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White Paper

Performance Comparison of E.SHDSL and MIMO on DMT Bonded Systems on Real Copper Cable

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Executive Summary

This paper presents performance comparison results of the MIMO on DMT based, Aktino AK4000 Ethernet system and a generally available E.SHDSL (G.992.1)[1] bonded copper system. The tests were performed on real copper cable at the request of a customer, in order to get to the bottom of contradicting and confusing performance claims in the marketplace. The Aktino system outperformed the legacy system in all cases by margins of as much as 300%. The tests also illustrate how legacy E.SHDSL systems can mask their performance weakness if the tests are not performed on real cable and interference is not considered.

[1]E.SHDSL as per G991.2, which is used in the EFM 802.3ah bonding standard.

Introduction

Bonded copper DSL systems have received considerable attention lately as a promising technology for delivering next generation business access services. Business customers today demand ubiquitous Ethernet connectivity at rates of at least 10 Mbps of symmetric bandwidth, necessitating multiple copper pairs per link. In response to this customer demand, many carriers have deployed DSL equipment that can bond multiple copper pairs into a high bandwidth Ethernet pipe. Two competing technologies in this market are the older SHDSL technology and the newer MIMO on DMT technology.

Given the high bandwidth requirements of the target Ethernet service, it is not surprising that rate/reach performance of the selected equipment is of paramount importance. Unfortunately, there is a lot of confusion about performance claims of bonded copper systems from different manufacturers and different technologies. These conflicting claims reduce the carriers' confidence that these deployments will reach the majority of their customers at acceptable service rates that support the deployment's business case.

Typically, equipment performance is tested in the lab before deployment commences and the validity of performance claims is sorted out. One has to be cautious with bonded copper systems however if lab testing is not done right, it can provide misleading results. The reason for this is that multiple copper pairs may interfere with each other and affect performance. This interference has to be accounted for during lab testing and if possible and practical, during field testing as well.

Performance Testing of Bonded Copper

In single pair DSL deployments, the pair's rate/reach performance is traditionally tested in the lab using a loop simulator. It is tempting to do the same for bonded copper Ethernet services, that is, measure rate/reach of one pair and then extrapolate this "per pair" performance by multiplying by the number of pairs in the bonded group. However convenient this method is, it provides misleading results. The reason is that the pairs of the bonded group interfere with each other and unless techniques like MIMO noise cancellation technologies are employed, this interference will reduce overall throughput of the bonded group.

Figure 1 shows the proper lab setup for the performance evaluation of bonded copper systems where the CO and CPE equipment is connected to spools of real cable. This methodology may be cumbersome, but it captures realistic crosstalk interference that will be present in actual deployments. Multiple systems can also be tested in the same binder in a variety of tests (not shown in the figure) to examine realistic deployment scenarios.

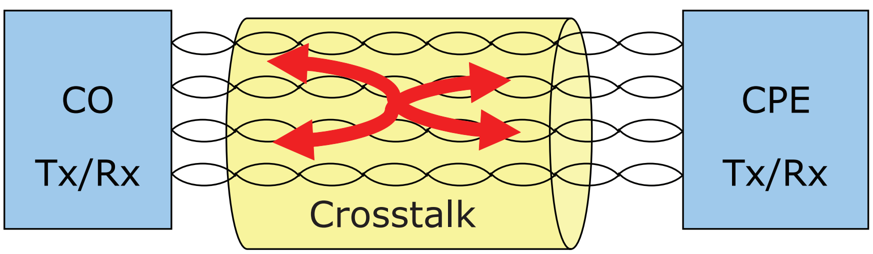

Figure 1: Performance evaluation with proper lab setup (real cable); includes crosstalk interference

Figure 2 shows a more convenient lab setup where the spools of cable have been replaced by a multi-pair loop simulator. Unfortunately, current multi-pair simulators are not appropriate for performance evaluation because they do not model crosstalk interactions among the pairs in a binder. The ATIS NIPP-NAI standardization committee is currently actively studying the appropriate mathematical models for multi-pair crosstalk, which in the future may be incorporated into realistic multi-pair loop simulators. For the time being, the only safe way to obtain accurate results is to use real cable as illustrated in Figure 1.

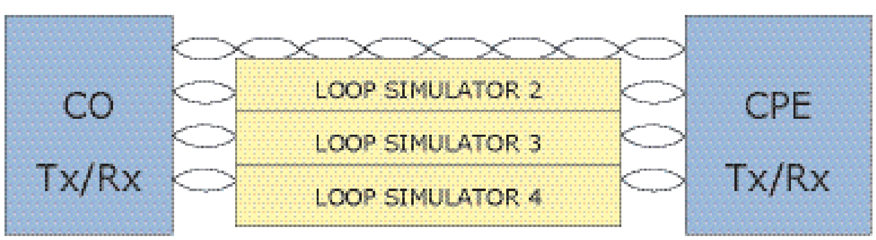

Figure 2: Performance evaluation with misleading lab setup (loop simulators); ignores crosstalk interference

Performance Comparisons

In this section we present direct performance comparison results between the Aktino MIMO on DMT based, AK4000 bonded copper system against a generally available product of an E.SHDSL bonded copper vendor. The performance measurement campaign was carried out at the Aktino cable farm using real cable at the request of a customer. The objective of the campaign has been to clarify the expected reach rate performance in real loops for the different technologies.

	E.SHDSL (G.991.2) Performance (aggregate bandwidth in Mbps)		Aktino (MIMO on DMT) Performance (aggregate bandwidth in Mbps)		Performance Comparison
Loop Length	No disturbers	Self disturbers only (two SHDSL systems in the binder)	No disturbers	Self and alien disturbers	Aktino performance as a % of E.SHDSL performance
	3 Pair BW	3 Pair BW	3 Pair BW	3 Pair BW	Performance Gains
3000	17.11	14.62	16.58	14.8	101%
6000	10.20	6.17	15.15	13	211%
9000	5.21	3.67	11.36	9	245%
12000	2.71	1.94	5.29	4.3	221%
15000	1.56	0.98	2.33	1.8	183%
	5 Pair BW	5 Pair BW	5 Pair BW	5 Pair BW	Performance Gains
3000	25.64	22.44	27.57	25.7	115%
6000	16.36	7.40	25.68	22	297%
9000	8.04	5.80	19.04	15.7	271%
12000	4.52	2.92	8.86	7.5	257%
15000	2.60	1.64	3.61	3.2	195%
	8 Pair BW	8 Pair BW	8 Pair BW	8 Pair BW	Performance Gains
3000	40.00	35.90	44.20	41	114%
6000	18.50	14.91	40.40	35.5	238%
9000	10.82	8.77	30.30	25	285%
12000	6.14	4.67	14.10	12	257%
15000	3.58	2.56	6.20	5	195%

Table 1: Summary of performance comparison results

The Aktino AK4000 system is a next generation symmetric access system that incorporates the latest “MIMO on DMT” signal processing and interference cancellation technologies and easily outperformed the legacy systems by a wide margin.

Table 1 shows a summary of the performance results. Tests were performed for loop lengths from 3,000 ft to 15,000 ft (26 AWG). The margin was set to 5dB and the total aggregate rate of the bonded system was recorded for bonded groups of 3, 5 and 8 pairs. Both systems were tested with and without disturbers.

The first column reports the results of the E.SHDSL system without any other service in the binder. The second column reports the results when two similar SHDSL bonded systems are present in the binder (i.e., 2x3 or 2x5 or 2x8 pair systems depending on the test). Notice the measurable drop in performance when a second bonded system is introduced as disturber.

The third column shows the aggregate rate of the Aktino system with no other disturbers in the binder and the fourth one shows the performance when more disturbers are added to the binder. One could try the same approach of adding an additional Aktino system in the binder as a disturber; however, the DMT transmission scheme does not measurably interfere with itself, so the results in this case are almost indistinguishable from the no disturber column and do not offer any more information. Instead, we added alien interferers in this column to represent a worst case scenario. A total of 10 interfering pairs were added in a typical mixture of services (4 ADSL, 3 HDSL2, 2 HDSL, 1 ISDN).

Although more interferers were added in the Aktino tests (compared to the SHDSL tests), the performance reduction from the no disturber case is only modest. At the same time, in comparison to the E.SHDSL system the performance is generally significantly higher. The last column summarizes the performance gains of the Aktino equipment versus the SHDSL equipment by comparing the results of the two columns where disturbers were present. Notice that the performance improvement in most cases is about 200% to 300%.

Conclusion

The difference in real world performance shared above is not just an interesting technical fact but translates directly into monetary advantages in the carrier's business case for deployment of ubiquitous "Ethernet over Copper" services. The ability to provide a minimum 10 Mbps footprint to 90% of your target customer base as opposed to less than 50% can easily be the difference between a viable service offering versus a failed endeavor. This MIMO on DMT based advantage along with the headroom for future growth allows the carrier to capture, retain and grow with their customers. Positron Access Solutions would be happy to share further details of this comparison with all genuine interested parties. We also welcome all competitors to an independent third-party hosted technology comparison to validate these results.

Positron Access Solutions, a member of the Metro Ethernet Forum, develops and manufactures copper and fiber optic transmission equipment. Its portfolio includes copper bonding, Pseudowire and converged SONET/Ethernet products offering extensive solutions for access, backhaul and aggregation of business, wireless and triple-play services. The Aktino product line delivers Carrier Ethernet solutions of up to 100Mbps on bonded copper for Ethernet Business services and mobile backhaul. The AEX Pseudowire product line delivers converged Ethernet TDM/ATM services for both business applications and mobile backhaul. With offices in Irvine, CA and Montreal, QC, Positron's global footprint extends from the United States and Canada through Europe, Latin America and Asia.
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