Delivering With Vectoring

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E = MORE SPEED^2

This equation is not new. Consumers, whether they are individuals or enterprises, always want more bandwidth, but they don't want their monthly subscription cost to increase. What are service providers supposed to do? Deliver services and extra bandwidth at little to no extra cost knowing the revenue stream may not increase. Is that even possible?

For the past several years, fiber-to-the-home (FTTH) has experienced tremendous growth in order to satisfy the need for this extra capacity. However, the fundamental problem for operators wanting to roll out FTTH lies in the final few meters, because this is where the majority of the overall costs are. According to recent data, despite the frantic growth of FTTH, only about 6% of copper-based access lines have been converted. Since some countries have a much higher take rate, this means that the percentage is very low in other places. Therefore, alternative and cheaper solutions for delivering bandwidth are required.

Indeed, some operators claim that as much as 80% of the overall cost of an FTTH deployment is in the section between the home and the manhole. This brings us to the DSL conundrum: how to increase bandwidth on twisted copper pairs, to avoid or push back FTTH deployment, and do so more cost-effectively. There is also a need to counter the competition from cable MSOs, who are deploying DOCSIS 3.0, and mobile broadband operators who are pushing long-term evolution (LTE) services.

A few new DSL technologies, such as Phantom Mode and G.Fast, are currently being discussed in labs and standards bodies around the world, but they are far from ready for commercial rollout. That being said, one technology is slowly becoming commercially available: VDSL2 vectoring!

WHAT IS DSL VECTORING?

Have you ever heard of noise-canceling headphones? In a nutshell, these headphones are able to reduce unwanted ambient sound, which is very similar to what VDSL2 vectoring does; conceptually-speaking that is. The difference is that VDSL2 vectoring deals with bandwidth limitation and data-rate reduction, which are caused primarily by crosstalk and signal loss.

The purpose of vectoring is to monitor and mitigate far end crosstalk (FEXT) in real time in order to apply the required signal processing that will cancel out the FEXT injected by other pairs into the desired one, and this for each end-user. By minimizing crosstalk, the signal-to-noise ratio and the capacity of VDSL2 can be significantly improved.

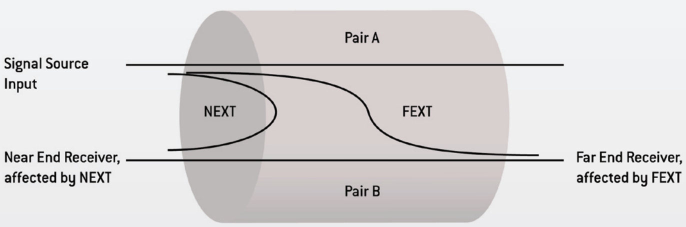

Figure 1. Crosstalk schematic

Vectoring pre-codes the signal at the transmitter end for downstream traffic. It does so by measuring crosstalk from all the other vectored lines and generates an inverse signal to cancel out the noise, as shown in Figure 1. In a similar matter, it post-codes the signal to cancel out crosstalk at the receiver end for the upstream traffic.

Vectoring is a standardized solution, having been adopted by the ITU in 2010, under the labeling G.993.5.

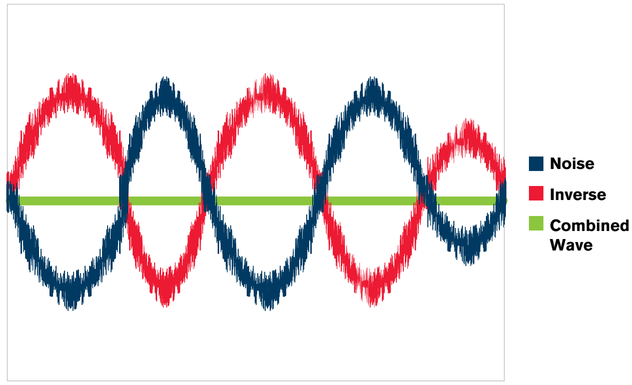

Figure 2. Noise cancellation schematic

BENEFITS AND CHALLENGES

The obvious benefit is the ease of deployment, since only the DSLAM might need to be upgraded, especially for next-generation CPE devices. While telcos will be forced to install new line cards in DSLAMs to accommodate vectoring, the implementation costs of this technology are estimated to be one tenth of the costs of FTTH. Plus, it can be deployed almost everywhere, and unlike other DSL bandwidth improvement approaches, vectoring is commercially available.

The complete reuse of the existing copper infrastructure is not just a huge CAPEX saver, it's a time saver as well, shortening time to revenue. Another non-negligible advantage is the ease of termination at the customer premises.

Vectoring can build on the bonding technologies that have been deployed for several years now. Bonding refers to using more than one VDSL2 line to provide service to a customer, thus enabling a much higher bit rate or service to longer lines (refer to Application Note 260 for more information).

Combining bonding and vectoring could make 100 Mbit/s service cost-effective at a distance of 500 meters, or 40 Mbits/s on loops of up to 1200 meters. Let's look at an example that illustrates the benefit of vectoring on the downstream scenario:

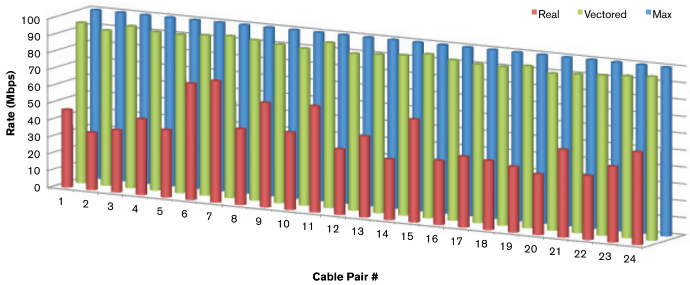

Figure 3. Actual versus vectored bit rates

As seen in Figure 3, another great benefit of this approach is that it makes the performance across the lines uniform. Since crosstalk can vary greatly, the spread between lines (shown in blue above) is much greater at pre-vectoring than at post-vectoring (shown in orange above). Operators can therefore constantly achieve the advertised speed.

One of the main issues with DSL vectoring is that it can only deliver the promised bandwidth if all the lines in a given binder are vectored together, which implies that they are all operated by the same provider. Crosstalk from non-vectored lines, or lines vectored by a different provider, cannot be canceled out using vectoring techniques and the overall performance is greatly reduced. Assuming that all lines are vectored together, the remaining noise (e.g., radio frequency interference (RFI), impulse noise from electrical services in the home, alien crosstalk) will become the primary limitation. In some lines, the performance gained may be nearly imperceptible because the uncancelable noise is nearly as high as or higher than the noise that can be canceled out. Worse yet, vectoring may be unable to improve the stability caused by the expected future variability of alien noise (i.e., the noise not currently present). Service providers want to maintain a minimum service level in the presence of moderate-to-worst-case scenarios. This means that performance will be limited by an assumed statistical level of noise. Alien-noise analysis tools can help prevent this potential loss in performance gain and increase line stability as well as proper copper-plant maintenance to mitigate other alien noise.

TESTING FOR VECTORING

The DSLAM and the vectoring management system at the CO (or remote) side are responsible for vectoring. This vectoring system must be able to collect data from each and every pair, develop and deploy a solution for each and ensure that its impact does not significantly affect the other pairs as vectoring is rolled out.

Before, during and after deploying vectoring, it is essential that operators understand the environment with respect to noise. Although vectoring will mitigate FEXT, other noise sources may appear and there is a chance that the vectoring system will not be able to provide an adequate solution algorithm in a timely manner. Other sources of noise can include, but are not limited to, impulse noise and other crosstalk disturbers (T1, ADSL2+, unvectored VDSL2 or 2 Mbit/s E1).

Cost-effective test solutions are currently available for users who want to test the amount and type of power spectral density noise or the amount of impulse noise that exists in a given circuit. In addition to providing proof of noise, a test solution must also be able to locate physical faults, which are more often than not, the point in the circuit where noise ingress/egress occurs. Time-domain reflectometry (TDR) and/or resistive fault location (RFL) are perfect candidates for hunting down these physical faults. It should come as no surprise that conducting voiceband tests (metallic and impulse noise) may not reveal any issues related to noise affecting vectored solutions. Therefore, conducting wideband (high-frequency VDSL2) testing is the only sure-fire way to advise engineers/technicians that there could be a problem or that there exists a high probability for problems as vectoring is rolled out. There are mitigation methods available to the DSLAM operator to alleviate impulse noise such as G.INP (physical layer retransmission) or just impulse noise protection (INP), and these should be proactively used.

Once vectoring is enabled, a vectoring-compliant test set will be able to connect and disconnect from the vectored system without causing any adverse effects. Please note that sync time may be much longer, up to 10 minutes in some instances. This is by no means a show stopper, but something to be aware of. In addition, the test set will not only be able to indicate the negotiated DSL data rates and signal-to-noise ratio margins, it will also detect whether or not vectoring is being used.

CONCLUSION

When faced with brownfield scenarios, DSL vectoring is a cost-effective alternative to expensive and complicated FTTH deployment. It will substantially increase and ensure the uniformity of DSL services, and barring a few challenges and a little bit of extra testing, the benefits are obvious and certainly worth the investment for most operators and providers around the world. As with any deployment and rollout, a good testing and characterization strategy will make the entire process simpler, increase deployment speed, ensure first-time-right results and decrease the time to revenue.

In short, testing before, during and after vectoring deployment is key to assuring system performance. Ultimately, your subscribers will be happy knowing that they are getting the maximum bandwidth available to them.

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