BROADBANDSUITE™ SOLUTION SERIES

Enabling IPTV Service Delivery

Version: 0.22
Date: November 12th, 2008

TABLE OF CONTENTS

Introduction

This application note reviews the opportunities and challenges associated with the delivery of IPTV. It discusses how the Broadband Forum is providing the necessary standards' specifications to ensure the successful transport and delivery of these services through its BroadbandSuite initiative. And finally it looks at how the BroadbandSuite and the Broadband Forum integrate with other standards organizations to address the complete IPTV ecosystem.

Audience

The target audience for this application note is service providers looking to implement IPTV as a value added to existing voice and data services. This Application Note highlights the application of the Broadband Forum standards to support IPTV deployments.

The IPTV Experience

What is IPTV?

Internet Protocol Television (IPTV) is the delivery of multimedia content to a home entertainment system over an IP-based packet network. The packet network protocol is based upon the same standard used on the Internet. In addition to providing traditional broadcast TV, IPTV can provide 2-way interactive services. The user can select non-linear video services such as Video on Demand (VoD) content and watch a movie at his or her convenience and pace rather than at a broadcast scheduled time (linear video). Extensions to the IPTV experience are bringing a new dimension to TV watching from the traditional "lean back and watch" to enabling newer "lean forward and interact" services to engage the user.

The 2-way features of IPTV now include camera selection while watching sporting events; interactive voting for political candidates during televised debates, gaming and interaction with advertisements – by pressing a button on the TV remote a user can click to request additional information on a product. This instantaneous feedback engages the subscriber and provides a direct connection to the advertiser.

Users can watch broadcast (linear TV), VoD or use a Personal Video Recorder (PVR) to watch at a later time (time shifting) or even in a different room (place shifting). These new features will work on the traditional Standard Definition TV (SDTV) and High Definition TV (HDTV) sets but also Personal Computers (PCs) and mobile phones – device shifting.

Content can be the traditional broadcast stations (CNN, BBC, …) but since IPTV is based upon the Internet Protocol (IPv4 or IPv6), Content Distribution Networks (CDN) and even small community network stations can provide content from all over the world. The end viewer's quality of experience (QoE) takes on new meaning as IPTV expands to incorporate thousands of external content sources with different attributes, taking the IPTV ecosystem from a provider managed network and service to also providing support of un-managed content and in-house networks.

Why is IPTV important?

IPTV represents significant value to both consumers and the service providers.

Benefits to Subscribers:
- More choices of content with individualized offerings
- Interactive features such as camera selection, and voting
- Greater access to video programs beyond "packaged" offerings
- Integration with home networking enabling TV to display photo and home video collection
- Time Shifting, Device Shifting, Place Shifting … enabling watching at your convenience

Benefits to Service Providers:
- Triple Play (Voice, Data, Video) or Quadruple Play (Voice, Data, Video, Mobile) bundled services are a significant draw to retain customers
- New revenue opportunities to replenish declining voice revenue
- A single network to reduce deployment cost (CAPEX)
- A single network to reduce operation and management costs (OPEX)

Point Topic Ltd (http://point-topic.com/) reports that the world-wide total number of IPTV subscribers have doubled in the last two years to over 17 million in June 2008. Synergy Research Group (http://www.srgresearch.com) estimates the number of IPTV users will be close to 40 million by 2010.
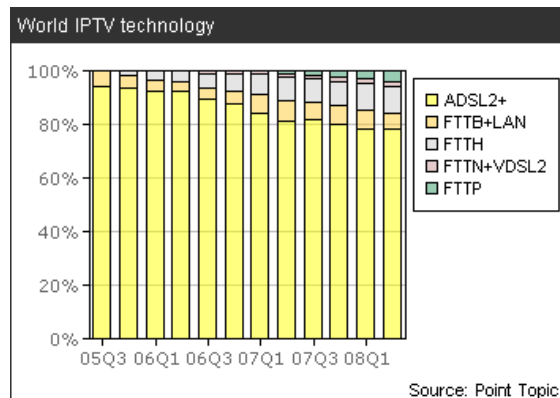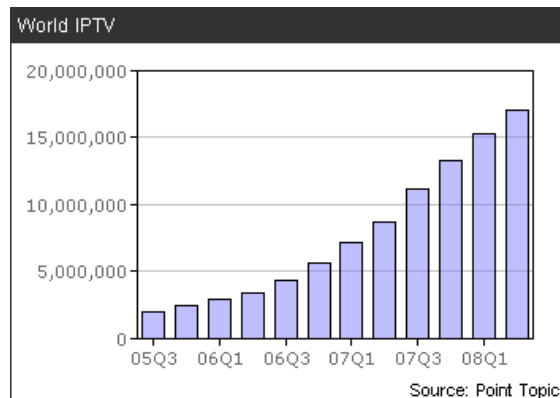
The IPTV Ecosystem

If we step back and look at the big picture, IPTV service deployment entails a complex ecosystem that can be represented in a delivery chain consisting of four domains: Content, Service, Network, and Consumer domains.
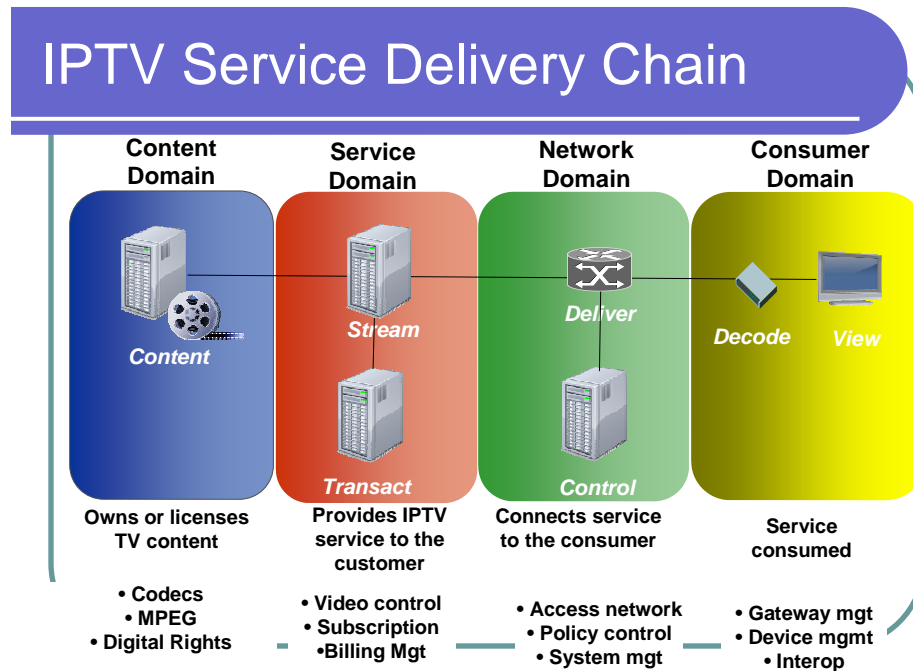
Many standards bodies and consortia have been actively working in various areas, with different focuses and in varied capacities. The Broadband Forum focuses on the broadband transport from the core/distribution network to the home. It is most concerned with Network Domain and Consumer Domain, while providing enabling functionalities to the other domains. Many organizations have referenced the Broadband Forum's work as part of the building blocks of the complete architectures.

The Broadband Forum has liaisons with most organizations actively working on IPTV specifications, and is working to establish liaisons with the rest. It leverages its strengths to provide the most value for the IPTV industry, avoids unnecessary overlaps and tries not to reinvent if progress is being made elsewhere.

Service Provider Challenges

Service providers face many challenges to successful delivery of a quality experience for IPTV subscribers. With the introduction of IPTV services, the service provider is forced to address many new variables, from intelligently admitting video sessions onto the network to reducing the "zap time" – the total time from when a user requests a channel until they start seeing the channel – as well as assuring the quality. The service provider now has to manage a diverse ecosystem with many complex parts, such as multicast Internet Group Management Protocol (IGMP), Digital Rights Management (DRM), Set Top Boxes (STB), RG (Routing Gateway), identity management, charging, customer care and programming content. Moreover, the service demarcation point (termination point for service provider) has now moved from the side of the house to the set-top box (STB). This factor now extends the service providers management sphere deeper into the home network arena. This creates a large potential opportunity, but also introduces many new variables that add complexity and potentially cost to any IPTV service deployment.

Traditionally broadband has been a 'best-effort service' in that there are no hard requirements placed upon the delivery of the data packets that deliver the users data. It must be fast and it must be relatively reliable, but the applications that utilize broadband services are tolerant to many of these issues in the best-effort Internet. Unfortunately, this best-effort Internet is unsuitable for IPTV. Cable and Satellite TV already offer a level of viewing experience for digital TV that is found acceptable by viewers. At minimum IPTV must match this experience. In fact if the user is to migrate to an IPTV offering the experience must exceed that provided by these existing services in value received; the image and sound must be as good or better, the program selection must be more varied, and the users experience must be more flexible and enjoyable. Put simply IPTV must provide an experience measurably better for the user than the already acceptable incumbent services of cable and satellite TV.

Much of the focus to date has been at the IPTV application layer, ensuring that the IPTV middleware and the set-top box can effectively manage the application set-up and delivery. However, as these services are mass deployment, the transport architecture is proving to be a competitive differentiator that spells the difference between success and failure. To be successful in this highly competitive environment, service providers must create an end-to-end architecture that supports high bandwidth, multicast group management, dynamic policy-driven resource control, subscriber management, and home networking; all while continuously monitoring and ensuring the subscriber's quality of experience.

The Broadband Forum through its Technical Reports (TRs) and work in progress (WTs – Working Texts) has defined requirements for establishing an optimized network and management platform for ITPV. As will be discussed in this paper, the work of Broadband Forum addresses specific issues in each of these three network realms that are necessary if the IPTV user is to experience quality beyond what is already provided by existing TV delivery methods.

BroadbandSuite™ – Addressing the IPTV Delivery Challenges

The Broadband Forum's BroadbandSuite (BBS) extends the concept of traditional end-to-end solutions by developing an access and management platform responsive to devices beyond the customer gateway as well as the distribution network. This "blueprint" is designed to minimize provisioning and maintenance issues for service and application providers who must support vast and growing requirements of new applications and hardware. With BroadbandSuite, components work together seamlessly, delivering a high quality consumer experience vital for driving next-generation voice, video, data and mobile services.

Through its BroadbandSuite, the Broadband Forum is addressing these important requirements to help the industry expedite the rollout and ensure the quality of experience for IPTV. The BroadbandSuite defines a robust architecture that spans from the home to the access and aggregation network and includes an intelligent control plane to orchestrate the successful delivery of IPTV. These efforts address the following key areas:

BroadbandAccess – Defines specifications for broadband "agnostic" access network architectures that deliver inherent quality, scalability, resiliency, and inter-working capabilities that enable services to be delivered via multiple business models.

BroadbandControl – Creates an intelligent, programmable control layer that unifies all next-generation network assets and empowers service providers to deliver personalized services that enhance the subscriber experience.

BroadbandHome – Unifies the home networking environment by establishing a common set of CPE capabilities as well as automating device activation and configuration in order to simplify the service delivery process.
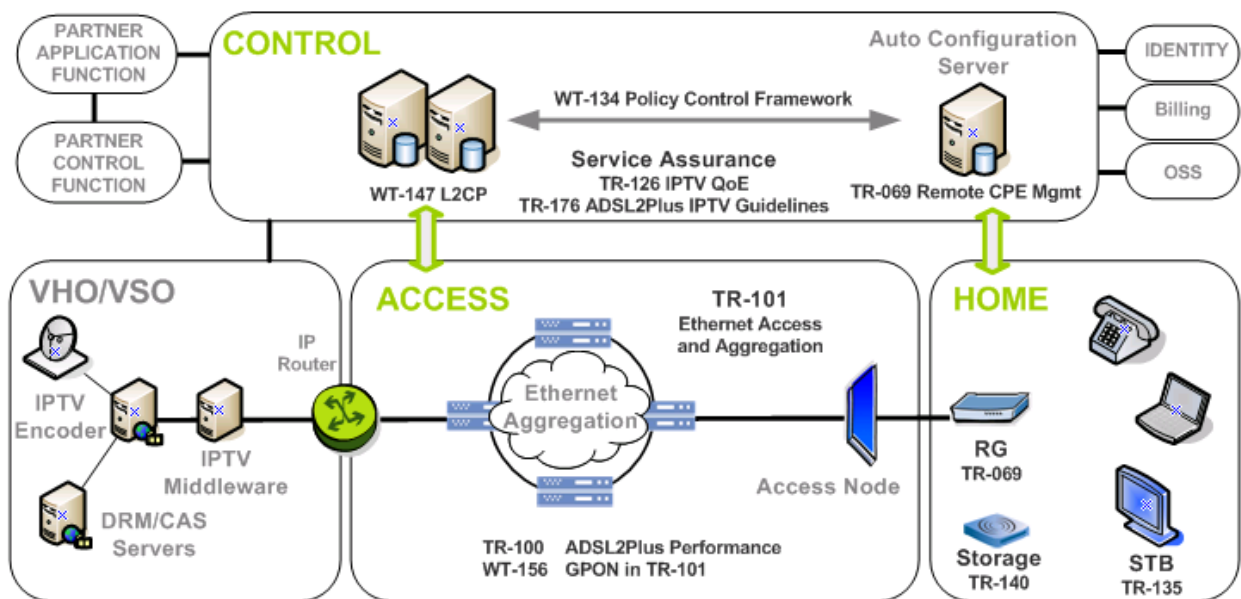

Figure 2: BroadbandSuite Architecture

Collectively the BroadbandSuite domains provide an end-to-end transport architecture that gives service providers a solid foundation on which to deliver next-generation services such as IPTV, while reducing operations costs through automated network operations.

BroadbandAccess

BroadbandAccess defines specifications for broadband agnostic access network architectures, which deliver inherent quality, scalability, resiliency and inter-working capabilities. These capabilities enable service providers to successfully deliver video across an infrastructure that offers faster bit rates at less cost, support packet based QoS, IP multicast group management, and reduces management costs.

TR-101 "Migration to Ethernet Based DSL Aggregation" is a cornerstone in BroadbandAccess architecture. While TR-101 was originally defined for DSL aggregation, a majority of the requirements are access-agnostic. Specifications such as WT-156, which addresses GPON in the context of TR-101 architecture, will extend TR-101 to other access technologies such as fiber and even fixed wireless.

Access Solutions for IPTV

TR-101 "Migration to Ethernet Based DSL Aggregation" is the migration from ATM based access aggregation to Ethernet. One of the driving factors for this change is for IPTV deployment. Ethernet not only reduces the equipment cost, but also provides the higher bandwidth demanded by high-definition TV.
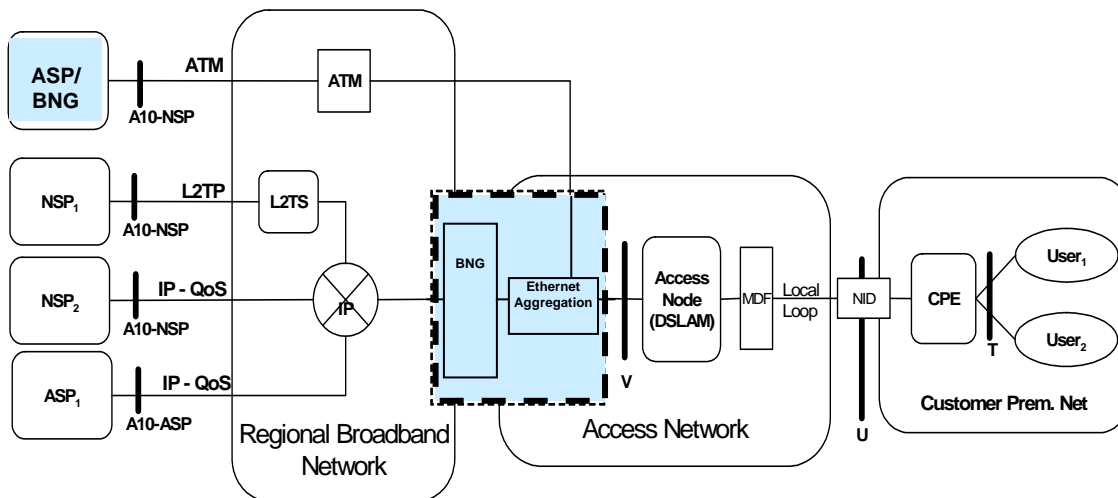
Figure 3: TR-101 Architecture

TR-101 describes general architecture aspects, with regards to application enabling capabilities. TR-101 also requires backward compatibility with existing IP services and existing connectivity models as well as enabling forward compatibility with native Ethernet on the access loop and supports both DHCP and PPP based access methods for residential customers.

TR-101 is attractive for service providers and vendors due to the fact Ethernet-based DSL aggregation architecture provide greater scalability, performance flexibility and efficiency than ATM-only networks.

TR-101 provides the specifications for:

- Multi-service end-to-end architecture capable of supporting IPTV
- IP and Ethernet QoS incorporation in the architecture
- Multicast replication in the Access Node (e.g.DSLAM) and/or aggregation switch
- PPP and IP wholesale services using BNG
- Multi-Edge architecture introduction

Bandwidth

Bandwidth – IPTV requires higher bandwidth than is traditionally offered today. The introduction of new protocols and streaming techniques improves dramatically the quality of the video transmission but requires a larger "chunk" of bandwidth to support this higher-quality broadcasting features. In any scenario increasing the bandwidth requires an additional CAPEX investment!

After analyzing the very high bandwidth requirements of the non-linear video services, it is obvious that network architects must strive to make the hop count and nodes counts from source to subscriber as short as possible. To shorten the hops and improve bandwidth capacity in the core network, a more distributed architectural solution is required whereby connections from the video servers (VOD NDVRS, Video caches etc.) are made closer to the aggregation network.   However, this also requires a better aggregation mechanism – and TR-101 addresses both needs.

- Migrating from low-speed/ best effort delivery to high-speed/ differentiated delivery to highly distributed access nodes
- Packet-based QoS to support multiple overlay applications
- Ability to decrease provisioning complexity of "per subscriber circuits"
- Optimized for multicast and hence IPTV
- Allows single and dual-edge architectures to co-exist
- Allows multiple content insertion points which are important for economic video insertion and gateway redundancy
- Offers DiffServ like per hop behavior and per class scheduling

Multicast Group Management

The availability of multicast capability in the access segment, and specifically in the access node makes IPTV/video services handling more efficient. Broadband Forum TR-101 describes required equipment functionality to facilitate several Multicast (MC) optimization points along the IPTV transmission path.

TR-101 includes the capability to use a multicast Ethernet VLAN to deliver linear IPTV content to multiple subscribers from the "service edge". Both single and dual edge topologies are supported. Single service edge architectures are where a single BNG (Broadband Network Gateway) s used to provide multiple services such as Internet Access (unicast) and IPTV (multicast). In a dual edge architecture separate equipment (multicast injection router) is used to provide the IPTV service (e.g. to the multicast VLAN. IGMP (Internet Group Management Protocol) is used to select the required multicast IPTV channel.
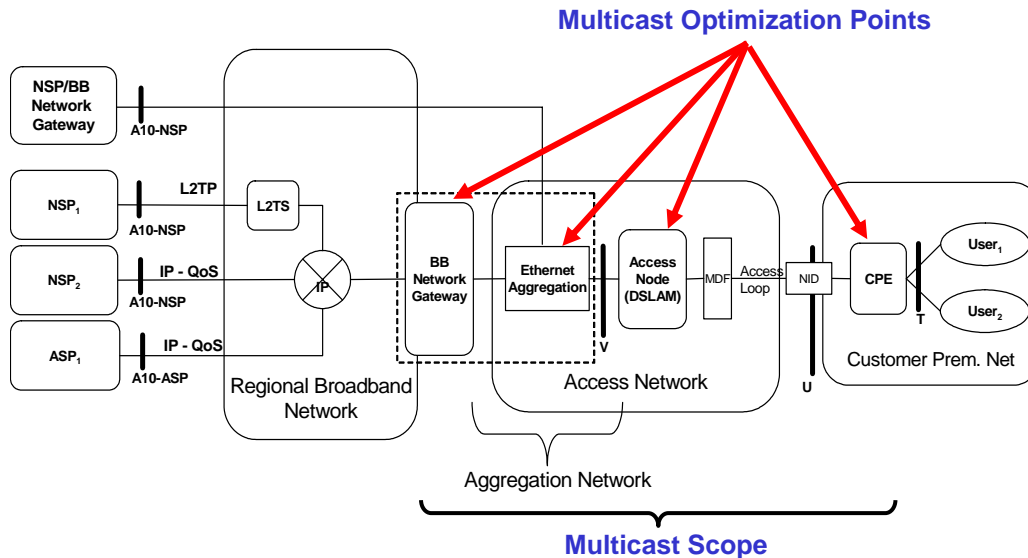
Multicast Optimization Points

Figure 4: Multicast Scope

Control Path

The control path is an essential part of the MC capability since it controls the distribution process. The desired goal is to support multicast optimization by controlling the flooding of Ethernet multicast frames by making use of IGMP agents in intermediate (Layer 2 Ethernet) devices. Such agents can locally adjust replication filters on the device such that packets are replicated only on those ports (physical and logical) that have specifically requested a multicast group. Specifically, the data plane uses Multicast MAC-address based filters which link L2 multicast groups to egress ports on bridging devices. These bridges potentially include aggregation switches and Access Nodes. The net effect is that a bridge, upon receiving a packet destined to a certain multicast group will limit the flooding of that multicast group to the list of ports attached to the filter.

In order to automate the setup of these filters, and as the multicast traffic is IP multicast, IGMP snooping is used. A bridge forwarding engine will redirect IGMP packets to its controlling function. Based on the requested IP multicast group, the bridge will set up a L2 multicast filter entry that allows or prevents packets to flow to the port on which it received the IGMP report. Ports that have routers attached (either directly or via other bridges) are automatically discovered based on IGMP general queries received on them. So in essence IGMP messages in the upstream direction (from user to router) on a certain VLAN will setup state (MAC-address filters) in bridges to limit the flooding of multicast data in the downstream direction. An N:1 multicast VLAN can be used in order to efficiently forward the multicast traffic.

The benefits of effective multicast group management include:

> **Fast Zapping –** Fast zapping is an appealing requirement when implementing an IPTV service. Imagine the subscriber reaction when trying to change channels and the time interval between the channel change is forever. The fast zapping capability is making use of the "Immediate Leave" attribute of the MC.

> **Fast Convergence–** The Fast Convergence in topology changes is required to allow rapid recovery time targeted at high-availability needs. This is to allow fast recovery in critical applications (such as telemedicine) or prime-time events (e.g. SuperBowl or WorldCup).

Statistics availability – MC Statistics help in understanding the service quality and can be used by the service provider to understand the actual service level being delivered, its usage patterns and how to improve it accordingly. The statistics are collected in a per-user or per-VLAN manner and help to better understand the actual service status. The statistics assist in improving the understanding of the subscriber's quality of experience (QoE, see TR-126). TR-101 provides several parameters for the statistics collection, such as how many successful or unsuccessful (rejected) IPTV channel "join" or "leave" requests were handled by the network.

VLAN Models

VLAN Models – In order to manage QoS in the Access Network, different services must be segregated based on traffic types. Each traffic type must be guaranteed the necessary resources to meet its QoS requirements, i.e. bandwidth must be reserved, jitter controlled and delay reduced to meet the limits for that particular traffic type. VLANs (Virtual LANs) provide a method for segregating services by differentiating between various traffic types. VLANs enable guaranteed resource attributes (such as BW, Jitter, and Delay) on a per application/service basis. Appropriate management of VLANs in the Access Network allows the IPTV streams to maintain their QoS and thus meet the viewers QoE expectations.

VLAN tagging is being used to differentiate between various traffic types. With multiple VLANs you can treat each traffic type with different and adequate resource attributes (such as BW, Jitter, and Delay).

VLAN usage is enhanced by the latest standards carrier-grade Ethernet transport to include hierarchies of VLAN tags which are used in the Broadband Forum's technical recommendations in order to differentiate between the customer VLAN (C-VLAN) and the service VLAN (S-VLAN). Each tagged VLAN can be prioritized differently to allow specific allocation of resources to it. This differentiation helps when addressing specific service requirements, such as in the IPTV case. The S-VLAN can be allocated to a single C-VLAN or multiple C-VLAN and address various service architectures and provide the service provider with better flexibility to address different requirements.

For example in a multi service environment which includes an IPTV application, the voice services could be carried by VLAN #1 and video services will be carried by a different VLAN # (e.g. #2). This enables different treatment capabilities for each VLAN's application.   The fact that the VLAN is used in a hierarchical way, (i.e. stacked VLANs, also called "Q-in-Q"), also offers an enlargement of VLAN address space (from 4K to 16K) which facilitates scaling in larger networks.

Another benefit of TR-101 is the ability to apply the hierarchical scheduling approach (a QoS technique to prioritize and schedule different application/traffic types) to VLANs. Each subscriber's VLAN(s) can be accompanied by different scheduling rules depending on the services that they have requested.

Quality of Service (QoS)

The Broadband Forum specifications define several methods to deal with quality of service (QoS) and support IPTV/ Video applications.   QoS ensures that IPTV sessions are guaranteed the correct network parameters for the duration of the session to ensure a quality experience for the subscriber. Dynamic and automated provisioning of network resources based on the defined business and network policies, ensures that the most valuable sessions receive adequate resources.

TR-101 uses the VLAN mechanisms and hierarchical scheduling to ensure sufficient end-to-end resources for IPTV. VLAN tags are used as the differentiation parameter among the different streams. Different VLAN tags allow allocating different precedence priority as well as Delay and discarding

priorities. The BNG (BRAS) performs hierarchical scheduling that allocates the required resources to the different instantaneous services. Nowadays, this hierarchical scheduling resides in different network elements as intelligence is distributed down towards the last mile segment (the sophistication can reside, for example in the access node as it has the best view of the last mile connections). A sequence of scheduling steps to model downstream congestion points (BNG port, Access Node uplink and DSL synch rate) is being performed by the BNG.
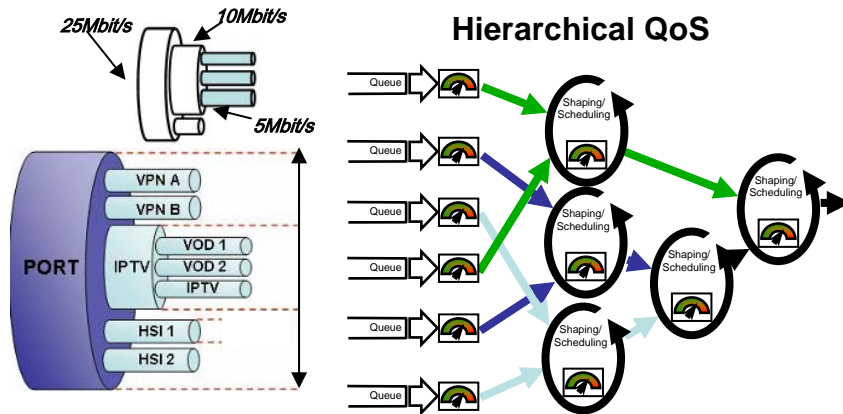

Figure 5: Hierarchical QoS

Hierarchical scheduling requires knowledge of the topology and available resources in the network from/ to end-device and manages the resources allocated, along the path from edge to home, to meet the IPTV service resource requirements. For example, if an IPTV stream needs 10Mbps to ensure sufficient QoS/QoE and the total available bandwidth is 25Mbps, than the scheduler will ensure up to 2 video streams transmission and the remaining bandwidth could be used by other services (same mechanism applies also to voice and other committed bandwidth services).

For additional ways to ensure quality of service and ultimately meet the customers' quality of experience (QoE) requirements, providers can turn to Technical Report 126 "Triple-Play Services Quality of Experience (QoE) Requirements". This document is a compendium of application based provisioning. It provides specifications for measuring and provisioning at each point in the network to ensure proper QoE based on the applications being supported. More on this in the BroadbandControl section.

Security

Service providers' main concerns, with regards to security, are spoofing (Ethernet MAC address), Denial of Service (DoS) attacks and the need to ensure correct mapping of customers to services. TR-101 brings elements to the DSLAM for PPPoE/DHCP as well as additional Ethernet MAC level policy elements to block malicious customers (i.e. protect against MAC spoofing & MAC flooding). The TR-101 offer is backed by various techniques to ensure the network security, for example - PPPoE Intermediate Agent, Layer 2 DHCP Relay Agent and ARP processing & IP spoofing protection.

When relating to IPTV, the TR-101 security aspects offer a way to solve specific related issues such as:

Broadcast storms - Limit U/S multicast and broadcast frames on port level for X,, and block D/S multicast and broadcast frames per S-VLAN for X

MAC addresses – Limit number of active source MAC addresses per user port (U/S direction) in order to help in preventing MAC address flooding attack

Frame filtering – Allow (Source Address) SA, Deny SA or Allow DA, Deny DA for X

BroadbandControl

The successful delivery of IPTV requires the real-time control of network and application resources based on established business and network policies. Since IPTV and other broadband video services employ a complex ecosystem that spans from the application delivery framework, through the aggregation and access networks right into the home network, it is imperative that an intelligent and programmable control layer be employed to help assure the successful delivery of these resource intensive and quality sensitive services. Moreover, since the user experience is critical to success, it is equally important the quality of experience be measured at critical junctions within the delivery path.

Policy and Network Management Solutions for IPTV

The Broadband Forum has recognized this need and answered the call within its BroadbandControl work which includes important specifications such as WT-134 "Policy Control Framework" and TR-126 "Quality of Experience for Triple Play Services".

Working Text 134 (WT-134) "Policy Control Framework" defines a policy driven control framework that can be driven by an extensible policy information model (PIM) to facilitate a robust conversation between application and network resources. A programmable control layer creates an environment that can intelligently evaluate requests in real-time and take action based on establish business and network level policies.
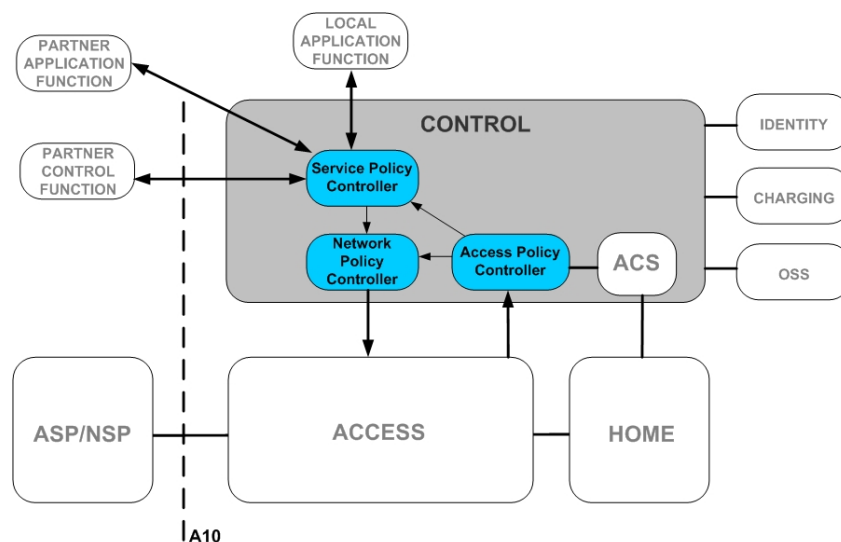

Figure 6: Control of IPTV Services

WT-134 helps service providers understand the context for effective control of application delivery for both local and partner originated applications by facilitating communication across network and application boundaries. WT-134 describes an open and extensible framework that has the potential to provide the following benefits:

Standardized API – provides a common language for flexibly describing network and business level policies.

Extensible information model – simplifies the introduction of new features and capabilities from network, application or back office vendors.

Flexible, Policy-driven Architecture – supports multiple business models and partner relationships.

Reusable Assets – enables pre-built interfaces, functions and policies to be rapidly assembled to accelerate the modification or creation of new services and capabilities.

For IPTV, a policy management framework such as WT-134 can assist with the provision of three key capabilities:
- Admission Control
- Quality of Service(QoS) and QoE
- Dynamic Resource Control

Admission Control

There are two types of admission control, service and network. Service admission control is designed to perform authorization checks based on service contract parameters. For example, a typical service admission control decision would be to check the maximum allowed simultaneous video sessions. If the user is allowed two and only one session is active, then the next request would be honored. However, any subsequent service requests would be rejected until on of the existing sessions is terminated.

Network admission control is a critical function designed to ensure that the limited resources of the access network are available to support the video session. Since video requires large amount of bandwidth with specific characteristics (latency, jitter), it is important that availability of these resources is guaranteed prior to admitting the session on to the network. Network admission control can perform this function in one of two ways. Either by directly communicating with all routers in the delivery path to check available bandwidth on the selected interface in real-time, or by keeping a table of interface bandwidth and incrementing or decrementing as session join and leave the network.

This enables the real-time evaluation of the initial IPTV session request to ensure and reserve bandwidth for the duration of the session.

Quality of Experience (QoE)

Broadband Forum TR-126 "Quality of Experience for Triple Play Services" defines Quality of Experience (QoE) as "*the overall performance of a system from the point of view of the users. QoE is a measure of end-to-end performance at the services level from the user perspective and an indication of how well the system meets the user's needs*." QoE is thus in a sense the only figure of merit that truly matters to the customer of any broadband delivery system. 'Do I, the user enjoy this experience, does it meet my needs'.

Quality of Experience is inherently subjective, objective measures of service quality, QoS measurements, such as error seconds, degraded packets, latency times, jitter and so forth only have import when they

can be related to the experiences of real viewers of video programming in their own homes. TR-126 identifies three aspects of service delivery that affect the QoE of an IPTV user:

1. Session set-up
    *   Delay before the selected program is delivered to the user. The analog TV environment has allowed TV viewers to expect a channel change to be nearly instantaneous. (10's of milliseconds.).
    *   Ease of the process of selecting the programming.
    *   Number of simultaneous sessions supported to a household
    *   Individuation. IPTV offers the promise of a virtually unlimited selection of programming as the access to video servers is decoupled from limitations of the physical method of delivery (Broadcast TV channels, frequencies in a Hybrid-Fiber COAX cable TV system or satellite). IPTV makes use of the Internet Protocol's ability to reach any number of video servers, each with an arbitrarily large amount of programming. Unless the IPTV system achieves this there is no differentiation from the existing methods of TV delivery.
    *   Adding new devices in the home should be painless.
    *   The provider should be able to accurately bill for services ordered.
2. Session performance
    *   Picture and sound quality. Viewers are often more sensitive to digital degradations than to analog noises ('pixilation' vs. 'snow'). HDTV increases the viewer's expectation with respect to image quality.
    *   Stability of the connection – a program stream cannot fail during viewing. Unlike existing TV delivery schemes IPTV requires that a session be established between a source and the viewers system, this session must be stable.
    *   Ability to support many types of devices in the home and to evolve to support the creativity of the consumer electronics, gaming, and home computer industries in providing new and creative home devices.
3. Session teardown (logging off, shutting down).
    *   Teardown should be invisible to user
    *   Teardown should be rapid
    *   Teardown should never leave the user in a 'peculiar state' that delays their access to next desired programming.

BroadbandHome

The BroadbandHome unifies the home networking environment by establishing a globally identifiable set of CPE specifications. BroadbandHome also automates device activation and management to simplify the service delivery and support process. These common specifications can work for set top boxes and other next generation quad-play devices to ensure they are adaptable to the varying broadband access networks needs, allowing customers to choose from a larger body of multimedia services that can be readily supported by services providers.

Remote Management of the Digital Home

With TR-069 " CPE WAN Management Protocol (CWMP)", an Auto-configuration Server (ACS) acts as a centralized control point for the CPE devices such as Residential Gateways (RG), Set Top Boxes (STB), and Network Attached Storage (NAS) devices. An ACS that implements TR-069 is built to mass support CPE devices that are TR-069 compatible.

Remote CPE troubleshooting
- Improve problem resolution abilities
- Shorten support calls
- Eliminate unnecessary CPE replacement
- Reduce truck rolls
- Enhance current custome support process

Web-based integration
- Service selection
- Customization
- Provisioning
- Eliminates subscriber need to access CPE GUI

deploy

support

New service establishment

install

Remote CPE management
- Automate management of millions of devices
- Firmware upgrades
- Enable new services
- Database of all installed CPE

Touch-less installation
- Auto-detection and configuration of CPE
- Automatic firmware downloads
- No need to modify or maintain CD's

manage

Figure 6: TR-069 enables the entire service cycle

As shown here, TR-069 enables IPTV STBs and RGs to be provisioned and installed without the subscriber hassle of accessing the CPE GUI, and configuring via home computer. It is built to remotely manage millions of devices, upgrade firmware and turn on new services. With its remote CPE troubleshooting capabilities, it can improve customer satisfaction while shortening support calls and reducing truck rolls.
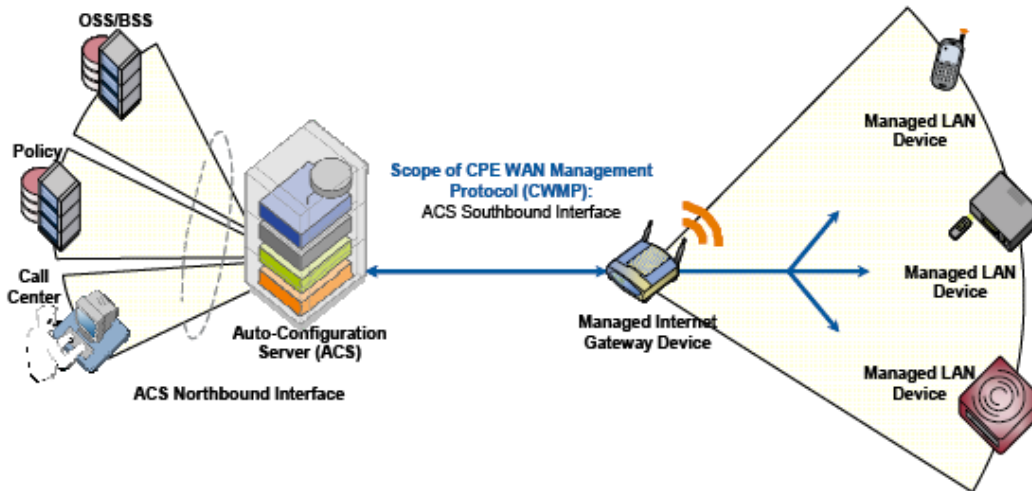
Figure 7: TR-069 Position in the network

From a purely functional perspective, TR-069 is intended to support a variety of functionalities to manage a collection of CPE, including the following primary capabilities:
- Auto-configuration and dynamic service provisioning
- Software/firmware image management
- Status and performance monitoring
- Diagnostics
- Identity management for web applications

Auto-configuration and Dynamic Service Provisioning

The CWMP allows an ACS to provision a CPE or a collection of CPE based on a variety of criteria. The provisioning mechanism allows CPE provisioning at the time of initial connection to the broadband access network, and the ability to re-provision or re-configure at any subsequent time. This includes support for asynchronous ACS-initiated re-provisioning of a CPE.

The identification mechanisms included in the protocol allow CPE provisioning based either on the requirements of each specific CPE, or on collective criteria such as the CPE vendor, model, software version, or other criteria. The protocol also provides optional tools to manage the CPE-specific components of optional applications or services for which an additional level of security is required to control, such as those involving payments. The mechanism for control of such Options using digitally signed Vouchers is defined in Annex C of TR-069.

The provisioning mechanism allows straightforward future extension to allow provisioning of services and capabilities not yet included in this version of the specifications.

Software/Firmware Image Management

The CWMP provides tools to manage downloading of CPE software/firmware image files. The protocol provides mechanisms for version identification, file download initiation (ACS initiated downloads and optional CPE initiated downloads), and notification of the ACS of the success or failure of a file download. The CPE WAN Management Protocol also defines a digitally signed file format that may optionally be used to download either individual files or a package of files along with explicit installation instructions for the CPE to perform. This signed package format ensures the integrity of downloaded files and the

associated installation instructions, allowing authentication of a file source that may be a party other than the ACS operator.

Status and Performance Monitoring

The CWMP provides support for a CPE to make available information that the ACS may use to monitor the CPE's status and performance statistics. It also defines a set of mechanisms that allow the CPE to actively notify the ACS of changes to its state. TR-143 facilitates throughput testing to be able to assess the subscribers experience in terms of broadband speed.

Diagnostics

The CWMP provides support for a CPE to make available information that the ACS may use to diagnose and resolve connectivity or service issues as well as the ability to execute defined diagnostic tests.

Identity Management for Web Applications

To support web-based applications for access from a browser within the CPE's local network, the CWMP also defines an optional mechanism that allows such web sites to customize their content with explicit knowledge of the associated CPE.

TR-069 Plays a Critical Role in IPTV Success

Overall, TR-069 CWMP is an important component of ensuring QoE for the customer in the IPTV application as it empowers the ACS to work seamlessly with the video devices in the home to ensure stable network connections, hands-off device provisioning, ongoing image monitoring and correction, automated software and firmware updates to keep the video device working at peak performance. This specification has become an industry de-facto standard as other organizations such as ATIS, DVB, HGI, ITU-T and DLNA reference it in their own specifications.

Common Object Models Simplify Device Provisioning

To ensure that consumer electronics, including residential gateways (RG), Set Top Boxes (STB) and Network Attached Storage (NAS) Devices are easily provisioned and managed, it is important that a common set of parameters are established to make the device easily recognizable from the network ACS and allow auto-provisioning and ongoing management.

User experience is a critical driver when introducing a new feature or device in the home network in support of a new service. This is an important reason to allow Service Providers a means to access complex devices by preventing trouble calls (auto-configuration) and resolving trouble calls in a timely fashion by directly accessing the device(s).

Three critical technical reports that establish these parameters are:
- TR-106 Amendment 1 Home Network Data Model Template for TR-069 Enabled Devices
- TR-135 Data Model for a TR-069 Enabled Set Top Box
- TR-140 TR-069 Data Model for Storage Service Enabled Device

TR-106 Benefits

This home network data model template specifies the generic data model for all TR-069 enabled devices. TR-106 specifies a baseline object structure and set of TR-069 accessible parameters to be available. For a particular type of device, it is expected that this baseline would be augmented with additional objects and parameters specific to the device type, such as a STB. The data model used in any TR-069 capable device must follow the guidelines described in this document.

The guidelines include the following aspects:
- Structural requirements for the data hierarchy
- Requirements for versioning of data models
- Requirements for defining profiles
- A set of common data objects
- A baseline profile for any device supporting these common data objects

TR-135 Benefits

This data model for a TR-069 Enabled STB provides the specifications for remote management of Digital Television (IPTV or broadcast) functionality on STB devices via CWMP as defined in TR-069 and TR-106. It covers the data model for describing a STB device as well as rules regarding notifications on parameter value change. This provides standard data model profiles that would typically be seen while remotely managing a device of this nature. Access to network and PVR content is managed by an IPTV service platform. The ACS may perform some initial configuration of a newly installed STB, but its main functions are configuration of STB parameters for trouble management and collection of statistics for QoS /QoE monitoring.

Set Top Box Role

The STB can be connected to a number of external networks, including broadband networks like IPTV and broadcast networks like DTT (Digital Terrestrial Television), CAB (Cable) and SAT (Satellite). The STB receives AV Streams from these external networks, if necessary via the Residential Gateway, and combines them in various ways for presentation on one or more display devices, each of which can present different content. The end user selects which content is displayed. The displays can be connected to the STB via an analog connector (e.g. a SCART [33] connector), a specific digital connector (e.g. an HDMI connector), or a digital network connector (e.g. Ethernet or WLAN interfaces). Consumption of AV content can be subject to rules imposed by means of CA (Conditional Access) or DRM (Digital Rights Management) systems. These may require the use of a Smart Card or may rely on secrets integrated into the decoding chip.

The PVR (Personal Video Recorder) function of a STB can send AV content, in compressed and possibly encrypted form, to a storage device. As well as recording the content and allowing it to be viewed after the recording is over, the PVR can include a time-delay, or time-shift, function. This allows the end user to suspend consumption of the content and subsequently to resume it from the point at which it was suspended. To do this the PVR acts as a buffer with length equal to the time for which viewing was suspended. Trick modes (Fast Forward, Rewind, and Pause) can be supported on live, recorded and time-delayed content. Other PVR functions can include the recording of VoD (Video on Demand) events, in which a piece of (protected) content is streamed to the STB, or Push VoD, in which a piece of (protected) content is downloaded (pushed) to the PVR for possible subsequent viewing by the end user.

Access to network and PVR content is managed by an IPTV Service Platform.   In addition to this, the ACS monitors the operation and performance of STBs, allows specific STB parameters to be checked, and carries out (limited) configuration of STBs. Even though it is not easy to draw a line between the

IPTV Service Platform and the ACS domains, it is reasonable to assume that the STB is controlled by the IPTV Service Platform for all tasks related to provisioning, media processing and Conditional Access / Digital Rights Management, and is controlled by the ACS for all tasks related to trouble management and monitoring of performance and operational status.

A STB is also regarded as part of a Home Network, in which the STB can consume content as well as provide or relay content to other devices. Content may be stored locally within the STB, within another Home Network device such as a Media Center, or can come from one or more of the external networks to which the Home Network is connected. Local and remote access could be taking place at the same time.
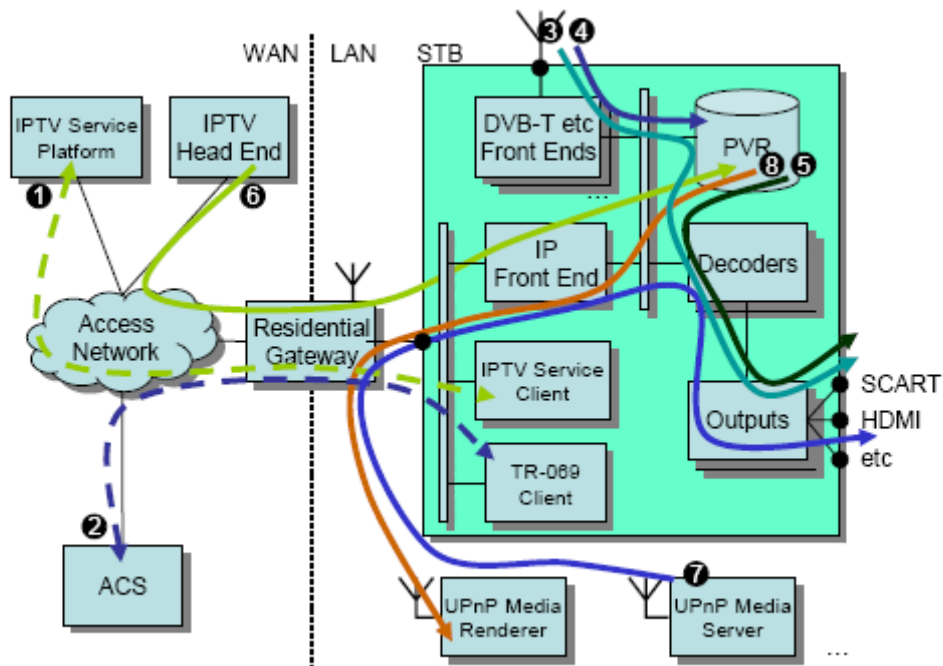
Figure 8: Set Top Box Context

Based on this scenario, the goals of the TR-135 specification are as follows:
- Enable configuration by the ACS of those objects and parameters that are not the responsibility of the IPTV Service Platform
- Enable operational status monitoring and checking of specific parameters of an STB from an ACS
- Enable performance monitoring of an arbitrary set of STBs, from one to millions, through estimates of QoS (Quality of Service) and QoE (Quality of Experience)
- Support various types of STB, including DTT and IP STBs, with or without PVR and other optional functionality
- Accommodate STB devices that are embedded as part of an Internet Gateway Device
- Accommodate STB devices that are standalone, i.e. implemented in separate hardware devices

Configuration

The ACS may perform some initial configuration of a newly installed STB. For example, it might initiate a channel scan in order to populate a DTT service list database, or it might set some user preferences such as audio and subtitling languages. During the initial configuration, the ACS can also update the STB firmware. Most of the initial configuration will be performed by the IPTV Service Platform.

Trouble management

A trained technician may take control of the STB, generally in response to a customer complaint. The STB malfunction may be the result of improper customer settings, or may be due to network Data Model error for a TR-069 Enabled STB TR-135 or hardware problems. Access to the STB data model allows the technician to carry out a number of tasks, namely:
- Verify/Restore the STB configuration. The STB data model parameters under the ACS control can be re-configured to the correct values contained in the ACS.
- Verify/Update software version. Incorrect software version (e.g. the STB was switched off for a long time and was not included in the last software upgrade campaign) can cause improper operation. In this case the operator can force an upgrade of the STB software to the latest release.
- Perform diagnostics. The technician can run diagnostic tests to identify whether the trouble is in the network (and at which point) or the STB and try to classify the trouble. Depending on the cases, the technician can carry out actions on specific subsets of STBs (identified e.g. by a range of serial numbers, by a specific software/hardware version, by the geographical area they are in) or on single devices.

Performance Management

The ACS carries out automatic monitoring of STB performance. Performance reports can include QoS parameters (e.g. network parameters such as average bit rate, jitter and packet loss ratio), QoE parameters (e.g. visual quality indicators or indicators of how fast on the average the channel change is), usage statistics (e.g. how many STBs were on at a certain time, or for how long each of them remained tuned to a certain channel).

Monitoring may be performed:
- Periodically on all STB devices to check that network and devices are working properly,
- On subsets of STB devices, for instance after identifying problems by means of periodic tests. Criteria to select subsets can be geographical or tied to specific characteristics of the STBs (manufacturer, hardware and/or software version),
- Periodically on specific STB devices. The problem here could be the management of an SLA (Service Level Agreement) with subscribers to premium services. Performance management could be used to identify problems on these lines as soon as they show up. Trouble management technicians could then act to (try to) solve them.

STB QoS and QoE reporting capabilities allow for "in service" "passive" measurements done at the service level. These are of fundamental importance to an operator in a number of cases, a number of which are listed hereinafter. Other cases are possible beyond those listed here:
- Understand and measure the QoE delivered to individual end users, via collection and aggregation of STB reports across the user base.
- Troubleshoot the service delivered: STB reporting allows near real time processing of collected reports and correlation of indicators that let the operator determine where the fault lies: in the head end, in the network, in the local loop, in the home network, or in the STB itself.

● Assess and measure the IPTV service as delivered in the mid to long term, and define and control whether performance objectives are being met.
● Pro-actively catch some hidden behavior which is increasing, and is reducing service performance, but has not yet been noticed by the end user.
● Pro-actively manage certain end users who are receiving a poor level of service but who have not yet called customer care.
● Configure and define operations management service quality thresholds on aggregated reports that can be tuned in order to take action before problems are noticed or reported by the end users.
● Understand loop and end-to-end behavior in order to design and assess error correction strategies for the IPTV service.
● Manage service maintenance and understand the impact on the IPTV service of any changes in the network, device upgrades or new device insertion.

Fault Management

The ACS automatically collects events from the STB for various reasons, including detection of faults. A way to detect faults taking advantage of TR-069 notification features could be the following: the data model contains parameters describing the operational status of specific functional blocks in the STB, and Active Notification is enabled for these parameters. In case of an STB error these parameters change their values and the Active Notification mechanism delivers information about the STB fault to the ACS. The ACS recognizes the fault and consequently notifies the OSS in charge of the End-to-End Fault Management operations.

TR-140 Benefits

Basic Managed Storage Service
A basic managed storage service offers a Service Provider the option to assist the customer as soon as the customer's Storage Service-enabled device is activated and being managed by the ACS. The following is a sample list of support capabilities an ACS can provide using CWMP (NOTE: Not all of these capabilities are handled with this data model; some are handled from a protocol perspective and some are handled via other data models):
● Basic configuration and setup during device activation [addressed by TR-140 (configuration parameters) & TR-106 (configuration parameters)]
● User credentials setup and file privilege access [addressed by TR-140 (Folder Access)]
● Firmware upgrade [addressed by TR-069 (Download command)]
● Retrieval of device status [addressed by TR-140 (parameters) and TR-106]
● Wireless setup (e.g., WEP security) for a Storage Service device with Wi-Fi access [addressed by a future version of TR-106]
● Configuration and log file retrieval for root cause analysis of problems [addressed by a future version of TR-106]
● Monitoring active/passive notification events, e.g., volume capacity reached, and potential physical media failures [addressed by TR-140 (parameters) and TR-069 (notification mechanism)]
● Network diagnostics and troubleshooting, e.g., network connectivity to the Internet gateway device, and to the Internet [addressed by TR-106 (connection parameters)]

With such support capabilities from the ACS, a technical support agent will be better equipped to help a customer with Storage Service issues during trouble calls. This is in addition to the ACS performing basic configuration/setup tasks during device registration/activation. Overall, the goal is to provide a true *"plug-and-play"* solution for the customers.

Remote Managed Services

A service provider can also offer a file back-up service for selected volumes or folders on a Storage Service device. A Storage Service device allows the ability to upload files residing locally, initiated by a centralized network storage server via standard file transfer mechanisms such as SFTP and HTTPS. The file back-up operation can be initiated automatically on a regular basis using a time schedule selected by the customer or based on a default schedule established during service activation.

This is a service option that customers can use to back-up their *"precious content"* remotely on a network server in case of potential device disk failures. Since a majority of Storage Service devices currently do not have RAID support for disk redundancy, the remote back-up service can be a viable alternative for a certain segment of customers.

Remote Access of Storage Service Content from a Remote Location

This service provides a simple and secure solution for a customer to remotely access (over the internet) content (videos, pictures) on a Storage Service device installed in his/her home network. Access implies that the customer will be able to retrieve or load files to the Storage Service device. Since the Storage Service device is typically sitting behind a NAT-enabled Internet Gateway Device, this service would need to consider how the customer could access it through the NAT-enabled device.

Summary of the Broadband Forum's Solutions for IPTV

BroadbandSuite 3.0

The key IPTV-centric specifications are captured in BroadbandSuite 3.0, a release that groups the technical reports into a solution set to assist the industry in effective IPTV deployments.

BroadbandSuite 3.0 includes the following major areas of work:
- the triple-play services augmented by new access methods such as GPON and Bonded-DSL over a QoS-enabled Ethernet architecture based on TR-101
- full support for multicast to enable IPTV streaming, and
- Integrated remote management of set-top boxes, attached storage devices using TR-069.

The chart below provides a snapshot of the solution set:

ACCESS R3.0	HOME R3.0	CONTROL R3.0
TR-101 : Ethernet-centric multicast-capable architecture	TR-135 : Residential Data Model for a TR-069 Enabled Set Top Box	TR-117 : Broadband Trouble Reporting
WT-156 : Extending TR-101 to GPON fiber access systems	TR-140 : Data Model for a TR-069 Enabled Storage Device	TR-141 : Protocol Independent Management Model for TR-101 Compliant Access Node
	TR-142 : Framework for use of TR-069 with PON Access	TR-176 : ADSL2plus Profiles for IPTV
	TR-143 : CPE Throughput Performance Test Mechanism	WT-147 : Layer 2 Control Mechanism
	TR-098 Issue 1 Amendment 2 (WT-107) : Internet Gateway Device Data Model for TR-069	WT-159 : Management Framework for xDSL Bonding
	TR-106v2 (PD-154) : XML Data Model Descriptions and Object Library	WT-169 : EMS-NMS Functional Requirements for Access Nodes Supporting for TR-101

Future Work

In the BroadbandSuite Release Plan, the Broadband Forum continues to work on next generation access methods for both fiber and copper.   In the access network architecture area, newly released TR-144 is an important update to TR-058, the Broadband Multi-Service Architectural & Framework Requirements. TR-144 is the basis for a new set of detailed specifications in BroadbandAccess and BroadbandControl. Policy control is becoming an important area of work, and is a component of the Fixed Mobile Convergence (FMC) related work that is beginning. Finally, energy efficiency and IPv6 considerations are being addressed in all new work.

Relation to the Work of Other Standards Bodies

As mentioned earlier, the Broadband Forum addresses only part of a bigger IPTV ecosystem, focusing on Network Domain and Consumer Domain. The following is a brief overview of the other standards bodies and consortia actively involved in IPTV related work.

- **ATSC (Advanced Television Systems Committee)**
  - http://www.atsc.org/
  - standards for digital television
- **ATIS**
  - http://www.atis.org/
  - IPTV Interoperability Forum (IIF)
  - End-to-end solution for IPTV
- **Broadband Services Forum**
  - Focused on IPTV Monetizing IP traffic and IPTV content
  - "Accelerating Business. Enhancing Life"
  - http://www.broadbandservicesforum.org/
- **CEA (Consumer Electronics Association)**
  - http://www.ce.org/
  - Consumer mass market product focus

- **DLNA (Digital Living Network Alliance$^{SM)}$**
  - Provides interoperability guidelines and product certification for home entertainment devices
  - http://www.dlna.org/
- **DVB (Digital Video Broadcasting Project)**
  - MHP and GEM middleware published by ETSI
  - MHP (Multimedia Home Platform) is the collective name for a compatible set of Java™ based open middleware specifications developed by the DVB Project. MHP was designed to work across all DVB transmission technologies.
  - GEM (Globally Executable MHP), is a core of MHP APIs, where the DVB-transmission specific elements were removed, thus allowing other content delivery platforms, which use other transmission systems, to adopt MHP middleware. GEM is thus a common core engine on which interactive applications can run; implementing GEM requires the definition of how those applications actually connect with that core.
  - http://www.dvb.org
- **IETF (Internet Engineering Task Force)**
  - Provides standards for the underlying technology including IP, IGMP, …
  - http://www.ietf.org
- **IMS Forum (IP Multimedia Subsystem)**
  - http://www.imsforum.org/
  - Focused on advancement of IP Multimedia Subsystem applications and services interoperability
  - organizer of IMS Plugfest™, NGN Plugfest™, and IMS/NGN Certified™
- **ITU-T**
  - http://www.itu.int/ITU-T/
  - International communications standards
  - IPTV Focus Group (FG)
  - Global Standards Initiative (the IPTV-GSI)
- MSF (MultiService Forum)
  - http://www.msforum.org
  - Focused on open architecture for next generation networks

- o GMI 2008, interoperability event with ATIS IIF focused on testing of authentication and initialization of IPTV services
- **OpenIPTV Forum**
  - o http://www.openiptvforum.org/
- **SMPTE (Society of Motion Picture and Television Engineers)**
  - o http://www.smpte.org/home
  - o Provides technical standards for the motion imaging industry
- **TM Forum**
  - o http://www.tmforum.org/
  - o Focused on monetizing on-line Information, Communications and Entertainment services.
- **UPnP Forum**
  - o http://www.upnp.org
  - o Focused on enabling simple and robust connectivity among consumer electronic devices

Summary

IPTV is a global reality that still represents a large opportunity for service providers. The access, control and home specifications that the Broadband Forum has developed will empower providers to deploy more efficient and responsive networks, better able to meet the exciting challenges of the next generation of digital homes and offices.   All technical reports and releases mentioned here are available for free at www.broadband-forum.org.

Glossary

3GPP	3rd Generation Partnership Project
AAA	Authentication, Authorization, and Accounting
ACS	Auto-Configuration Server
ADSL	Asymmetric Digital Subscriber Line
AF	Assured Forwarding
AN	Access Node
API	Application Program Interface
ASP	Application Service Provider
BE	Best Effort
BNG	Broadband Network Gateway (from TR-141)
BoD	Bandwidth on Demand
BRAS	Broadband Remote Access Server
CFM	Connectivity Fault Management (from TR-141)
CoS	Class of Service
CPE	Customer Premises Equipment
CPN	Customer Premises Network
Diffserv	Differentiated Services
DNS	Domain Name Service
DRM	Digital Rights Management
DSCP	Differentiated Services (Diffserv) Code Point
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
EF	Expedited Forwarding
EMS	Element Management System
FQDN	Fully Qualified Domain Name
IGMP	Internet Group Management Protocol
IMS	IP Multimedia Subsystem
IP	Internet Protocol
IPsec	Secure Internet Protocol
IPTV	Internet Protocol Television
ISP	Internet Service Provider
L2TP	Layer 2 Tunneling Protocol
LAA	L2TP Access Aggregation
LAC	Layer 2 Access Concentrator
LAN	Local Area Network
LDAP	Lightweight Directory Access Protocol
LNS	L2TP Network Server
MPEG	Motion Pictures Expert Group
NAPT	Network Address Port Translation
NSP	Network Service Provider
OAM	Operation, Administration and Maintenance
OSPF	Open Shortest Path First
PADT	PPPoE Active Discovery Terminate
PC	Personal Computer
PHB	Per Hop Behavior
PPP	Point-to-Point Protocol
PPPoE	Point-to-Point Protocol over Ethernet
PTA	PPP Terminated Aggregation
PVC	Permanent Virtual Circuit

QoE   Quality of Experience
QoS   Quality of Service
RADIUS   Remote Access Dial-In User Service
RAN   Regional / Access Network
RFC   Request For Comments
RG   Routing Gateway
SIP   Session Initiation Protocol
SLA   Service Level Agreement
SLO   Service Level Objective
STB   Set Top Box
TCP   Transmission Control Protocol
TE   Traffic Engineering
TR   Technical Report (Broadband Forum)
TV   Television
UDP   User Datagram Protocol
VC   Virtual Circuit
VLAN   Virtual Local Area Network
VoD   Video on Demand
VP   Virtual Path
VPC   Virtual Path Connection
VPN   Virtual Private Network
VoIP   Voice over Internet Protocol
WFQ   Weighted Fair Queuing