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TR-176

ADSL2Plus Configuration Guidelines for IPTV

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Notice

Issue History

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Summary

This Technical Report contains generic ADSL2plus configuration parameter settings for use in the deployment of IPTV over ADSL2plus. Included are ranges of deployed parameter values derived from the experiences of service providers and vendors who have already tested, trialled and/or deployed IPTV over ADSL2plus and hence represent current industry practise. In addition, specific recommendations are made for a baseline set of parameters supporting IPTV. Every IPTV implementation is different; the service offering, serving area, noise models, plant characteristics and vendor capabilities all combine to a very specific environment in which the baseline parameters described herein may be inappropriate. Service Providers are encouraged to use this Technical Report as a starting point to thoroughly research their environment and establish appropriate profiles for their specific IPTV deployment.

1 Purpose

The Quality of Experience (QoE) and Quality of Service (QoS) requirements for delivery of IPTV over DSL are much more onerous than those of best effort internet access. If the capacity management and QoS engineering (typically at Ethernet and IP layers) of the core and aggregation networks are adequate, the main source of network impairments to the TV application will be the DSL access or home networks. Noise and time-varying channel conditions on the copper pair can result in packet loss and hence video application artefacts. The impact of noise and other changes to the DSL transmission channel can be alleviated by judicious choice of parameter values in the DSL profile settings. This Technical Report makes recommendations for such profile parameters in order to facilitate successful transport of IPTV over ADSL2plus. These recommendations represent a generic baseline set of parameters supporting IPTV.

Every IPTV implementation is different; the service offering, serving area, noise models, plant characteristics and vendor capabilities all combine to a very specific environment in which the baseline parameter values described herein may be inappropriate. Hence each of the parameters are discussed in depth enabling operators to make informed decisions about how they may wish to alter them from the baseline values in order to generate the appropriate parameters for their own unique environment. These baseline parameters are not an alternative to developing an in depth understanding of the noise environment encountered on a particular network. The result in terms of QoE will give an indication of the actual effectiveness of the chosen DSL profile.

2 Scope

This Technical Report provides baseline recommendations for ADSL2Plus profile parameters for IPTV. Future work in the Broadband Forum may extend the work of this Technical Report to encompass profiles for DSM/DLM and VDSL2 profiles for IPTV.

This Technical Report enhances the use of rate-adaptive mode as described in TR-101 [10] by introducing a hybrid approach based on a fixed-rate component of a rate-adaptive profile. The minimum bitrate parameter of an ADSL2Plus profile is used to specify the bandwidth required for IPTV and other traffic-engineered services and best-effort services are provisioned within a rate-adpative zone between minimum and maximum bitrate, facilitating compatibility with a TR-101[10] based architecture which is the architecture recommended by the Broadband Forum for delivery of multicast IPTV and bundled services with a variety of QoS requirements.

2.1 Definitions

The following terminology is used throughout this Technical Report.

ANCP Access Node Control Protocol

BLC	Broadband Loop Carrier
BNG	Broadband Network Gateway
DLM	Dynamic Line Management
DMT	Discrete Multi-Tone
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexor
DSM	Dynamic Spectrum Management
EMS	Element Management System
HD	High Definition (TV)
HSIA	High Speed Internet Access
IPTV	Internet Protocol Television
INP	Impulse Noise Protection
ITU-T	International Telecommunications Union – Telecommunication Standardization Sector
MSAN	Multi-Service Access Node
NOC	Network Operations Center
PPP	Point to Point Protocol
QoE	Quality of Experience
QoS	Quality of Service
RG	Residential Gateway (i.e. end-user's ADSL2plus router)
SD	Standard Definition (TV)
SNR	Signal To Noise Ratio
SNRM	Signal To Noise Ratio Margin
SRA	Seamless Rate Adaptation
VoD	Video On Demand

2.2 Conventions

In this Technical Report, several words are used to signify the requirements of the specification. These words are often capitalized.

MUST	This word, or the adjective "REQUIRED", means that the definition is an absolute requirement of the specification.
MUST NOT	This phrase means that the definition is an absolute prohibition of the specification.
SHOULD	This word, or the adjective "RECOMMENDED", means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications must be understood and carefully weighted before choosing a different course.
MAY	This word, or the adjective "OPTIONAL", means that this item is one of an allowed set of alternatives. An implementation that does not include this option MUST be prepared to inter-operate with another implementation that does include the option.

3 References

The following references constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Technical Report are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below. A list of the currently valid Broadband Forum Technical Reports is published at www.broadband-forum.org.

[1] TR-126	Triple-Play Services Quality of Experience (QoE) Requirements	Broadband Forum Technical Report	December 2006
[2] G.992.1	ADSL Transceivers	ITU-T Recommendation	July 1999
[3] G.992.3	Asymmetrical Digital Subscriber Line Transceivers-2 (ADSL2).	ITU-T Recommendation	February 2003
[4] G.992.5	Asymmetric Digital Subscriber Line (ADSL) transceivers – Extended bandwidth ADSL2 (ADSL2plus)	ITU-T Recommendation	May 2003
[5] G.992.5 Amendment 1	Asymmetric Digital Subscriber Line (ADSL) transceivers – Extended bandwidth ADSL2 (ADSL2plus) Amendment 1	ITU-T Recommendation	July 2005
[6] G.992.5 Amendment 3	Asymmetric Digital Subscriber Line (ADSL) transceivers – Extended bandwidth ADSL2 (ADSL2plus) Amendment 3	ITU-T Recommendation	December 2006
[7] G.994.1	Handshake procedures for DSL transceivers	ITU-T Recommendation	May 2003
[8] G.997.1	Physical layer management for Digital Subscriber Line (DSL) transceivers	ITU-T Recommendation	June 2006
[9] DSM TR	Dynamic Spectrum Management Technical Report ATIS-0600007 [pre-pub], May 2007, ATIS	ATIS Technical Report	May 2007
[10] TR-101	Migration to Ethernet Based DSL Aggregation	Broadband Forum Technical Report	April 2006
[11] TR-059	DSL Evolution - Architecture Requirements for the Support of QoS-Enabled IP Services	Broadband Forum Technical Report	September 2003

4 Overview of DSL Profile Approaches

DSL Network operators have three options for their approach to ADSL2plus profiles:

(a) Fixed rate profile
(b) Rate adaptive profile without use of SRA (Seamless Rate Adaptation)
(c) Rate-adaptive profile with use of SRA

A further option discussed as an informative reference is Dynamic Line Management (DLM) / Dynamic Spectrum Management (DSM) to automatically select an appropriate profile on a per-line basis

4.1 Fixed Rate Profiles

Fixed rate profiles were used in the early days of ADSL deployment and some of these deployments were used to carry IPTV (multicast and VoD) traffic. The downside of this approach is that good prequalification processes and systems are required before ANY service is sold to the customer (including best-effort Internet access). This is because it is necessary to determine whether a customer is within range of the requisite fixed rate. Such profiles often formed part of a tiered service offering where any change in product (such as upsell to a faster speed) required the operator to re-provision the end-user's DSL line profile via the DSL Access Node element manager. However, fixed rate profiles have the potential benefit of greater service stability than rate adaptive profiles. Service stability is essential for IPTV delivery.

4.2 Rate-Adaptive Profiles

With more recent architectural developments as described in Broadband Forum TR-059 (for ATM architectures) and Broadband Forum TR-101 [10] (for Ethernet architectures) DSL Network Providers have moved to the use of ADSL2plus together with rate-adaptive profiles. ADSL2plus offers greater rate/reach performance compared to ADSL and hence can improve IPTV service penetration among the customer base. However, the use of rate-adaptive profiles also has benefits:

The first benefit of rate-adaptive DSL profiles is that line pre-qualification for a particular DSL product can be less onerous. If a line is allowed to "train" or synchronize at the maximum speed it can, then a product strategy for best-effort Internet Access doesn't need to specify a particular fixed rate such as 5 Mbit/s. Instead it can advertise "up to 5 Mbit/s". Thus before the product is sold to the end-user, it is not necessary to so accurately determine whether their line will be below the 5 Mbit/s distance threshold. This approach can be extended to bundled services including IPTV. For example, consider a triple-play bundle comprising 2 Mbit/s standard definition video, 100 kbit/s derived voice and 1 Mbit/s Internet Access. With a fixed rate-profile, pre-qualification would need to accurately identify whether the line could support a traffic payload of 3.1 Mbit/s. However, with a rate-adaptive profile, the product definition could be slightly modified so that the Internet Access component is advertised as "up to 3 Mbit/s" with the objective of delivering a minimum of 500 kbit/s when the video service is in use. Hence any line that pre-qualifies in the range 2.6 Mbit/s to 3.1 Mbit/s could be viable (this assumes the 2 Mbit/s capacity for video can be re-used for Internet Access when nobody is watching IPTV). Such product approaches have become more common and have allowed service providers more latitude in the accuracy of pre-qualifying prospective customer lines. The consequence is greater service penetration and less provisioning failures.

The second benefit of rate-adaptive profiles is more efficient product change processes. It is feasible to deploy a single default rate-adaptive profile that is good enough for a triple-play bundle (and hence will work for single-play data, double-play voice + data as well as triple play) and seeks to train the line to the fastest speed it can achieve (given line-length and local noise environment). An end-user's DSL "product speed" in a tiered service can then be controlled centrally via user profiles on the Broadband Network Gateway (BNG) which can throttle the throughput to a speed lower than the actual line-rate. The BNG can have visibility of the end-user's actual DSL line rate via either the PPPoE Intermediate Agent (IA) described in TR-101 [10] or via the Access Node Control Protocol (ANCP). Knowledge of the actual synch rate of the line then enables the BNG to facilitate accurate traffic shaping and to dynamically adjust QoS on the fly[1] to best exploit the DSL line-rate depending on which services (data, voice &/or video) are being used at any point in time. It also enables more targeted product "upsell" since the BNG will be aware of the maximum speed that a user's DSL line can support. For example, by polling the user line-rates of the existing customer base[2] it is feasible to work out which existing customers for Internet Access could be upsold to IPTV or which customers who already have single-channel Standard Definition (SD) IPTV could be upsold to two simultaneous SD IPTV channels or a single High-Definition (HD) IPTV channel.

The use of rate adaptive profiles in the manner described in the preceding paragraph will (by design) cause a significant fraction of lines in the network to operate with an excess data rate. It needs to be noted that supporting such data rates at the DSL layer can cause operational side effects. In particular, additional transmit power is wasted in supporting any unused portion of the data rate, which reduces energy efficiency and increases crosstalk. Additionally, DSL lines operating at an unnecessarily low margin are vulnerable to instability. Impulse Noise Protection (INP)/delay is also constrained (refer to Table 1) on such lines. For these reasons, operation with excess data rate tends to reduce DSL-layer network stability. When designing profiles, these drawbacks should be carefully evaluated by operators against the benefits of using a single rate-adaptive profile.

Another way to use Rate-Adaptive Profiles is to aim for a Fixed Rate profile based on a particular bundle of services but allow Rate Adaptation to benefit the best-effort portion of the bundle. One way of thinking of this is to consider a rate adaptive line's actual speed to be comprised of two components – the fixed (minimum) guaranteed component

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[1] E.g. via the use of the hierarchical scheduling techniques described in TR-059 [11] and TR-101

[2] Such max line-rate information may be held by the Access Node element manager and also the BNG if PPPoE IA or ANCP are employed

and the variable component[3]. The latter can be considered as “elastic bandwidth” available for Best-Effort traffic like Internet Access. The exact speed of this component is less critical to the functioning of the overall service bundle and so a part of it can be “sacrificed” to reduce the rigor and accuracy required in pre-qualifying a user’s line for the service bundle.

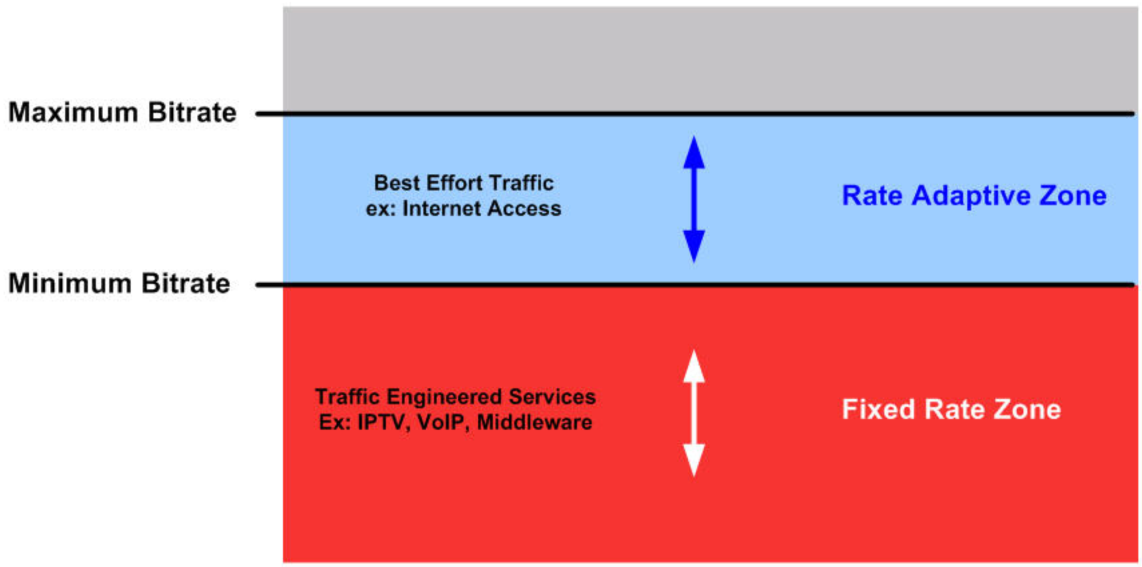

Figure 1 - Concept of Rate-Adaptive DSL Comprising Two Components

As illustrated in Figure 1, the minimum-bitrate parameter specifies the fixed-rate component of the service. This could be used to ensure that sufficient bandwidth is available for IPTV, VoIP and any other traffic engineered service that requires a fixed bandwidth allocation. The maximum-bitrate parameter is set to the total bandwidth required for traffic engineered services + best effort services such as Internet Access. As an example, suppose a Service Provider offered three channels of IPTV, each encoded at 3Mbit/s and required an additional 0.5Mbps for VoIP and middleware (EPG STB management etc.). Furthermore, the service provider guarantees a minimum SLA for Internet Access of 0.5Mbps. The minimum bit rate would be set to 10Mbps. The Service Provider could advertise an Internet Access capability supporting "up to" 5Mbit/s. The corresponding maximum-bitrate would be set at 15Mbps. With these settings the line could achieve DSL synchronization (“showtime”) at any rate between say 10 Mbit/s and 15Mbps, covering a far broader serving area than if the line could only train up at 15Mbps as could be the case in a pure fixed-rate scenario. Hence line pre-qualification requirements are eased.

[3] Analogous to CBR + UBR components in ATM service bundles

4.3 Seamless Rate Adaptation (SRA)

With rate-adaptive ADSL2plus profiles, the DSL Network Provider has the option to choose whether to use Seamless Rate Adaptation (SRA) or not. SRA allows DSL Access Nodes to make seamless data transfer rate changes to avoid dropping a connection. The DSL modems at either end of a copper DSL line (e.g. in DSLAM and CPE router) are affected by cross talk from adjacent lines, environmental changes and electrical interference such as radio signals. Any significant change in interference levels on the connection can cause a modem to retrain and drop the existing connection. SRA makes dynamic data transfer rate changes to accommodate changes in noise conditions on the line thus preventing dropped connections and retraining. Hence with SRA, ADSL2plus technology can change the data rate of the connection while in operation without any service interruption or bit errors. ADSL2plus simply detects changes in the channel conditions (for example, the introduction of more cross-talk as a new line trains up) and adapts the data rate to the new channel condition transparently to the user.

SRA is based on the decoupling of the modulation layer and the framing layer in ADSL2plus systems. This decoupling enables the modulation layer to change the transmission data rate parameters without modifying parameters in the framing layer which would cause the modems to lose frame synchronization resulting in uncorrectable bit errors or system restart. SRA uses the sophisticated online reconfiguration (OLR) procedures of ADSL2plus systems to seamlessly change the data rate of the connection.

The protocol used for SRA works as follows:

1. The receiver monitors the SNR of the channel and determines that a data rate change is necessary to compensate for changes in channel conditions.
2. The receiver sends a message to the transmitter to initiate a change in data rate. This message contains all necessary transmission parameters for transmitting at the new data rate. These parameters include the number of bits modulated and transmit power on each subchannel in the ADSL multicarrier system.
3. The transmitter sends a "Sync Flag" signal which is used as a marker to designate the exact time at which the new data rate and transmission parameters are to be used.
4. The Sync Flag signal is detected by the receiver and both transmitter and receiver seamlessly and transparently transition to the data rate.

There are advantages and disadvantages of SRA and hence a DSL Network Provider has to decide whether to use it or not. Without SRA, it is necessary to set target margin in the ADSL2plus profile at a sufficient level to ensure that “normal” noise levels and crosstalk variations won’t result in bit-errors and hence video artefacts. Such a target margin setting may cause some reduction is service penetration (percentage of homes within range). Moreover it could be difficult to determine a correct target margin value for all deployed lines. However, the advantage is that the customers line speed will only change under extreme noise level changes[4] and hence the requirements are far less onerous for systems upstream (such as BNGs, policy managers etc.) that perform traffic shaping to the line-speed and dynamic QoS adjustments.

If SRA is turned on then the ADSL2plus line can adjust its line speed to more dynamically optimize the maximum throughput at any instance in time. The downside to this is that any traffic shaping and QoS/policy systems that may use this maximum speed parameter also have to respond more rapidly and to a higher volume of speed change events. Note also that if the traffic shaping systems/policies coarsely quantized the actual line speed into categories of say 500 kbit/s increments (e.g. shaped downstream traffic to the next lowest n*500 kbit/s speed) then the benefits of SRA speed optimization on the DSL line will not be realized by the end-user. Hence to fully glean the line speed benefits of SRA, any upstream traffic shaping, QoS, and policy management systems may need to also dynamically track and use the actual instantaneous speed of the line.

It is worth noting that SRA with a high INP parameter value may have limited application due to constraints on framing.

When using SRA, the upshift and downshift margin parameters in the ADSL2plus profile may be fine-tuned to “dampen” the dynamics of line speed changes. Hysteresis techniques[5] may also be used to decouple instantaneous DSL line speed changes from say BNG traffic shaping response in order to achieve a balance between overall responsiveness to noise level changes and processing load on BNGs and policy managers.

Note that many operators deploying either rate-adaptive or SRA ADSL2plus profiles as the default profile also have some “back-up” profiles configured on the Access Node that can be used[6] by the their technical support teams to stabilize unusually noisy or challenging lines. Such profiles may include additional noise margin, interleaving delay and INP. They may even include a selection of fixed-rate profiles to remove dynamic operation from the line. Typically, such back-up profiles may be needed for ~ 1% to 6% of provisioned rate-adaptive lines depending on the DSL Network Operator’s choice of default rate-adaptive profile and copper access network quality.

While SRA is beneficial in coping with slowly fluctuating line conditions such as time-varying crosstalk and radio frequency interference it will not prevent retrains under certain conditions such as large rapid changes in noise.

Dynamic Line Management (DLM)/Dynamic Spectrum Management (DSM) Level 1 goes a step further and can adjust other DSL profile parameters such as margin, interleaving delay, minimum INP and max/min speed range.

[4] Especially when the Minimum Margin setting is also carefully chosen in conjunction with the Target Margin setting
[5] Such as using a post-provisioning and post line-speed change stability monitoring period
[6] May even be “manually” applied to the line by the NOC or Tech Support engineer

4.4 Dynamic Line Management/Dynamic Spectrum Management : Level 1

The ATIS Dynamic Spectrum Management (DSM) Technical Report [9] contains a list of the DSM Level 1 Data and Control parameters that may be supported by a DSM-capable transceiver. DSM Level one is also referred to as Dynamic Line Management and will be referred to as DSM L1/DLM henceforth. The DSM Technical Report does not contain specific DSM L1/DLM algorithms as these are proprietary and left to the designer of the Spectrum Management Center (SMC).

4.4.1 Examples of DSM L1/DLM algorithms.

Rate-adaptive ADSL2plus adjusts the actual speed of a line in response to a change in noise environment. DSM L1/DLM can go a step further and adjust other DSL profile parameters such as margin, interleaving delay, INP and max/min speed range. The overall objective of DSM L1/DLM is to automatically configure lines dynamically to ensure high quality (low error rates) and stability. These DSM L1/DLM algorithms determine the best configuration profile for a service, depending on the measured line conditions. If line problems are detected, settings can be adjusted automatically, minimizing (or avoiding) service interruptions. This can help to reduce help-desk calls, technical support operating expenditures and customer churn.

For some DSM L1/DLM algorithms, the automatic tuning of the DSL line’s profile is based on the collection of detailed historical performance data. Performance is assessed over time and the line is reconfigured as necessary. Performance can be based on the number of errors on a line detected by the receiver and the number of retrains (that is when a modem loses synchronization with the far-end modem and has to reconnect at a lower speed). An example approach is where the DSL Provider’s lines are regularly classified (e.g. daily) on these performance measures. A line’s categorization can then be tracked over time. The DSM Level 1 system can then vary parameters such as INPMIN and DELAY-MAX, max/min speed range and target margin in an attempt to improve the balance between maximum throughput performance and stability. Adjustment of these parameters can optimize the performance of the IPTV over DSL service in terms of speed, packet errors and line stability.

With DSM Level 1, the profile tuning process takes place automatically and no action is required by the DSL Network Provider or end-user. However, end-users may notice a brief loss of service (of the order of a minute or so) whilst the line re-trains following a profile change. Such interruption to user service can be avoided if the changes are made during times when the line is observed to be idle.

Note that a feature of some DSM Level 1 approaches is to record the operating status of the line (actual margin, code violations, synch loss events etc.) periodically such as every 15 minutes. The profile tuning algorithms can then be based on historical operating performance of the line as well as the current performance. Given that the performance history of the line is stored as part of this DSM Level 1 process (e.g. for the previous week or previous month), it is available to use for other means. Examples could include identifying existing Internet Access customers that could safely be upsold to IPTV or to use the historical information in the assure process to more accurately diagnose the root cause of problems and faults.

To achieve a good DSM Level 1/DLM implementation, some conditions should be satisfied:

1) The performance data collection system should be scalable such that neither the Network Elements nor the EMS introduces bottlenecks.
2) An effective data analysis algorithm utilizing the relevant parameters should be implemented.
3) The Network Elements and/or EMS should not introduce constraints on the number of stored parameters and the number of line profile configuration commands that can be issued simultaneously

4.5 Dynamic Spectrum Management (DSM) : Level 2 and Higher

The DSM Technical Report [9] contains a list of the DSM Level 2 Data and Control parameters that may be supported by a DSM-capable transceiver. The DSM TR does not contain specific requirements for DSM Level 2 algorithms, as these are proprietary and left to the designer of the SMC (Spectrum Management Center). Examples of DSM Level 2 are provided for information in Annex A of the DSM TR.

Rate adaptive DSL adjusts speed and DSM Level 1 (DLM) can adjust speed, margin, INP setting and interleaving delay. Dynamic Spectrum Management Level 2 extends the set of variable parameters to allow adaptive allocation of transmission spectrum to be coordinated across multiple DSL lines as a function of the physical-channel demographics. By contrast, static spectrum management uses transmission spectrum allocation to ensure that mutual cross-talk degradation between DSL lines sharing the copper cable are within acceptable limits

DSM Level 2 increases capacity utilization by adapting the transmit spectra of DSL lines to the actual time-variable crosstalk interference making use of information about network topology. The gains in rate/reach performance are most significant for deployment scenarios where crosstalk is the dominant noise source and where a significant reduction in crosstalk can be achieved. DSM Level 2 in the DSL context optimizes transmit power levels and spectral allocation across multiple copper pairs in the cable. The resulting crosstalk avoidance can produce beneficial tradeoffs amongst tiered services, especially when the transmitters are not collocated, like in mixed CO/RT (Central Office / Remote Terminal) transmission within the same cable. When applying DSM Level 2, care also has to be taken to ensure the stability of the DSL lines.

5 Access Node DSL Profile Configuration

The DSL Access Node (e.g. DSLAM, BLC or MSAN) is responsible for defining the parameters of a DSL connection, ensuring that the DSL Network Provider controls the connection characteristics irrespective of settings on the RG.

The operating configuration is negotiated between the DSL Access Node and the RG based on the parameters provisioned on the DSL Access Node, the capabilities of the RG and the length and quality of the local loop. The collection of DSL parameters is known as the DSL line profile. DSL Profiles contain all the information required for configuring the Layer-1 DSL connection. This does not include information required for defining ATM VCs and mapping them to Ethernet for network transport, rather it determines the values of all parameters beneath the ATM layer.

DSL Profiles allow the specification of maximum and minimum bit rates. This information is exchanged during a handshake process and is used to ensure that the DSL Access Node and RG will never attempt to exceed the maximum bit rate and will not enter SHOWTIME (i.e. synchronized and ready to pass user traffic) without achieving the minimum bit rate. ADSL2plus will train as close to the maximum bit rate as possible as long as the target margin is achieved. The higher the requested target margin, the fewer bits can be supported per DMT tone and thus, the lower the attainable bit rate.

The DSL Access Node and RG continually exchange information allowing determination of SNR margin at any point in time. The DSL Access Node provides a number of configurable parameters that constitute the DSL line profile and determine the behaviour of the user's DSL line associated with an SNR margin setting as illustrated in Figure 2.

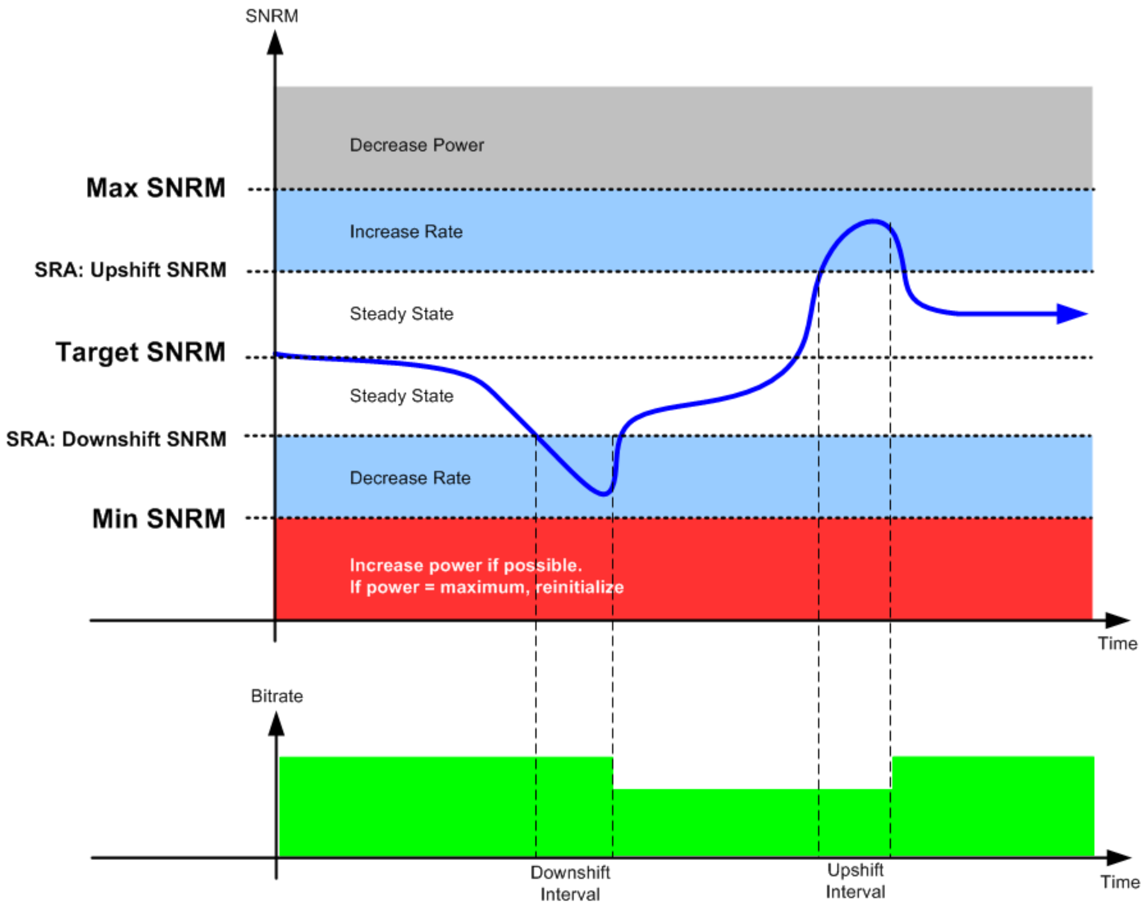

Figure 2 - Signal To Noise Ratio Margin (SNRM) Parameters and Seamless Rate Adaptation Interaction

6 ADSL2plus Configuration Guidelines for IPTV

The convention used in the following sections is to discuss each parameter with the intention of providing a Service Provider with the basic information required to further research and analyze settings appropriate to their specific deployment. Following the discussion, the range used in existing deployments is identified and specific baseline values are provided for a "generic" ADSL2Plus Profile for IPTV. These recommendations are considered reasonable starting points for a Service Provider wishing to deploy IPTV over ADSL2plus. However, since each Service Provider's network environment is unique, the base-line values may be inappropriate for any particular combination of network, equipment and service. Hence Service Providers are encouraged to perform their own testing and analysis to adjust the parameter values beyond the initial base-line values in this Technical Report.

6.1 Target Noise Margin

Target Noise Margin defines the SNR margin that must be available when the handshake process (between the ADSL modems at either end of the line in the Access Node and in the RG) is determining the capability of each DMT subcarrier. This has a direct impact on the attainable bit rate as a higher margin will force fewer bits per DMT tone.

Many standards bodies and DSL Network Providers recommend a target margin of 6dB for both upstream and downstream communication paths in High-Speed Internet Access (HSIA) DSL deployments. However, the subsequent Bit Error Rate and robustness to noise events associated with HSIA deployments on typical copper loop plant tends to be inadequate for IPTV.

Downstream Target Noise Margin for IPTV

Operational experience with IPTV has lead to the conclusion that a 6dB margin often does not provide sufficient separation from the noise floor for a high quality user experience.

Existing Deployments	6 – 10dB
Baseline Value	8dB

Upstream Target Noise Margin for IPTV

The downstream path uses error correction techniques that introduce delay in order to better protect the IPTV in transit. IPTV Control traffic used to communicate channel change, content on demand and other functions related to IPTV QoE are delay sensitive. Furthermore, IPTV is often deployed with other applications such as gaming and voice which may be impacted if too much latency is introduced in both the downstream and upstream path, affecting the total round-trip-time of traffic from the home, to a remote server, and back. DSL Network Providers typically provide upstream data rates that are far lower than the rate/reach capabilities of the upstream path. In addition, the upstream data path is generally less sensitive to errors. This provides an opportunity to optimize the upstream path as follows:

a) Minimize latency
b) Maximize stability
c) Achieve required upstream bit rates

To achieve the aforementioned latency goals a low Impulse Noise Protection (INP – discussed in Section 6.6) setting must be used. In order to maximize stability given the lower INP setting, the upstream target margin should be set higher[7] :

Existing Deployments	6 – 8 dB
Baseline Value	8 dB

[7] Note that although the focus here is on IPTV, it is worth being aware that upstream throughput can be the bottleneck for high downstream TCP throughput if TCP ‘ACK’s are not delivered with integrity.

6.2 Maximum Noise Margin

The Maximum Noise Margin defines the maximum noise margin that should be sustained. If the operating Noise Margin exceeds the Maximum Noise Margin, power should be reduced.

Maximum Upstream and Downstream Noise Margin for IPTV

Power cutback algorithms may reduce power too much in certain scenarios, especially in the context of short loops. Unless careful characterisation can be done on the noise-models, loop distances and power cutback implementation of a particular solution, it may be advisable to disable power cutback altogether. However, doing so will introduce additional power and crosstalk.

Existing Deployments	12 - 31 dB
Baseline Value	16

6.3 Minimum Noise Margin

The Minimum Noise Margin defines the minimum acceptable level of operation. A line that trains to a healthy operating margin may experience an increase in its noise floor from the activation of adjacent lines or introduction of external noise sources. When operating margin dips below Minimum Noise Margin for a certain period of time, power is increased. If power is operating at the maximum possible for ADSL2plus and the operating margin dips below Minimum Noise Margin for a certain period of time, the line will retrain.

Line retrain events initiated by the operating margin sinking below its minimum level have 3 negative effects:

a. The DSL line will likely retrain to a lower bit rate as the noise floor must be higher than it was originally.
b. Service will be interrupted through the retrain, which may be as long as 60 seconds.
c. The handshake process can be destructive to neighbouring lines, inducing errors.

Given the effects caused by a retrain it is important to select a Minimum Noise Margin that is low enough to not cause a retrain unnecessarily. Conversely, allowing a line to stay synchronized in SHOWTIME while it is incapable of providing quality service is unacceptable, especially for IPTV. The use of Seamless Rate Adaptation is another option for managing degrading or dynamic noise floors without impacting IPTV.

Downstream Minimum Noise Margin for IPTV

Existing Deployments	0-3 dB
Baseline Value	0 dB

Upstream Minimum Noise Margin for IPTV

Existing Deployments	0 – 3 dB
Baseline Value	0 dB

6.4 SRA Upshift & Downshift Noise Margins

The Upshift and Downshift Noise Margins are introduced with the Seamless Rate Adaptation feature of ADSL2plus. Upshift Noise Margin defines an SNR margin above the Target Margin which, when exceeded, initiates a bit rate "upshift" (see Figure 2). If the bit rate is already operating at the provisioned maximum bit rate, this parameter has no effect. Note that a line whose speed continually "wanders" will cause problems in some implementations of a TR-101 [10] architecture. Some DSL Providers rely on the DSL Access Node passing the line's sync rate to the BNG (via the PPPoE Intermediate Agent or L2CP) to determine traffic shaping or adjustment of hierarchical QoS schedulers. Hence the ability of a DSL line's speed to wander too dynamically should be dampened via appropriate setting of DSL profile values.

It is not necessary to use SRA with ADSL2plus when only real-time IPTV applications are to be delivered. However, some service providers may consider using it when a bundled service offering is to be delivered. For example, if it is intended to deploy ADSL2plus at a speed in excess of the minimum required for IPTV in order to accommodate best effort Internet access then SRA may be of some interest. However, before employing SRA a service provider should assess the impact of SRA's dynamic behaviour on their traffic shaping and QoS approach in the aggregation and IP edge networks.

The settings proposed as baseline values in this Technical Report are conservative, avoiding the dynamic wander that may affect some implementations of a TR-101 architecture: the Upshift Noise Margin is set at half way from the target to the maximum margin value, and the Downshift Noise Margin - at half way from the target to the minimum margin.

Downshift Noise Margin

Existing Deployments	Generally not used
Baseline Value	(target-min)/2

Upshift Noise Margin

Existing Deployments	Generally not used
Baseline Value	(maximum-target)/2

6.5 Delay

ADSL supports two latency paths. The "fast" path is designed for delay sensitive applications like voice. The "interleaved" path is designed for loss sensitive applications like IPTV. The "interleaved" path interleaves DSL frames to optimize error protection in the presence of impulse noise sources that are common to DSL.

It is recommended that DSL Network Providers use the interleaved latency path, especially for the downstream direction when supporting IPTV. Delay is tuneable when using the interleaved path. The goal is to balance maximum downstream impulse noise protection against total round-trip delay via minimizing upstream delay. The settings for maximum delay are thus high for the downstream and relatively low for the upstream, attempting to minimize total round-trip-time while maximizing impulse noise protection.

A key consideration in the use of interleaving is the expected duration of impulse noise. The characteristics of impulse noise both in strength and duration will be different for each operator and thus warrants a careful study of the noise environment prior to deployment.

Maximum interleaver delay has historically been set based on the notion that impulses are infrequent relative to the DMT interval i.e. the inter-arrival period if an impulse is much larger than the DMT symbol time. Under this assumption, the larger the interleaver spread the better. In the case of Repetitive Electrical Impulse Noise (REIN) the inter-arrival period occurs at the second harmonic of the AC power frequency. At 60Hz this relates to a 16.6ms period and thus 8.3ms inter-arrival time. At 50Hz the period is 20ms and thus a 10ms inter-arrival time. This relates to roughly every 32 DMT symbols (8.3ms/250μs) at 60Hz and 40 DMT symbols (10ms/250μs) at 50Hz. Maximizing the interleaver delay beyond the inter-arrival period of the REIN is not advised because the decoder would prefer that the interleaver buffer be completely flushed before the next impulse event occurs. This means that for regions with 60 Hz AC power the maximum interleaver delay setting should be 8ms and those regions using 50 Hz AC power a maximum delay of 9ms should be used. Power and frequency utilization by region are illustrated in Figure 3:

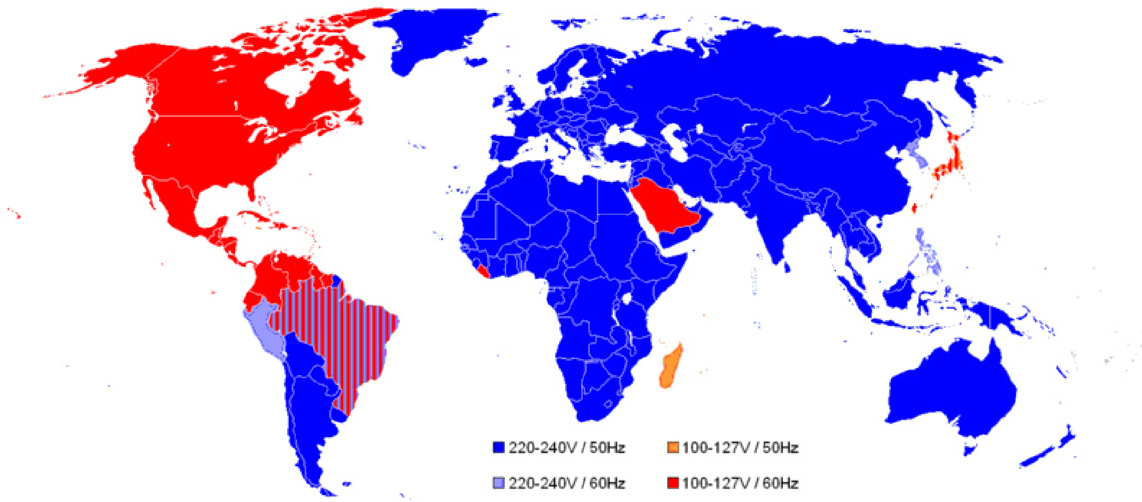

Figure 3 – Power and Frequency by Region

Initial Recommendation: IPTV Delay Configuration
Maximum Downstream Delay

Existing Deployments	10-16ms
Baseline Value	8 ms[8]

Maximum Upstream Delay

Existing Deployments	1-8ms
Baseline Value	2 ms

6.6 Impulse Noise Protection

Impulse noise is defined as electrical interference that occurs in short bursts. It may be caused by any number of sources, from large motors to arc welders, improper AC power and grounding to consumer electronic devices not performing to normal EMC design requirements. These types of disturbers cause an electrical impulse that is brief but powerful and may temporarily interfere with transmission on the DSL circuit.

ADSL2plus Profiles offer a parameter for defining the minimum amount of Impulse Noise Protection. At the transmission layer, DMT symbols are of fixed duration of 250 microseconds. The INPMin parameter defines the minimum number of DMT symbols that will be protected from impulse noise and thus the minimum duration of impulse noise from which error correction should be able to recover. To provide maximum error protection, INPMin should be set as high as possible without unduly compromising bit-rates and latency.

[8] Service Providers have noted that 8ms delay may not adequately protect against REIN in 60Hz regions due to sub-optimal conditions including but not limited to imperfect waveforms and variance in the repetition of REIN. Under these circumstances, 7ms may be more appropriate.

There is a direct relation between INPMin and symbol rate such that higher values of INPMin will restrict the DSL circuit to a lower maximum bit rate. This relationship is dependent in part on the interleaving capabilities of the DSL chipsets at both ends of the DSL line (S, D, framing parameters and interleaving memory defined in [3]). There is also a relationship between INPMin and the delay incurred as higher INPMin values require more buffering and thus incur longer delay. INP defines the maximum number of successive corrupted DMT symbols that can be corrected within the duration corresponding to the delay. As a result, an INP of 2 can correct up to two successive DMT symbols during one delay period. As an impulse of 250µs duration can occur randomly compared to DMT symbols, it will generally corrupt two DMT symbols. So an INP of 2 will fully protect against 250µs max impulsive noise. An INP of 1 or lower will give some protection but without a guarantee concerning the duration of pulses.

There is an interaction between fixed FEC parameters (interleaving depth and delay) and INP setting. Low delay and high INP can actually help stabilize a DSL connection (the low delay being counter intuitive). However, such a setting forces the FEC parity ratio (R/N) to values like 1/3 or 1/2, so lots of errors in every codeword are corrected (so if the line is not extremely long it is possible to use the extra bits it nominally could carry without impulse to actually counteract the impulse). Alternative ranges of such INP/delay can be useful but should be tested since there can be a wide variation of support between vendors.

Changing the value of INP and/or Delay influences the error correction capability of the Reed-Solomon code. The ability to improve the line protection against impulsive noise has to be traded-off against increased FEC parity ratio and hence lower achievable net data rate. More specifically the INP (expressed in symbols) and Delay (in ms) are related to the FEC parity ratio by the following equation:

FEC parity ratio = ½ * (INP/Delay)

The FEC parity ratio is a component of the total overhead that will exist on the line. The tables below, from ITU-T G.992.5 Annex K, illustrate how the net data rate is affected as the INPMin and Max-delay are varied. The bitrates in these tables represent theoretical maximums which are not necessarily achievable with real DSL equipment but rather provide guidance to theoretical ceilings in bitrates for the corresponding parameters. Service Providers are encouraged to undertake testing on the actual ADSL2plus equipment that they plan to use in order to determine more realistic achievable net data rates.

Table K.3a/G.992.5 – INP_min and delay_max-related downstream net datarates limits (in kbit/s)

		INP_min						
		0	**½**	**1**	**2**	**4**	**8**	**16**
delay_max [ms]	**1 (Note)**	24432	0	0	0	0	0	0
	2	24432	7104	3008	960	0	0	0
	4	24432	15232	7104	3008	960	0	0
	8	24432	22896	15232	7104	3008	960	0
	16	24432	22896	15232	7552	3520	1472	448
	32	24432	22896	15232	7552	3712	1728	704
	63	24432	22896	15232	7552	3712	1728	704
NOTE – In ITU-T Rec. G.997.1, a 1 ms delay is reserved to mean that $S_p \leq 1$ and $D_p = 1$.								

Table 1 Maximum Downstream Attainable Rate, no Extended Framing Parameters [4]

Table K.3c/G.992.5 – INP_min and delay_max related downstream net data rates limits using the optional D_0 values for downstream latency path #0 (in kbit/s)

		INP_min						
		0	**½**	**1**	**2**	**4**	**8**	**16**
delay_max [ms]	**1 (Note)**	29556	0	0	0	0	0	0
	2	29556	25718	20928	7616	0	0	0
	4	29556	27613	25718	21093	7616	0	0
	8	29556	27809	26042	22244	14455	8112	0
	16	29556	27809	26042	22244	14455	8112	4024
	32	29556	27809	26042	22244	14455	8112	4024
	63	29556	27809	26042	22244	14455	8112	4024
NOTE – In ITU-T Rec. G.997.1, a 1 ms delay is reserved to mean that $S_p \leq 1$ and $D_p = 1$.								

Table 2 Maximum Downstream Attainable Bitrate with 16K Interleaver and Extended Framing Parameters [5]

Table K.3d/G.992.5 – INP_min and delay_max related downstream net data rates limits using the optional D_0 values and optional $(N_{FEC0} - 1) \times (D_0 - 1)$ values for downstream latency path #0 (in kbit/s)

delay_max (ms)	INP_min 0	INP_min ½	INP_min 1	INP_min 2	INP_min 4	INP_min 8	INP_min 16
1 (Note)	29556	0	0	0	0	0	0
2	29556	25718	20928	7616	0	0	0
4	29556	27612	25718	21092	7616	0	0
8	29556	28394	27217	24703	19092	8112	0
16	29556	28394	27217	24703	19092	10844	4024
32	29556	28394	27217	24703	19092	10844	5393
63	29556	28394	27217	24703	19092	10844	5393

NOTE – In ITU-T Rec. G.997.1, a 1 ms delay is reserved to mean that $S_p \leq 1$ and $D_p = 1$.

Table 3 Maximum Downstream Attainable Bitrate with 24K Interleaver and Extended Framing Parameters [6]

Initial Recommendation: Downstream Impulse Noise Protection for IPTV

The downstream direction carries the IPTV picture and so is more important to protect against impulse noise than the upstream direction. Higher INP settings will provide better error protection if supported but may adversely impact achievable bit rates and/or latency. If a service provider has a loop plant that is considered susceptible to longer duration impulse noise events then they may wish to consider increasing the value of the downstream INP parameter recommended below (e.g. from 2 to 4). However, they should be aware of the impact on maximum achievable line rate which is equipment dependent as per Table 1-3 above. This may for example limit the ability of their marketing department to honestly advertise “up to 24 Mbit/s” service, even though the actual user experience with respect to IP throughput, line stability and IPTV QoE could be improved.

Downstream Impulse Noise Protection

Existing Deployments	1-2
Baseline Value	2 (increase to 4 if equipment permits without overly degrading throughput)

Upstream Impulse Noise Protection

Existing Deployments	0-1
Baseline Value	0.5

7 IPTV over ADSL2Plus: Summary

Bitrate Attributes	**Downstream**		**Upstream**
Maximum	Total bitrate required for all services offered, including overhead.		Total bitrate required for all services offered, including overhead.
Minimum	Minimum bitrate required for IPTV and supporting applications.		Minimum upstream bitrate required for IPTV control signaling.
Margin Attributes	**Downstream**		**Upstream**
Target	**8 dB**		**8 dB**
Maximum	**16 dB**		**16 dB**
Minimum	**0 dB**		**0 dB**
SRA downshift	**<target-min>/2**		**<target-min>/2**
SRA Upshift	**<max-target>/2**		**<max-target>/2**
Error Protection Attributes	**Downstream**		**Upstream**
INP	**2** **(increase to 4 if equipment permits without overly degrading throughput)**		**0.5**
Max-delay	**8 ms**		**2 ms**

Table 4 IPTV ADSL2plus Profile Initial Recommendations

The above parameter ranges are based on the experience of a number of service providers and vendors who have been active in the deployment of IPTV over ADSL2plus in the 2006 – 2008 timeframe. This should be used as a guide only. The baseline values may provide a suitable starting point before a Service Provider has adjusted them for their own unique service and network environment. Hence Service Providers are encouraged to thoroughly research their environment in order to establish the appropriate profiles for their own specific IPTV deployment. In addition, it is recommended that a service provider thoroughly test the performance of any particular combination of parameters used in their default "IPTV" profile in order to identify any equipment limitations.