Dynamic Spectrum Management for Upstream Mixtures of Vectored & Non-Vectored DSL

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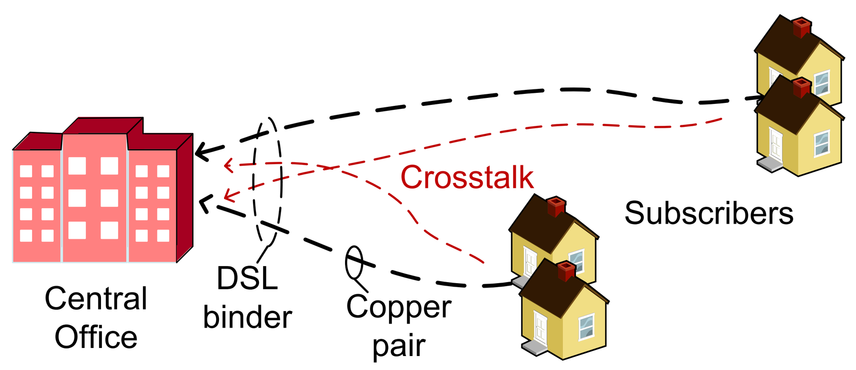
Introduction

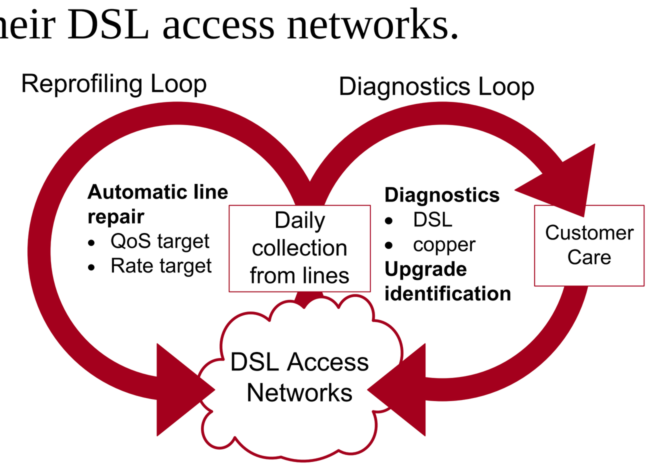
- Next-generation home networks will demand broadband connections with high data-rates for video-streaming, gaming,web-conferencing etc.
- 70% of broadband connections are Digital Subscriber Lines (DSL).



- Current DSL systems (non-vectored) are crosstalk-limited and they treat crosstalk (interference) as noise.
- Vectored DSL systems cancel crosstalk and push the data-rates to more than 100 Mbps.
- As field trials and initial deployments of vectored DSL materialize in the next few years, vectored DSL will often co-exist with non-vectored DSL sharing the same DSL binder.
- This work proposes Dynamic Spectrum Management (DSM) algorithms for upstream mixtures of vectored and non-vectored DSL to avoid crosstalk from vectored DSL into non-vectored DSL.

Dynamic Spectrum Management

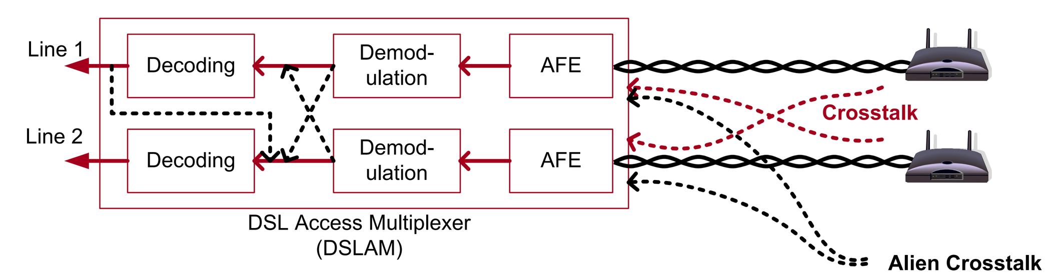
Dynamic Spectrum Management (DSM) enables DSL service providers to automate the management and maintenance of their DSL access networks.



- DSM improves operations cost (OPEX), data rate versus length, and power consumption.
- In Non-Vectored DSL systems (today), the signal processing functions are performed on line-by-line basis at the receiver (DSLAM).
  - To increase line stability (reduce retrains and packet errors), manage each line (DSM Level 1).
  - To minimize crosstalk (increase data-rates and power savings), use power control (DSM Level 2).
  - DSM Level 2 algorithms to optimize transmit power spectra – Iterative Water-filling(IWF) [3], Multi-level Water-filling (MLWF) [4], Optimal Spectrum Balancing(OSB) [5].

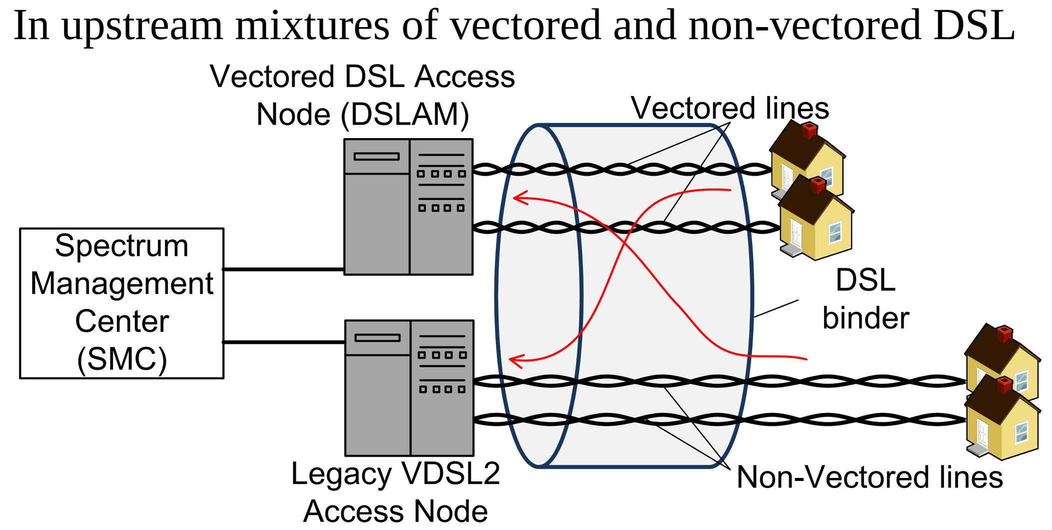
Vectored DSL

- In Vectored DSL systems, the signal processing functions are performed jointly among a group of lines at the receiver (DSLAM). This can completely eliminate crosstalk (DSM level 3).



Problem Statement

In upstream mixtures of vectored and non-vectored DSL



- Vectored lines cancel crosstalk from other vectored and non-vectored lines.
- But, non-vectored lines suffer from large crosstalk from the vectored lines running at very high data-rates *especially when the vectored lines are short and the non-vectored lines are long.*
- Existing DSM algorithms optimize the vectored DSL system and the non-vectored DSL system independently (MixIWF), but they do not reduce crosstalk from one system into another.
- We propose two DSM algorithms for reducing the crosstalk in mixed-binder scenarios - MixOSB and MixMLWF.

Problem Formulation

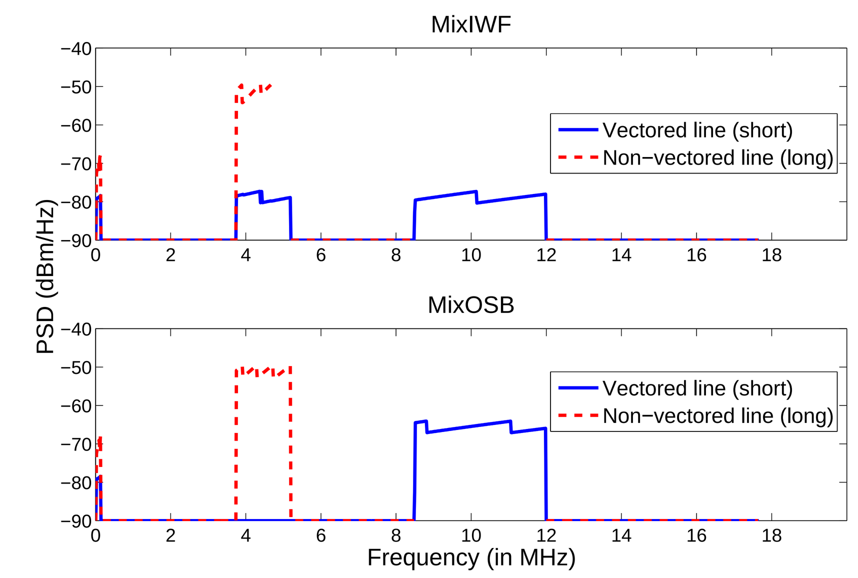
To reduce the crosstalk from vectored lines to non-vectored lines in upstream mixtures, we jointly optimize the transmit power spectra with the following objectives

- Maximize the weighted sum-rate of non-vectored lines
- Meet the target-rate constraints of vectored lines
- Include practical limitations (PSD mask, total power constraint & bitcap constraint)

The joint optimization problem is not convex. MixOSB solves the problem globally and optimally using lagrange dual decomposition and exhaustive search with exponential complexity.

Comparison

- 2 vectored lines (300m), 1 non-vectored line (1200m)

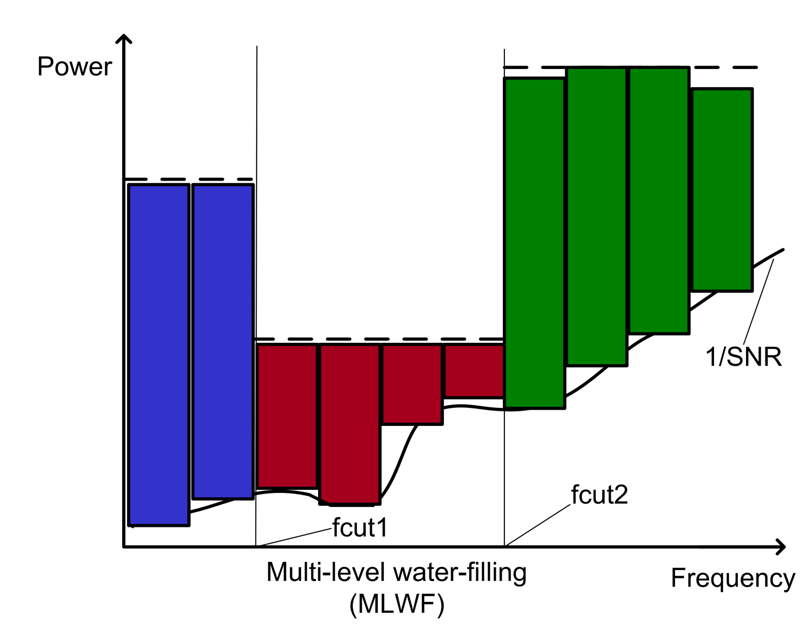


Here target-rate of vectored lines is 40 Mbps, and the data-rate of the long non-vectored line is 2.68 Mbps for MixIWF and 6.25 Mbps for MixOSB.

- MixOSB achieves higher throughputs than MixIWF because it exploits channel structure.
  - Strong vectored-line (short) uses higher frequencies.
  - Avoids interfering with weak non-vectored line (long) at low frequencies.
- MixOSB – centralized, high complexity, optimal
- MixIWF – distributed, low complexity, sub-optimal
- Similar to near-far scenarios in non-vectored DSL.

MixMLWF

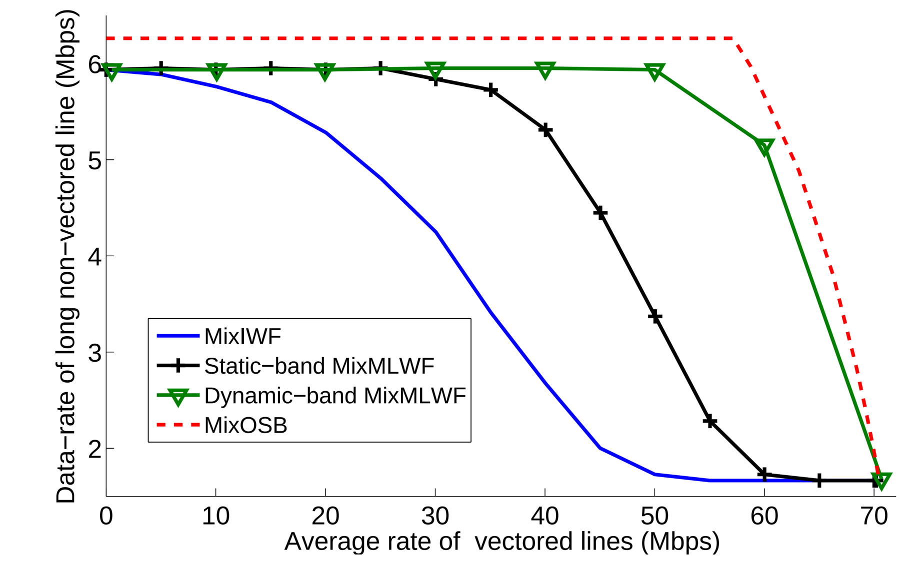
MixMLWF is a distributed DSM algorithm with near-optimal performance and low complexity.



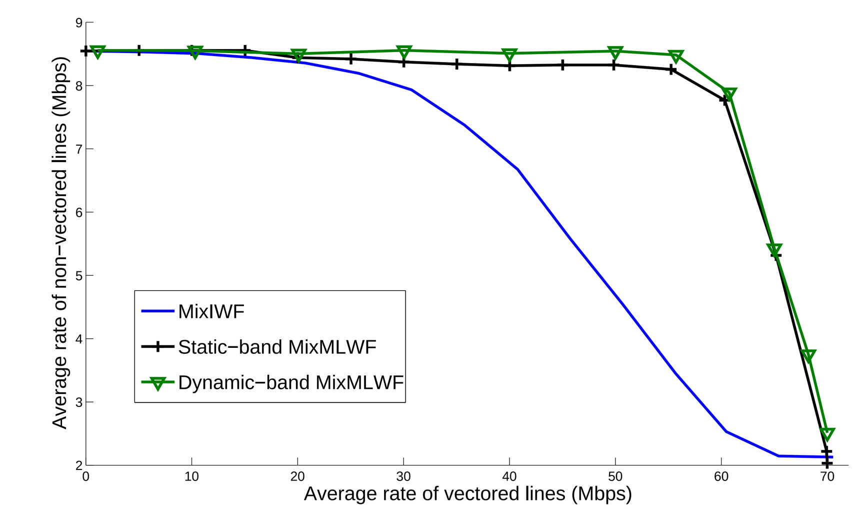
- Vectored line moves bits from frequency-band with lower preference (where they emit higher interference) to the band with higher preference (higher frequencies) until it violates the PSD mask or the power constraint.
- Two cut-off frequencies results in three bands. In dynamic-band MixMLWF, SMC searches for the optimal set of cut-off frequencies (gradient search), while in static-band MixMLWF, three upstream bands are used.

Simulation Results

- 2 vectored lines (300m), 1 non-vectored line (1200m)



- 3 vectored lines (200m), 3 non-vectored lines (1000m)



VDSL upstream bands US0 (25kHz–138kHz), US1 (3.75 MHz–5.2 MHz), and US2 (8.5 MHz–12MHz) are used.

Conclusions

- Vectored DSL brings copper pairs to the 100 Mbps performance region. Proper management will bring out the full benefits of the technology while maintaining the performance of the current DSL systems.
- In mixed-binders with short vectored DSL lines and longer non-vectored DSL lines, the crosstalk induced by vectored lines on non-vectored lines at an SMC needs to be managed using DSM algorithms.

References

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