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CONTRIBUTION

TITLE: **GDSL (Gigabit DSL)**

SOURCE:

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ABSTRACT

This information-only contribution suggests some configurations in which gigabit per second DSL (GDSL) is feasible on lengths of 150 to 300 meters of 4 twisted pair. Basically the full binder capacity of 4 drop wires is examined with 6 dB of margin and the usual 4 dB of coding gain to find that rates that exceed 1 Gbps are possible in a DSL of 300 meters or less.

Before too much surprise, one should remember that Gigabit Ethernet systems work today at 1 Gbps over 170m of category 5 twisted pair, so essentially range is doubled on an slightly inferior grade twisting by using sophisticated full-binder-vectoring methods to exploit crosstalk.

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GDSL (Gigabit DSL)

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This information-only contribution suggests some configurations in which gigabit per second DSL (GDSL) is feasible on lengths of 150 to 300 meters of 4 twisted pair. Basically the full binder capacity of 4 drop wires is examined with 6 dB of margin and the usual 4 dB of coding gain to find that rates that exceed 1 Gbps are possible in a DSL of 300 meters or less.

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1. Introduction

The last few hundred feet or meters of fiber installation to a customer is often prohibitively expensive. This last segment can encounter the difficult passage of roadways, under foliage, under fences and connection to premises, all the cost of which need be paid for a single customer. Usually this last "drop" segment has at least 4 pair, even though the binder back all the way to the distribution point or especially to wire center may not have that many excess pairs per customer, as shown in Figure 1. If fiber extends in any configuration (PON or otherwise) to the service terminal (or pedestal), this represents probably the last reasonable and closest-to-customer point for fiber termination that is not within the customer's premises. The drop can be up to a few hundred meters away from the network termination, but not much more. It is thus then of interest to assess the data-carrying capability of this last drop, particularly if 4 pair are bonded and vectored in the best way possible. This paper finds that over 1 Gbps is possible at distances to 300 meters on 4 bonded and vectored twisted pairs in the drop[2].

[1] The work of A. Leshem and L. Youming was supported by EU-FP6 U-BROAD project under contract no. 506790.

[2] One would hope the PON groups will deliver at least 10 Gbps to the pedestal then or DSL will over-run the fiber bandwidth (again).

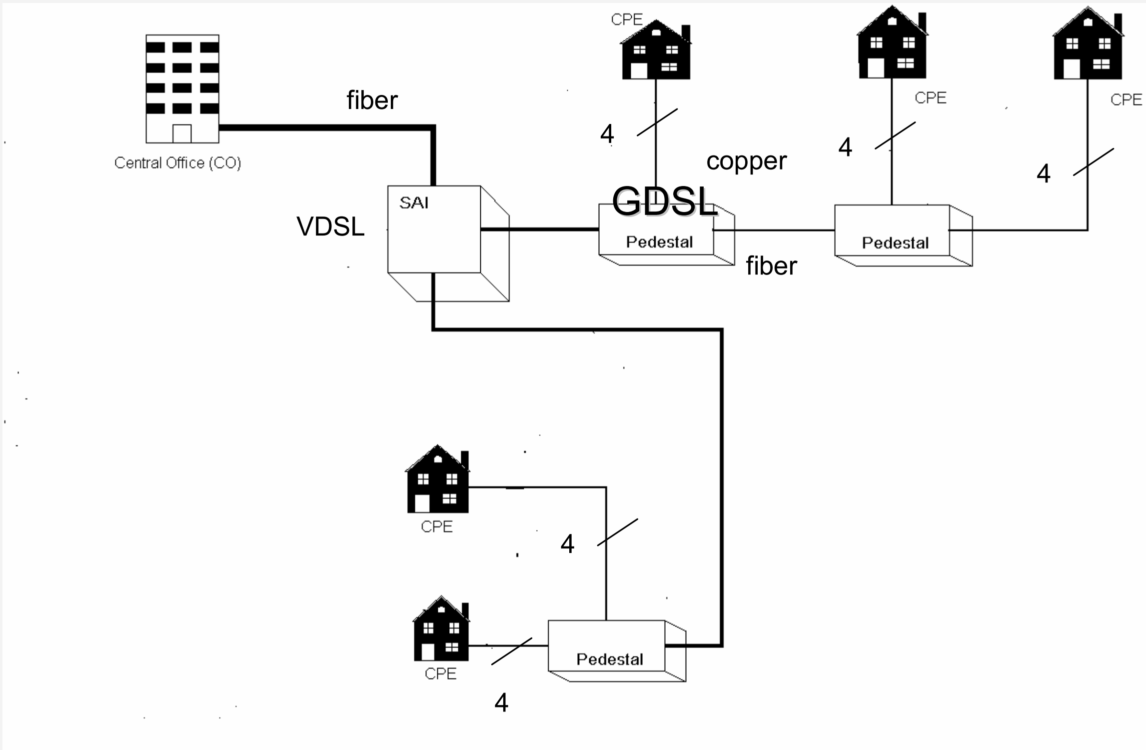

Figure 1 – Basic "Pedestal" or "Service-Terminal" drops (often with 4 pair, only in drop)

Two DMT VDSL-like situations are investigated in Section 2, to which basic single-sided vectoring methods are applied. In the first asymmetric situation, a simulated differential excitation of measured French cables using linear differential FEXT vector-precoding downstream. This first asymmetric system attains a downstream data rate of 250 Mbps/pair at about 200 meters (and thus would achieve 1 Gbps on 4 bonded pairs at 200 meters). A second asymmetric situation where ANSI DSM-modeled split-pair transfers and phantom modes are also excited (creating a vector 7x7 channel) and full nonlinear precoding downstream (and generalized decision feedback upstream) extends the range for 1 Gbps transmission (over the 4 pairs or 7 channels) to beyond 300 meters. (The asymmetric data rate in the second situation would then be 2 Gbps at 300 meters).

2. The Model

The situation for one of the pedestals in Figure 1 can be redrawn as in Figure 2. The pairs in the drop segment are all connected to the same fiber-fed terminal (shown as an ONU). That terminal might be the "NT" end of a PON or other fiber system that could deliver 1 Gbps or faster speeds to the drop point. The FEXT between lines is shown downstream, but there is also similar coupling upstream between the lines. The common termination point of copper creates an opportunity for "vectored" transmission downstream and vectored reception upstream. The fundamentals of vectoring are discussed in [1] and not repeated here. However, it is becoming well-known and accepted that the upstream vector receiver can eliminate all FEXT, and in fact can reduce or eliminate an number of other noises like radio or of other origin if correlated between the upstream lines. Downstream, only the FEXT on the coordinated lines can be eliminated; but with FDM systems, this is the majority of the noise.

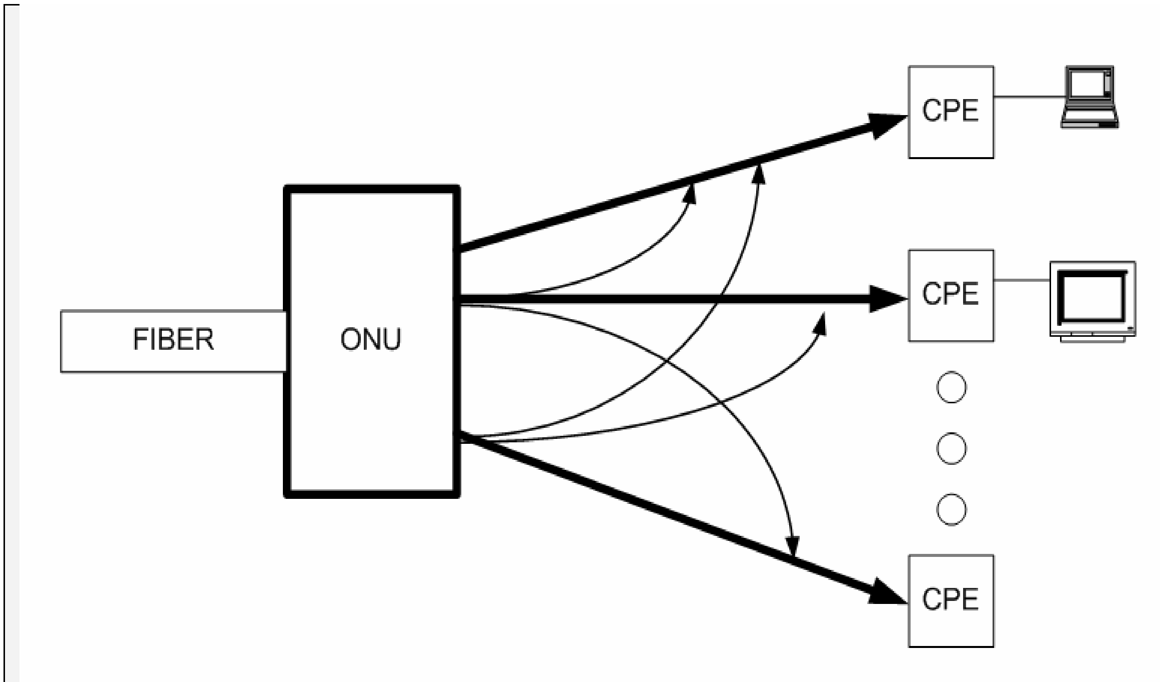

Figure 2 – common termination of binder lines on an ONU.

2.1 Differential Excitation and Vectoring

The first differential excitation model uses FEXT measured in French quad cables[3]. A digitally duplexed VDSL DMT system with common symbol clock on all coordinated lines is used with an extended frequency-plan 998 that adds downstream frequencies between 12 and 20 MHz. A simplified precoding method that makes use of only linear processing in Figure 3 is described in detail by Leshem [2] and can be independently applied to each tone of the DMT system. A gap of 12 dB was used, which roughly corresponds to about 3 dB of coding gain and 6 dB of margin. Water-filling was applied to the signals within the 998 frequency bands (see [1] for the 998 plan details). The precoding method downstream essentially eliminates all the FEXT between 12 lines (so presumably 3 customers with 4 lines each in our suggested configuration of 4 lines per customer) that emanate from the common ONU. 11 dBm of power was used on each line. The downstream data rate achievable in this system is displayed in Figure 4 (upper curve). 250 Mbps is achieved at 200 meters, so with 4 lines bonded this would be 1 Gbps service to a single customer.

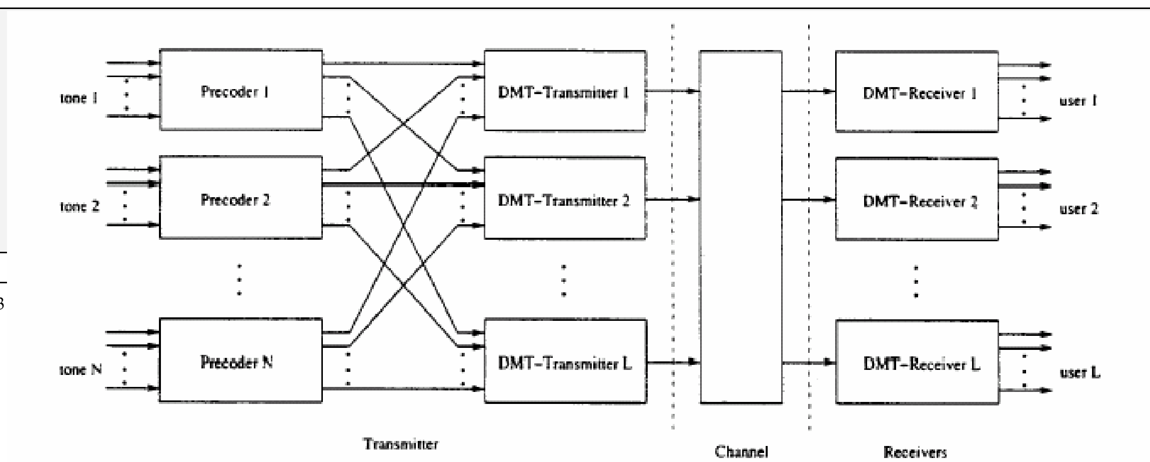

Figure 3 – linear precoding illustration.

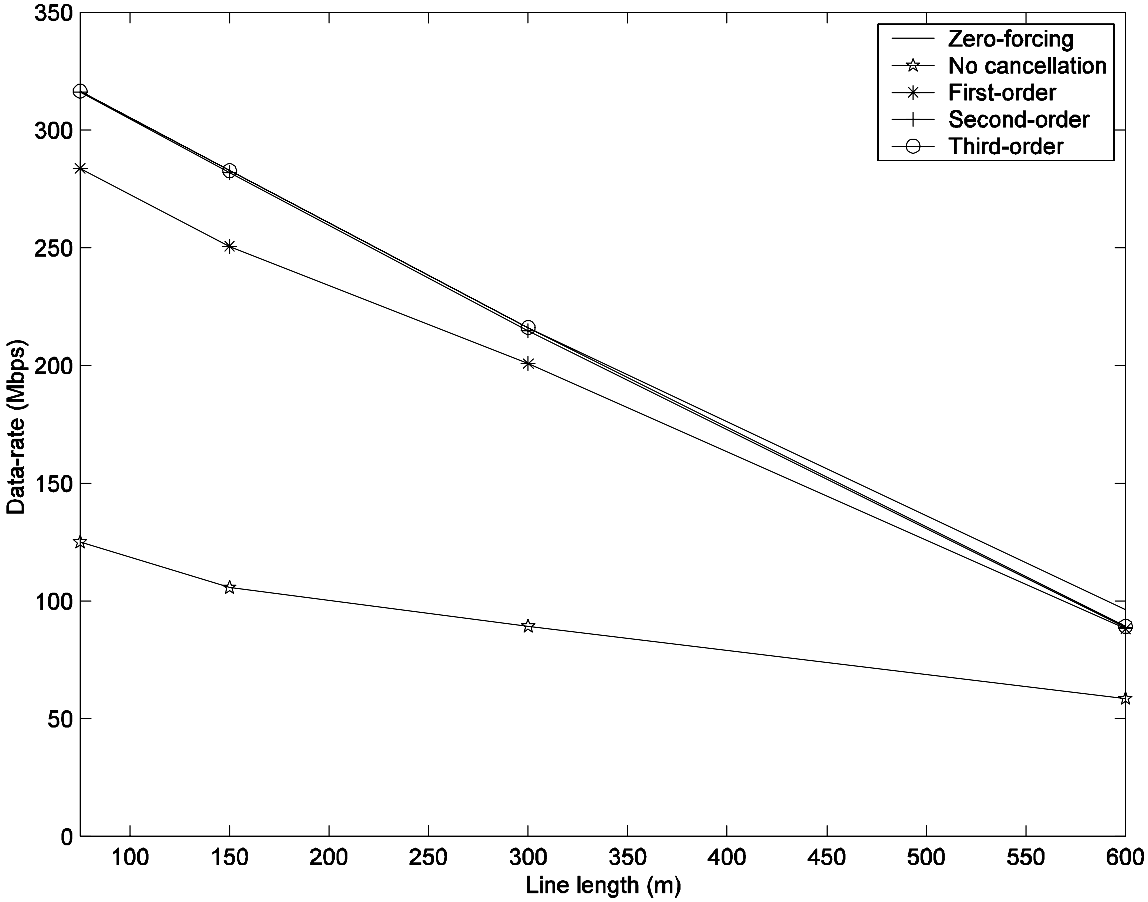

Figure 4 – Results of differential excitation and linear precoder (per line).

2.2 Full Binder MIMO

The second binder MIMO model used is for the 4 pairs in a drop is that of the DSM Report, Section 5 [1]. 26-gauge twisted pair with varying twist lengths of a few inches (category 3) were used with nominal intra-pair spacing. All 8 wires are used in full vector mode to create 7 channels as in Figure 5. Full termination of the 8 wires is achieved with 7 100 Ohm resistors connected between each wire and an arbitrarily chosen common reference wire (our results indicate that this simple resistive termination is close to full matrix-vector matching and achieves maximum binder power transfer to the load).

Again VDSL was used, but a VDSL2-like option of 8192 tones (twice as many as allowed in VDSL1) is used to allow the bandwidth to extend to slightly in excess of 30 MHz. SYMMETRIC transmission was attained by using either the 998 or the 997 plan below 12 MHz and then allocating the remaining frequencies above 12 MHz so that the upstream and downstream data rates were equal with frequency division multiplexing. We used a total of 4 times 10 dBm of power (so the total binder of 8 wires shares 400 mW of transmit power).

In this case of full MIMO, the downstream precoder needs a nonlinear element on each tone similat to the well-known Tomlinson precoder, and illustrated in detail in [1]. The upstream receiver uses a dual per-tone generalized decision feedback structure (also discussed in [1]) that not only eliminates all FEXT, but eliminates all other crosstalk and radio interference also in only the upstream direction.

The split-pair transfers are about 10 dB less in transfer magnitude than the on-channel differential channels, but still significant in contribution. Noise was set at -140 dBm/Hz. All upstream radio noise was cancelled in the vectored situation by advanced receivers. 12 dB gap was again used.

Figure 5 – Illustration of the 8 wires (without twisting shown) that create 7 channels, all with 0 wires as reference (see [1]).

Figure 6 illustrates the achieved SYMMETRIC data rates for the set of 4 pairs to a customer. The symmetric data rate achieved exceeds 1 Gbps beyond 300 meters. Well in excess of 1 Gbps is possible at shorter distances.

3. Conclusion

There is still quite a life left in the copper! A possible 4-line bonded objective of VDSL2 could be 1 Gbps DSLs (with double the number of maximum tones in VDSL1). The DSM Report concept of single-sided vectoring facilitates such an objective.

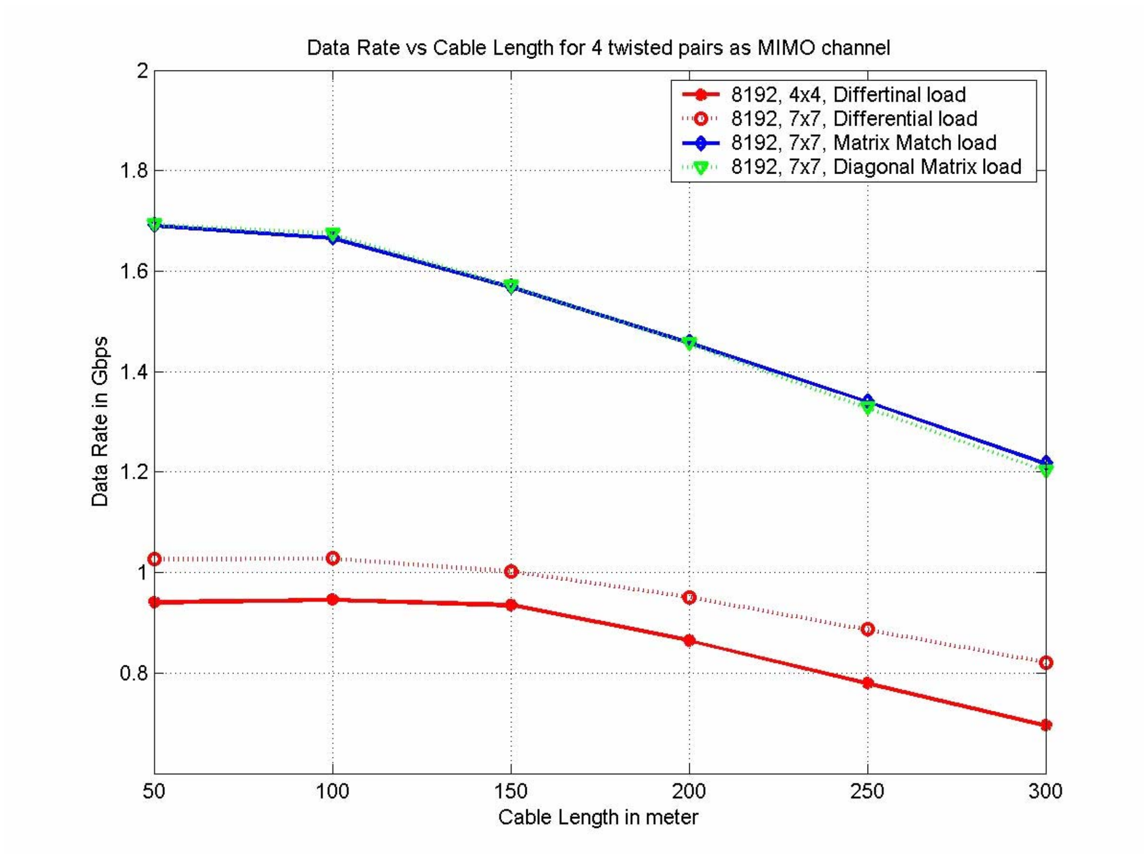

Figure 6 – data rates for the 2nd situation with full MIMO excitation.

4. References

[1] T. Starr, M. Sorbara, J. Cioffi, and P. Silverman, DSL Advances (Chapter 11), Prentice-Hall: Upper Saddle River, NJ, 2003.

[2] Amir Leshem and Li Youming – Precoding for multichannel DSL systems. Submitted IEEE trans. on SP. (also in ICECS 2004)

[3] DSM Draft Report, T1E1.4/2003-018RA, May 24, 2003, Charlotte, NC.