White Paper

Validating IPTV Service Quality Under Multiplay Network Conditions

This paper explains the importance of validating IPTV service quality under realistic Multiplay network conditions

Agilent Technologies

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The opening panel discussion at the recent IPTV World Conference at NAB 2006 was aptly titled 'War!', referring to the increasing competition between Telecommunication Service Providers and cable Multiple Service Operators (MSOs) as they battle to capture a household's total communications budget. Service providers have suffered dwindling service revenues as MSOs offering Multiplay service bundles secure an increasing share of their traditional stronghold, the voice subscriber base. For service providers, it's a war of survival, and the coveted Multiplay 'voice, Internet and television' service bundle is the strategic arsenal that will likely determine which rival will succeed as victor and capture the spoils (subscribers). The ability to provide multiple services to a single subscriber significantly increases average revenue per user (ARPU) and dramatically reduces subscriber churn.

Service providers are investing heavily in IPTV to complement their existing voice and data services, and compete with cable MSOs. IPTV is the key component to service provider growth and has been shown to as much as double ARPU. Analysts forecast that IPTV service revenues will increase at an average of 154% per year between 2004 and 2005, and worldwide IPTV service revenue will grow to over $44 billion in 2009.[1] The financial rewards and strategic impact of IPTV are triggering the most remarkable evolution of telecommunication networks in this decade. According to Infonetics Research, spending on IPTV-related services infrastructure will total $1 billion dollars this year, double by the end of 2007, and reach $4.4 billion in 2009. [2]

Before IPTV proliferation and Multiplay utopia is realized, service providers and network equipment manufacturers (NEMs) must first verify that IPTV services will in fact meet user quality expectations, and that this final piece of the puzzle completes a pretty picture overall. What happens when you converge and scale time/loss-sensitive video traffic with existing voice and data services contending for the same network resources? Viewers have come to expect a predictable level of service quality with their broadcast and satellite TV services and will not be tolerant to service interruptions, picture degradation, or long waiting periods to change channels with their new IPTV service.

IPTV Quality of Experience (QoE)

With so much at stake, it is not surprising that 'IPTV QoE' (IPTV Quality of Experience) has become one of the most popular buzz words within industry publications, tradeshows, and forums. IPTV QoE refers to how well the video service satisfies user's expectations. The IPTV quality experienced by subscribers must be equal to or better than today's cable and satellite TV services, or else service providers run the risk of significant subscriber churn.

IPTV QoE is influenced by commercial factors, such as the price, content and features of the service, as well as technical factors including channel change response times and the media quality itself. 'Measuring' IPTV QoE refers to testing the technical aspects that influence the subscriber's service experience. With acquisition costs estimated at $1000 per subscriber, it is important that IPTV QoE be validated on a per-subscriber basis.

Segmenting the IPTV equipment market

Four main systems of equipment are responsible for the delivery of IPTV services:

- The video head-end where the applications and program content are stored
- The network, which is the transport mechanism that delivers the TV content and interactive services from the head-end to the home
- The middleware, which is the software that controls the TV content and interactive services delivery from the head-end to the customer's home over the network
- The customer premise equipment, which is the Set Top Box (STB) that resides within the home and is connected to the television[3]

Each of these four systems can influence IPTV QoE, and has its own specific test considerations and relevant measurements. Before end-to-end testing and network integration, it is important to test each system (and individual elements within each system) independently to verify that each device meets performance expectations, and to pinpoint where problems exist. This discussion is focussed on the emerging test methodologies and metrics for verifying IPTV QoE across the IPTV delivery network, as illustrated in Figure 1.

1. Infonetics Research, Inc., IPTV Equipment and Services Market Outlook, 2005, p. 30.
2. Ibid, p. 26.
3. Frost & Sullivan, World IP Video Test & Measurements Markets F615-30, 2006, p. 2-1.

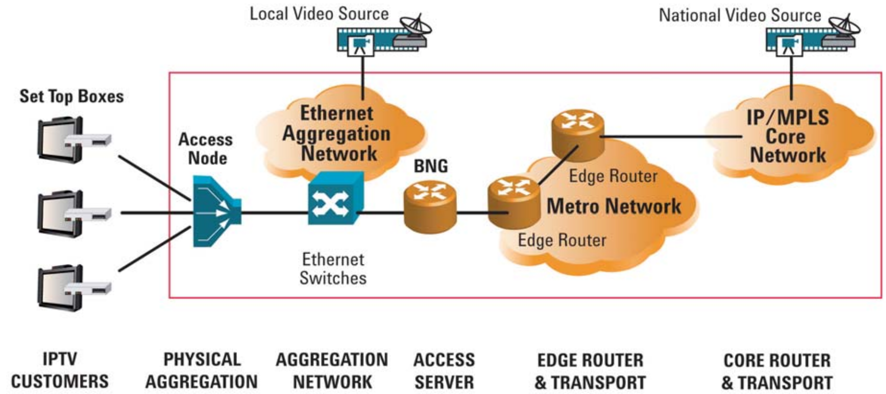

Figure 1: IPTV delivery network

IPTV QoE test measurements

There are two fundamental areas of IPTV QoE testing:
- Channel zapping measurements
- Media (audio and video) quality metrics

Channel zapping measurements measure how quickly subscribers can change channels, and verify that they are in fact receiving the correct channel. 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. Multicast protocols enable channel zapping within the network infrastructure. IGMP (Internet Group Management Protocol) or MLD (Multicast Listener Discovery) leave/join delay has a direct impact on 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.

Measuring IPTV media quality is a formidable challenge since there are many factors that can compromise the perceived media quality. The scale and behavior of IPTV subscribers and convergence of other Multiplay traffic contending for finite resources on the network has a significant impact on the timely and accurate forwarding of IPTV packets. The resulting network impairments (packet loss and sequence errors, latency and jitter) can have various detrimental effects on visible video quality such as blocking, blurring, edge distortion, judder (choppy picture) and visual noise. Therefore, a complex network environment that accurately reflects the characteristics of Multiplay networks must be represented in the lab in order to sufficiently stress network equipment, and evaluate IPTV media quality.

Network characteristics and media quality

Exponential subscriber growth

It's estimated that the number of IPTV subscribers worldwide will reach 53.7 million in 2009 and IPTV subscriber growth in North America alone will increase 12,985% between 2004 and 2009.[4] France, the leading European country in rolling out IPTV services, had 281,000 subscribers registered to the three main IPTV services (Maligne, Free and Neuf) at the end of 2005.[5] Digital video distributed via IP multicast (IGMP in most networks) doesn't ensure consistent video quality among all the users watching the same channel. It is therefore difficult to ensure that each and every subscriber is receiving the video properly. Since both bandwidth and processing resources in the IPTV delivery network are finite, it follows that the more subscribers requesting the IPTV service, the higher the threat of compromised QoE. It is critical that network equipment be tested under an increasing scale of both subscribers and IPTV channels to identify the point at which per-subscriber IPTV QoE reaches an unacceptable level (i.e., the performance limits).

Consider a major live sporting event, such as the World Cup, being televised via IPTV. The overwhelming number of sports fans requesting to join the IPTV multicast group for such an event could overload the network and create congestion. If the access network can only accommodate, for example, 1000 simultaneous subscribers for the World Cup in one community, the 1001st user could potentially degrade the experience for all of the 1001 viewers.

4. Infonetics Research, Inc., IPTV Equipment and Services Market Outlook, 2005, p. 28.
5. Franz Kozamernik, "IPTV - a different television," July 2006; available from www.ebu.ch/en/union/diffusion_on_line/tech/tcm_6-46276.php, accessed August 3, 2006.

Dynamic subscriber behaviors

In a realistic Multiplay user environment, subscribers behave in a dynamic fashion. A household receiving Multiplay services from a single provider may be simultaneously initiating channel-change and new Internet-connection requests while having multiple VoIP telephone conversations. When scaled across the subscriber base, this dynamic behavior can be very demanding on the control plane of IPTV network elements, and potentially jeopardize the quality of experience IPTV viewers receive.

Take, for example, a large number of simultaneous channel change requests (channel zapping) during the commercial break of the Academy Awards or season finale of Survivor. The rapid transition from a steady state of long-term viewing to a huge series of changes can significantly stress a Broadband Network Gateway (BNG) or edge router as it struggles to process thousands of IGMP group join/leave requests, update multicast forwarding tables, and replicate multicast traffic over the correct outgoing interfaces. This stress can result in packet forwarding delay and loss, and impact IPTV QoE. It is therefore critical to model dynamic subscriber behaviors in the test environment measure the impact on IPTV QoE metrics.

Converged Multiplay traffic

IPTV traffic will be in the presence of voice and data traffic on the same link either from the same Multiplay subscriber, or from other subscribers sharing an uplink from an aggregate router. All three services will contend for finite network bandwidth and equipment resources, and the different traffic types each require a different level of service from the network. It is imperative to include a combination of Multiplay traffic within the test environment to identify how the presence (or interference) of other service traffic, impacts quality of service and the timely forwarding of high priority video traffic.

Traditional approaches to achieving IPTV QoE measurements

The traditional, yet problematic, approach to achieving channel zapping and media quality measurements has in fact been to build an extensive test bed of equipment in the lab, as shown in Figure 2.

This type of test environment, which incorporates hundreds of real STBs and video sources, along with VoIP phones and personal computers to represent voice and Internet service traffic, is not a very practical approach to testing IPTV QoE. Obvious concerns include the high capital outlay required to source the equipment, space requirements for housing the test bed, and labour-intensive configuration required to control the tests. This methodology also has serious flaws since it doesn't scale well to reflect real-world subscriber numbers, which can reach from the thousands into the hundreds of thousands. The reliability of the tests can be further compromised by STBs overheating and requiring frequent rebooting. Overall IPTV QoE is ascertained by individuals who actually watch and 'surf' the television programming for hours on end, and 'rate' the overall quality of their experience within a defined numeric scale.

While this type of subjective testing can identify when service quality expectations aren't being met, it provides little insight into what's actually causing or contributing to the service degradation. The test measurements are difficult (if not impossible) to correlate with specific problems at the network-layer, thus the measurements have little value when it comes to troubleshooting and isolating network configuration problems.

Figure 2: Traditional approach to testing IPTV QoE

Next generation methodology for achieving IPTV QoE measurements

Next generation IPTV QoE test methodologies overcome the issues and limitations of traditional test approaches by using a single test system to simulate and make IPTV QoE measurements on a network environment that accurately reflects the scale and characteristics of real-world Multiplay networks. Figure 3 illustrates how a large test bed of equipment can be replaced with a single powerful test tool with the requisite ability to:

- Simulate IPTV subscribers and channels with scalability
- Emulate dynamic subscriber behaviors
- Generate a combination of Multiplay traffic
- Provide relevant test metrics for thousands of individual subscribers

By emulating and scaling multiple protocols simultaneously over the same test port, such as PPPoE (Point to Point Protocol over Ethernet), DHCP (Dynamic Host Configuration Protocol) and IGMP, a realistic and cost effective test environment that reflects IPTV subscriber growth expectations can be simulated. Test systems must be able to emulate and make measurements on tens of thousands of subscribers, watching hundreds of different channels, located behind a single device.

This simulated topology is much easier to manipulate and control than using real STBs, while providing excellent granularity. A unique channel zapping profile can be applied to each individual subscriber, or group of subscribers, to identify how different channel changing behaviors impact the performance of the device/system under test. By scaling the channel zapping activity, it is possible to saturate the device under test with thousands of individual requests for the same channel, as well as thousands of multicast group join/leave requests from subscribers flipping through channels in sequence. The simulated topology in Figure 4 can be used to quickly achieve per-subscriber channel zapping measurements, as well as the average/minimum/maximum for different subscriber groups. Key channel zapping test scenarios include:

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

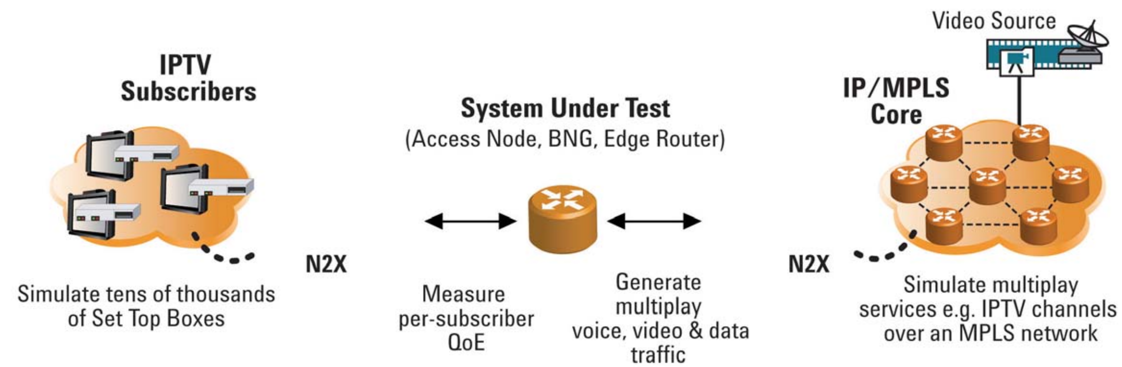

Figure 3: Next generation IPTV QoE test methodology

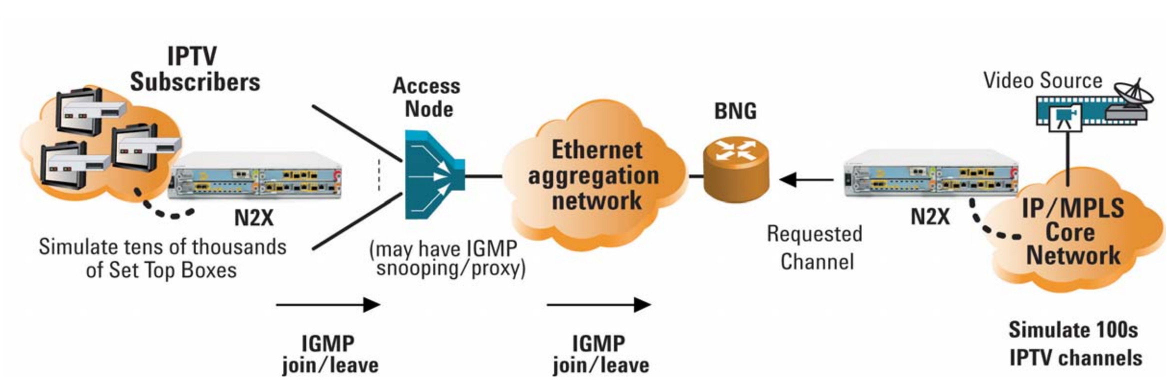

Figure 4: Simulated topology for making channel zapping measurements

The behavior of each subscriber can be further scoped by defining their interaction with other Multiplay voice and data services. Applying a dynamic and comprehensive profile to each subscriber allows the modeling of ever-changing network conditions, such as DHCP session-flapping and new Internet connection requests, which can put significant stress on network equipment, and impact IPTV media quality. These profiles can be used to define and generate different combinations of Multiplay traffic types, with corresponding priorities, including:

- Video multicast traffic (representing broadcast IPTV) with different video payloads (e.g., MPEG-2 SD and MPEG-4 AVC/H.264 SD/HD traffic, and Windows Media® 9/VC-1) and encapsulations (e.g., MPEG-2 TS/RTP/UDP/IPv4, MPEG-2 TS/UDP/IPv4, and multiple VLAN tags)
- Video unicast traffic (representing Video on Demand)
- VoIP (voice) traffic
- Internet traffic

The oversubscription and convergence of this traffic over the same port will force the device/system under test to forward traffic according to service prioritizations.

The realistic simulation of Multiplay subscribers and services creates an ideal environment for verifying overall IPTV media quality. The media quality test metrics themselves must be scalable, repeatable, and provide insight into the reasons behind performance problems (i.e., relevant).

The Media Delivery Index (MDI) is gaining widespread industry acceptance for testing media quality over network elements in a video delivery infrastructure. MDI is an industry standard defined in RFC 4445 and endorsed by the IP Video Quality Alliance. MDI's two components, the delay factor (DF) and the media loss rate (MLR), are based on concepts that translate directly into networking terms: jitter and loss. MDI correlates network impairments with video quality which is vital for isolating problems and determining their root cause. "A high delay factor directly indicates that increased latency, which can degrade video quality, has been introduced by the device/system under test. It also warns of possible impending packet loss, as device buffers approach overflow or underflow levels. This points to congestion in the network or inadequate buffer resources as potential reasons for the poor performance. Similarly, the MDI's media loss rate component clearly highlights packet loss events as contributors to poor video quality. This provides much greater insight into the network conditions that contribute to video quality than, say, a simple video quality score on an arbitrary scale." [6]

MDI values are also more relevant for assessing network equipment performance than video quality metrics that decode the video and consider compression and codec properties since network devices can only switch, delay, or drop packets. In order to isolate the effect of the network equipment on IPTV QoE, metrics must be based on packet-level measurements. Furthermore, since MDI does not rely on the processor-intensive activity of decoding, measurements can be scaled to tens of thousands of subscribers at once to achieve critical media quality metrics including:

- The impact of protocol stress & instability on media quality
- The impact of voice and data services on media quality
- The impact of channel zapping on media quality
- The number IPTV subscribers and channels the device can support within an acceptable media quality

QoE standards for IPTV are still under debate, but the DSL Forum's WT-126 recommends a maximum loss of up to five consecutive IP packets per thirty minutes for SDTV and VOD, and four hours for HDTV. If translated into MLR terms, this assumes the loss is a single IP packet in the specified timeframe to account for the fact that the packets loss must be consecutive.

A recent study by Agilent Technologies recommends the following cumulative MDI measurements throughout the delivery network:

- Maximum acceptable DF: 9-50 ms
- Maximum acceptable average MLR (all codecs): 0.004 for SDTV and VOD, and 0.0005 for HDTV[7]

6. Andre Dufour, Agilent White Paper: Scalable IPTV Quality Testing, 2006.
7. Andre Dufour, Agilent White Paper: Understanding the Media Delivery Index, 2006.

Figure 5 below illustrates how packet loss is manifested in the viewed video quality.

MLR = 0

MLR > 0

Figure 5: Packet loss manifests itself in viewed video quality

Conclusion

IPTV QoE is the critical factor underlying the success of IPTV deployments and service provider Multiplay service bundles. There have already been several widely publicized IPTV trials that have failed to turn into actual deployments. There have also been a number of IPTV deployments that have been delayed for over 12 months. The obvious consequences in terms of loss of face and impaired financials have been very costly. The best way for service providers to mitigate this risk is to ensure that their customer's viewing experience meets expectations from day one.

It is critical to select the test tools and methodologies with the ability to test IPTV in the larger context of Multiplay networks to verify IPTV QoE under increasing scale, and amidst other voice and data services. Diligent and thorough pre-deployment testing, under realistic and dynamic network conditions, will have a direct influence on subscriber satisfaction, and whether IPTV is in fact the tipping point in this war.

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