IPTV Test and Measurement

Best Practices

White Paper

May, 2007

Overview

Scope:

The use of Test and Measurement (T&M) in IPTV service rollouts can be divided into two broad categories: Service Assurance and Performance Analysis. Performance Analysis is concerned with analyzing a pre-operational IPTV setup in the lab or in the field. Service Assurance on the other hand is primarily concerned with assuring IPTV service quality in a live operational environment. This paper focuses on providing a pragmatic set of test and measurement guidelines that can be implemented on a live operational IPTV service for the purposes of service assurance. The audience is engineers, operations, and operations managers concerned with providing quality IPTV experience over a controlled IP Network. While, the recommendations here are generally applicable to any IPTV system, specific middleware implementations have unique requirements. Recognizing this, this paper is focused on Microsoft's IPTV Edition software platform. (MSTV)

Reader familiarity with Alcatel-Lucent's triple play service delivery and Microsoft TV service architectures is assumed.

Goal:

The goal of this paper is to provide a recommendation for the three important operations-engineering decisions for service assurance:

Definition of the generic demarcations where measurements should be made in a live IPTV network

Recommendations on measurement methodologies

Recommendations of a minimum set of measurements to gain visibility and troubleshoot IPTV & Microsoft TV quality issues.

These recommendations have been developed, tested, and calibrated with the industry leading vendors of test and measurement equipment. The goal of the recommendations was to 'keep things simple' and do not represent an academic optimization, but rather represent pragmatism.

Fully instrumenting every possible place in the network is likely to be prohibitively expensive—on the other hand not instrumenting anywhere in the network will not lead to a good customer experience. This paper does not attempt to build a business case around where to put probes and how many probes to put into the network because that is highly dependent on individual operator architecture trade-offs—the recommendations here can be used as engineering guidelines for making those operator-specific business decisions.

Methodology:

To accomplish these goals, Alcatel-Lucent setup an IPTV service assurance calibration environment and formed a working group of industry leaders in the IPTV T&M space. The invited T&M vendors included Agilent, IneoQuest, JDSU, and Spirent Communications. Over a period of 6 months, the working group architected the demarcations, measurement methodology, and defined the minimal measurements needed. The group then calibrated available service assurance equipment in a Microsoft TV environment. This paper presents those results.

Key Findings:

IPTV service assurance requires pulling data from a combination of test and measurement probes and network/service devices. The network/service devices to pull data from and limitations are enumerated in the document.

The key measurement demarcations for probes are:

SHO/Headend (Multicast UDP from the encoder),

Transport Network (core network validation of the MPLS traffic),

Last Mile (Central Office monitoring or remote location),

xDSL (DSL validation),

House (Internal home wiring and residential gateway testing)

For reasonable installations of probes, there is a strong recommendation for probes to be installed on port mirroring or monitoring ports on routers, switches, and Access Gear (i.e. DSLAMs). There are a choice of configurations and tradeoff's to be made.

There are key measurements that should be made at each point which are listed in the document. Due to added quality optimizations in Microsoft TV, generic standard measurements do not always produce an accurate reflection of video quality.

Contents

IPTV Architecture and Demarcations:

This section provides a generic IPTV/ Microsoft TV architecture and set of service assurance demarcations. While individual IPTV service architectures may vary in the details, the basic formula described here holds.

For this discussion, we are focused on service assurance of the IP network components of IPTV. It is assumed that video feeds are clean from the source, assured by using typical video T&M equipment.

There are 4 major locations that need to be monitored for IPTV service delivery. A typical implementation of Microsoft TV on the Alcatel-Lucent triple play service delivery architecture is shown below:

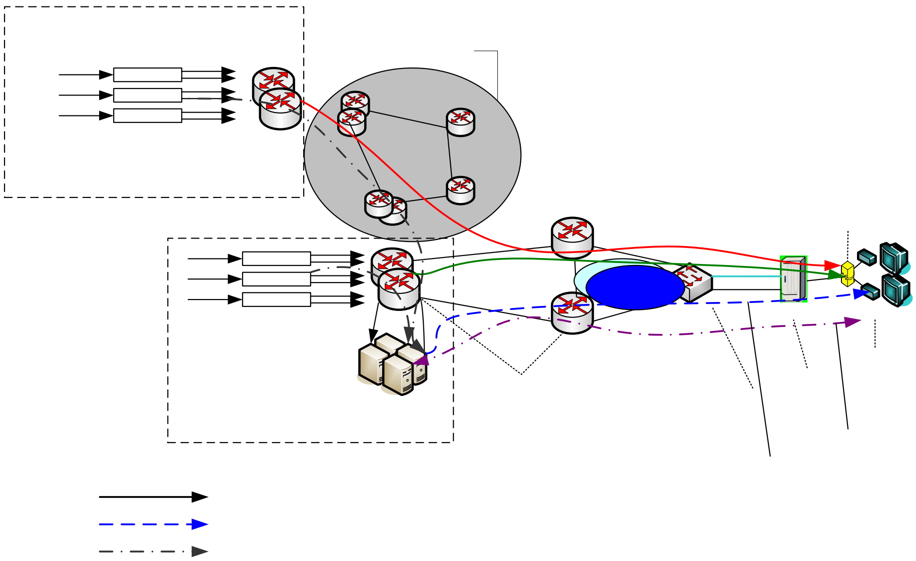

Figure 1: Microsoft TV over TPSDA Architecture

Generally demarcation points in each of the four areas must be defined considering the different groups and units within a service provider's organization that will handle issues based on where they are found:

First Network Monitoring point – The"Head-End"

The first monitoring location is between the traditional cable head-end, and the network interface. This would typically be the interconnection between the MPEG2/H.264 encoders, and the video software platform (in this case Microsoft IPTV Edition) ingestion point, the A-servers. This can be found in the SHO and VHO of the diagram above.

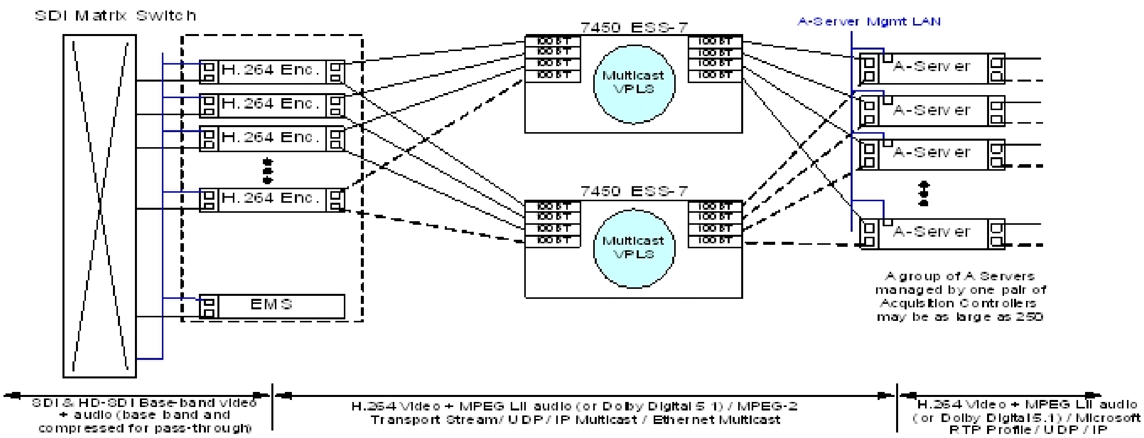

Figure 2 Typical Architecture of First Monitoring Point

Second monitoring point – "Transport"

The second monitoring point is network transport monitoring. This would typically be monitoring at the VHO/Regional center egress from the transport network and represents issues that can occur in the transport of video from the SHO to the VHO.

Third Monitoring Point – "Last Mile"

The third monitoring point is the VDSL or FTTH line. Some T&M can be done at the egress from the VHO or at a remote DSL cabinet with the use of a permant or longer term leave behind test device. In addition to IPTV measurements with a measurement probe in the DSLAM qualification of the copper lines can be completed without having a technician "onsite". These type of a devices can have drawbacks due to CAPEX cost and space availability at each DSLAM. Ultimately field monitoring may need to be done at the customer premises, but would require a "truck roll" service call for the installation of a handheld or other device. (i.e. the termination point for the VDSL or FTTH) causing OPEX cost. Note this is single user monitoring.

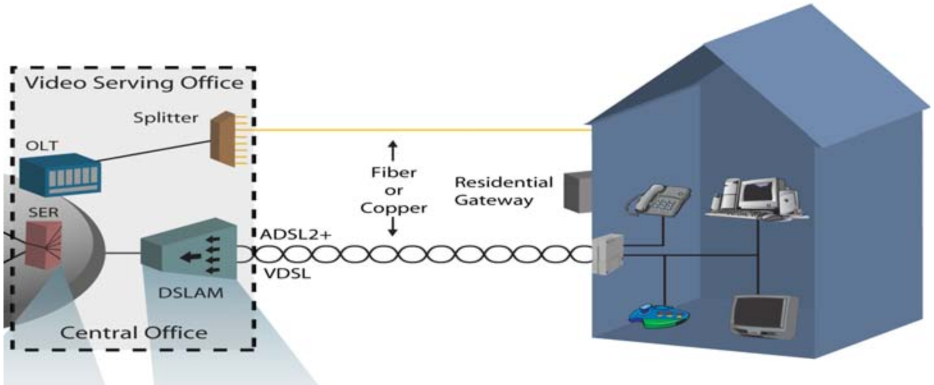

Figure 3: "Last mile" architecture

Fourth Demark – "In House Network (Home wiring)"

The last demark being the actual Set-Top-Box, residing behind the Residential Gateway, and connected through a variety of LAN technologies (Ethernet, MOCA, HPNA, etc.).

Measurements and methodology:

Broadly, measurements at the various monitoring points can be taken either from equipment in the network already or by placing probes at key points in the network. The recommended measurements appear in Appendix B. What follows is a discussion of how to get the measurements with either probes or from the network itself:

What to get from the network and how:

Figure 4 provides an iconic overview of the key element management systems from which data can be collected in the Microsoft TV network. These are as follows:

1. Middleware Servers (Microsoft TV application generated parameters collected directly from the A/D servers)
2. Middleware EMS (Microsoft MOM/SOM)
3. Access Equipment EMS (Alcatel-Lucent's AMS 5526)
4. Service Quality Calculation Software (Alcatel-Lucent's SQM 8920)
5. Network Equipment EMS (Alcatel-Lucent's SAM 5620)
6. Test and measurement probes

Since items 1-5 are placed in the network for management purposes, the tendency is to investigate their applicability before instrumenting the network with probes as suggested by 6. This section will cover the use of non-probe solutions—probes are covered later.

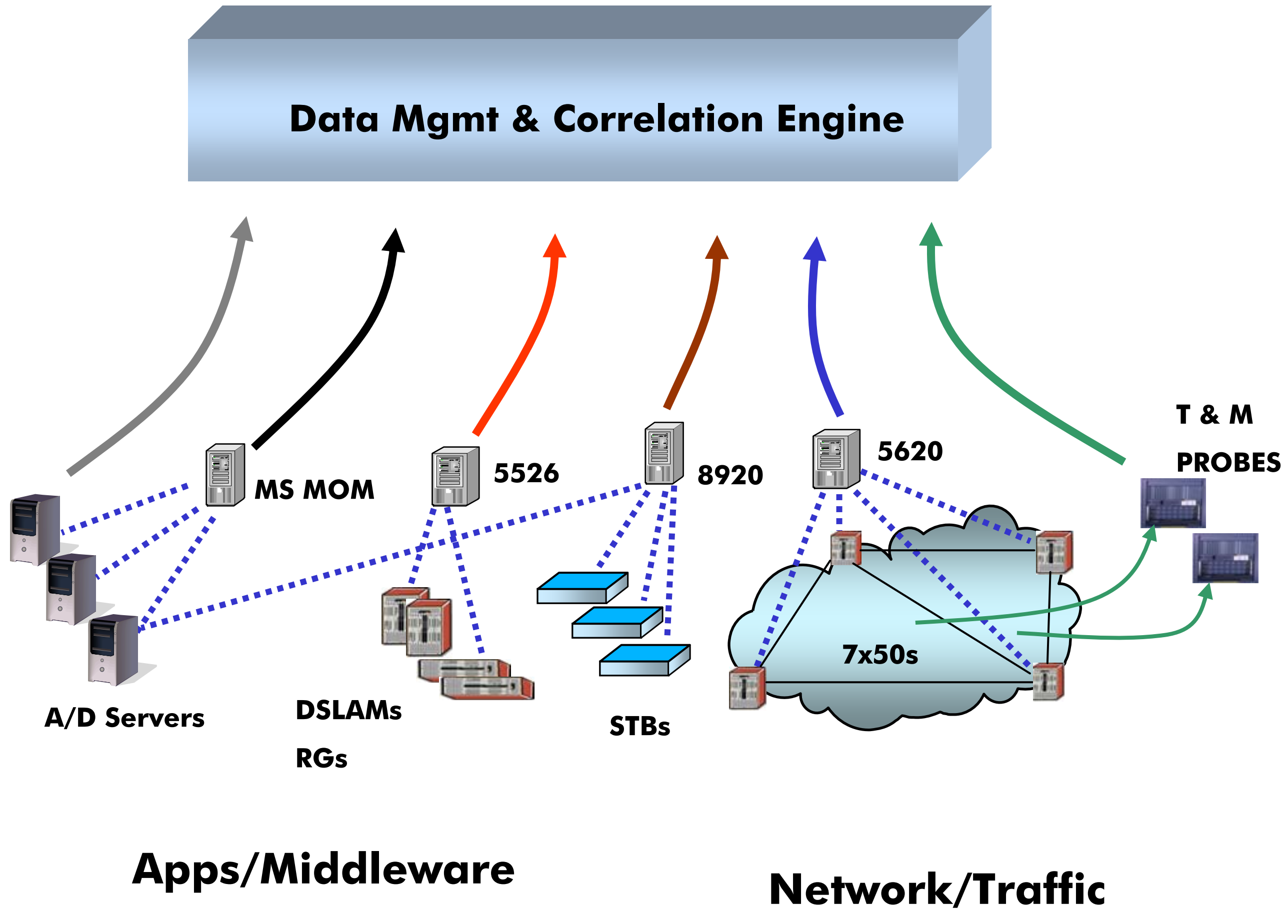

Figure 4 Data collection points in the Alcatel-Lucent Microsoft TV network

The following is a brief description of each of these systems.

Microsoft TV application parameters collected directly from the A/D servers – Here, the parameters are collected directly from the log files generated on the A or D server by the *perfmon* utility of Windows. For the A servers, 24 per-channel parameters and 8 aggregate parameters are -generated. For the D servers, 33 per-channel parameters and 24 aggregate parameters are generated. Tools can be easily developed to extract these parameters and send northbound notifications to a data/fault management engine. (see tables below for the performance impact data on the integration of real time alerts with a data correlation engine).

Appendix A provides the architecture for a northbound integration system to dynamically set trigger points on specific parameters and receive customized notifications.

The following tables show the impact on the CPU (2.6 GHz, 3.8 GB) when near real-time direct data collection and notification tools are running on the Microsoft TV server. Note, for this method, the load on the hard disk from logging *every available parameter every second* (i.e., a table entry with 150 columns, every second) is only about 22 MB per day (or 8 GB per year).

# params monitored & alerts generated	polling/ notification interval (secs)	% mem increase	% CPU increase
32	5 secs	0.5%	1%
32	3 secs	0.5%	1%
76	2 secs	0.5%	1.5%
128	1 sec	1%	2%

Table 1 A Server performance impact for the Direct Collection Method

# params monitored & alerts generated	polling/ notification interval (secs)	% mem increase	% CPU increase
57	5 secs	0.5%	1%
57	3 secs	0.5%	1%
90	2 secs	1%	2%
122	1 sec	1%	2%

Table 2 D Server performance impact for the Direct Collection Method

Microsoft SOM – The Microsoft Server Operations and Management (SOM) is a system of tools (this includes the Microsoft Operations Manager (MOM)) designed for a large scale Microsoft TV network. It consists of the following sub-systems for data gathering and collection:

Systems Management Server – This can manage up to 20,000 client (A/D server) inventories.

Microsoft Operations Manager - This can collect parameters from up to 3000 A/D servers. The basic MOM architecture is similar to the direct data collection approach mentioned above in terms of requiring installation and configuration of the MOM agent on every A/D server (similar to a tool collecting data from the log file on every server). The scaling advantage afforded by MOM is to the northbound element. As it allows the manager to be a first level filter, potentially reducing total northbound alerts.

The SOM also has other tools that provides automated deployment services and data protection as well as a software library server enabling expedited application development (allows up to 600 simultaneous accesses)

Access EMS: (Alcatel-Lucent AMS 5526) – This system is ideal for monitoring QoS parameters from the DSLAM to the Residential Gateway. It allows monitoring of traffic and diagnostic data with user-defined alarm views. 100% of local functionality can be accessed remotely (TBD when docs are available).

Service Quality Calculation Software: (Alcatel-Lucent SQM 8920) – This is a comprehensive tool that takes measurements from the network and processes them, producing a metric indicating the picture quality perceived by end-users. It uses a combination of A and D server, STB, and probe based measurements gathered by the methods mentioned in this section and also incorporating data available from probes such as real-time MPEG TS analysis and monitor video source and encoding quality. (note that it is also an audience measurement and inventory management tool).

Network Equipment EMS: (Alcatel-Lucent SAM 5620) – This system manages the 7750 Service Router and the 7450 ESS. Router specific SNMP traps for thresholds (rising and falling edges) can be set to generate specific fault and alarm specifications (TBD when docs are available).

The following table summarizes the advantages and limitations of the above system and clarifies some of the overlapping functionality of three of the above systems. A need for a strong fault diagnosis engine could necessitate the simultaneous deployment of most of the systems mentioned below.

Note, the sole deployment of the direct access method in lieu of some of the systems is not recommended, but it can mitigate the limitations of the other systems to allow for a highly effective fault management and correlation engine.

SYSTEM	ADVANTAGES	LIMITATIONS
1. Middleware Servers (Microsoft TV application generated parameters collected directly from the A and D servers)	full range of IPTV application parameters + a wide range of system parameters, such as CPU, memory utilization and debug parameters (queue counts) which can enable a predictive alert *before* the actual fault arises in the system good for small-size deployment as it eliminates the installation, configuration, and maintenance overhead of more complex systems and does away with a single point of failure minimal performance impact on the Microsoft TV servers, even at near real-time notifications	not for large scale IPTV deployment requires some in-house development effort (though not large, from our experience)
2. Middleware EMS – (Microsoft MOM/SOM)	well suited for large scale IPTV deployment compatible with SOM inventory management and deployment tools. can be configured to act as a first level filter to northbound elements	only a subset of server parameters can be monitored, more difficult to develop fault predictions algorithms if deployed without other systems. can be a single point of failure if deployed without other systems
3. Access Equipment EMS (Alcatel-Lucent's AMS 5526)	allows for hierarchical monitoring views from system to node level allows for user defined alarm views optimal for ADSL in small to medium-sized networks	monitors only a subset of the IPTV network elements. not easily scalable to large IPTV networks
4. Service Quality Calculation	scalable to large scale IPTV networks integrated product which can monitor A/D servers and STBs, do audience measurement,	smallest subset of server parameters monitored, difficult to develop fault predictions

Software (Alcatel-Lucent's SQM 8920)	and manage inventory can be configured to act as a first level filter to northbound elements	algorithms if deployed in isolation can be a single point of failure if deployed without other systems.
5. Network Equipment EMS (Alcatel-Lucent's SAM 5620)	large number of alerts possible with granular threshold setting capability very scalable, and can be configured to act as a first level filter to northbound elements	application level impairments may not be reflected accurately in this system data access requires significant configuration effort, multiple types of access required to obtain all the data
6. Test and measurement probes/handheld	Full set of detailed measurements No impact on service delivery	Higher cost means targeted deployment is prudent

Table 3 Analysis summary of data collection systems

Measurements with Probes

As specified in the previous section, there are some cases where due to accuracy concerns or scalability concerns an operator should put equipment in the network specific to service assurance. While taking measurements directly in-line at a demarcation may seem to be the most straightforward method of inserting these probes it is not recommended in an operational environment. Inserting anything more than absolutely necessary in the actual service stream provides a higher potential to negatively impact service and should be avoided—particularly where multiple customers can be impacted. There are five recommended ways to insert T&M probes:

Option One: In-line equivalent passive monitoring

Passive monitoring is the safest method for adding a probe because the probe cannot impact service. If a probe is required to be in-line then an in-line equivalent can be setup using two mirror ports on a router as shown in the figure below.

Advantages:

Provides an equivalent setup to in-line, but assures passive behavior meaning the probe will never impact the service.

Disadvantages:

Requires two ports on a router/switch. Depending on the router/switch mirror ports can be service impacting. (note this is not the case with Alcatel-Lucent's 7750 and 7450 hardware).

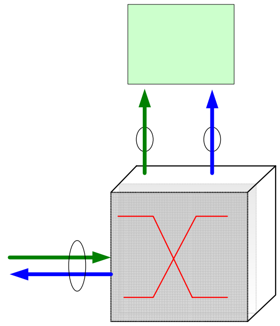

Figure 5: Passive monitoring, in-line equivalent

The ingress and egress to the router/switch are configured to be mirrored to two separate ports on the probe. This allows for the continuation of Full-Duplex on the lines. Mirror ports, if implemented correctly in router or switch hardware can provide a complete equivalent of in-line monitoring while not creating a potential for negative service impact from T&M equipment.

Option Two: Passive Monitoring, Potentially Measurement Impacting

The second option is to mirror both ingress and egress of a line under test to a single mirror port, likely on two different VLANs using distinct VLAN IDs.

Advantages:

Provides all line data as if in-line, and assures passive behavior meaning the probe will never impact the service. Requires only one mirror port.

Disadvantages:

Because you are mirroring a full duplex line onto a single direction of a mirror port line, there is a potential for congestion on the mirror port that could impact measurement.

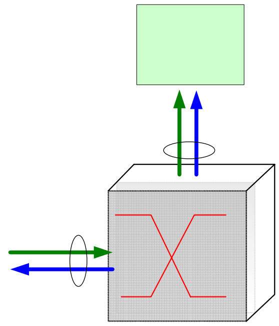

Figure 6: Passive monitoring, potential measurement impact

From a probe perspective, this doesn't look exactly like an in-line setup so the probe must support this configuration (i.e. support measurement VLAN's) or the measurement of concern must not be directional in nature (for example, getting a "program ID" wouldn't matter).

Option Three: Active, but no unicast monitoring

Sometimes passive monitoring is not possible. For example if you would like to test the response of a D-Server to a channel change request you would need to join the service. Any multicast can be joined to provide semi-passive monitoring of multicast streams. In this case you can setup a probe to be a part of the service (e.g. in the VPLS domain of the service similar to how an end-user would be attached if directly Ethernet connected).

Advantages:

Requires only one port for monitoring. Can join/receive the service and provide an "end-user" view. Can support active testing.

Disadvantages:

Potentially service impacting. Cannot passively monitor unicast traffic on the network.

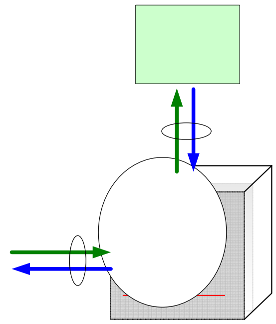

Figure 7: Active monitoring, no unicast

Option Five: Access Probe In-line

There are two special cases where in-line devices may be appropriate to use, both of them apply for single users (i.e. in the home or on an access line). These are 'Option Five: Access Probe In-Line' and 'Option Six: In-home Ethernet'.

Option five entails placing a handheld or other device on a DSL or other access line. This is generally a temporary installation by a field technician at the end of an access line for troubleshooting purposes. The use of an in-line device at times is not considered a best practice measurement technique due to the fact that it introduces another point of failure in the solution. "If the device fails, then perhaps the network traffic fails to pass through."

Option Six: In-home

Depending on device costs and level of service issues an option is to leave a device in the home for monitoring of in-home networking and service.

Calibration activities and results

A major activity with regards to this IPTV Edition test and measure document was to understand the current landscape of the various network probe manufacturing companies. Four of the industry leading vendors were given the opportunity to take part in a calibration activity in the Alcatel-Lucent Proof of Concept lab for this document. These four vendors were Agilent Technologies, IneoQuest, JDSU, and Spirent Communications.

As part of the eco-partnership that was formed all the parties met and created a list of essential measurements that can be used for IPTV Edition. (Appendix B) Some of these measurements are also used during the calibration exercises.

Each of these companies was then asked to bring their latest test and measurement platforms for IPTV Edition and calibrate against each other and the measurements agreed upon. The testing was based on the injection of artificial impairments as outlined in the "Impairment" section.

Five points were selected as major measurement locations in the Alcatel-Lucent IPTV Edition architecture. Each of these points allowed for the maximum flexibility in monitoring the solution without integrating a large number of probes into the network. More probes can be added at the other points listed in appendix C if more detailed monitoring is required for a specific service.

The following points were listed as major measure points: (see Appendix C)

SHO/Headend: for Multicast UDP from the encoder **(Point A)**.

Transport Network: for core network validation of the MPLS traffic **(Point E)**

Last Mile: for Central Office monitoring or remote location. **(Point O)**

xDSL: for DSL validation **(Point J or K)**

House: for internal home wiring and residential gateway testing. **(Point L)**

The two most common methods that were used to measure the statistics of the IPTV Edition streams were active and mirror ports by the four vendors. Each vendor was able to select the method that they wished to use for the calibration activities. There was one exception with the test case using the IneoQuest Geminus being used to drop packets. For this testing the vendors were required to use mirror ports that were enabled at the locations located above.

Impairment Methodology

In order to calibrate the four vendors against the list of selected measurement types displayed in appendix B, artificial IP based impairments were injected to the streams. Two devices were used to do this, a Spirent Converged Network Impairment Emulator “CoNIE” and an IneoQuest Geminus with a G1 module. Both of these devices were used physically in-line to the IP streams at several locations in the PoC lab environment.

With a traditional IPTV service only one impairment location maybe needed to test the impacts of a corrupted stream. But with the R-UDP methods that Microsoft deploys with its IPTV Edition it was decided that three locations were needed to test the impacts of a corrupt stream. The locations selected were as follows:

Point **A** (Multicast UDP stream, Pre A-server)

Point **E** (Multicast RTP in the network core, Post A-Server and Pre D-Server)

Point **O** (Multicast RTP in the Last Mile before the 7330, post D-Server)

See Appendix C for location reference.

At each point the tests were conducted against both a High and Standard Definition stream. The streams consisted of H.264 encoding in a MPEG2 transport stream.

The Spirent CoNIE allowed for complete impairment of the IP stream. It utilizes the ITU-T G.1050 network impairment model. For the impairment test cases only two were used, 132c and 132f. The 132c test case represented a medium level of impairment for the IPTV Edition system. The medium level was to simulate occasional quality issues on the STB and TV located in the residence. High impairments of test case 132f cause sever quality issues on the STB. Both cases for the CoNIE was run at each of the three demarc locations for impairments.

The IneoQuest Geminus was used at points A and O and allows for a very detailed simulation of packet loss. An individual video stream can be selected using the IQMediaAnalyerII software. During testing in the PoC lab a loss of 16 per 1000 packets were issued on the streams. The precise nature of these test allowed for a more detail analysis of the MDI measurements.

Measurement Results

The following charts will outline the measurement results from each vendor. These tables have recorded all the measurements that the vendors were able to take along with the calibration results from the agreed upon metrics.

The chart has been laid out in the following manner.

Line items in **Red** are “Calibration” metrics. These are the agreed upon measurement to validate the same value from all the vendors.

Line items in **Green** are “Non-Calibration” metrics. Measurements that were also deemed important but not calibrations are also outlined. We did not attempt to agree on exact formulas or values for the metric allowing for variation in the specific measurement result meaning that while it was agreed to be an important metric,.

Line items in Grey are measurement that can not be taken at a given demarc or are of no importance in monitoring the IPTV Edition solution.

Actual measurement scores from each of the vendors have not been included in this document because the actual value was not an important result for an engineer designing an Microsoft TV T&M solution. Instead each vendor received the following scores,

Completed – Measurements were taken in at a calibration point, but no other vendor completed a result at this point. Therefore no calibration could take place.

Measured – A result was recorded for a "non-calibration" measurement.

Calibrated - Two or more vendors matched to receive a calibrated score.

Completed N/C – A score of Not Calibrated is a measurement that was taken at a "calibration point" but it did not resemble another vendor's score.

A Blank entry in the table means that no information was provided by the vendor for that measure or demarc point.

A result of Completed Not Calibrated means that the measurement was taken but did not match with in the 2.5% margin of error between vendors.

* Note: Program Name was not available during the time of testing. It has been included in this document as it is considered an important measurement.

Agilent Technology Results

Agilent Technologies used their J6900A Triple Play Analyzer in conjunction with the Distributed Network Analyzer (DNA) and DNA PRO product line. Triple Play Analyzer testing occurred on the DNA Hardware probe as well as "off the self" NIC cards. The DNA's and NICS were attached via mirror ports, aka "passive testing" for all the information provided.

Agilent Calibration Results

Measurements		Pre A-Server Point A	Post A-Server Point E	Post D-Server Point O	vDSL Access Point J	vDSL Termination Point K	Home Ethernet Point L
MDI MLR, Network based, CBR		Completed N/C					
MDI DF, Network based, CBR		Calibrated					
Audio Quality (MOS or Other)							
Audio & Video Sync (Delta-T)							
Quantization							
Frame Rate Total							
Slice Type (I,P, or B Frames?)		Measured					
Spatial Measurements							
Video MOS (Multiple Algorithms, No recommendation on actual method)							
Total Bit Rate for Stream at the IP Layer		Calibrated					
Bit Rate per PID, per Audio, per Video		Measured					
Program Name (MPEG2 Transport Stream Descriptor)		N/A					
Measurements Defined by ISO 13813-1:	Sync byte error	Measured	Measured	Measured			Measured
	PAT errors (Frequency and is it scrambled?)	Measured	Measured	Measured			Measured
	Continuity count error (Per PID and/or Total)	Measured	Measured	Measured			Measured
	PMT errors (Frequency and is it scrambled?)	Measured	Measured	Measured			Measured
	PID errors (Presence not periodicity)	Measured	Measured	Measured			Measured
	Transport error (TEI=1?)	Measured	Measured	Measured			Measured
	ISO 13818-1 Defined **Late** PCR error (Presence)	Measured	Measured	Measured			Measured
MDI MLR, RTP Based (RFC 4445 for Multicast)			Calibrated	Completed N/C			Calibrated
MDI DF, RTP Based (RFC 4445 for Multicast)			Completed N/C	Completed N/C			Completed N/C
Packet Loss %, RTP Based			Calibrated	Calibrated			Calibrated
Burst Packet Loss (Hole Size) (as defined in RFC3357)			Calibrated	Calibrated			Calibrated
Distance between Holes (as defined in RFC3357)							Calibrated
Packet Sequencing (RTP OOS)							
Packet Sequencing Accounting for RUDP (RTP OOS++)			Measured				
Total Bit Rate for Stream at the IP Layer			Completed N/C	Calibrated			Calibrated
Bit Rate per PID, per Audio, per Video			Measured	Measured			Calibrated
Discontinuity Errors [PCR (note valid to measure, but only relevant to post A-Server context)]			Measured	Measured			Measured
Program Name (MPEG2 Transport Stream Descriptor)			N/A	N/A	N/A	N/A	N/A
RTT from Point N, E, G, F (Active mode likely here, e.g. ping test)							Calibrated
One-way delay from Points F & G (based on NTP)				Measured			
IGMP ZAP Time (Delta-t from when "Join" Msg leaves set-top to rcv 1st multicast pkt)							Calibrated
ICC ZAP Time (Delta-t from when webservice msg to D-Server leaves set-top to rcv 1st unicast pkt)							
RUDP Fulfillment (If I see a request do I get the requested packets?)							
ICC/IGMP Overlap (Time of overlap between Multicast arrival and end of associated unicast)							
ICC/IGMP Under-run (Is ICC/IGMP Overlap Negative?)							

IneoQuest Results

IneoQuest applied three methods of network monitoring with their Geminus G1, G10, Singulus G1-T, and Singulus Lite "Cricket". The Geminus access was implemented using both active and passive ports to monitor the video streams in the IPTV Edition solution. The Cricket was used in-line between the residential gateway and the set top box and also standalone in set top box emulation mode. These devices were controlled using the IQMediaAnalyzer and the IP Video Management System products.

IneoQuest Calibration Results

Measurements		Pre A-Server	Post A-Server	Post D-Server	vDSL Access	vDSL Termination	Home Ethernet
		Point A	Point E	Point O	Point J	Point K	Point L
MDI MLR, Network based, CBR		Completed N/C					
MDI DF, Network based, CBR		Calibrated					
Audio Quality (MOS or Other)							
Audio & Video Sync (Delta-T)							
Quantization							
Frame Rate Total		Completed N/C					
Slice Type (I,P, or B Frames?)		Measured					
Spatial Measurements							
Video MOS (Multiple Algorithms, No recommendation on actual method)							
Total Bit Rate for Stream at the IP Layer		Calibrated					
Bit Rate per PID, per Audio, per Video		Measured					
Program Name (MPEG2 Transport Stream Descriptor)		N/A					
Measurements Defined by ISO 13813-1:	Sync byte error	Measured	Measured	Measured			Measured
	PAT errors (Frequency and is it scrambled?)	Measured	Measured	Measured			Measured
	Continuity count error (Per PID and/or Total)	Measured	Measured	Measured			Measured
	PMT errors (Frequency and is it scrambled?)	Measured	Measured	Measured			Measured
	PID errors (Presence not periodicity)	Measured	Measured	Measured			Measured
	Transport error (TEI=1?)	Measured	Measured	Measured			Measured
	ISO 13818-1 Defined **Late** PCR error (Presence)	Measured	Measured	Measured			Measured
MDI MLR, RTP Based (RFC 4445 for Multicast)			Calibrated	Completed N/C			Calibrated
MDI DF, RTP Based (RFC 4445 for Multicast)			Completed N/C	Completed N/C			Completed N/C
Packet Loss %, RTP Based			Calibrated	Calibrated			Calibrated
Burst Packet Loss (Hole Size) (as defined in RFC3357)			Calibrated	Calibrated			Calibrated
Distance between Holes (as defined in RFC3357)			Completed N/C	Completed N/C			Calibrated
Packet Sequencing (RTP OOS)							
Packet Sequencing Accounting for RUDP (RTP OOS++)							
Total Bit Rate for Stream at the IP Layer			Completed N/C	Calibrated			Calibrated
Bit Rate per PID, per Audio, per Video			Measured	Measured			Calibrated
Discontinuity Errors [PCR (note valid to measure, but only relevant to post A-Server context)]			Measured	Measured			Measured
Program Name (MPEG2 Transport Stream Descriptor)			N/A	N/A	N/A	N/A	N/A
RTT from Point N, E, G, F (Active mode likely here, e.g. ping test)				Calibrated			Calibrated
One-way delay from Points F & G (based on NTP)				Measured			
IGMP ZAP Time (Delta-t from when "Join" Msg leaves set-top to rcv 1st multicast pkt)							Completed N/C
ICC ZAP Time (Delta-t from when webservice msg to D-Server leaves set-top to rcv 1st unicast pkt)							
RUDP Fulfillment (If I see a request do I get the requested packets?)							Measured
ICC/IGMP Overlap (Time of overlap between Multicast arrival and end of associated unicast)							
ICC/IGMP Under-run (Is ICC/IGMP Overlap Negative?)							

JDSU Results

The JDSU Qt-600 was used on the passive mirror ports to monitor the IPTV Edition traffic in the SHO, Core network, and VHO demarcs. For the home demarc the HST-3000 was used. It allowed for both DSL and Ethernet monitoring of the video streams.

JDSU Calibration Results							
Measurements		**Pre A-Server**	**Post A-Server**	**Post D-Server**	**vDSL Access**	**vDSL Termination**	**Home Ethernet**
		Point A	**Point E**	**Point O**	**Point J**	**Point K**	**Point L**
MDI MLR, Network based, CBR		Completed N/C					
MDI DF, Network based, CBR		Calibrated					
Audio Quality (MOS or Other)							
Audio & Video Sync (Delta-T)							
Quantization							
Frame Rate Total		Calibrated					
Slice Type (I,P, or B Frames?)							
Spatial Measurements							
Video MOS (Multiple Algorithms, No recommendation on actual method)		Measured					
Total Bit Rate for Stream at the IP Layer		Calibrated					
Bit Rate per PID, per Audio, per Video		Measured					
Program Name (MPEG2 Transport Stream Descriptor)		N/A					
Measurements Defined by ISO 13813-1:	Sync byte error	Measured	Measured	Measured	Measured *	Measured	Measured
	PAT errors (Frequency and is it scrambled?)	Measured	Measured	Measured	Measured *	Measured	Measured
	Continuity count error (Per PID and/or Total)	Measured	Measured	Measured	Measured *	Measured	Measured
	PMT errors (Frequency and is it scrambled?)	Measured	Measured	Measured	Measured *	Measured	Measured
	PID errors (Presence not periodicity)	Measured	Measured	Measured	Measured *	Measured	Measured
	Transport error (TEI=1?)	Measured	Measured	Measured	Measured *	Measured	Measured
	ISO 13818-1 Defined **Late** PCR error (Presence)	Measured	Measured	Measured	Measured *		
MDI MLR, RTP Based (RFC 4445 for Multicast)			Calibrated	Completed N/C	Measured *	Completed(1)	Calibrated
MDI DF, RTP Based (RFC 4445 for Multicast)			Completed N/C	Completed N/C	Measured *	Completed(1)	Completed N/C
Packet Loss %, RTP Based			Calibrated	Calibrated	Measured *	Completed(1)	Calibrated
Burst Packet Loss (Hole Size) (as defined in RFC3357)			Calibrated	Calibrated	Measured *	Completed(1)	Completed N/C
Distance between Holes (as defined in RFC3357)					Measured *	Completed(1)	Completed N/C
Packet Sequencing (RTP OOS)			Measured	Measured	Measured *	Measured	Measured
Packet Sequencing Accounting for RUDP (RTP OOS++)				Measured	Measured *		
Total Bit Rate for Stream at the IP Layer			Completed N/C	Calibrated	Measured *	Completed(1)	Calibrated
Bit Rate per PID, per Audio, per Video			Measured	Measured	Measured *	Completed(1)	Calibrated
Discontinuity Errors [PCR (note valid to measure, but only relevant to post A-Server context)]							
Program Name (MPEG2 Transport Stream Descriptor)			N/A	N/A	N/A	N/A	N/A
RTT from Point N, E, G, F (Active mode likely here, e.g. ping test)					Measured *	Completed N/C	Calibrated
One-way delay from Points F & G (based on NTP)							
IGMP ZAP Time (Delta-t from when "Join" Msg leaves set-top to rcv 1st multicast pkt)					Measured *	Completed(1)	Calibrated
ICC ZAP Time (Delta-t from when webservice msg to D-Server leaves set-top to rcv 1st unicast pkt)							
RUDP Fulfillment (If I see a request do I get the requested packets?)							
ICC/IGMP Overlap (Time of overlap between Multicast arrival and end of associated unicast)							
ICC/IGMP Under-run (Is ICC/IGMP Overlap Negative?)							

* "Due to time constraints, JDSU declined to calibrate at point J. Based on the measurement at point K It was judged that JDSU could have made the measurements at point J using their handheld probe in a continuous monitoring mode, justifying the 'measured' designation."

Spirent Communications Results

Spirent's used several of their network appliances for this activity in the Alcatel-Lucent PoC lab. The Video Test System (VTS) along with the SmartSight Triplay Solution using SmartSight Central and IPMax were all used in both active and passive testing of the IPTV Edition streams.

Spirent Calibration Results							
Measurements		**Pre A-Server**	**Post A-Server**	**Post D-Server**	**vDSL Access**	**vDSL Termination**	**Home Ethernet**
		Point A	**Point E**	**Point O**	**Point J**	**Point K**	**Point L**
MDI MLR, Network based, CBR		Completed N/C					
MDI DF, Network based, CBR		Completed N/C					
Audio Quality (MOS or Other)		Measured					
Audio & Video Sync (Delta-T)							
Quantization		Measured					
Frame Rate Total		Calibrated					
Slice Type (I,P, or B Frames?)		Measured					
Spatial Measurements		Measured					
Video MOS (Multiple Algorithms, No recommendation on actual method)		Measured					
Total Bit Rate for Stream at the IP Layer		Completed N/C					
Bit Rate per PID, per Audio, per Video		Measured					
Program Name (MPEG2 Transport Stream Descriptor)		N/A					
Measurements Defined by ISO 13813-1:	Sync byte error	Measured	Measured	Measured	Measured		Measured
	PAT errors (Frequency and is it scrambled?)	Measured	Measured	Measured	Measured		Measured
	Continuity count error (Per PID and/or Total)	Measured	Measured	Measured	Measured		Measured
	PMT errors (Frequency and is it scrambled?)	Measured	Measured	Measured	Measured		Measured
	PID errors (Presence not periodicity)	Measured	Measured	Measured	Measured		Measured
	Transport error (TEI=1?)	Measured	Measured	Measured	Measured		Measured
	ISO 13818-1 Defined **Late** PCR error (Presence)	Measured	Measured	Measured	Measured		Measured
MDI MLR, RTP Based (RFC 4445 for Multicast)				Completed N/C	Completed(1)		Calibrated
MDI DF, RTP Based (RFC 4445 for Multicast)				Completed N/C	Completed(1)		Completed N/C
Packet Loss %, RTP Based			Completed N/C	Calibrated	Completed(1)		Calibrated
Burst Packet Loss (Hole Size) (as defined in RFC3357)			Calibrated	Calibrated	Completed(1)		Calibrated
Distance between Holes (as defined in RFC3357)				Completed N/C	Completed(1)		Completed N/C
Packet Sequencing (RTP OOS)			Measured	Measured	Measured		Measured
Packet Sequencing Accounting for RUDP (RTP OOS++)			Measured	Measured	Measured		
Total Bit Rate for Stream at the IP Layer			Completed N/C	Completed N/C	Completed(1)		Completed N/C
Bit Rate per PID, per Audio, per Video				Measured	Completed(1)		Calibrated
Discontinuity Errors [PCR (note valid to measure, but only relevant to post A-Server context)]			Measured	Measured	Measured		Measured
Program Name (MPEG2 Transport Stream Descriptor)			N/A	N/A	N/A	N/A	N/A
RTT from Point N, E, G, F (Active mode, ping test)				Calibrated	Completed(1)		Calibrated
One-way delay from Points F & G (based on NTP)				Measured	Measured		
IGMP ZAP Time (Delta-t from when "Join" Msg leaves set-top to rcv 1st multicast pkt)				Completed N/C	Completed(1)		Completed N/C
ICC ZAP Time (Delta-t from when webservice msg to D-Server leaves set-top to rcv 1st unicast pkt)							
RUDP Fulfillment (If I see a request do I get the requested packets?)							
ICC/IGMP Overlap (Time of overlap between Multicast arrival and end of associated unicast)							
ICC/IGMP Under-run (Is ICC/IGMP Overlap Negative?)							

Application of MDI (Media Delivery Index) to Microsoft TV IPTV Edition

As a result of testing during these exercises for IPTV Edition platform some conclusions were formed around the use of the Media Delivery Index.

The Media Delivery Index (MDI) is described in RFC 4445 as being a "measurement that can be used as a diagnostic tool or a quality indicator for monitoring a network intended to deliver applications such as streaming media, MPEG video, Voice over IP, or other information sensitive to arrival time and packet loss." The MDI measurement is made up of 2 separate measurements typically displayed separated by a colon. They are Delay Factor (DF) and a Media Loss Rate (MLR). The IPTV Edition has some very unique tools that allow the solution to function in situations with greater packet loss and jitter than what is acceptable in a tradition IPTV service.

Delay Factor (DF)

The Delay Factor measurement relates to the amount of jitter in the stream – that is the variations in packet spacing from one packet to the next. This is typically measured over periods such as a second. The calculation for this value is to take the maximum delay variation minus the minimum delay variation and divide by the data rate of the stream. The result is a value in milliseconds that directly correlates with the size that the client buffer need to be (in ms for the given data rate), in order to effectively decode and play this stream.

The normal behavior of Microsoft TV IPTV Edition 1.1 is very differently to this in several ways. First, the services delivered by Microsoft TV IPTV Edition are by no means Constant Bit rate and have potentially enormous levels of jitter inherent in them. This is the case for the multicast streams out of the A-Server (which operate essentially as a Capped VBR stream that would have unacceptable jitter in most other environments). As a result, the DF numbers for Microsoft TV video services will be wildly variable, and might not correlate to an end-user QoE, but offers direct insight into the health of the flows throughout the network.

Second, the client's capacity to deal with this jitter is unique. The client contains managed buffers that are at least 1 second deep for any service (more for HD broadcast), which means that they are more than capable of absorbing enormous amounts of jitter without visual impairment. As mentioned earlier however the real parameter that needs to be monitored in this regard is the latency (or rather Round Trip Time) which actually may have a bearing on the service., particularly for services such as HD VoD and R-UDP for broadcast channels,,

While not necessarily an indicator of changing end-user experience, Maximum Delay Factor may be useful if taken during pre-operational phase of an IPTV Edition service to create a baseline for network performance. Once the high point is found on the system this value can be used as an alarm to indicate to the service operation that network jitter may exceed established limits indicating network problems that should be resolved.

Media Loss Rate (MLR)

Media Loss Rate is more relevant to Microsoft TV IPTV Edition, though not entirely. The deep, managed buffers on the Microsoft TV IPTV Edition clients provide two things that drastically affect the usefulness of MLR as an indicator of the customer quality of service. First, the Microsoft TV IPTV Edition buffers are managed such that out of order packets typically not an issue because of the nature of how RTP handles the sequencing. MLR appears to weight an out or order packet with the same weight as a lost packet, which simply isn't appropriate in this scenario. Second there are extensive recovery mechanisms for lost packets built into the platform, so while there is value in knowing there is loss, there is not necessarily a correlation between loss and affect on quality of experience.

Small levels of loss are perhaps an indication of a looming problem and will be absorbed by the client. What is more useful to know are the characteristics of the loss events. Such as how large are the holes, what is their frequency, the thresholds to trigger action and what are the thresholds that are customer affecting. Additionally, the issues are different according to the service being delivered.

Consideration can also be given to RFC 3357 "A One-way Packet Loss Metric for IPPM". This RFC discusses one way delay from a source. In the multicast world of IPTV this can be a important issue when dealing with video delivery and the quality of experience for the end user.

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Appendix A: Microsoft TV ALERT NOTIFICATION ARCHITECTURE (DIRECT ACCESS METHOD)

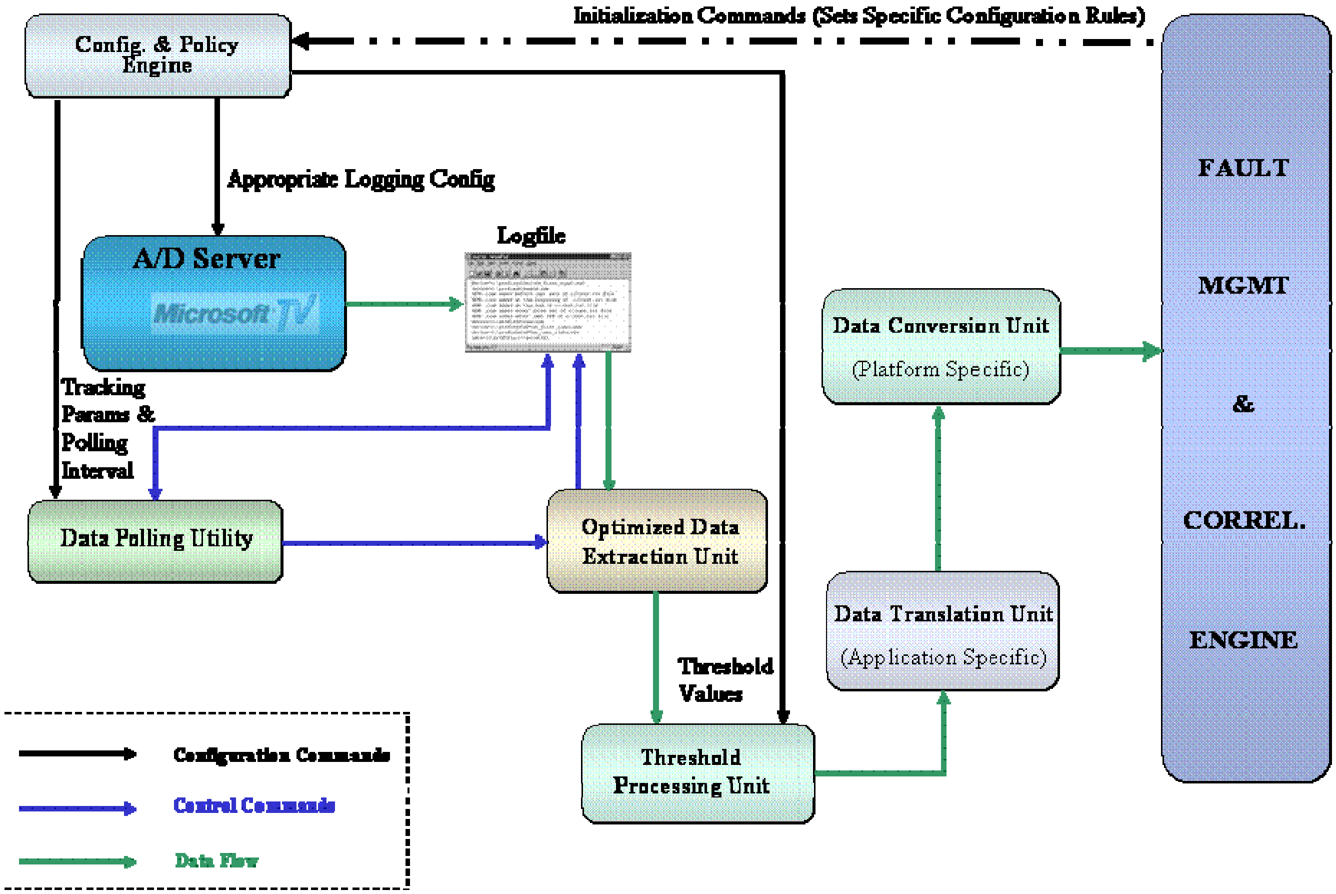

Figure 8 Direct Access Configuration & Notification Architecture

In this design, the fault management and correlation engine controls the parameters to be monitored and their trigger thresholds via a central configuration & policy engine (CPE). The CPE could reside on any IPTV server (as Tables 1 & 2 indicate, the performance impact of this method is minimal). The CPE then sets the appropriate log levels on the servers and configures the poll intervals on the data polling unit (DPU). It also sets the specified threshold values in the threshold processing unit (TPU) which can then make decisions on whether notifications need to be forwarded or not.

When a new log entry is generated on the Microsoft TV server, the DPU notifies the data extraction unit (DEU) to collect data related to the specified parameters. The DEU then performs an optimized (performance and memory wise) extraction and forwards the data to the TPU which makes a notification decision. A notification is then sent, if needed, after the appropriate end-system-specific data translation and conversion.

This modularity also allows for multi-OS/multi-application interoperability.

Appendix B: Table of Measurements, Methodology, and Calibration Attempt

Reference Chart

Measurements		Pre A-Server Point A	Post A-Server Point E	Post D-Server Point O	vDSL Access Point J	vDSL Termination Point K	Home Ethernet Point L
MDI MLR, Network based, CBR		C					
MDI DF, Network based, CBR		C					
Audio Quality (MOS or Other)		M or NA					
Audio & Video Sync (Delta-T)		M or NA					
Quantization		M or NA					
Frame Rate Total		C					
Slice Type (I,P, or B Frames?)		M or NA					
Spatial Measurements		M or NA					
Video MOS (Multiple Algorithms, No recommendation on actual method)		M or NA					
Total Bit Rate for Stream at the IP Layer		C					
Bit Rate per PID, per Audio, per Video		M or NA					
Program Name (MPEG2 Transport Stream Descriptor)		C					
Measurements Defined by ISO 13813-1:	Sync byte error	M or NA	M or NA	M or NA	M or NA	M or NA	M or NA
	PAT errors (Frequency and is it scrambled?)	M or NA	M or NA	M or NA	M or NA	M or NA	M or NA
	Continuity count error (Per PID and/or Total)	M or NA	M or NA	M or NA	M or NA	M or NA	M or NA
	PMT errors (Frequency and is it scrambled?)	M or NA	M or NA	M or NA	M or NA	M or NA	M or NA
	PID errors (Presence not periodicity)	M or NA	M or NA	M or NA	M or NA	M or NA	M or NA
	Transport error (TEI=1?)	M or NA	M or NA	M or NA	M or NA	M or NA	M or NA
	ISO 13818-1 Defined **Late** PCR error (Presence)	M or NA	M or NA	M or NA	M or NA	M or NA	M or NA
MDI MLR, RTP Based (RFC 4445 for Multicast)			C	C	C	C	C
MDI DF, RTP Based (RFC 4445 for Multicast)			C	C	C	C	C
Packet Loss %, RTP Based			C	C	C	C	C
Burst Packet Loss (Hole Size) (as defined in RFC3357)			C	C	C	C	C
Distance between Holes (as defined in RFC3357)			C	C	C	C	C
Packet Sequencing (RTP OOS)			M or NA	M or NA	M or NA	M or NA	M or NA
Packet Sequencing Accounting for RUDP (RTP OOS++)			M or NA	M or NA	M or NA		
Total Bit Rate for Stream at the IP Layer			C	C	C	C	C
Bit Rate per PID, per Audio, per Video			M or NA	M or NA	C	C	C
Discontinuity Errors [PCR (note valid to measure, but only relevant to post A-Server context)]			M or NA	M or NA	M or NA	M or NA	M or NA
Program Name (MPEG2 Transport Stream Descriptor)			C	C	C	C	C
RTT from Point N, E, G, F (Active mode likely here, e.g. ping test)				C	C	C	C
One-way delay from Points F & G (based on NTP)				M or NA	M or NA		
IGMP ZAP Time (Delta-t from when "Join" Msg leaves set-top to rcv 1st multicast pkt)				C	C	C	C
ICC ZAP Time (Delta-t from when webservice msg to D-Server leaves set-top to rcv 1st unicast pkt)				M or NA(1)	M or NA	M or NA	M or NA
RUDP Fulfillment (If I see a request do I get the requested packets?)				M or NA(1)	M or NA	M or NA	M or NA
ICC/IGMP Overlap (Time of overlap between Multicast arrival and end of associated unicast)				M or NA(1)	M or NA	M or NA	M or NA
ICC/IGMP Under-run (Is ICC/IGMP Overlap Negative?)				M or NA(1)	M or NA	M or NA	M or NA

(1) Single/few user measurements in an aggregate flow (i.e. not all users, all the time)

C = Calbration measurements for all vendors

M or NA = Items that can be measured, but are not required for the calibration activity

Appendix C: Proof of Concept Lab Diagram