determine the point at which nonlinear voice quality scores degrade beyond tolerance.

Beyond test configuration and setup, monitoring is another critical element of converged testing. The ability to observe real-time information about a particular test in progress on both sides of the network (for example, calls originated versus calls terminated, and latency or speech quality measurements overlaid on call volumes) is necessary for efficient testing. Monitors allow users to quickly predict thresholds and targets that can be refined over time with more deterministic testing.

Clearly a Converged Network Emulation approach provides a more realistic assessment of QoE than traditional approaches alone are capable of delivering. Although diagnosing and isolating problems can still be a challenge with this approach, converged analysis and reporting can be great aids. Information about specific calls originating on one side of the new world and terminating on the other side can quickly point users in the right direction and can suggest experiments for determining problems.

Isolated Device Testing

The next converged testing approach is Isolated Device Testing. It simply means "wrapping around" a device or perhaps small set of edge devices and directly testing it. This approach has traditionally only been possible for homogeneous devices. This is the way routers are typically tested in the data world, and it has been used for testing voice devices in TDM networks as well. The challenge for converged networks is testing the heterogeneous gateways on the edge between TDM and data devices. This approach requires (again) a logical test system that can interact with both sides of the gateway and can create realistic conditions for each.



Isolated Device Testing Approach

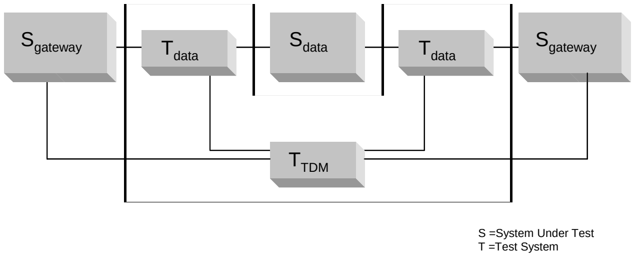
A comprehensive Isolated Device Test solution can uncover issues that would impede QoE of the systems well before they are even close to deployment. Testing devices in an isolated fashion enables quick testing early in the design process. It provides control and visibility to the isolated device.

Thus, a converged solution that is capable of generating TDM traffic and terminating IP-based media streams (and vice versa) from a single interface overcomes many of the limitations of back-to-back testing. Straightforward call load and path confirmation are the obvious benefits. For such a solution to provide a measure of QoE under real-world operating conditions also requires voice quality and media (tone, fax, modem) verification.

If the test system supports the ability to compare the PSTN signaling messages to a device with the associated IP messaging then signaling handoff problems identification and resolution is accelerated. For equipment manufacturers this translates into a time-to-market advantage. For solution or service providers testing the interoperability of equipment from multiple vendors, it eliminates the finger pointing that sometimes accompanies those installations.

Complete End-to-End Testing

For all the benefits of the aforementioned converged testing approaches, there is a further step in test technology that combines the benefits of both. The Complete End-to-End approach provides the QoE perspective and real-world nature of Converged Network Emulation and the problem-solving strengths of Isolated Device Testing. This methodology retains the notion of a single logical test interface and expands the visibility and control by placing smart data probes between each device of interest.



Complete End-to-End Testing Approach

From this vantage point users will not only be able to control the data backbone and observe the effects on QoE, they will also be able to trace the hops and conversions as media and signaling traverse these next generation networks. Device isolation is taken to the next level and pinpointing problems within these vast networks is more easily attained.

communications infrastructure test group

A test approach of this type will provide engineers access to extremely valuable diagnostic information. For example, after traditional signaling is verified for correctness upon conversion from the PSTN to the packet network through the edge device (probably SS7 to SIP), bearer traffic could be assessed for voice quality. At the same time QoS metrics, such as jitter, packet loss, and bandwidth utilization could be garnered. QoS-enabled routers and devices would then be measured against SLAs as packets continued to traverse the network. Interdevice messages, such as MGCP, could also be validated between signaling and media gateways. This process would continue across multiple hops until the media stream reached its destination within the packet-switched network or back into the PSTN world. End-to-end assessment would include time and quality measurements, as well as interdevice statistics and overall QoE.

The value of the approach is clear; however, the implementation challenges and the breadth of technical expertise required make this a formidable challenge. The extensive number of handoffs and conversions in next generation networks (particularly wireless networks) implies long lists of protocols and interfaces. It is unlikely that a single vendor could cover the entire spectrum. Industry standards and open architectures must evolve before the Complete End-to-End Approach testing becomes a reality.

Summary

Converged testing solutions enable test approaches that have never before been possible with traditional testing. Converged Network Emulation provides a much more realistic assessment of the QoE that network users will ultimately experience in deployed networks. Isolated Device Testing on converged devices enables much quicker problem isolation than ever before possible with back-to-back testing. Complete End-to-End testing provides the realism of Converged Network Emulation with the diagnostic capability of Isolated Device Testing.

More Like Real World →

Better Problem Isolation ↓

Traditional Approaches	Converged Network Emulation
Isolated Device Test	Complete End-to-End

Assuring QoE on Next Generation Networks with Empirix Converged Testing Solutions

Hammer test equipment leads the industry in being able to assess QoE with high volumes of real-world, multiple-media TDM traffic including voice, tones, fax and modem. The Hammer VoIP Test System was the industry's first step toward the goal of Complete End-to-End Testing because it combines TDM-side capabilities with data network monitoring and packet generation.

This system has been state of the art for assessing QoE in next generation networks. With the introduction of the Hammer PacketSphere platform, Empirix is the first vendor to address the need for converged test solutions designed to help assess QoE on next generation networks.

The new wire speed platform (greater than 1.4 million packets per second) is based-on cutting-edge network processor technology that enables it to support multiple interfaces and applications. The first available application is a network emulator integrated with the Hammer system to support the Converged Network Emulation approach. In development is an RTP media streamer that advances the Hammer Isolated Device Test solution for edge devices. Future developments of test applications straddling both sides of the gateway enable us to continue to lead the way to Complete End-to-End Testing solutions.

The success of next generation networks ultimately depends on satisfying the high expectations of network users. Testing converged network equipment demands converged testing approaches. Equipment manufacturers and carriers who assure QoE in the lab by adopting these new approaches will enjoy the ultimate competitive advantage…happy customers.

Empirix
205 Lowell Street
Wilmington, MA 01887
United States
T: 978-661-4800
F: 978-988-0148

Empirix Europe
Building A, Trinity Court
Wokingham Road
Bracknell, Berkshire
RG42 1PL
United Kingdom
P: 44-1344-66-80-80
F: 44-1344-66-81-72

Empirix Japan
Yamate-K Building
2-10-15 Nakameguro Meguro-ku
Tokyo, Japan
153-0061
P: 81-3-3791-2336
F: 81-3-3791-5353

Empirix Singapore
87 Science Park Drive #03-01
The Science Hub
Singapore Science Park 1
Singapore, 118260
P: 65-872-7239
F: 65-872-5239

Internet
www.empirix.com
E-mail
info@empirix.com