Standards project: T1E1.4: VDSL

Title : Zipper performance when mixing ADSL and VDSL in terms of reach and capacity

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Abstract: In this contribution we have examined how the maximum reach vary at different bit rates on a VDSL system, when different numbers of ADSL and VDSL systems share the same binder.

In this context it is concluded that when using the Zipper duplex scheme, VDSL can coexist with ADSL in the same binder without a significant degradation in reach. Further, it is shown that the Zipper duplex scheme secure that ADSL is not disturbed by NEXT from VDSL

The Zipper performance has also been compared with both a TDD proposal and a FDD proposal. The results from this comparison shows that Zipper outperforms FDD and TDD in terms of extended reach at all studied mixes of ADSL and VDSL sharing the same binder. For example with a moderate number (5) of ADSL disturbers, the Zipper reach is 150 meters longer than for TDD, and is 350 meters longer than for FDD when studying the medium range asymmetrical bit rate (26:3.2 Mbps).

1. Introduction

In this contribution, we investigate VDSL in a network with ADSL customers, where ADSL and VDSL coexist in the same binder group. When coexisting in the same binder, ADSL and VDSL always disturb each other with far-end crosstalk (FEXT). If the systems transmit in different directions in shared frequency bands, near-end crosstalk (NEXT) will also occur, which can lower the capacity significantly for both systems.

One way to avoid NEXT is to use Zipper [6] as VDSL duplex scheme. Zipper is based on multicarrier technology [1] and each subcarrier can be used arbitrarily in up- or downstream direction. If the subcarriers are arranged as in Figure 1, VDSL and ADSL transmits in the same direction in the shared frequency bands, thus avoiding NEXT.

In this contribution, the performance of Zipper is evaluated in terms of bit rate versus reach, when coexisting with ADSL. Zipper is also compared with time division duplex (TDD) [3] and frequency division duplex (FDD) [5].

The presentation will proceed as follows. In Section 2 models for the signals and crosstalks are presented. In Section 3 Zipper is evaluated and compared with TDD and FDD in terms of bit rate versus reach. Section 4 contains tables showing further results. Conclusions are made in Section 5.

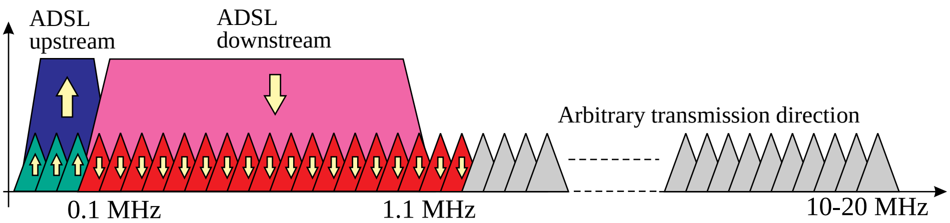


Figure 1 Zipper coexisting with ADSL.

2. Models for ADSL and VDSL signals and crosstalk

Our scenario is depicted in Figure 2. The chosen VDSL scheme occupies the band from 30 kHz to 12 MHz and the ADSL scheme occupies the band from 28 kHz to 138 kHz in upstream direction and 20 kHz to 1.104 MHz in the downstream. In the band between 28 kHz and 138 kHz ADSL transmits in both directions. In the following, the narrow ADSL-upstream band is sometimes left out from the pictures and discussion for simplicity, but it is always taken into account in the forthcoming calculations.

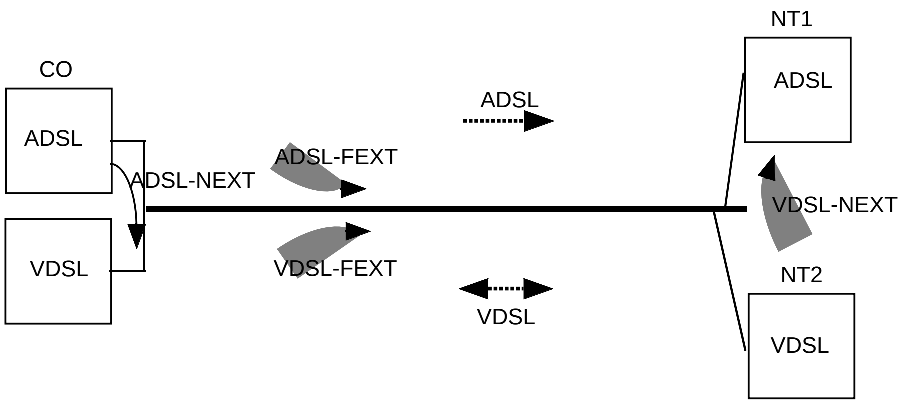


Figure 2 ADSL and VDSL scenario.

2.1 ADSL-crosstalk into VDSL

To compare the capacity of the three VDSL-duplex methods, the signal to noise ratio (SNR) for downstream and upstream direction is calculated from the power spectral densities (PSD) of the VDSL signal and the ADSL-induced disturbance. The PSD of the ADSL NEXT and FEXT are specified in [4]. The models we use for the TP1- and TP2-cables are also from [4].

The ADSL-induced disturbance is shown in Figure 3. The ADSL signal is transmitted at -40 dBm/Hz and the VDSL signal at -60 dBm/Hz. The plots show the PSD of the received signals at the VDSL receivers, both at the central office and the NT. The HAM bands are shown as gaps in the plots.

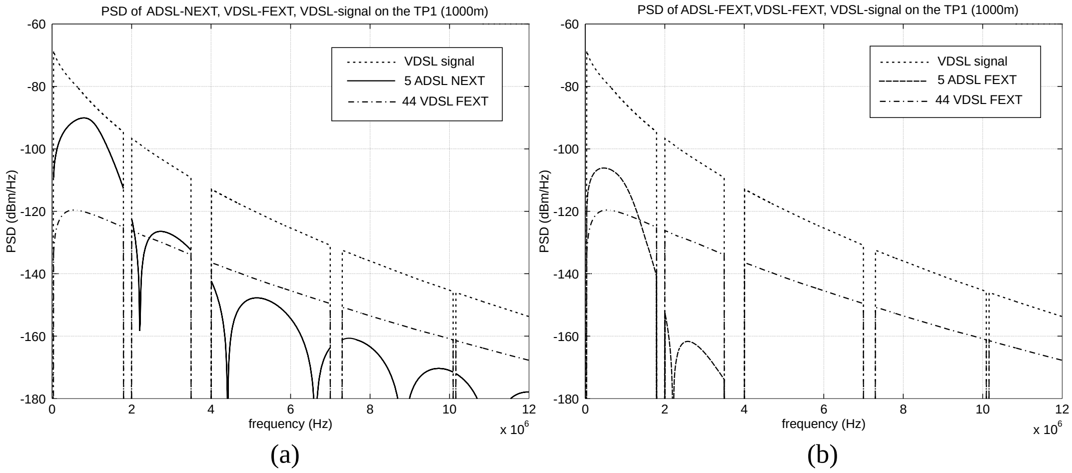


Figure 3 PSD of VDSL signal, disturbing NEXT and FEXT from 5 ADSL- and 44 VDSL-disturbers on TP1. (a) received at the CO and (b) received at the NT.

The resulting SNR for the VDSL signals in upstream and downstream direction are shown in Figure 4. Up to 4 MHz, the plot shows a significant difference in SNR between the up- and downstream signal. This means that when TDD transmits upstream, there will always be capacity loss due to the lower SNR. With Zipper it is possible to minimize the impact of ADSL-NEXT by using the subcarriers in the most advantageous direction. An FDD system also has the possibility to handle this problem by selecting the frequency bands in a clever way, but it would probably need more than two frequency bands.

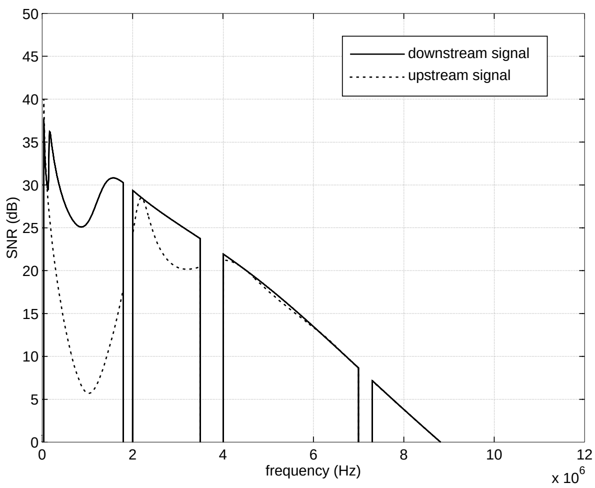


Figure 4 SNR of an upstream and a downstream VDSL signal disturbed by 5 ADSL- and 44 VDSL systems on a 1000 m TP1-cable.

2.2 VDSL-crosstalk into ADSL

The disturbance pattern of VDSL into an ADSL signal received at the NT is shown in Figure 5. As shown in the plot, the FEXT produced by VDSL is below the FEXT of ADSL, while the VDSL NEXT is above the ADSL FEXT. This implies that as long as no transmission is done in the opposite direction of ADSL up to 1.1 MHz, it is possible to exchange ADSL with VDSL and at the same time decrease the crosstalk. With a carefully chosen frequency plan, Zipper and FDD can avoid injecting NEXT.

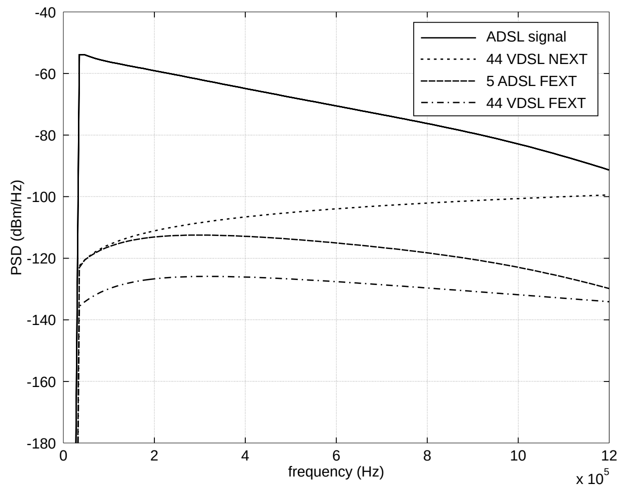


Figure 5 Power spectral density of an ADSL signal received at the NT on a 1500 m TP1-cable, together with disturbing NEXT and FEXT from 44 VDSL wire pairs and FEXT from 5 ADSL wire pairs

Questions have been raised about whether or not crosstalk is significant at the NT side. Recent measurements made at Telia Research AB indicate that, e.g., with the distance of 200 m between the NTs, the crosstalk is only 2-5 dB below NEXT at 1 MHz. This implies that NEXT produced by TDD based VDSL in coexistence with ADSL can not be neglected.

3. Performance Evaluation and Comparison of Zipper, TDD and FDD

In this section we compare Zipper, TDD and FDD. The performance is measured in terms of bit rate and reach.

The results in this section are all based on the situation with 5 ADSL- and 44 VDSL-disturbers on the TP1-cable. For other mixes of ADSL and VDSL on TP1- and TP2-cables, we refer to Section 4, where the reach for all three systems for different bit rates is tabulated. The HAM-bands, which we specify in Section 3.1, are all excluded and are not used for transmission.

When evaluating Zipper [6], the subcarriers are assigned according to the principles discussed in Section 2. The evaluation of the TDD method is based on the proposal in [3] and the FDD method is based on the proposal in [5]. No performance calculations will be done for symmetrical rates for FDD, since the frequency bands are not specified exactly in [5].

3.1 System parameters

The following are the parameters used in all calculations throughout the paper.

Zipper, TDD and FDD		
HAM-bands removed	1.8-2.0, 3.5-4.0, 7.0-7.3, 10.1-10.15 MHz	
AWGN	-140 dBm/Hz	
System margin	6 dB	
Coding gain	3 dB	
SNR-gap[1]	9.8 dB	
Usable bandwidth	30 kHz - 12 MHz	
Zipper	**TDD**	**FDD**
Number of carriers: 1024 CP: 40 samples CS: 180 samples (1500m with fs=24 MHz)	Number of carriers: 256 CP: 40 samples	Up = 0.8-1.8 MHz Down = 2.0-12 MHz 20% excess bandwidth

[1] An SNR-gap of 9.8 dB [2] is used to achieve a BER of approximately 10^{-7}.

3.2 Asymmetrical rates (8:1)

For Zipper we have chosen the subcarriers in the frequency bands (0.05-0.12), (2.16-2.27), (3.63-4.45), (8.20-8.32) and (10.9-11.3) MHz for the upstream directions.[2] TDD uses a (15-1-3-1) superframe structures as suggested in [7], where a TDD superframe consists of several downstream frames, one or more upstream frames and two empty turn-around frames. For compatibility between FDD VDSL and ADSL it is suggested in [5] that the frequency band between 0.8 and 1.8 MHz is used in the upstream and the rest of the available bandwidth is used downstream.

Downstream bit rates and 8 times upstream bit rates are shown for Zipper, TDD, and FDD in Figure 6. The ratio between the up- and downstream bit rates is close to 8:1 for Zipper all the way up to 1200 meters, but for TDD and FDD the ratio varies considerably depending on the length of the wire pair.

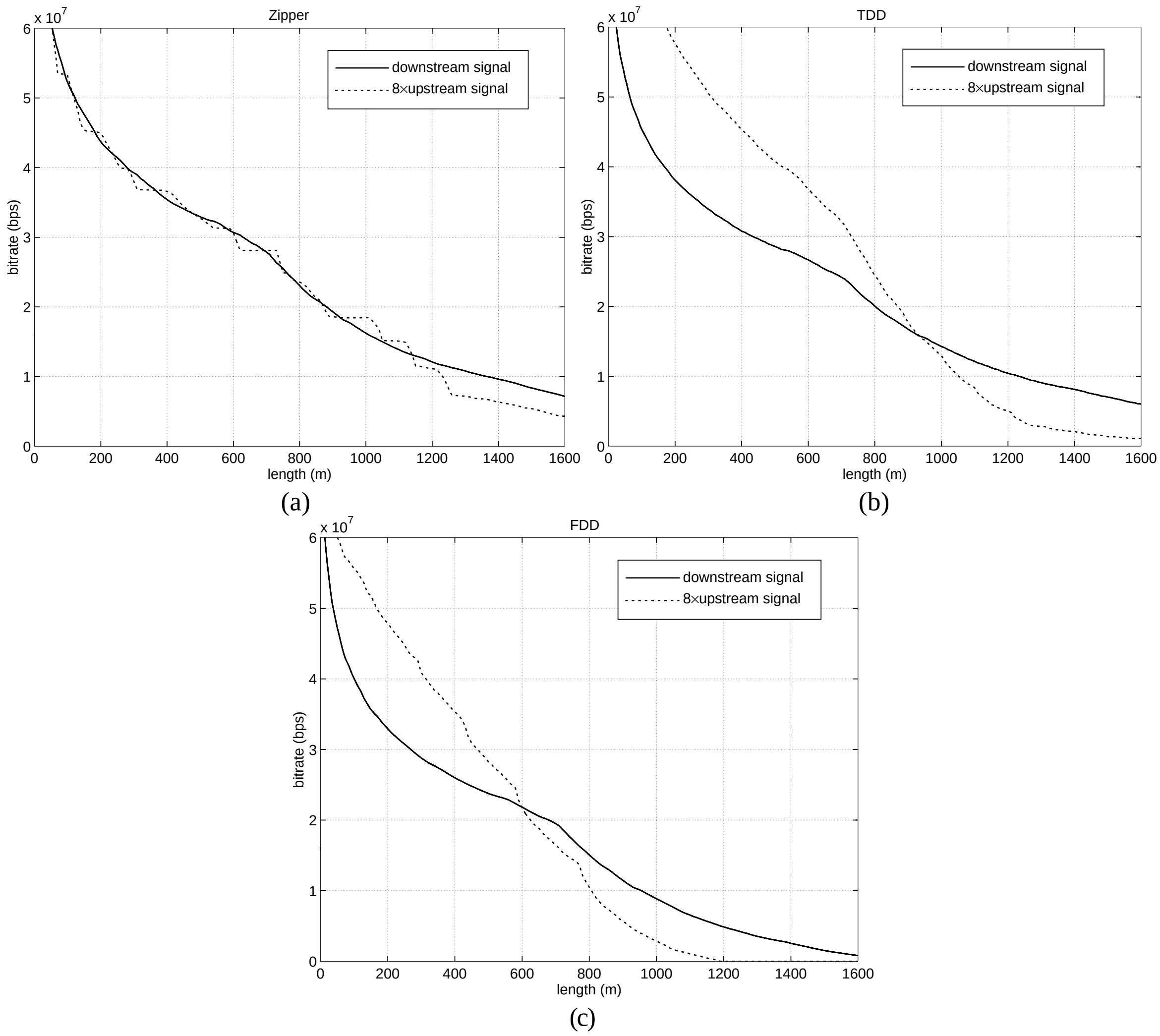
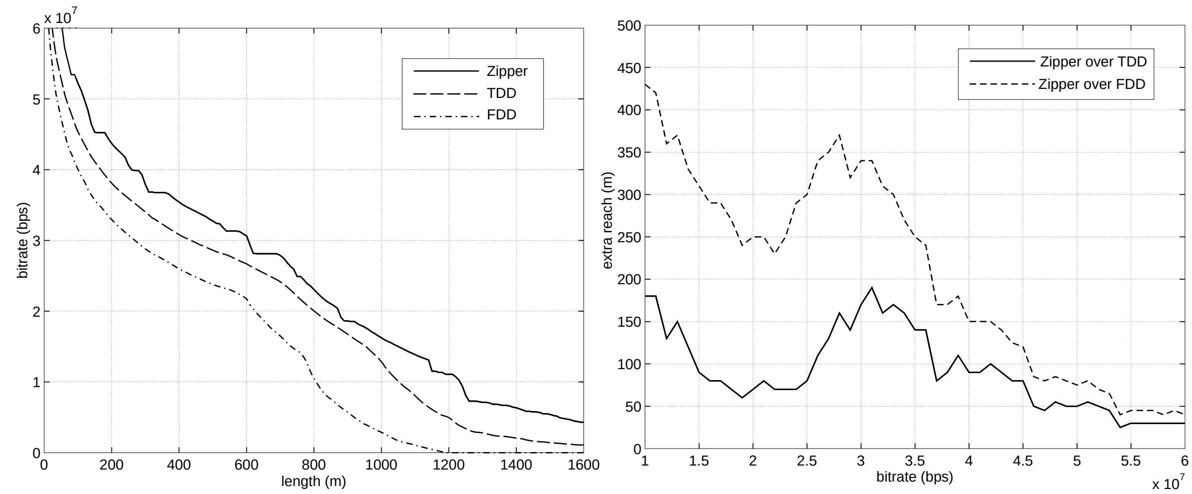


Figure 6 Downstream and 8*upstream rate with 44 VDSL- and 5 ADSL-disturbers. Plots for (a) Zipper, (b) TDD and (c) FDD.

For a desired ratio 8:1, it is the smallest of downstream bit rate and 8 times the upstream bit rate that limits the system performance. This bit rate is plotted in Figure 7 for all three methods. Zipper has a ratio closer to 8:1 in Figure 6, which is one of the reasons why it performs better than both TDD and FDD in the entire range between 100 and 1600 m in Figure 7 (a). Figure 7 (b) shows how much longer a VDSL system based on Zipper reaches compared to TDD and FDD based systems. It can be seen that Zipper often has a gain in the range of hundreds of meters.

[2] This is not an optimal way to partition the bandwidth, but rather an example which is used in this section.



(a) (b)

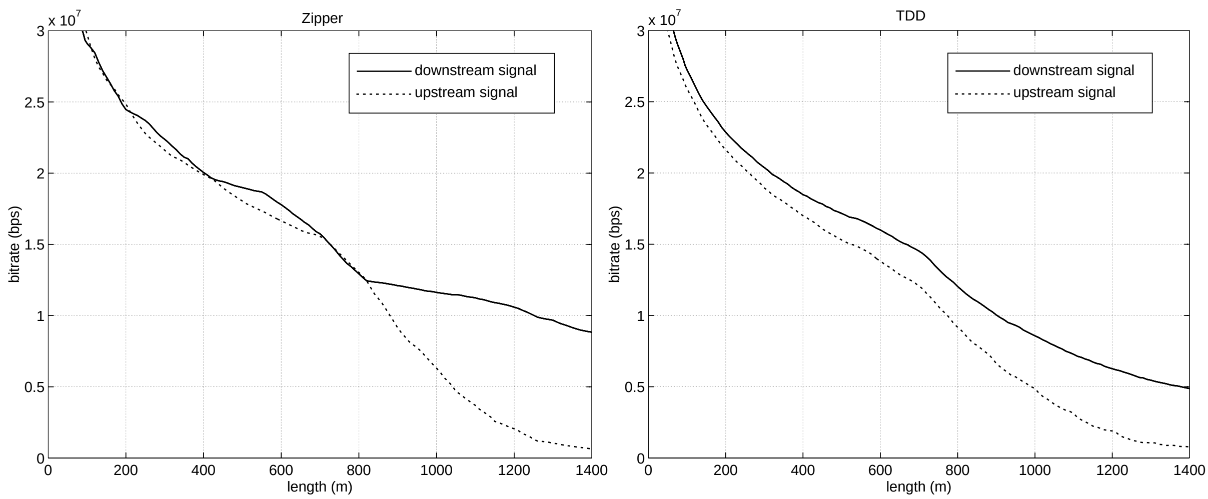
Figure 7 (a) Achievable (8:1) asymmetrical rates with Zipper, TDD and FDD on TP1 and (b) extended reach for Zipper over TDD and FDD.

3.3 Symmetrical rates

To achieve symmetric bit rates with Zipper the frequency bands (2.11-2.66) and (3.40-9.26) MHz are used in the upstream direction. For TDD a (9-1-9-1) superframe structure is adopted. As mentioned earlier FDD is not included since the frequency bands are not exactly defined in [5].

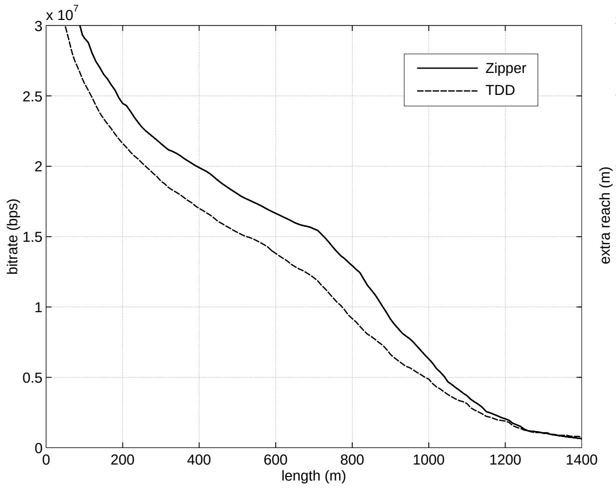
In Figure 8 we show the bit rates on the upstream and downstream signal for Zipper and TDD. Both Zipper and TDD perform close to the desired 1:1 ratio up to 800 m. However, Zipper outperforms TDD, as can be seen in Figure 9, since ADSL-NEXT is avoided with Zipper and not with TDD.

Above 800 m it is difficult to achieve symmetrical bit rates for both Zipper and TDD because of the low SNR of the upstream signal. For Zipper the bit rate in downstream direction is still high enough to offer asymmetric service (13/1.6) up to 1000 m, which is not the case for TDD. This shows that it is possible with Zipper to offer asymmetrical rates for longer wire pairs and offer symmetrical rates for the shorter pairs at the same time.

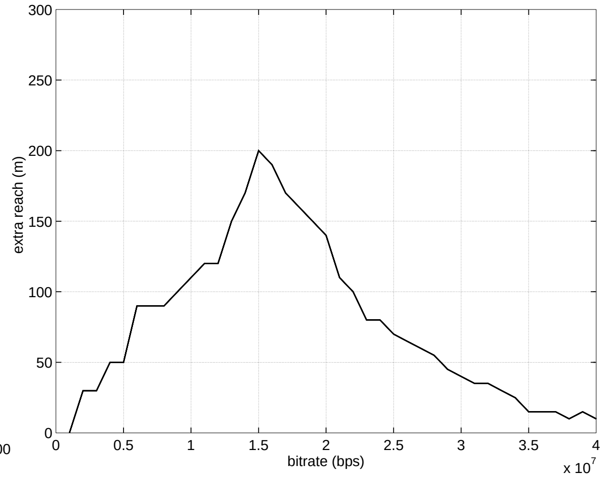


(a) (b)

Figure 8 Up- and down-stream bit rates in symmetrical case with 5 ADSL and 44 VDSL disturbers on the TP1-cable. Plots for (a) Zipper and (b) TDD.



(a)



(b)

Figure 9 (a) Achievable symmetrical rates with Zipper and TDD on TP1. (b) Extended reach for Zipper over TDD.

4. Results from different combinations of ADSL/VDSL

The same environment as described in Section 3 is used here, but this time calculations are made on both the TP1- and the TP2-cable. Three different (8:1) asymmetrical rates (52/26/13) and two symmetrical rates (26/13) are taken under consideration. There are 4 tables below, each showing different bit rates and corresponding cable lengths for varying number of ADSL disturbers.

4.1 Environment with no ADSL Disturber

Table 1 shows figures for an environment with no ADSL disturbers where only VDSL-systems are present. 49 FEXT disturbers are used. In this case TDD uses a (16-1-2-1) superframe structure for asymmetrical rates. FDD uses the bands recommended for pure VDSL systems in [4].

Bit rates (Mb/s)	Reach (meters)			Extra reach for Zipper (meters)	
TP1	Zipper	FDD	TDD	FDD	TDD
13/1.6	1400	980	1310	420	90
26/3.2	800	630	750	170	50
52/6.4	110	75	75	35	35
13/13	880	N. A.	830	N. A.	50
26/26	190	N. A.	130	N. A.	60
TP2	Zipper	FDD	TDD	FDD	TDD
13/1.6	1700	1200	1590	500	110
26/3.2	950	680	890	270	60
52/6.4	110	75	75	35	35
13/13	1070	N. A.	990	N. A.	80
26/26	190	N. A.	130	N. A.	60

Table 1 Performance in an environment with 49 VDSL and no ADSL disturbers**.**

4.2 Environment with 5 ADSL Disturbers

Table 2 shows results from Section 3 where a mix of 5 ADSL and 44 VDSL disturbers were used.

Bit rates (Mb/s)	Reach (meters)			Extra reach for Zipper (meters)	
TP1	Zipper	FDD	TDD	FDD	TDD
13/1.6	1140	770	990	370	150
26/3.2	730	390	620	340	110
52/6.4	100	30	50	70	50
13/13	790	N. A.	640	N. A.	150
26/26	160	N. A.	95	N. A.	65
TP2	Zipper	FDD	TDD	FDD	TDD
13/1.6	1380	960	1240	420	140
26/3.2	850	400	660	450	190
52/6.4	100	30	50	70	50
13/13	940	N. A.	730	N. A.	220
26/26	160	N. A.	95	N. A.	65

Table 2 Performance in an environment with 44 VDSL and 5 ADSL disturbers.

4.3 Environment with 25 ADSL Disturbers

Table 3 covers the case of 25 ADSL disturbers and 24 VDSL disturbers

Bit rates (Mb/s)	Reach (meters)			Extra reach for Zipper (meters)	
TP1	Zipper	FDD	TDD	FDD	TDD
13/1.6	1100	610	950	490	150
26/3.2	740	410	670	330	70
52/6.4	120	40	65	80	55
13/13	800	N. A.	660	N. A.	140
26/26	190	N. A.	110	N. A.	80
TP2	Zipper	FDD	TDD	FDD	TDD
13/1.6	1340	760	1180	580	160
26/3.2	900	510	750	390	150
52/6.4	120	40	65	80	55
13/13	980	N. A.	790	N. A.	190
26/26	190	N. A.	120	N. A.	70

Table 3 Performance in an environment with 24 VDSL and 25 ADSL disturbers.

4.4 Environment with 44 ADSL Disturbers

This case includes 44 ADSL disturbers and 5 VDSL disturbers

Bit rates (Mb/s)	Reach (meters)			Extra reach for Zipper (meters)	
TP1	Zipper	FDD	TDD	FDD	TDD
13/1.6	1120	560	960	560	160
26/3.2	830	350	760	480	70
52/6.4	260	0	130	260	130
13/13	860	N. A.	740	N. A.	120
26/26	420	N. A.	240	N. A.	180
TP2	Zipper	FDD	TDD	FDD	TDD
13/1.6	1380	700	1210	680	170
26/3.2	1020	440	940	580	80
52/6.4	260	0	130	260	130
13/13	1050	N. A.	920	N. A.	130
26/26	420	N. A.	250	N. A.	170

Table 4 Performance in an environment with 5 VDSL and 44 ADSL disturbers**.**

4.5 Performance of Zipper

In table 5 the result for Zipper from the cases above are gathered. There are always 49 disturbing pairs, i.e., 0 ADSL disturbers means 49 VDSL disturbers.

Bit rates (Mb/s)	Reach (meters) for different number of disturbers			
TP1	0 ADSL	5 ADSL	25 ADSL	44 ADSL
13/1.6	1400	1140	1100	1120
26/3.2	800	730	740	830
52/6.4	110	100	120	260
13/13	880	790	800	860
26/26	190	160	190	420
TP2	0 ADSL	5 ADSL	25 ADSL	44 ADSL
13/1.6	1700	1380	1340	1380
26/3.2	950	850	900	1020
52/6.4	110	100	120	260
13/13	1070	940	980	1050
26/26	190	160	190	420

Table 5 Performance of Zipper at different bit rates and with different number of ADSL disturbers.

5. Conclusions

In this contribution we have examined how the maximum reach vary at different bit rates on a VDSL system when different numbers of ADSL and VDSL systems share the same binder. The aim with this analysis is to assist the T1E1.4 committee in the ADSL compatibility discussion.

Three different duplex scheme proposals (Zipper, FDD and TDD) has been analyzed and compared at different bit rates and different mixes of ADSL and VDSL.

When using the Zipper duplex scheme VDSL and ADSL can share the same binder without a significant degradation in reach. The degradation is considerably smaller than if TDD or FDD are used. Further, the Zipper duplex scheme secures that ADSL is not disturbed by NEXT from VDSL. Recent performed measurements at Telia Research indicate that the disturbance from VDSL NEXT into ADSL should not be neglected.

Results presented in table 5 shows that Zipper is an efficient method for optimizing the use of the available bandwidth at different mixes of ADSL and VDSL sharing the same binder. The degradation in reach compared with a pure VDSL scenario is largest for the long node asymmetrical transport class. In other transport classes, defined in T1E1.4/96-153R3, the available reach can even be improved for some mixtures.

The results from the comparison between Zipper, TDD, and FDD show that Zipper outperforms FDD and TDD in terms of extended reach for all studied mixes of ADSL and VDSL. For example, with a moderate number (5) of ADSL disturbers, the Zipper reach is 150 meters longer than for TDD, and is 350 meters longer than for FDD when studying the medium range asymmetrical bit rate (26:3.2 Mbps).

6. References

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[7] K. Jacobsen and J. Bingham, *Mixing ADSL and VDSL,* ANSI T1E1.4/96-330.