ASSIA®

Adaptive Spectrum and Signal Alignment, Incorporated

THE RE-PROFILER

DSM CLOSES THE CASE ON DIAGNOSING DSL / VDSL TROUBLES

PETER J. SILVERMAN - ASSIA INC.

FIRST PUBLISHED IN OSP MAGAZINE, SEPTEMBER 2007 WWW.OSPMAG.COM

THE RE-PROFILER

DSM Closes the Case On Diagnosing DSL/VDSL Troubles

Peter Silverman, ASSIA Inc.

Outside plant conditions fundamentally affect DSL service quality and customer satisfaction. Physical loop impairments such as bad splices and bridged taps limit the rate and reliability of DSL services, as do crosstalk among services in a cable and ingress noise from sources such as AM radio and electric motors. As a result, there is increasing industry interest in management tools that automatically identify loop impairments. The most advanced tools in this class go a step further: they automatically reprogram (reprofile) the DSL modems on the affected links to circumvent physical plant problems. While some problems can only be resolved via a truck roll, this new class of tools reduces their number and makes truck rolls more effective through enhanced diagnostic data.

The recently released *ATIS Dynamic Spectrum Management (DSM) Technical Report* describes how the DSL signal, as transmitted and received by the DSL modems, can be used to diagnose and repair service degradation caused by loop impairments and noise. DSM provides a number of techniques that allow a DSL network operator to have a clear view of what is actually ongoing with a DSL signal on a particular loop, and to use this information for automatic increase of service reliability and rate/reach.

DSM techniques are supported by the ability of standard ADSL and VDSL devices to report numerous parameters to the carrier's operations support systems, including: the modem's current configuration and automatic response to line conditions; the noise actually found on the DSL Line; transmission errors, and other impediments. Standard DSL modem implementations also have controls that allow the operator to reconfigure the modems to ameliorate problems. DSM is the use of software in operations systems to analyze the reported data, to determine and to automatically implement remedies or proactively dispatch a technician based on the data.

Dynamic Spectrum Management improves DSL performance by doing following things:

- Optimizing rate/reach and minimizing delay for a particular customer by choosing the best allowed DSL-parameter settings for a DSL Line: **DSM Level 1:** Selecting the best allowed settings for individual subscribers on a line-by-line basis, based on the observed noise and crosstalk for each line; **DSM Level 2:** Reducing the effects of crosstalk among all the DSL lines in a cable by selecting DSL configurations that reduce coupling of energy between pairs in a cable. This decreases crosstalk between customers to a minimum and results in the improved services for all customers served by a cable.

- Detecting Loop Problems that degrade DSL services such as bridged taps and bad splices. The use of DSM techniques enables the non-invasive detection of these loop problems while a

This paper was first published in OSP Magazine, September 2007 - www.ospmag.com

modem is in operation. The specific location of the problem can be estimated automatically, thus shortening job time to remove the impediment from the loop.

- Accurately estimating the maximum rate that a DSL line can achieve. This can aid in enhanced marketing services to a carrier's customers.

In the DSM technical report, the Spectrum Management Center (SMC) is the operations system that performs the DSM functions. The SMC collects the DSL state information, runs the DSM algorithms that calculate the best allowed settings or diagnoses the problems, and automatically reconfigures the DSL service or notifies other systems in the carrier's operations flows of any detected problems. An SMC could be a standalone OSS, or be integrated into other operations systems. Figure 1 provides a schematic view of the SMC within a carrier's operations architecture.

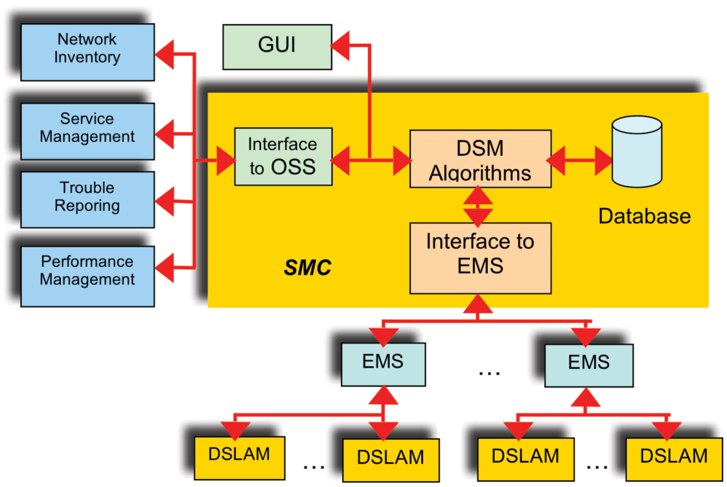

Figure 1. The Architecture of an SMC within a carrier's operations architecture.

Getting the Culprit's Signature

Loop degradations and noise are the primary causes of DSL service problems. Each cause of these problems has a particular signature in the characteristics of the DSL signal. The art of DSM is developing the algorithms that can analyze the information reported by a DSL modem to determine the precise cause of suboptimum service performance. These same systems can then propose the solution for an automatic reconfiguration of the lines parameters or for a technician dispatch to remove a bridged tap or other impairment from the loop.

In the following three examples, the effects of bridged taps, bad splices, and crosstalk noise on a DSL signal are discussed.

<u>Example 1: Bridged Taps with Bad Attitudes</u>

Bridged taps have the effects of a) attenuating certain frequencies in the DSL signal and b) creating reflections of the DSL signal. These effects are a function of the length of the loop, the number of bridged taps, the length of the bridged taps, and their locations along the loop. The effects of bridged taps on a line's insertion loss are notches of increased attenuation at the frequencies affected by the bridged tap that reduce the maximum rate of a DSL service. Additionally, bridged

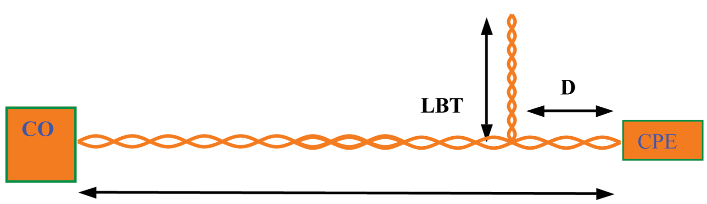

Figure 2. Schematic view of a DSL loop with a bridged tap.

taps can increase the echo noise experienced by a DSL receiver. At its worst, a bridged tap can prevent a DSL service from synchronizing; and at best, it reduces the achievable data rate.

In the inside wiring at the customer's premises, bridged taps are extremely common, often resulting in multiple bridged taps on the loop, and are of course not tracked by any (non DSM) operations system.

The attenuation of a DSL signal on a DSL loop is referred to as *insertion loss.* Figure 3 shows the effect of bridged-tap length and its location on the loop insertion loss.

On any loop, insertion loss increases with loop length and frequency. A bridged tap will increase the loss in specific frequencies, creating notches in the DSL Signal. In these examples, a loop of length 'L' = 3,000 feet is assumed to have a bridged tap of length 'LBT' located at distance 'D' from the CPE side modem.

In Figure 3, the distance of the bridged tap from the DSL modem at the customers premises (D) is fixed at 100 feet, and the length of the bridged tap (LBT) varies from 50 feet to 200 feet. The loop length (L) is 3,000 feet. The effect of bridged tap length on the insertion loss is shown in this figure.

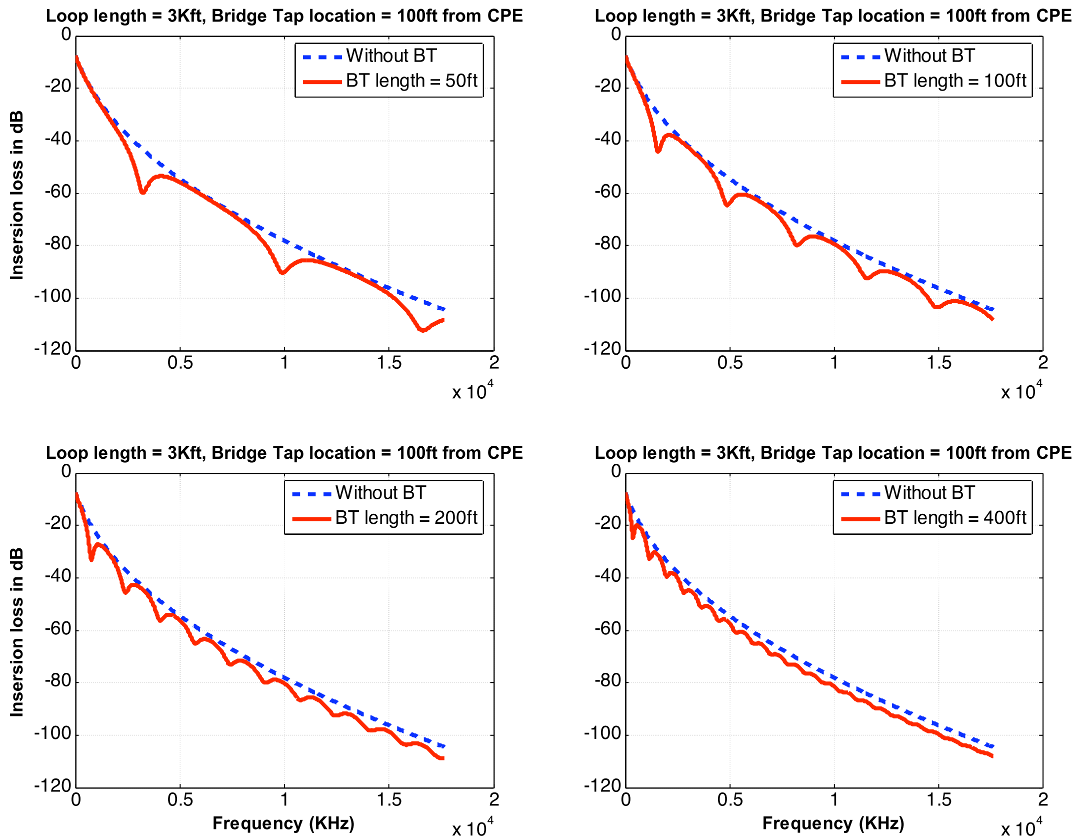

Figure 3. Effect of bridged tap length on the loop insertion loss.

The specific effects caused by the bridged tap vary with its length. The notches of increased attenuation at certain frequencies can be as much as 10 or even 20 dB: a significant frequency-dependent loss that will affect the customer's DSL service.

The location of the bridged taps can have a significant effect on the DSL service. Bridged taps located close to the DSL modem may cause strong reflections, which act destructively at the receiver. In this case, the level of DSL signal degradation can be strongly dependent on the DSL equipment implementation.

As shown in Figure 3, each bridged-tap configuration has its particular signature of attenuation. Multiple bridged taps on a loop produce even more complex patterns of attenuation.

A DSL modem reports a number of parameters that can be used by a DSM SMC to detect these signatures. The algorithms in a DSM SMC can detect and use these signatures to estimate the effect of any bridged taps on the DSL performance, as well as their number, locations, and lengths. The SMC's algorithms can estimate the performance improvement resulting from the removal of bridged taps, and estimate their locations to facilitate a rapid and inexpensive removal by a technician.

Example 2: A Splice Gone Bad

Similarly to a bridged tap, a bad splice on the loop attenuates the DSL signal and degrades performance. A bad splice acts very much like a capacitor in series with the loop and will attenuate the DSL frequencies. Figure 4 shows the effect of a bad splice on the loop insertion loss. Again a 3,000 ft long loop is considered. The bad splice is effectively modeled by a capacitance (C_{bs}) placed in series with the loop.

Figure 4 shows the insertion loss plots for two choices of capacitance: C_{bs}= 100pF and C_{bs} = 1.5nF. As can be seen, the bad splice has considerable effect at lower frequencies. The low frequencies affected are precisely those where the ADSL signal is transmitted and where much of the payload of a VDSL signal is transmitted.

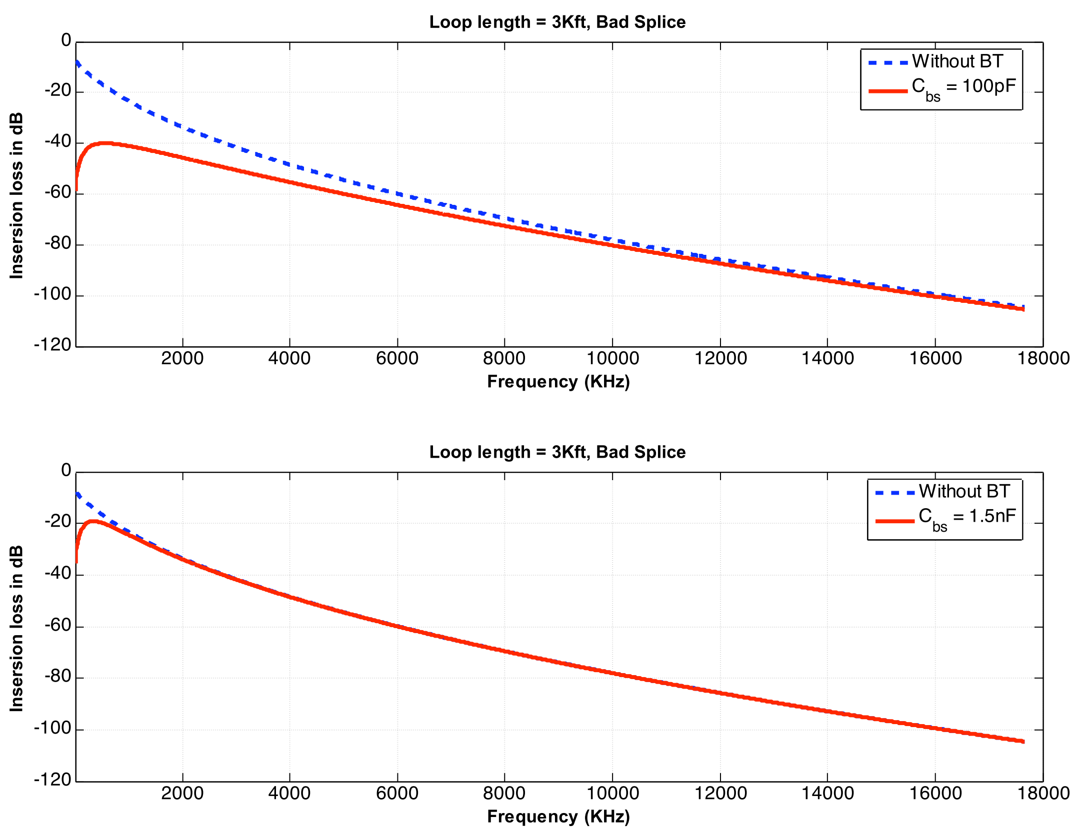

Figure 4. Effect of bad splice on the loop insertion loss

As with bridged taps, an SMC's algorithms can detect the signature of a bad splice and provide guidance for its repair. **- Crosstalk Noise**. Interference into a DSL service from other signals carried in the same cable or binder. These signals can be other DSL services, or services such as T1 circuits.

- Impulse Noise. Time-varying, and often intermittent, noise signals that interfere with DSL signals. Impulse noise can have periodic characteristics, or can occur in random bursts. The causes are often electrical equipment such as motors at the customer premises that radiate noise in the DSL band that is sensed by the loops acting as antennae.

- AM Radio. Ingress noise is caused by the DSL loop acting as an antenna and sensing interference from nearby AM broadcast stations. Since the AM band is within the DSL bands, AM broadcast signals will interfere with DSL signals.

- Background Noise. Stationary noise from various sources that appears on all loops.

Standard ADSL and VDSL technology provides tools to both identify the source of interference and to remedy it. The tools for dealing with noise include the configuration of error correcting techniques at the DSL equipment (Forward Error Correction and Interleaving), and adjustment of power and signal margin parameters for the DSL Service. An SMC adds the ability to analyze the reported information regarding the noise and, in combination with information about the outside plant configuration and the customer's service, select the appropriate remedies from the suite of tools available. As with detecting physical loop impairments, the SMC's algorithms can detect the signatures of the specific noise conditions, and automatically recommend and implement the appropriate reconfiguration.

<u>Example 3: Crosstalk and Crossed Signals</u>

The following example illustrates DSM being used with one common cause of service-affecting crosstalk. DSL services in the same binder will interfere with each other as the signal from one service couples into other loops in the binder. A situation where this crosstalk could have a very significant effect would be the situation shown in Figure 5

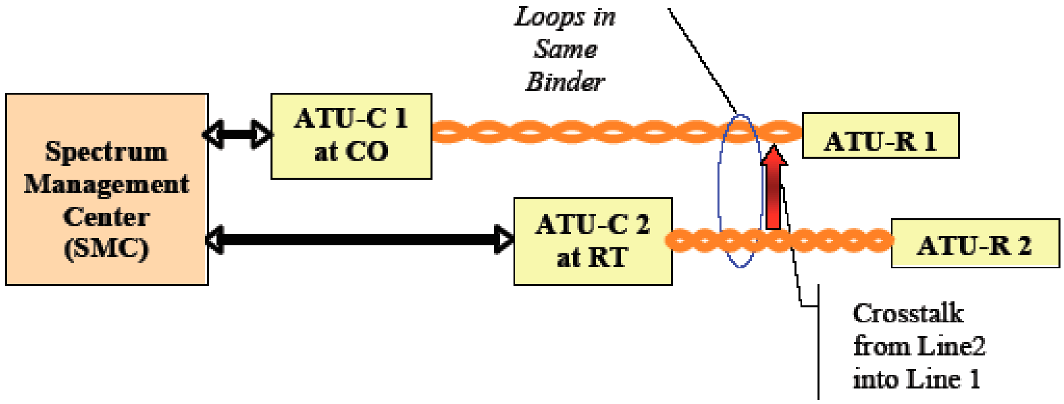

Figure 5. ADSL services from both remote terminal and CO are in same binder.

In this situation a service is provided from a DSLAM in the CO to a customer, while a remote DSLAM provides service to another customer. The same outside plant cable serves both customers. In this situation the signal transmitted from ATU-C 1 at the CO and received by ATU-R 1 is strongly degraded by the crosstalk signal coming from ATU-C 2 from the Remote Terminal.

Without DSM, excessive crosstalk may occur on loop 1 (for the service from the CO) at the far end (near the customers premises) caused by the relatively un-attenuated signal from line 2 served from the RT. Without the use of an SMC, both the services on line 1 and line 2 will transmit at full power, and significant interference from line 2 into line 1 is likely.

If an SMC is utilized, coordination of the power transmitted into each line can occur. In the case of an SMC providing algorithms that support DSM Level 1, the overall transmitted power for line 2, served from the remote, can be reduced to a level that still preserves the service for line 2 while reducing the crosstalk into line 1. If the SMC supports DSM Level 2 functionality, the power at particular frequencies for both line 1 and line 2 are mutually managed to reduce interference between the two lines.

In this example, line 2 served from the remote DSLAM can be instructed to put less power into the lower frequencies tones of its Discrete Multitone (DMT) signal. This protects the low frequencies of the CO-served loop from interference. The longer CO-served loop puts more of its signal at the lower frequencies, which are less attenuated on long loops than higher frequencies.

Since the loop served by the remote DSLAM is shorter, it experiences less attenuation at the higher frequencies and thus can use the DMT tones at higher frequencies to carry its signal. The result is significantly less crosstalk and significantly higher line rates and improved stability for both lines.

Both DSM Level 1 and DSM Level 2 make use of the standard control and reporting capabilities available today from ADSL, ADSL2/2+, and VDSL2 modems.

Calling In the Big Guns: DSM and SMC

Although DSM is an emerging operations technology for DSL, already there are vendors building Spectrum Management Center (SMC) software into management systems. Among the vendors is ASSIA Inc. whose *DSL Expresse*™ SMC is currently providing both DSM Level 1 and DSM Level 2 services to several million lines.

Existing SMCs already automatically optimize the performance of DSL services, and provide diagnoses of service problems either proactively, or upon request of a customer care center, or field technician. The automation of DSL service optimization provided by DSM reduces trouble calls and churn. And by reducing the effect of noise and crosstalk, this optimization can also increase the service footprint for any tier of DSL service, thus resulting in increased revenue and higher levels of customer satisfaction. An SMC accomplishes this using standard information available from DSL modems.

In the noisy world of the DSL outside plant, Dynamic Spectrum Management provides the operations tool that clears the din and lets the DSL signal through.

About the Author: Peter Silverman is Director Technical Marketing and Standards Strategies at ASSIA Inc. He is serving as editor of the *Dynamic Spectrum Management Technical Report* in the ATIS Standards Committee NIPP-NAI and is a co-author of *Understanding Digital Subscriber Line Technologies* and *DSL Advances*, both published by Prentice Hall. He has more than 20 years experience in network operations architecture planning working for both carriers and vendors. For more information, visit www.assia-inc.com.

Marc Goldburg, George Ginis, and Mehdi Mohseni - all of ASSIA Inc. - are thanked for their assistance in preparing this article.