

White Paper
**Ensure IPTV
Quality of Experience**



IPTV is Heating Up

Communication Service Providers (CSPs) are developing Multiplay services to increase revenue and retain customers. IPTV, as the key component of CSP Multiplay strategy, enables traditional Telco carriers to compete with Cable operators, who are eroding Telco voice service revenue by adding VoIP to complete their own Multiplay strategy.

IPTV service delivery is triggering the most remarkable evolution of Telco networks in this decade. The pace and extent of this evolution are enormous. Network infrastructures, throughout access, edge and core networks, have to be reshaped. Video Sources are becoming part of Telco equipment. After several years of Capex decline in the early 2000's, CSPs are beginning to increase their investment, the largest portion of which is represented by IPTV. There are opportunities as well as challenges for Network Equipment Manufacturers (NEMs) to provide IPTV-enhanced equipment.

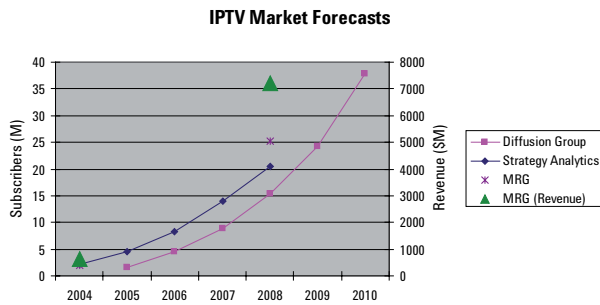


Figure 1: Market forecast for IPTV

The industry is in close agreement about the size of the IPTV opportunity. The above graph, which combines and compares the market forecasts of several analysts, shows an 80% per year expected increase in IPTV subscribers and revenue, continuing until at least until 2008.

QoE: Paramount for IPTV Service

Quality of Experience (QoE) describes how well a service satisfies user expectations. It is a rating of service performance from the user perspective. For IPTV, CSPs are expected to achieve equal or better QoE than traditional cable and satellite TV providers. Unfortunately, early implementations of IPTV are proving that this is quite a challenge.

Before service deployment, CSPs and NEMs evaluate equipment and systems in their lab by quantifying performance. Since IPTV QoE assessment is subjective, CSPs and NEMs need to understand all the factors of IPTV QoE and how to translate these subjective QoE factors into objective metrics that can be quantified using a proper test methodology. Comprehensive knowledge of individual devices as well as end-to-end network systems is also required.

Factors of IPTV QoE

Figuring out the factors of IPTV QoE is the first step to measuring it. IPTV QoE encompasses many factors, describing customer experience of technology, service value and usability.

Technical Factors of IPTV QoE are closely related to technologies and equipment that are being adopted to deliver IPTV service. Here, we map these factors into metrics that can be objectively measured, and develop test requirements and scenarios for each factor. Technical factors of IPTV QoE are:

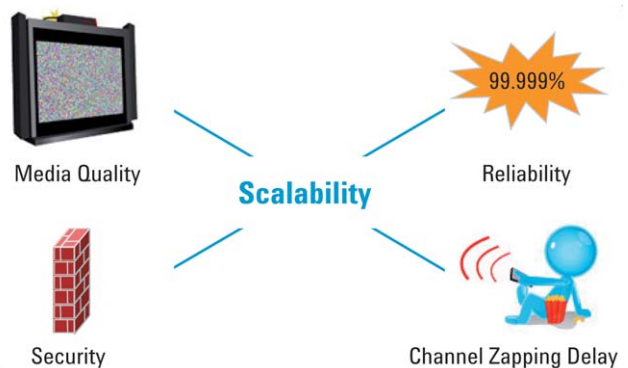


Figure 2: Technical factors of IPTV QoE

- Media (video and audio) Quality: How good is the IPTV service video and audio quality as perceived by the subscriber?
- Channel Zapping (also called channel surfing): Is the channel changed quickly and correctly?
- Reliability: Is the IPTV service reliable and stable?

- Security: Is the IPTV service secure in the IP network? Could subscribers experience disruptions caused by hackers or other malicious users?

Individual subscriber QoE is not enough to measure the service. Users' experience of the technical factors must be evaluated under maximum expected load. Scalability – the system performance under load, and capacity – the maximum number of subscribers that can be supported, are important issues that must be fully considered.

Commercial factors of IPTV QoE include price and content. These are not measurable by test devices. Subscribers will compare IPTV service with cable and satellite TV, and will expect service consistent with the plan for which they pay. Reasonable price offerings and popular content partners will help IPTV in a highly competitive entertainment marketplace.

Usability factors can be described as ease-of-use issues, also not measurable by test equipment. The speed of Set Top Box (STB) setup, the electronic program guide ease of use, and the simplicity of remote control operation will influence user experience of IPTV.

User expectation is a combination of all the IPTV QoE factors. Ignorance of any factor will result in a failure of the service. However, as a technical white paper exploring how to ensure and improve IPTV QoE, we will draw our focus toward technical factors.

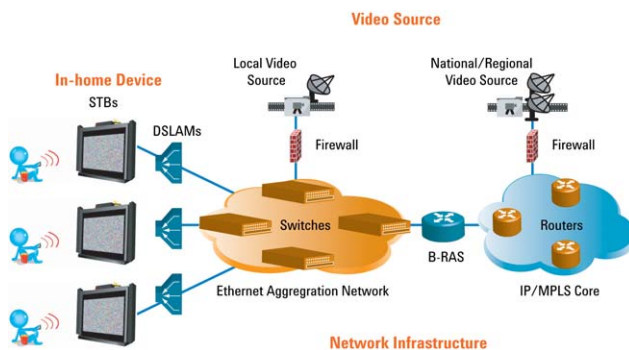


Figure 3: End-to-end IPTV delivery system

The Video Source, responsible for aggregating and managing IPTV content, is a new component of Telco networks. It is composed of many devices including IPTV encoders and Video on Demand (VoD) servers.

The Network Infrastructure is responsible for transport of IPTV traffic from the video source to household. The most popular network devices are DSLAMs (DSL Access Multiplexers), Ethernet/ATM aggregation switches, B-RASs (Broadband Remote Access Servers), and edge and core

routers. Since traditional network infrastructure lacks the functionality, capability and scalability to carry IPTV traffic, CSPs are investing heavily to upgrade their infrastructure, all the way from the “first mile” access through to edge and core networks.

In-home Devices include STBs, TVs, DSL modems, splitters, and in-home cables. High quality STBs and high resolution televisions will definitely improve QoE. These devices normally belong to the consumer electronics product category and are not the prime focus of service providers. Since each in-home device serves only one household, scalability doesn't impact performance. Customers can judge the performance and functionality of these devices by product demonstration.

As in-home networks become more prevalent, this may become a more important area of focus for QoE, however for the purposes of this paper we will focus on the carrier network infrastructure.

Why IPTV QoE Evaluation is Hard

CSPs and NEMs are keen to evaluate and improve IPTV QoE, but lack methodologies to quantify subjective experience. Although IPTV trials have accumulated customer feedback, evaluation is still hard. Cultural background, personal experiences, economic status, and expectations will strongly influence users' QoE ratings. Objective measurements are strongly desired.

IPTV QoE has so many factors to be concerned about. Each factor will generate a chain of challenges. The network designers and managers often feel there are too many problems to look after. Moreover, QoE could vary dramatically when the number of subscribers is increased.

As an emerging service, IPTV relies on some new technologies and equipment which are not 100% verified. Complicated processes and numerous devices are in the path of IPTV delivery, making troubleshooting extremely difficult. Even a minor problem might downgrade several QoE factors, or even cause service failure.

How to Ensure IPTV QoE

Telco CSPs and NEMs are fighting their way out of an IPTV QoE maze. Here are some steps recommended to make life easier.

- Step 1: Understand the key challenges of each IPTV QoE factor. Determine which equipment and technologies are most likely to impact quality.
- Step 2: Translate subjective QoE factors into objective measurements. Develop test scenarios, and metrics to characterize performance and scalability.
- Step 3: Write test plans and select appropriate test tools to measure IPTV QoE.
- Step 4: Analyze test results, troubleshoot and optimize network devices and systems.

The following section introduces the main challenges and testing methodologies of each IPTV QoE factor. Some recent “shock results” we measured in our test lab will also be shown.

Media Quality

Media (video and audio) quality is the obvious monster challenge for IPTV QoE. TV is fundamentally a media service providing visual and auditory entertainment for subscribers.

Perceived media quality of IPTV is sensitive to network impairments including packet loss, latency, jitter and packet sequence errors. Video problems created by these impairments such as blocking, blurring, edge distortion, judder and visual noise will poison QoE. Audio is the other dimension of media quality. Noisy or unsynchronized sound is not acceptable.

Challenges of Media Quality

IPTV is transmitted over an IP infrastructure, which is traditionally a “best effort” transmission platform for non impairment-sensitive data services. Some key challenges have to be resolved before actual deployment of IPTV service:

- **Bandwidth Availability.** A standard IPTV channel using MPEG-2 encoding requires 1.5 to 4 Mbps. If service providers allow for 2-3 TVs per household and have other network services running on the same physical connection, the minimum requirement for access bandwidth will be 10 Mbps or higher. Moreover, since user concurrence of TV service is much higher than other data services, the aggregation, edge and core networks will also need considerable bandwidth upgrades.

- **Forwarding Performance.** Broadcast IPTV uses multicast to transmit content in order to minimize bandwidth consumption. However, most installed network equipment is inefficient for multicast traffic forwarding. Routers, switches, B-RASs and DSLAMs need major upgrades to enhance multicast capabilities and performance. Because unicast applications share bandwidth with broadcast IPTV, network equipment must forward a mix of unicast and multicast traffic at wire rates.

- **Bandwidth Management.** Simply increasing available bandwidth is not sufficient to guarantee that IPTV bandwidth requirements will be met. Peer-to-peer (P2P) file sharing applications, the “all you can eat” bandwidth hogs, already gobble up 50% to 80% of global network bandwidth. Many of these P2P applications are cleverly disguised by piggybacking on well-known service port numbers (including port 80), encapsulation within other application protocols (such as HTTP), and by using payload data encryption. To protect sensitive IPTV traffic from impairment, QoS policies have to be implemented in networks from end to end. Another tip for bandwidth management is to rate-limit or shape harmful traffic in the network, such as P2P and email viruses and spam. Clever bandwidth management equipment employing deep packet inspection should be considered.

In addition, as the new family members of the Telco world, the maturity and stability of video source devices are still evolving.

- **VoD Server Performance.** To differentiate from traditional TV, IPTV providers are announcing new enhanced services in which “on demand” is a principal benefit. However, the performance of today’s VoD servers can be a bottleneck. The maximum number of users and maximum aggregate throughput of VoD servers must be increased.
- **IPTV Encoder Performance.** Compared to VoD servers, the load of IPTV encoders is relatively easier since they do not need to respond to thousands of subscribers directly. IPTV encoder performance is mainly influenced by video format and the number of channels encoded simultaneously.

Improve Media Quality by Measurement

Network impairments seriously downgrade IPTV service. The objective of infrastructure test is measuring performance under load and observing behaviors of DUTs (Devices Under Test) or SUTs (Systems Under Test). The tester generates video traffic consisting of hundreds or even thousands of IPTV channels as well as other traffic (such as VoIP, TCP and P2P) to stress the network infrastructure, and then analyzes the impact of impairments on QoE by measuring the performance experienced by large numbers of emulated subscribers.

DUT: Core/Edge Router, B-RAS, DSLAM, Switches
SUT: End-to-end network system



Figure 4: Media Quality test scenario for Network Infrastructure

Based on this fundamental test scenario, test cases can be created to include:

- Baseline performance testing
- QoS policy testing
- QoE/performance “per-subscriber” testing
- Multicast video, unicast video, and multicast/unicast mixture testing
- P2P traffic management testing

Packet-level test results (such as packet loss, latency/jitter and sequence errors) characterize the basic performance of network infrastructure equipment. Telco standards bodies are currently researching new standards for video quality measurement. PSNR (Peak Signal-to-Noise Ratio) is an existing metric that is very simple but poorly correlates with perceived video quality and subjective testing. The ITU VQEG (Video Quality Experts Group) is developing an objective MOS (Mean Opinion Score). A new MDI (Media Delivery Index) standard reports media stream quality based on packet loss and packet latency variation (jitter) network impairments.

MDI, which was proposed by RFC4445, gives an indication of video quality based on the delay factor(DF) and the media loss rate(MLR). As a lightweight and codec independent measurement, MDI is feasible to perform simultaneous measurements on 100s of video streams passing through. This is key for achieving per-subscriber QoE measurements in a scalable testing environment.

Please note that per-subscriber and per-channel statistics are important and necessary for QoE measurement. CSPs and NEMs need to know the service performance and quality experienced by every customer. Average/minimum/maximum data are not adequate for QoE assessment.

Performance of Video-on-Demand systems is the biggest video source challenge. RSTP (Real Time Streaming Protocol) is the most popular VoD protocol. It is important to know how the RTSP server behaves under maximum load. Does it crash? Does it drop packets from existing streams? Does it start to respond more slowly to new streaming requests? Does RTP (Real-time Transport Protocol) packet latency or jitter increase? The test scenario for VoD performance verification is straightforward. The tester emulates a large number of subscribers and measures the impact on the video server to characterize server scalability and user capacity.



Figure 5: Test scenario of VoD server

Based on the basic scenario above, measurements include:

- Packet loss, sequence errors, latency and jitter
- Maximum number of simultaneous streams
- Maximum session rate
- Maximum video throughput

Scalability and user capacity are inter-related. Scalability measures how well the system performs as the number of users increases. Capacity is a measure of the maximum number of users, within given performance bounds. Another important measurement is the maximum rate of new RTSP sessions. This is important because providers will receive multiple requests in a short period of time when certain events occur, such as when broadcast TV programs finish, or after an outage, or following an advertisement.

“Shock Result”

A commercially available VoD server was tested to create the following test results.

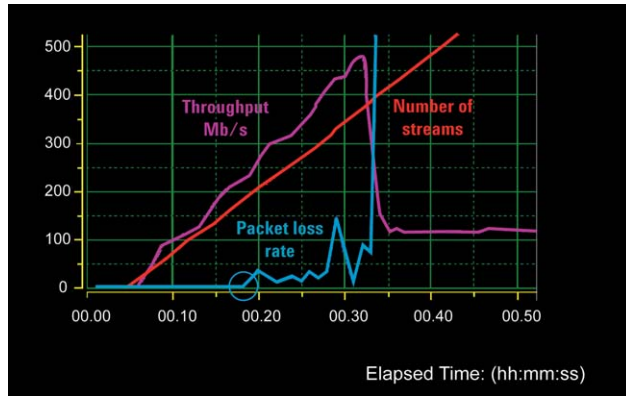


Figure 6: Test result – RTSP server performance

The RTSP server was tested using multiple RTSP clients, emulated by Agilent’s NetworkTester application performance tester. Each client was configured to request a file to be streamed from the RTSP server, and to repeat this request upon file transfer completion. The number of clients was slowly ramped up to characterize the RTSP server’s maximum performance, while measuring throughput and packet loss at the same time.

As the number of clients increased, the response time of the server decreased. Real users would notice this as an increased time between selecting a movie and seeing the movie playback begin. At a level of just over 200 Mb/s of aggregate throughput, the RTSP server began to ‘drop’ packets – this was observed as gaps in the RTP media streams, measured as packet loss by the tester. Therefore, 200 Mb/s was the maximum lossless throughput. As load was increased further, throughput increased up to a maximum of about 475 Mb/s, but at this rate there were considerable gaps in the media streams. Eventually, the server could not cope with the load, and throughput dropped to only 120 Mb/s while sustaining huge packet loss that would make the media stream unwatchable.

This demonstrates that it is insufficient to measure maximum server throughput in isolation. Test equipment must be used that can verify the integrity of every stream at the same time.

Channel Zapping

How quickly and correctly the subscribers can change channels is an important part of IPTV QoE. Acceptable channel zapping delay is generally considered to be around 1 second total, end-to-end. A channel zapping time of 100~200 ms is considered by viewers to be instantaneous. Sources of channel zapping delay include network equipment (such as B-RASs, DSLAMs, and aggregation switches) and STBs.

STBs, the IPTV enabler in subscribers’ homes, add several hundred milliseconds of delay when changing channels due to command processing, buffer delay, MPEG decoder delay and video buffer delay. Fortunately, each STB serves only one home (so there are no scalability issues) and the main STB functions are processed in hardware. Therefore, STB performance is relative stable and repeatable.

Multicast protocols are used as the technique to enable channel zapping in network infrastructure. IGMP (Internet Group Management Protocol) or MLD (Multicast Listener Discovery) leave/join delay is the main source of channel zapping delay. To keep overall channel zapping delay within one second, the target multicast leave/join delay of each network component needs to be about 10-200 ms.

Channel Zapping Testing Challenges

Channel zapping testing is full of challenges:

Accuracy: IGMP/MLD leave and join commands are control plane messages that are normally handled by the CPU, both within DUTs and within most testers. However, CPU-based measurement implementations typically have an accuracy of only 10s of milliseconds, which is not accurate enough. As a result, hardware-based IGMP join/leave measurement is required.

Realistic environment emulation: In a realistic ‘Multiplay’ user environment, protocols at multiple layers such as PPPoE (Point to Point Protocol over Ethernet), DHCP (Dynamic Host Configuration Protocol) and TCP, as well as unicast and multicast traffic, are running simultaneously. The test solution must realistically emulate these complicated conditions.

Scalability: The IPTV channel zapping testbed must be able to emulate thousands of subscribers and hundreds of channels in a single test scenario. Only large-scale simulation can help CSPs and equipment vendors evaluate realistic performance under load, to determine scalability thresholds.

Improve Channel Zapping by Measurement

The following figure shows an IPTV channel zapping scenario for testing network infrastructure devices and systems. The testers emulate both the video provider side (with hundreds of channels) and the subscriber side (with thousands of subscribers). The test interfaces send large numbers of IGMP leave and join commands to stress network equipment IGMP performance.

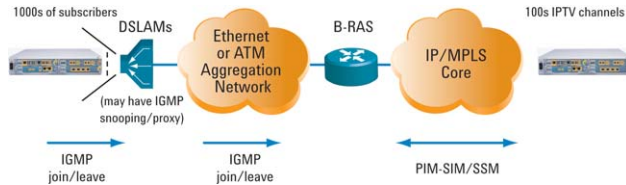


Figure 7: Test scenario for IPTV Channel Zapping

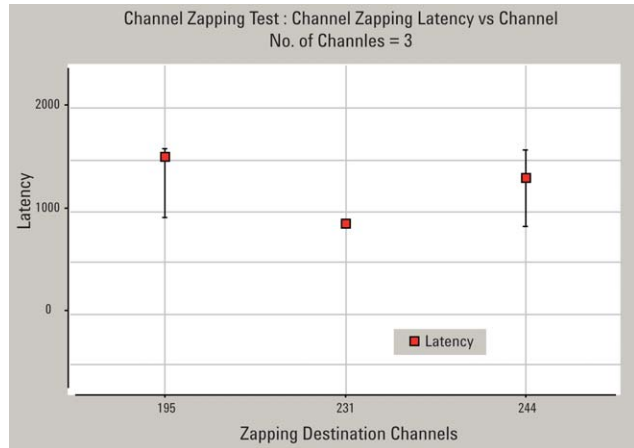
Base on the scenario above, tests include:

- IGMP or MLD leave and join delay for subscribers
- Sustained channel zapping performance
- Channel zapping performance under peak load

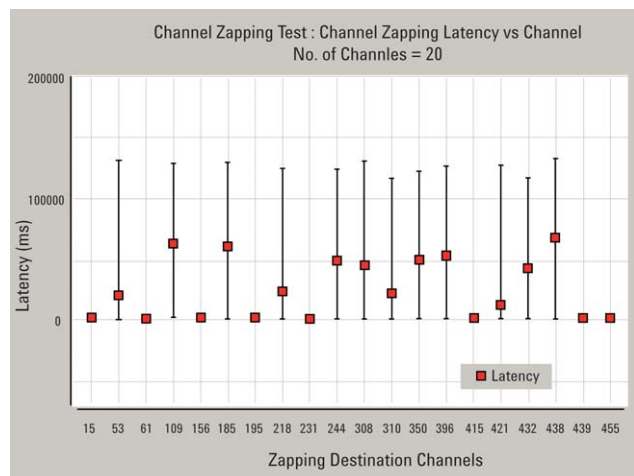
The test metric is simple: channel zapping time. CSPs and equipment vendors can improve QoE by enhancing equipment Multicast performance. To achieve the target, an accurate, scalable and realistic test solution is essential.

“Shock Result”

We tested a widely deployed B-RAS to generate the following channel zapping result.



150 users, 50 user per group Zapping delay: 0.9 ~ 1.5 s



1000 users, 50 user per group Zapping delay: 0.9 ~ 70s

Figure 8: Test result – B-RAS IGMP leave/join performance

For this test, Gigabit Ethernet interfaces of the Agilent N2X tester were used on both the subscriber side and the network side. The test result shows a dramatic zapping time (IGMP leave and join) change when the number of subscriber was increased from 150 to 1,000. Maximum channel zapping time increased from 1.5 seconds to 70 seconds.

From a technical point of view, the result is unexpected but reasonable since the DUT apparently uses its CPU to handle IGMP control plane messages. When 1,000 leave and join messages arrived at the DUT simultaneously, the CPU was overloaded and took a long time to process all IGMP messages. However, for subscribers, waiting 70 seconds for changing a channel is not a pleasant experience.

Reliability

Subscribers expect reliable IPTV services that service providers must guarantee. Before we discuss IPTV reliability expectations, it is worth considering the precedent set by cable and satellite TV services. Industry statistics show that cable TV outages average 3% to 5% per year, while satellite TV outages average about 1% per year. J.D. Power and Associates has ranked satellite TV higher in reliability satisfaction than cable TV for the last five years.

For many years, Telco operators have maintained a “five-nines” (99.999%) reliability standard, also known as High Availability (HA), for fixed-line phone systems. Operators are keen to keep the “reliable” image for IPTV services. When SBC announced a \$4 billion investment in IPTV, “getting IPTV to meet a five-nines standard” was at the top of the to-do list.

A high availability of just 5 minutes service outage per year is an aggressive target for IPTV. That requires all of the components of IPTV to exceed the five-nines standard.

The following techniques will help CSPs and equipment vendors to improve the reliability of IPTV network infrastructure:

Hardware Redundancy is widely used in Telco equipment to improve reliability. Although most hardware redundancy technologies are not based on public standards and vary from vendor to vendor, the general method is the same – to use redundant hardware to take over the job when in-service hardware malfunctions.

HA Protocols and protocol extensions improve the availability of IP networks. These protocols eliminate or minimize data forwarding disruptions in the event of disturbances and network or node failures. Example HA protocols are Graceful Restart (for routing protocols such as OSPF, BGP4 and IS-IS) and MPLS Fast Reroute.

Hot-Swappable Hardware enables the addition, removal or replacement of hardware modules without stopping the chassis or service.

The reliability of video source devices must also be considered. The main question is whether “software dominated” VoD servers can meet availability standards.

Ensure Reliability by Testing

Proper techniques improve reliability of IPTV systems. Reliability test methodologies help CSPs and equipment vendors verify the functionality, performance and robustness of the techniques described above, and measure the failover performance of IPTV equipment and systems.

Key tests for reliability:

- HA routing protocols: HA routing is a new and essential technology that can improve the reliability of IPTV. It is vital to measure the functionality, performance and interoperability of HA protocols for IPTV services. Visit Agilent’s website for detailed test methodologies on High Availability testing: <http://advanced.comms.agilent.com/n2x/docs/whitepapers/highavailability.htm>
- Hardware Redundancy and Hot Swap: These tests are not new for Telcos. As always, usability and efficiency of these techniques have to be verified.
- VoD Server: Test VoD servers for a long duration, and increase the load to measure the impact on reliability of a large number of subscribers.

Security

Security issues don’t bother Cable TV users but can be a big barrier for all applications and services running over public IP networks. Thousands of hackers are busy attempting to crack everything in the Internet. IPTV is no exception – the motivation for hackers is to obtain free TV service, or to disrupt IPTV networks or devices in order to deny service to paying subscribers.

Security of IPTV is a rather broad topic, covering content protection and encryption, DoS attacks, malicious traffic and user authentication... thus making a long working list for network managers.

Security Challenges

Customer experience of security is not as complicated as service provider opinion; for example, content copy protection is a concern for CSPs but not for the end users. Users expect the system to authenticate them correctly, enable their services, and offer them the content that they want.

Consequently, user authentication and video source protection are the main security challenges from the QoE viewpoint.

User authentication: DSL is a point-to-point access network that uses PPP or DHCP to establish user connections. PPP employs a username and password for user authentication. However, users would not like to input a name and password before watching TV! As a result, DHCP is becoming a preferred technique for access connection. DHCP does not have an authentication mechanism equivalent to that of PPP. DHCP Option 82, a relatively new feature of DHCP, enables the validation of subscribers by location – typically by using a router port number or a virtual circuit identifier.

Video source protection: Video sources, especially VoD servers, are under DoS (Denial of Service) attack like other servers (such as web, email and FTP servers). To protect video sources, application-aware firewalls or application layer gateways (ALGs) are used to pass “good” video traffic but filter DoS attacks and other threats by inspecting deep into the application layer of packets. However, application-layer filtering and intrusion prevention are computationally intensive and can reduce the performance of a firewall by 10-40% or more.

Ensure Security by Testing

Security testing covers numerous test scenarios and test cases. Here are two selected security tests related closely to IPTV QoE.

1. Test DHCP Option 82 subscriber authentication

Option 82 enables user authentication by location within the DSL network. It is important to verify functionality as well as performance by emulating the real environment. In the following test scenario, the DSLAM acts as a DHCP Relay Agent and adds DSL line identification information to the DHCP requests coming from the clients. Tens of thousands of DSL clients are simulated by the tester to test address assignment and authentication via DHCP with Option 82. This test measures maximum DHCP session capacity, session setup rate and setup latency, and validates sessions established via traffic through the B-RAS. This test also allows measurement of throughput, latency and loss of IP traffic over the established DHCP sessions.

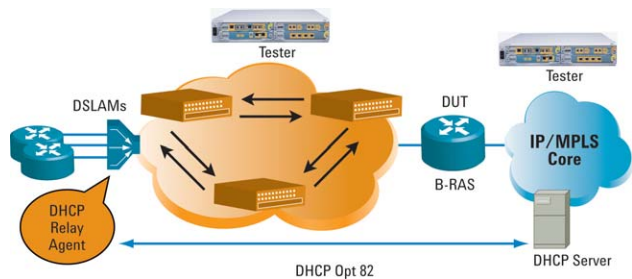


Figure 9: DHCP Option 82 Test Scenario

2. Test the application-aware firewall, the protector of video sources

The functionality and performance of application-aware firewalls must be verified. Since there is a trade-off between security and performance, protecting but not bottlenecking video sources has to be carefully balanced.

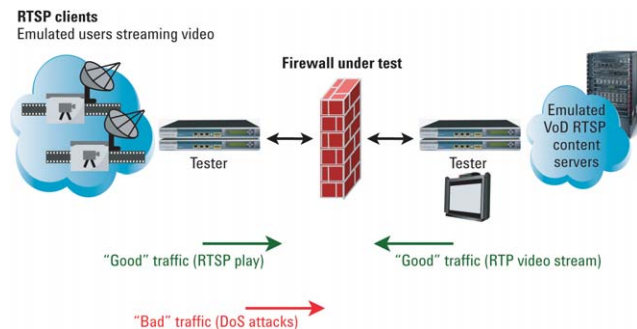


Figure 10: Application-aware Firewall Test Scenario

In this test scenario, the tester emulates both video subscribers and VoD servers and generates bidirectional video traffic to stress the firewall. Malicious DoS traffic is also generated from the subscriber side simultaneously. The firewall's behavior and performance under attack can be evaluated.

“Shock Result”

This test used the test configuration illustrated in figure 10. The DUT was a firewall with application intelligence.

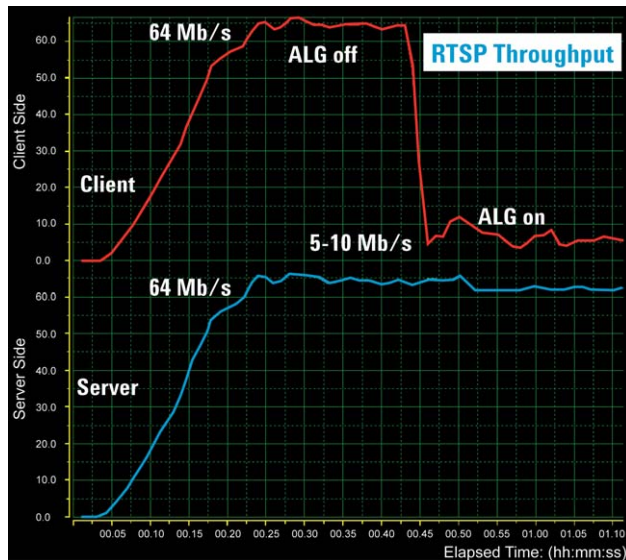


Figure 11: Test result – RSTP-aware firewall performance

The test measures the performance impact of application-layer processing on aggregate RTSP throughput. Agilent NetworkTester emulated both the VoD server and subscribers.

From the result, we found that the emulated subscribers experienced a dramatic performance drop after enabling the firewall's RTSP ALG (Application Layer Gateway) feature, which is a key function for VoD server protection.

Conclusion

QoE, which is paramount for the success of IPTV services includes many factors. Failure of any one of these factors will reduce subscriber satisfaction. However, subjective QoE factors are not easy to measure.

CSPs and equipment vendors need new evaluation methods for network infrastructure equipment and video sources to ensure and improve IPTV QoE. Understanding the challenges of each QoE factor can help them adopt new test methodologies to verify the performance, scalability and functionality of key network components as well as end-to-end service.

Agilent N2X and NetworkTester

The Agilent N2X offers service providers and equipment manufacturers a powerful solution for accurately measuring the scalability and capacity of IPTV infrastructure devices, and characterizing end-user Quality of Experience (QoE) under real-world loads.



www.agilent.com/comms/n2x

Agilent's Networktester is the most comprehensive product for testing the performance of security, bandwidth management and content networking devices and systems used in Multiplay networks.



www.agilent.com/comms/networktester

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