The effects of in-home wiring for VDSL transmission

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***Abstract*-**In this paper, it is shown how the downstream en upstream capacity of a VDSL connection will be affected if the in-home splitter is not installed according to the client installation instructions. The established data rate will be investigated for several real-life in-home cabling topologies.

I. Introduction

VDSL (Very high-speed Digital Subscriber Line) is a newer generation of DSL systems. It makes use of the telephony access network and uses a much larger bandwidth than the original POTS (Plain Old Telephony Services) twisted copper pairs were originally intended for. VDSL provides data rates up to 52Mbps in the downstream direction, and 13Mbps in the upstream direction. So it enables a broad range of applications such as video-on-demand, video-conferencing and online education. Such high data-rates are supported by operating over short loop lengths (max. 1500m) and transmitting in frequencies up to 12 MHz. [1-3]

In order to separate the POTS signals and the VDSL band signals, one has to insert VDSL splitters, enabling the simultaneous transmission of both services on the same twisted pair. The splitter also serves to protect telephony signals from interference from VDSL signals and at the other side to protect the VDSL transmission from transients generated during POTS signaling [4].

As shown in figure 1, the splitter has to be connected to the telephone line before the in-home wiring. From the splitter, a twisted pair without taps is allied to the modem. The branched in-home network is connected after the splitter. So the different taps are not visible for the modem and there is no problem. However, in many situations the splitter is badly installed or misplaced (figure 2), or there is even no splitter! Now we want to investigate how this affects the bitrate of several topologies.

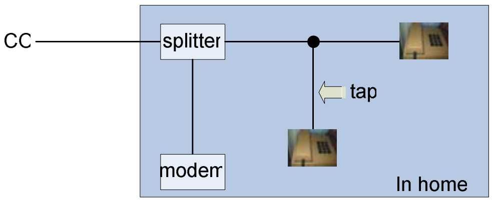

Figure 1: good positioning of the splitter

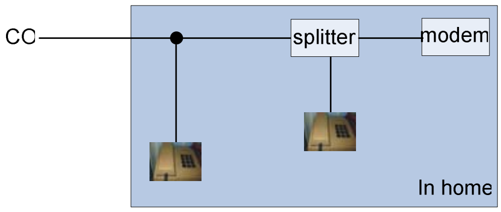

Figure 2: bad positioning of the splitter

II. Simulator

Because the bitrate is dependent of the signal-to-noise ratio, we need a parameter which gives an indication of the signal strength and we also need an approximation of the noise.

So, I developed a simulator which calculates the transfer function, based on ABCD matrices. The topology has been split up in single lines and taps. Each part may be represented by an ABCD matrix. Multiplying all the matrices in reverse order, gives the overall behaviour. Starting from this matrix, it's easy to find the transfer function. In order to verify if this simulator works for all topologies, we compared a simulated transfer function with the appropriate measurement. The topology between the central office (CO) and the customer premises equipment (CPE) is shown in figure 3. As can be seen in figure 4 both curves lay nearly on each other, which means that the simulator is very accurate.

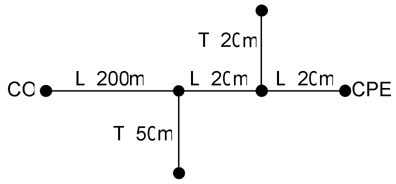

Figure 3: LTLTL topology

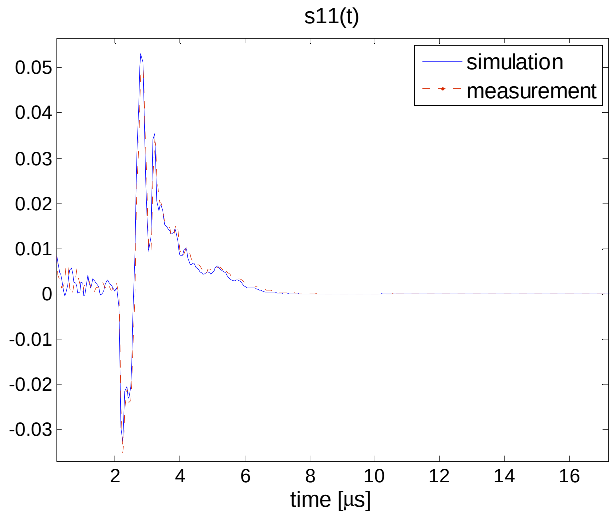

Figure 4. The comparison measurement-simulation for L(LTL)L topology

In the following simulations, beside a backgroundnoise of -120 dBm/Hz, we also consider Near-end crosstalk and Far-end crosstalk. We assume that our VDSL line is located in a binder containing 20 ADSL lines and 5 VDSL lines. All the lines are Belgacom lines with a diameter of 0.5mm.

III. Length

In this section we will explore how the upstream en downstream capacity will be influenced if the distance between the central office and the in-home topology changes. We consider a simple line without taps and let vary his length.

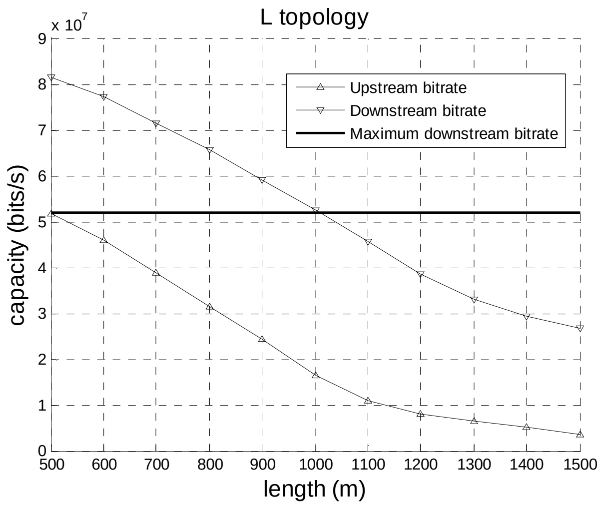

Figure 5. The influence of the length on the capacity

Figure 5 shows both the upstream and downstream bitrate. Also the maximal downstream bitrate (52Mbit/s) is plotted as a straight line. If the length between the central office and the in-home wiring exceeds 1000m, this theoretical value can not be offered anymore. If the length increases, the downstream and upstream capacity decreases. It's nearly impossible to send information to the central office if the distance from the house is 1500m away from the central office: the upstream bitrate is only 7% anymore of the original bitrate!

IV. Taps

Depending of the distance between user and central office, the attainable bitrate will diminish. This situation can get even worse: if the splitter is misplaced, the modem sees no single line. The in-home wiring, which contains several taps in many cases, becomes visible. It will be investigated how and to what level those taps cause an extra decrease in data transmission capacity.

A. number of taps

In order to see the influence of the number of taps, we consider the downstream and upstream bitrate for 3 configurations. The first topology is a single line of 800m. The second structure (figure 6) contains one tap between central office and user. In the third topology (figure 7) the last line segment of the second configuration is split up in 2 lines of 10m with an extra tap of 30m between. In these simulations (figure 8), the length of the first tap varies from 10 to 50m.

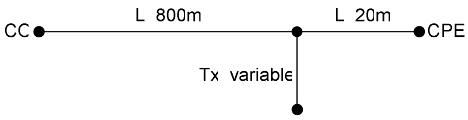

Figure 6: Topololgy with one tap

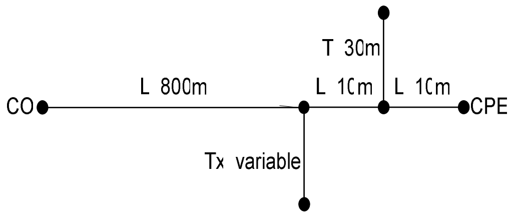

Figure 7: Topology with two taps

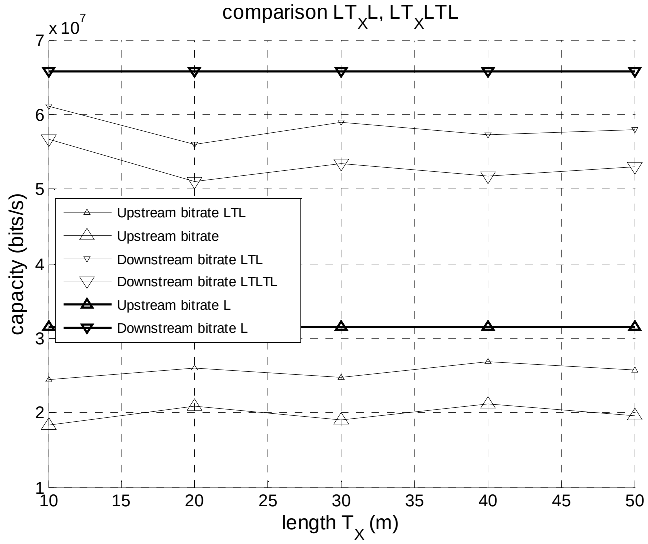

Figure 8. The influence of the number of taps on the capacity

If more taps are involved, e.g. the change from a single line topology (L) into a topology with one tap (LTL) or a topology with two taps (LTLTL), then the upstream and downstream capacity decreases significantly. Again, it can be seen that the relative decrease is much higher for the upstream bitrate. The upstream capacity of the topology with two taps is only 60% of the capacity without taps, the downstream capacity is still 80%. The capacities don't decrease monotonously if the length of the first line increases, because of constructive and destructive interference.

B. kind of tap

The in-home wiring contains both simple and complex taps (these are taps which are branched themselves). In this part we will examine if the kind of tap affects the capacity. Therefore a simulation is done for the following two topologies. The first structure (figure 9) has one tap from which the length increases from 10m up to 50m. In the second configuration (figure 10) the original tap has an extra branch of 50m.

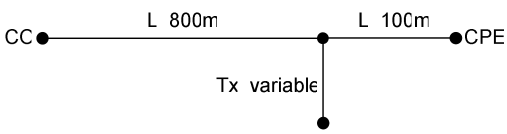

Figure 9: Topology with a simple tap

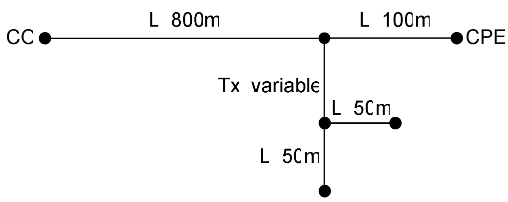

Figure 10: Topology with a complex tap

In figure 11, the upstream and downstream capacity for both topologies are compared with those for a single line segment.

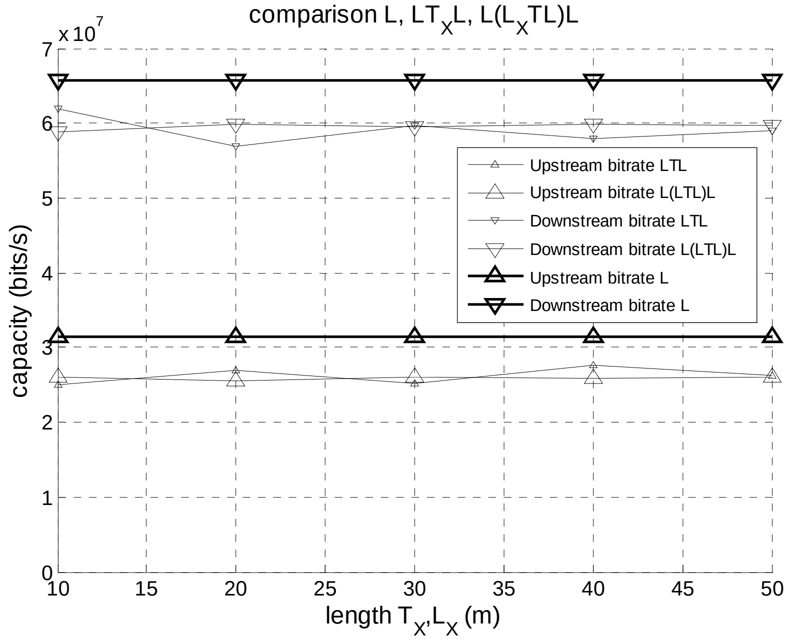

Figure 11: the influence of the kind of tap on the capacity

As already mentioned, the presence of taps deteriorate both upstream and downstream capacities. However the relative decrease in bitrate is greater in the upstream direction. If this tap is simple or complex, is less important. If the length of the tap is $10 \cdot x$ m, with x even, than the downstream bitrate is higher for a topology with a complex tap than for a structure with a simple tap, but the downstream bitrate is lower. If x is odd, it's the inverse.
If the in-home wiring contains both a simple and a complex tap, the order hardly changes the capacities.

V. Conclusions

It's very important to pay enough attention to the correct positioning of the splitter, particularly if the distance between the central office and the user is not small. If the splitter is badly installed, the taps of the in-home wiring become visible. Increasing the number of taps causes destructive interference and consequently extra dips in the transfer function appear. Less bits may be transmitted in these frequency areas. Depending of the position of the dips, the downstream or upstream bitrate will decrease. However, changing the length of the taps, the location of the dips may vary. The relative diminishment is much greater for the upstream than for the downstream bitrate. If the distance between central office and user exceeds 1200m and if the in-home wiring contains 2 taps, it's nearly impossible to send information in the upstream direction!

References

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