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CONTRIBUTION

TITLE: **Dynamic FDM and Dynamic DS power back-off: A simplified DSM algorithm for coexistence between RT and CO based deployments**

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ABSTRACT

In this contribution we propose a simplified power allocation algorithm for remotely deployed VDSL. We show that the proposed algorithm has very good rate region for the common deployment case. We propose to add the algorithm to the DSM level 1 specification. We also propose that a DSM level 1 compliant device should have the possibility of performing a DPBO on the lower part of the band. The algorithm is very attractive for QAM based VDSL where management complexity is also very low due to the low number of parameters optimized in the selection process.

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A simplified dynamic frequency allocation algorithm for RT VDSL that is spectrally friendly to CO based ADSL

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ABSTRACT

In this contribution we propose a simplified unsupervised (but coordinated) power allocation algorithm for remotely deployed VDSL. The algorithm which performs dynamic frequency division multiplexing (DFDM) has three stages: Bandwidth minimization, spectral efficiency and reduction of excess power. We show that the proposed algorithm has very good rate region both for common and remote deployment cases. We propose to add the algorithm to the DSM level 1 specification. The proposed algorithm can be shown spectrally compatible at all stages. Moreover it provides theoretical justification to the UK ANFP spectrum allocation together with some simple enhancement. The algorithm is very attractive for QAM based VDSL where management complexity is also very low due to the low number of parameters optimized in the selection process.

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1 Spectrally friendly VDSL

Issue 2 of T1-417 allows for remote deployment which is spectrally compatible with ADSL from the CO. In countries like the UK the regulator opted to forbeed the use of the spectrum below 1.1 MHz in remote terminal deployments. In this contribution we show that wisely selecting the usable band of VDSL may allow a spectrally friendly operation without compromising the performance of VDSL. The algorithm is uncoordinated, easy to operate and results in near optimal rate region. We propose to add this algorithm as a possible implementation of level 1 dynamic spectrum management for both QAM and DMT sections.

2 Dynamic spectrum allocation algorithm

In this section we propose an a-priori coordinated rule for dynamic allocation of spectrum. We can show that the proposed dynamic co-ordination through co-operation yields enhanced results

compared to unsupervised competitive power allocation. We also provide some insight to this result using combination of physical and game theoretic interpretation of the proposed scheme.
The proposed spectral allocation algorithm consists of three steps:

1. Spectrum is used from the highest available frequency.
2. Spectral efficiency is optimized for the given rate (i.e., a narrower bandwidth with more efficient modulation is used). For that purpose either channel capacity with a gap or the well known Saltz's formula for DFE performance can be used.
3. Power back-off is performed if excess margin exists. Since this adjustment is minor , provided that first two steps have been performed we propose flat power back-off.

The implementation details of the above algorithm for QAM VDSL modem are described in Table 1.

Table 1: DFDM implementation for QAM based VDSL

1. R=preassigned target rate for VDSL.
2. $f_{\min}$ =minimal f such that the VDSL can achieve rate R using frequencies $\geq f_{\min}$.
3. Setup carrier frequencies f_{C_1}, f_{C_2}, symbol rates R_{SYMB_1}, R_{SYMB_2} and constellation sizes $2^{D_1}, 2^{D_2}$ for the two DS bands, such that $f_{\min} \leq f_{C_1} - R_{SYMB_1}$ is maximal, $R = D_1 \bullet R_{SYMB_1} + D_2 \bullet R_{SYMB_2}$ and this transmission profile provides sufficient margin for operation.
4. Use the above transmission profile for steady state operation.

The idea underlying the approach above is that CO based deployment typically uses the lower part of the spectrum, and therefore use of this part of the spectrum should be minimized in remote deployments. One extreme realization of this is the use of dynamic FDM between CO and RT. In this case the RT begins above a frequency determined either by the modem or by instruction of the network management / DSM center. In the following sections we demonstrate the rate region for the above algorithm in several typical cases. We also compare to previous DSM results using iterative water-filling.

3 Simulation results: Dynamic FDM for RT-VDSL and CO-ADSL

In this section we analyze the rate region for RT based VDSL together with CO based ADSL. We compare the results of our proposed rule to the uncoordinated allocation through iterative water-filling (IW). We show that the rate region achieved is superior to that of the uncoordinated case relying on the game theoretic Nash equilibrium. We also compare the rate region to the rate region of remotely deployed ADSL using the same scheme as well as iterative water filling. We show that VDSL from the RT can co-exist with ADSL from CO even for very high downstream rates. This puts VDSL as the better choice for remote deployment, being more friendly to ADSL.
Figure 1 presents the setup where we have N_1 VDSL lines originating from the RT fed by fiber, and N_2 ADSL lines originating from the CO sharing the same binder as theVDSL lines. As we will show using a friendly mask does not cause any degredation to the ADSL from the CO

without compromising the VDSL DS performance. All simulations used 26 AWG line. The first simulation presents the results when the RT was located at 3 kft from the CPE and the CO was located at 9, 10, 12, 14 and 16 kft. For each of these cases we have compared the rate region achieved by VDSL performing DS power back-off of the frequency band $138 \le f \le f_b$ kHz to a level of –110 dBm/Hz, where f_b is any frequency between 138 kHz and 1.1 MHz. The results are presented in Figure 2. We now compare these results to the results of iterative water-filling for unsupervised DSM [9].

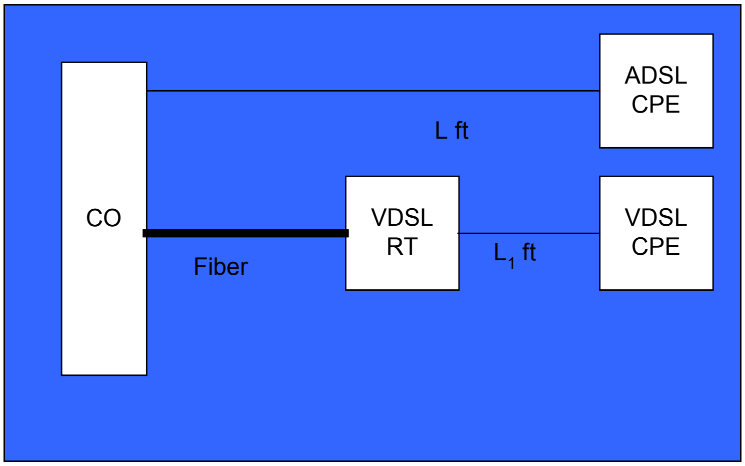


Figure 1: Simulation setup- VDSL from the RT and ADSL from the CO.

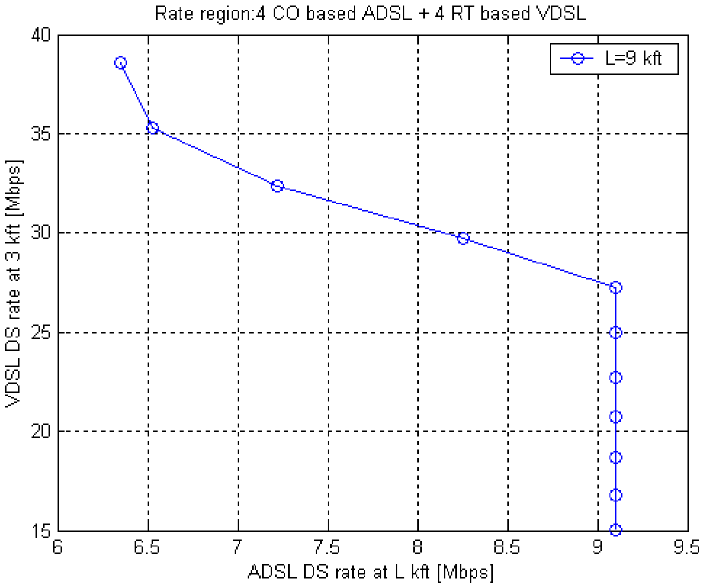


Figure 2: Rate region for 4 VDSL from RT and 4 ADSL from CO using the DFDM algorithm. Gap of VDSL is 12 dB and of ADSL is 11 dB. L=9 kft, L1=3 kft.

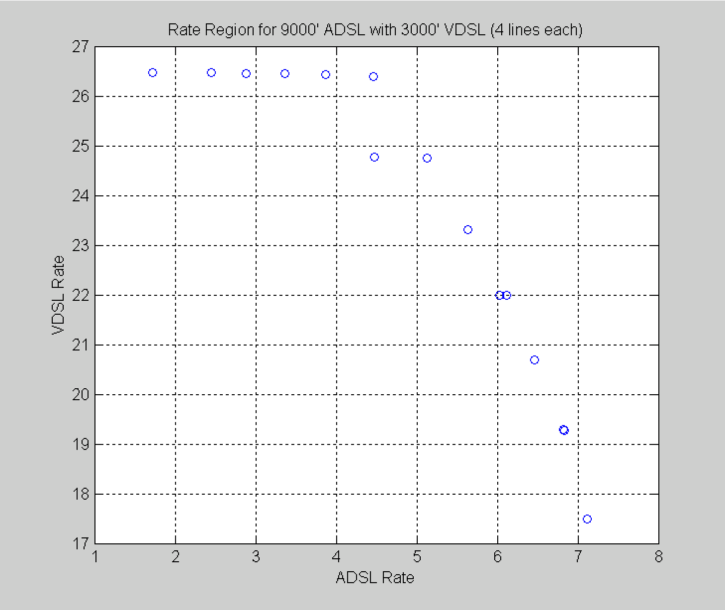


Figure 3: Rate region for CO based ADSL and RT based VDSL, with unsupervised iterative water-filling (from [6]). L=9kft, L1=3kft.

We can see that the rate region for the iterative waterfilling algorithm is substantially less than that for the Dynamic FDM algorithm (DFDM). There are two main reasons: First reason is that [4] uses uncoded systems. This amounts to 4 dB for VDSL and 5 dB for ADSL. Howevr there is also a second reason: The VDSL tends to put some of its energy in the ADSL DS band and therefore limits the ADSL performance more substantially than when it is forced out of this band. For better comparison with [6] we also provide the results for an uncoded system. Indeed we see that the maximal ADSL capacity is now reduced to 7.6 Mbps which is slightly more than with the IW, however the VDSL rates are also slightly higher for any given ADSL rate.

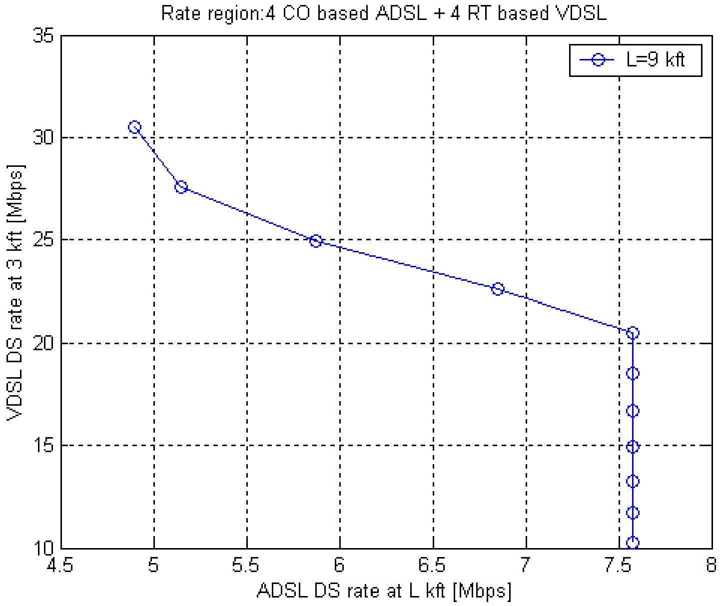


Figure 4: Rate region for 4 RT based VDSL and 4 CO based ADSL. Uncoded systems. L=9kft, L1=3 kft.

To better understand the superiority of the pre-coordinated DFDM algorithm we now check the crosstalk environment for the 9 kft case. Figure 5 presents the signal and noise as received by the CPE of both ADSL and VDSL systems, as well as signal to noise ratio. We can see that the VDSL modem observes a very high SNR in the region below 1.1 MHz. Moreover no matter how much power the ADSL receiver will allocate in this band, it will not be able to keep the VDSL modem out of any part of this band. Therefore the FDM solution is not a stable Nash equilibrium point even though it is better for both players. This is much like the “prisoners dilema” in game theory where the only stable equilibrium is bad for both players. Hence the iterative water-filling algorithm which converges (if it converge) to the Nash equilibrium is highly suboptimal in this case. It clearly suggest that dynamic FDM, where the multiplexing point is chosen dynamically according to the DFDM algorithm is preferable.

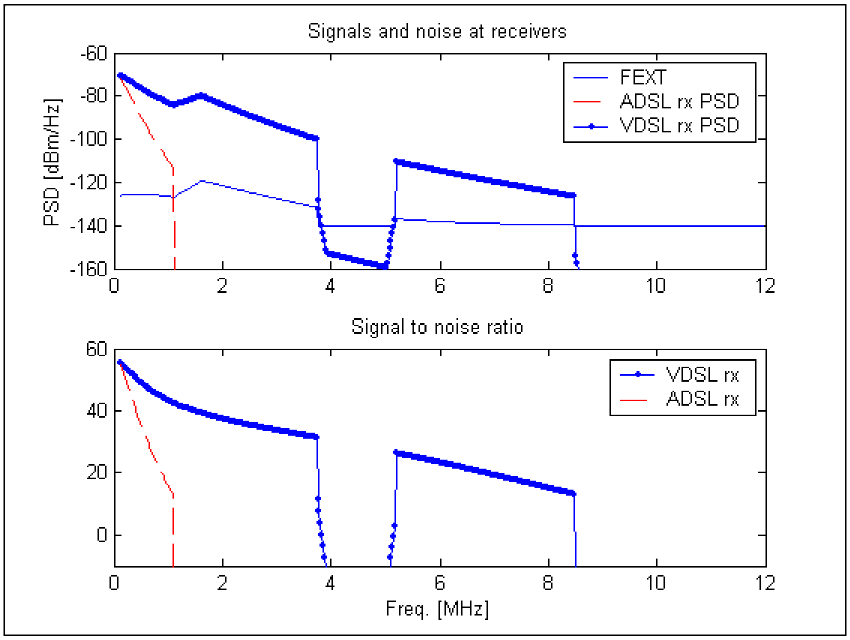
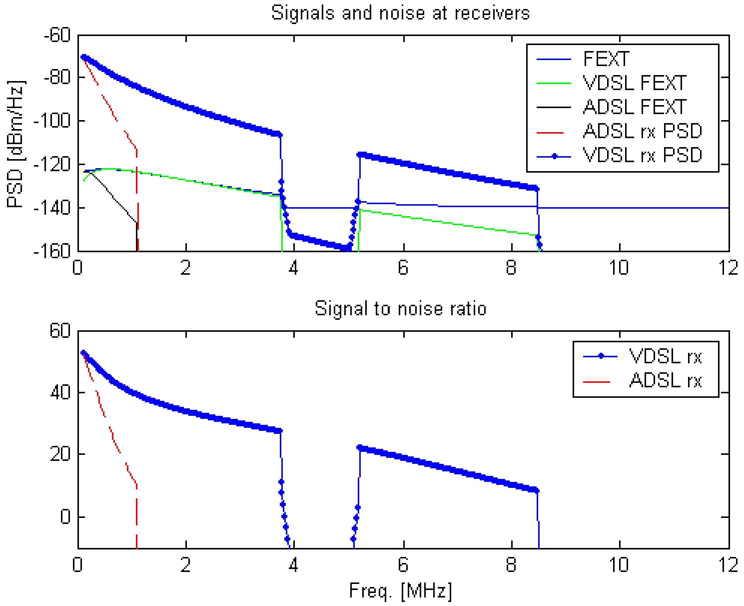


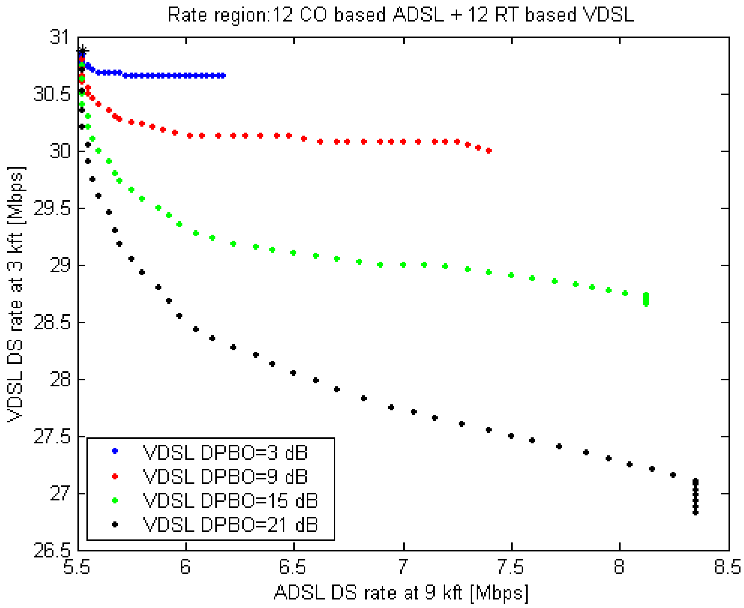
Figure 5: Signals and noise at receivers.

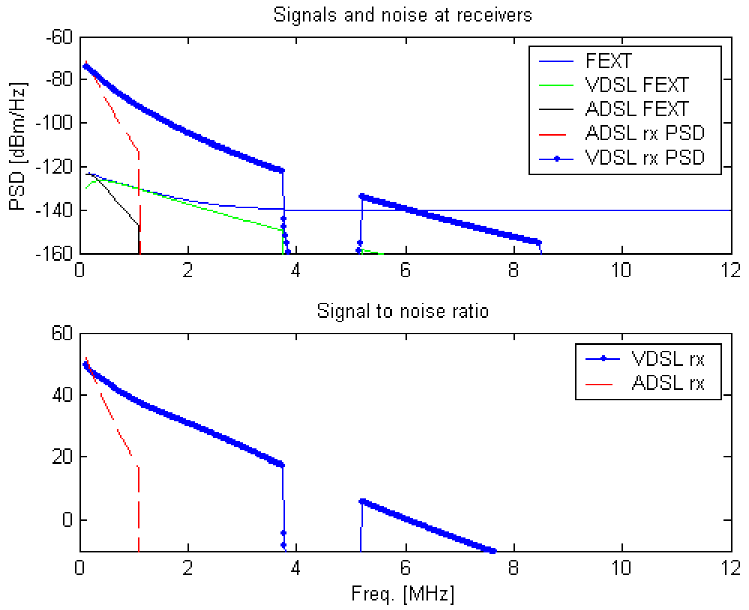
Below we provided further simulation scenarios to support the performance of the DFDM algorithm. We note that unlike iterative algorithms, the complexity of the DFDM algorithm does not scale up with number of pairs in the binder

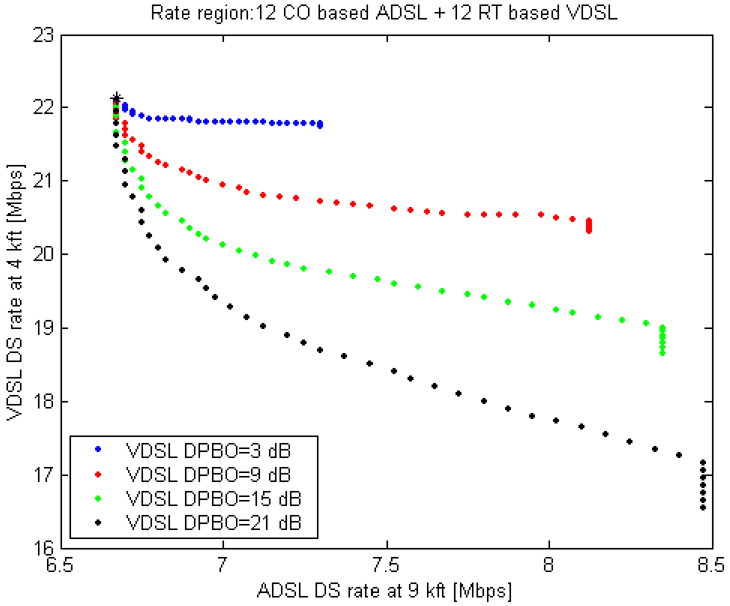
4 Dynamic power back-off for RT-VDSL and CO-ADSL

In this section we elaborate the dynamic FDM to obtain a simple power back-off technique that enables even better co-existence for remote deployment with CO deployment. Surprisingly the rate-region for this algorithm is even better than the dynamic FDM. The dynamic power back-off includes one more parameter beyond f_b. It is P_b the amount of flat power back-off performed at frequencies below f_b. The remote terminal backs-off its power at frequencies below f_b by P_b dB compared to the nominal PSD mask.


Signals and noise at receivers
PSD [dBm/Hz]
-60
-80
-100
-120
-140
-160
0
2
4
6
8
10
12
FEXT
VDSL FEXT
ADSL FEXT
ADSL rx PSD
VDSL rx PSD
Signal to noise ratio
60
40
20
0
VDSL rx
ADSL rx
Freq. [MHz]


Rate region:12 CO based ADSL + 12 RT based VDSL
VDSL DS rate at 3 kft [Mbps]
31
30.5
30
29.5
29
28.5
28
27.5
27
26.5
5.5
6
6.5
7
7.5
8
8.5
ADSL DS rate at 9 kft [Mbps]
VDSL DPBO=3 dB
VDSL DPBO=9 dB
VDSL DPBO=15 dB
VDSL DPBO=21 dB





5 Conclusions

In this paper we have provided an alternative to the IW algorithm. The proposed algorithm relies on a-priori agreement to prefer dynamic FDM allocation on between CO and RT. This is done by enforcing the RT to prefer higher frequencies and reduce excess margin. The algorithm has rate region which is very competitive to the IW algorithm. We have shown that such a solution cannot be a stable point of the IW algorithm at under many real life deployment scenarios. Due to its deterministic nature it can be proved to comply with T1-417 at all steps of operation. The solution also avoids possible non-stationarity issues related to the IW algorithm. Finally we have demonstrated that a simple power back-off mechanism can greatly relax the requirements of the DFDM thus enabling better RT performance with minor effect on CO based deployment.

6 Proposal

1. Add the DFDM and the dynamic power backoff description to informative annex A (Algorithms for QAM based VDSL).
2. Agree to define optional MIB functions that enable QAM-VDSL to support DSM.

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