# DYNAMIC LINE MANAGEMENT FOR VECTORING SCENARIOS

STRATEGIC WHITE PAPER

Operators are embracing vectoring technology as a means to extend and protect their legacy investments in copper access. However, the deployment of vectoring could be slowed by performance issues that arise when vectored and VDSL2 lines are combined in the same binder, or when vectored lines from multiple operators are deployed at the same location.

This white paper proposes solutions to the key challenges associated with deploying vectoring in these mixed scenarios. These solutions include virtual unbundling, which can address performance issues created by multi-operator vectoring deployments while preserving a competitive landscape. They also include Zero-Touch Vectoring and Dynamic Line Management (DLM), two Alcatel-Lucent innovations that enable operators to streamline VDSL2 vectoring deployment and reduce the negative impact of legacy VDSL2 equipment on the gains offered by vectored lines.

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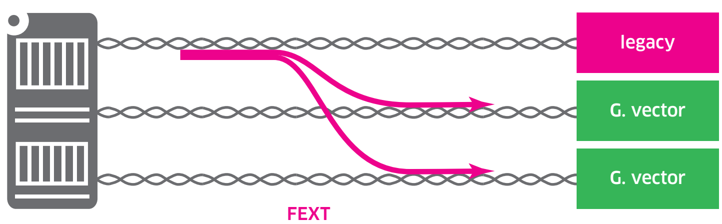
# INTRODUCTION

Vectoring is a noise cancellation technology that reduces interference between bundled copper lines and boosts the speed and reach of VDSL2 broadband connections. Defined by International Telecommunication Union (ITU) standard G.993.5, vectoring extends the bandwidth capacity on copper lines to more than 100 Mbps by removing far-end crosstalk (FEXT) from coordinated lines. In growing numbers, operators are embracing vectoring as an opportunity to extend and protect their legacy copper investments.

However, mass-market deployment of vectoring could be delayed by challenges that arise when vectored lines are mixed with legacy VDSL2 lines in the same binder. One such challenge is the occurrence of FEXT between the two different types of lines, as illustrated in Figure 1.

**Figure 1. The combination of vectored and legacy VDSL2 lines can create FEXT**




This paper describes and offers solutions to operational challenges created by two specific mixed deployment scenarios. In the first scenario, lines sharing the same binder are connected to digital subscriber line access managers (DSLAMs) from different operators using a local-loop unbundling (LLU) process. Shown in Figure 2, this type of shared deployment can increase FEXT and degrade performance for both operators.

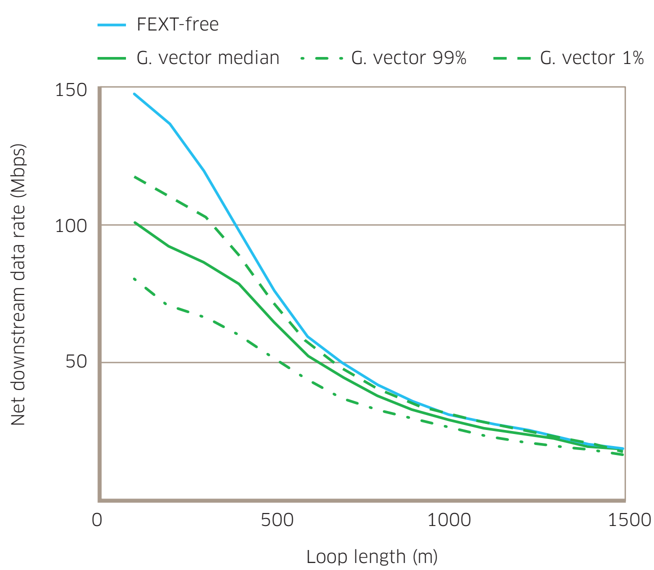
**Figure 2. Operators can deploy vectored and VDSL2 lines in a shared binder using LLU**


In the second scenario, legacy VDSL2 and vectored lines coexist in the same binder. This situation occurs when an operator introduces vectoring in increments. The challenge for the operator is to ensure that the combination of line types does not offset or eliminate the performance gains offered by the vectored lines.

# DEALING WITH MULTIPLE OPERATORS

When two or more operators deploy access node equipment at the same location through an LLU process, their digital subscriber lines will experience mutual crosstalk. Figure 3 shows the performance degradation that can be expected in cases where two different vendors deploy vectored lines independently of one another at the same location.

**Figure 3. Expected performance degradation where two vendors deploy vectoring at a shared location**




A single-operator deployment can provide performance that is nearly free of FEXT, as indicated by the blue curve in Figure 3. The introduction of vectoring by a second service provider leads to significant performance degradation for both operators, as indicated by the solid green line in Figure 3. The spread between the two lines is explained by loop distribution and other simulation factors (see the exact simulation conditions in reference paper [1]). Performance degradation can be expressed in terms of bitrate drop at a given distance (from 125 Mbps to 80 Mbps on average at 250 m) or in terms of range reduction for a given bitrate (from 700 m to 500 m to offer 50 Mbps).

It is theoretically possible to correlate DSLAMs from different service providers using a standardized interface that supports crosstalk cancellation. However, this approach raises several key practical issues, including the need to address security problems that could arise through the sharing of the management network. In addition, adoption of this approach would require input from an external authority to guarantee fair competition.

## Virtual unbundling as an alternative to LLU

Virtual unbundling techniques like bit-stream unbundling, wholesale access and Virtual Unbundled Local Access (VULA) offer service providers viable alternatives to LLU. Many prefer these techniques because they allow service providers to retain the full benefits of vectoring in shared binders.

With virtual unbundling, one operator owns the access equipment, and multiple service providers offer services over this access equipment. Each technique (de)-multiplexes service provider data at a different location in the network (access, edge or core) and offers service providers a different degree of freedom to manage their lines.

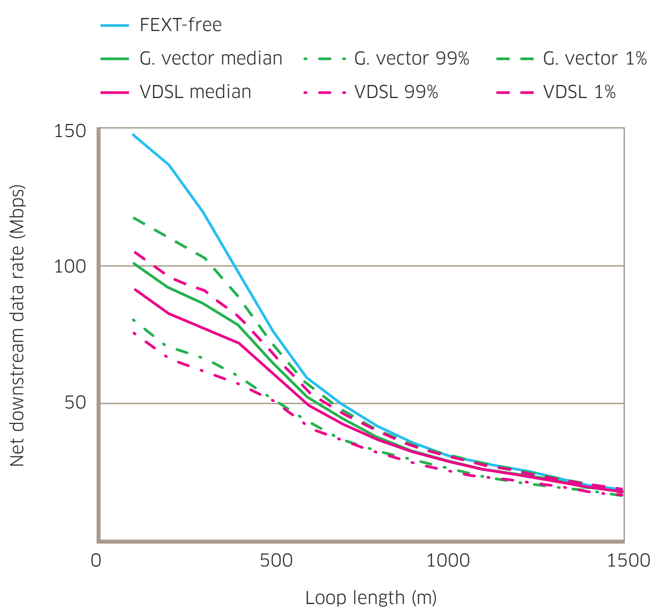
# MIXING VDSL2 AND VECTORED LINES

The presence of just one VDSL2 alien modem can hinder the performance of adjacent vectored subscribers, even in cases where one operator manages the entire physical loop access network.

It is very difficult for an operator to upgrade all of its customers to vectoring in a single step. The operator must either upgrade the VDSL2 CPE firmware to a vectoring-friendly mode or replace CPE that cannot support the vector-friendly mode or be upgraded remotely. Vectored and legacy VDSL2 lines need to coexist, at least during the upgrade phase.

The performance of vectored lines drops significantly when these lines are introduced into a network that includes legacy VDSL2 lines. As illustrated in Figure 4, the resulting performance level is comparable to that provided by the VDSL2 lines. In other words, most of the vectoring gain is lost.

**Figure 4. The performance of vectored lines drops when they are combined with VDSL2 lines**




It is notable that the performance drop that legacy VDSL2 lines create on vectored lines is similar to that created when multiple operators deploy vectored lines in an LLU context. These performance drops make it difficult for operators to simultaneously manage vectored and non-vectored lines.

Alcatel-Lucent offers solutions to the challenges that can arise when VDSL2 and vectored lines are combined in the same network. The Zero-Touch Vectoring innovation addresses the need for simpler VDSL2 vectoring deployment processes. The Dynamic Line Management technique preserves quality of service and reduces the negative impact of legacy VDSL2 on vectored lines.

## Zero-Touch Vectoring

Available only from Alcatel-Lucent, Zero-Touch Vectoring removes the final barrier to mass-market deployment of VDSL2 vectoring technology. This unique innovation uses advanced signal processing to enable operators to deploy VDSL2 vectoring without touching the legacy VDSL2 modems in their customers' homes. Zero-Touch Vectoring eliminates the time-consuming, network-wide CPE upgrades traditionally required for VDSL2 vectoring deployments. It automatically ensures that legacy VDSL2 CPE has no impact on vectoring gains.

Zero-Touch Vectoring is available exclusively on Alcatel-Lucent DSLAMs. It cannot be used to support vectoring deployments that leverage DSLAMs from other vendors.

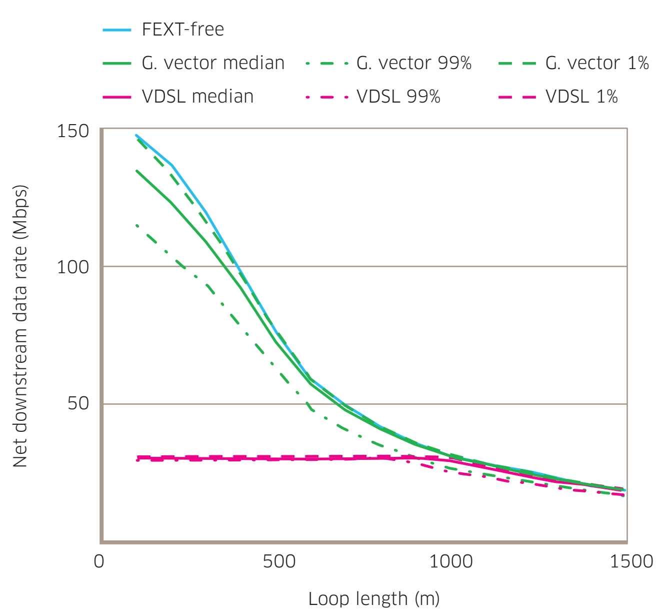
## Dynamic Line Management

In practical VDSL2 deployments, the bitrate is typically capped at a value that is specific to a commercial offer. In other words, the achievable bitrate that a line could offer is often limited to a lower bitrate chosen by the operator. As a consequence, the signal-to-noise ratio (SNR) available on the lines is always higher than the SNR required to support the bitrate offered by the operator. Modems can use this excess SNR in a variety of ways, including:

- **Increasing the SNR margin:** A modem can use the extra SNR as a noise margin that provides additional protection against the varying degrees of crosstalk from legacy lines.
- **Increasing the Reed-Solomon (RS) overhead:** A modem can provide better impulse noise protection by using the extra SNR capacity to transmit more redundancy information.
- **Lowering the transmitted power:** A modem can reduce the transmitted power of the signal so that the bitrate chosen by the operator is still provided, together with the configured noise margin and minimum impulse noise protection.

When a modem uses excess SNR to lower transmitted power, it reduces the crosstalk toward neighboring legacy and vectored lines. Figure 5 shows an example of how reducing the target bitrate on legacy lines can increase the attainable data rate on neighboring vectored lines.

**Figure 5. Reducing the target rate of legacy lines to 30 Mbps significantly increases the attainable data rate of vectored lines**



When the extra SNR capacity is used to reduce the transmitted power, vectored line performance improves significantly, averaging close to FEXT-free performance.

However, reducing the transmitted power on all VDSL2 legacy lines in line with the chosen bitrate can put stability at risk. Some lines may still require a higher noise margin to deal with varying crosstalk problems. Other lines will need high protection against impulse noise. Existing asymmetric digital subscriber line (ADSL) and VDSL2 deployments have revealed a large spread in the amount of noise margin and impulse protection needed to stabilize all the lines in a network.

Dynamic Line Management (DLM) offers an effective response to this problem. Using a real-time and per-line approach, DLM automatically finds the best trade-off between SNR margin, impulse noise protection and transmitted power reduction. It applies the required amounts of SNR margin and impulse protection to each line, and then allocates the remaining SNR budget to power reduction. These allocations optimize the vectoring gain and preserve stability. In addition, DLM automatically ensures that this trade-off remains aligned with agreed service delivery levels for all lines.

In mixed legacy–vectoring deployments, the use of DLM guarantees quality of service (QoS) for all lines while improving the performance of the vectored lines. DLM offers the advantage of being compatible with DSLAMs from Alcatel-Lucent and other vendors.

Some vendors claim that vectoring performance can only be improved using a complex PSD shaping algorithm, such as optimal spectral balancing. Simulations with realistic loop length distribution have proven that operators can achieve very good results with a simple DLM optimization tool that focuses on configuring scalar parameters such as the maximum PSD level or the target SNR margin (SNRM). By contrast, the use of a more complex PSD shaping algorithm leads to marginal gains. For more details, see reference paper [1].

# CONCLUSION

Physical local loop unbundling is not a practical solution for deploying vectoring technology. It cannot easily and effectively address the performance degradation that occurs when multiple operators deploy their own vectored lines at a shared location. Virtual loop unbundling offers a viable opportunity to preserve vectoring gains in multi-operator deployment scenarios. However, it does not address the performance degradation that occurs when legacy VDSL2 and vectoring technologies are combined in the same binder.

Alcatel-Lucent's unique Zero-Touch Vectoring innovation offers a practical approach to deploying VDSL2 vectored and non-vectored CPE to the mass market. Offered exclusively on Alcatel-Lucent DSLAMs, Zero-Touch Vectoring leverages intelligent signal processing at the access level to eliminate the need for operators to upgrade all legacy CPE. This approach is well aligned with the industry's ongoing shift toward a bit-stream or virtual unbundling model for LLU.

Operators seeking to use DSLAMs from multiple vendors can rely on Dynamic Line Management (DLM) to preserve QoS and reduce the negative impact of legacy VDSL2 on vectored lines. Alcatel-Lucent's Motive Network Analyzer — Copper product offers a rich suite of diagnostics that includes the DLM function. With Motive Network Analyzer — Copper, operators can manage legacy and vectored lines in real time by observing crosstalk levels and fine-tuning Tx power levels to ensure optimal performance across the binder.

# REFERENCES

[1] J.Maes, M. Guenach, M. Ben Ghorbel and B. Drooghaag, “Managing Unvectored Lines in a Vectored Group,” in Proc. IEEE Globecom 2013.

# ABBREVIATIONS

| | |
|---|---|
| ADSL | asymmetric digital subscriber line |
| CPE | customer premises equipment |
| DLM | Dynamic Line Management |
| DSLAM | digital subscriber line access manager |
| FEXT | far-end crosstalk |
| ISAM | Intelligent Services Access Manager |
| ITU | International Telecommunication Union |
| LLU | local-loop unbundling |
| QoS | quality of service |
| RS | Reed-Solomon |
| SNR | signal-to-noise ratio |
| VDSL2 | very high-speed digital subscriber line 2 |
| VULA | Virtual Unbundled Local Access |