

xDSL crosstalk cancellation

Technology potentials derived from measurements
on a VDSL2-vectored system

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Outline

- **Vectoring**
 - Definition and status.
- **Prototype and setup**
- **Performances**
 - Co-located topology
 - Distributed topology
- **System level vectoring**
- **Conclusions**

- **Vectoring**

- Cancelling of upstream and downstream crosstalk through
 - Coordination of lines in the binder.
 - Bulk signal processing done at the VTU-O side (CO).
 - Back-channel from VTU-R to VTU-O is required for downstream cancellation.
- ITU-T scope is narrowed down to self-FEXT cancelling
 - Considered as the worst case disturbers at high frequency
- Alien crosstalk may also be partially cancelled but
 - Only applicable to “multi-receiver” product (typically not residential CPEs)
 - Cancellation performance highly variable and function of :
 - Number of available receivers
 - Crosstalk signal characteristics

- **‘MIMO’ = vectoring + bonding**

- **Expected (self-FEXT cancelling) gain**

- Performances near from “self-FEXT”-free environment

- **Status**

- G.993.5 (G.vector), now in AAP process in ITU-T.
- Expected approval beginning of 2010.

Vectoring Prototype

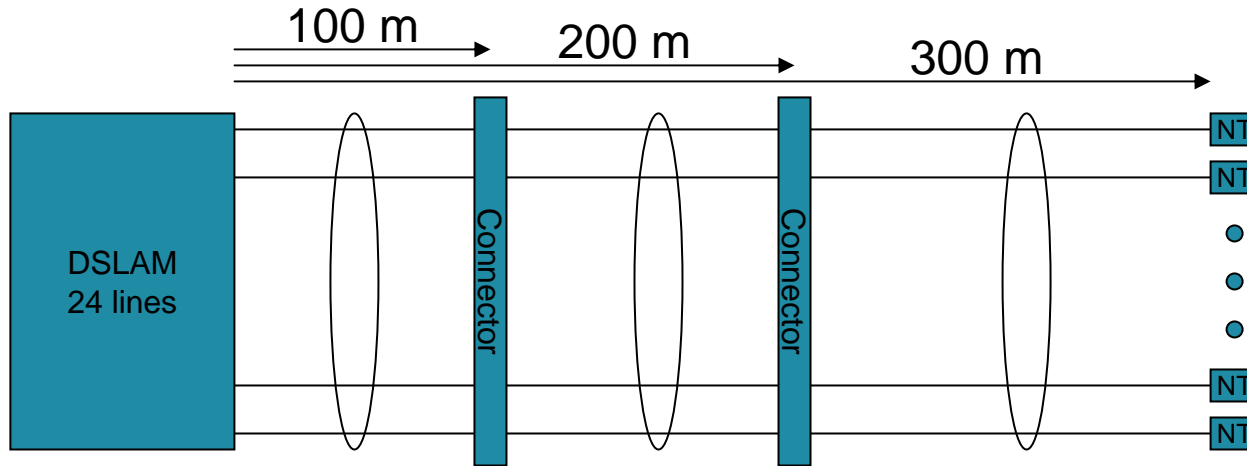
Characteristics



- Based on a standard VDSL2 profile 17a reference design
- Up to 24 Self-FEXT cancelled
 - Simultaneously in both upstream and downstream directions.
- Implemented protocol was close to ITU G.vector definition
 - Sync symbols modulated with pilot sequence in upstream and downstream direction.
 - Back channel from CO to CPE with reduced precision.

Co-located topology

Setup overview



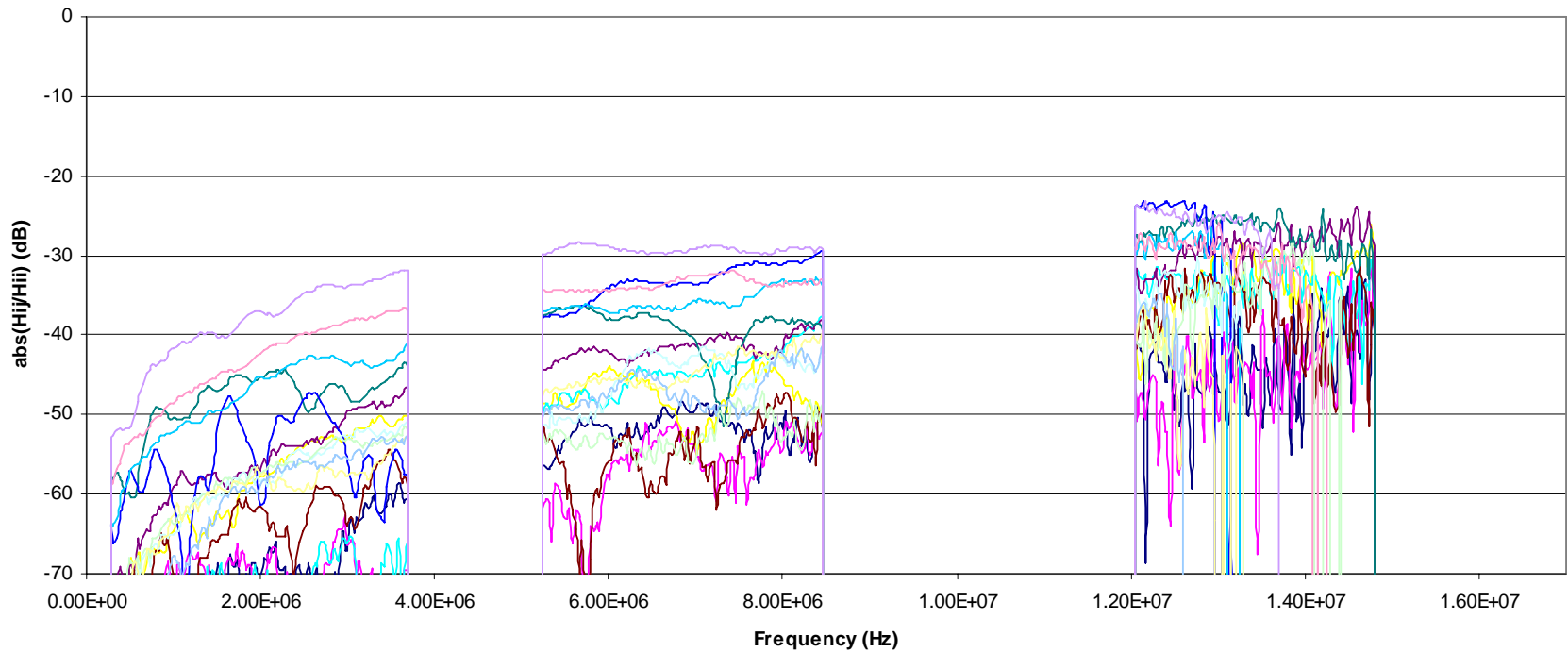
- **Distributed topology**
 - 16 NTs@300m.
 - Commercial PE cable 0.4mm.
- **Configuration**
 - 17a profile, A-EU-32, 6dB margin, concatenated gains
- **Connectors are present in the loop at 100m and 200m.**
 - They generate additional/parasitic crosstalk.

Co-located topology

Example of Downstream crosstalk channels (300m loop)



Downstream crosstalk channel normalized by direct channel



● Observations

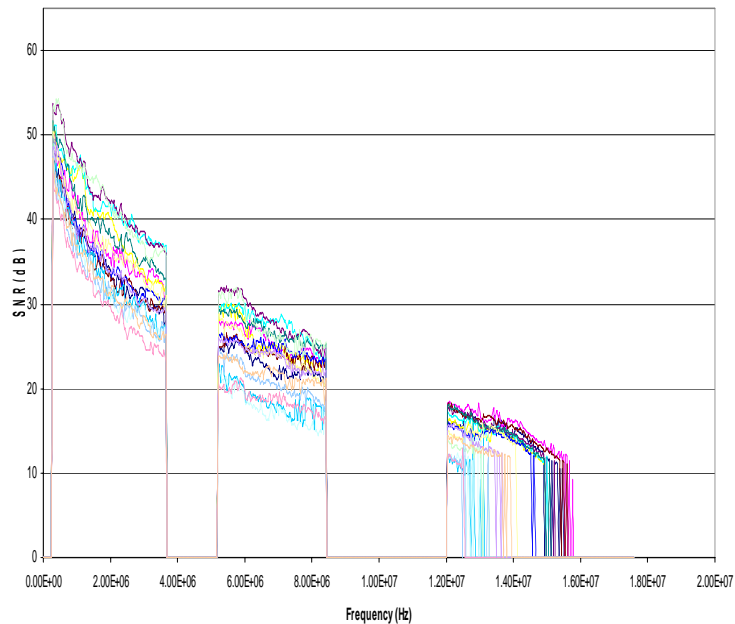
- Set of dominant crosstalkers varies with frequency ...
- Need 8 or more lines to reduce crosstalk significantly ...
- Lines with smaller crosstalk levels have a significant contribution once summed together ...

Co-located topology

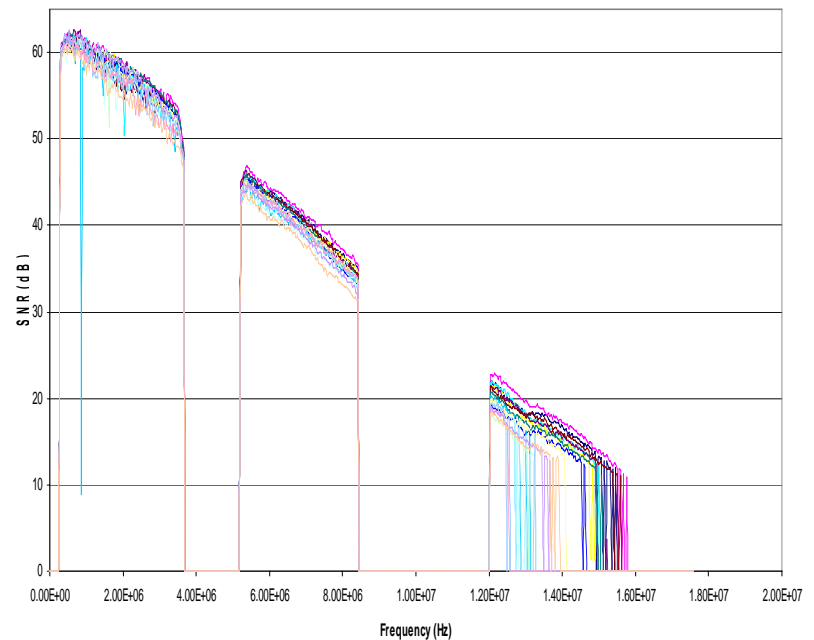
Example of SNR gain

- SNR approaching no crosstalk limit

Without crosstalk cancelling

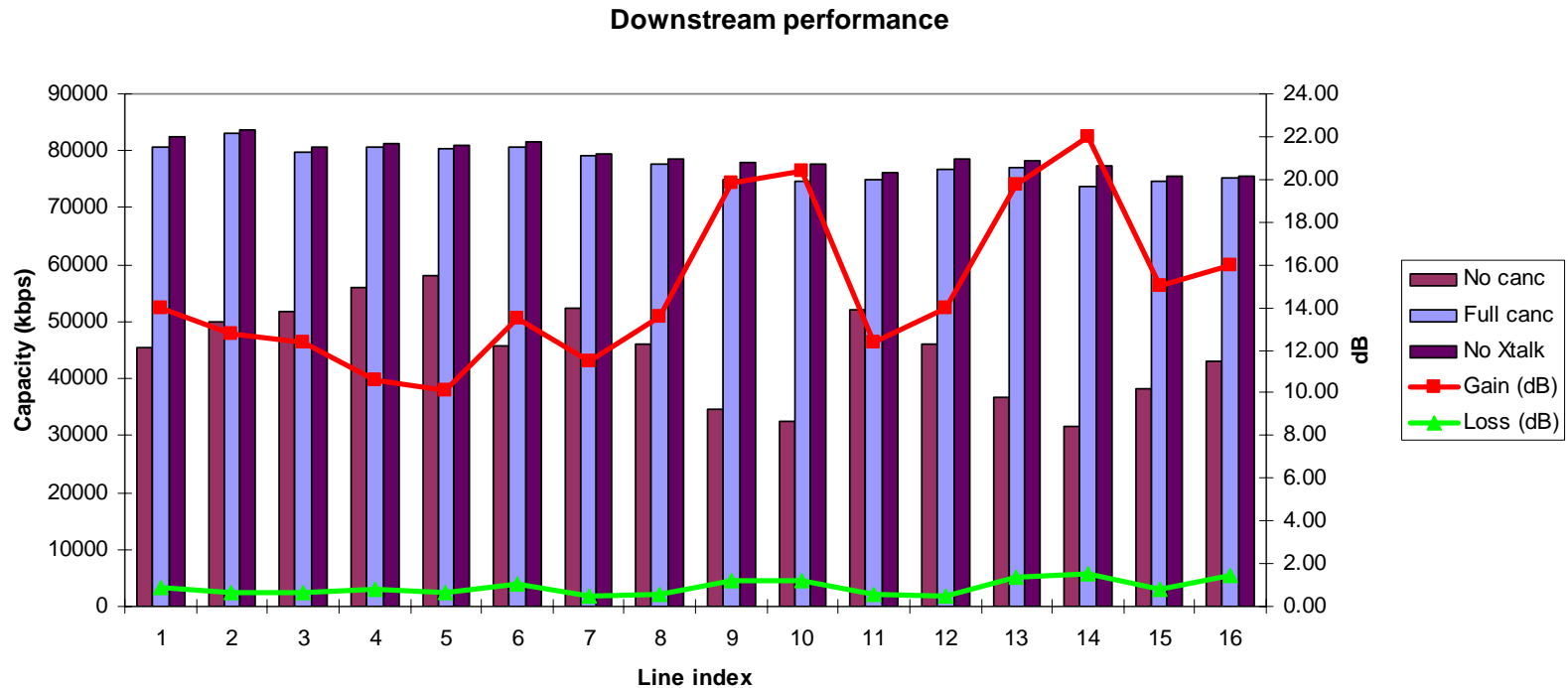


With crosstalk cancelling



Co-located topology

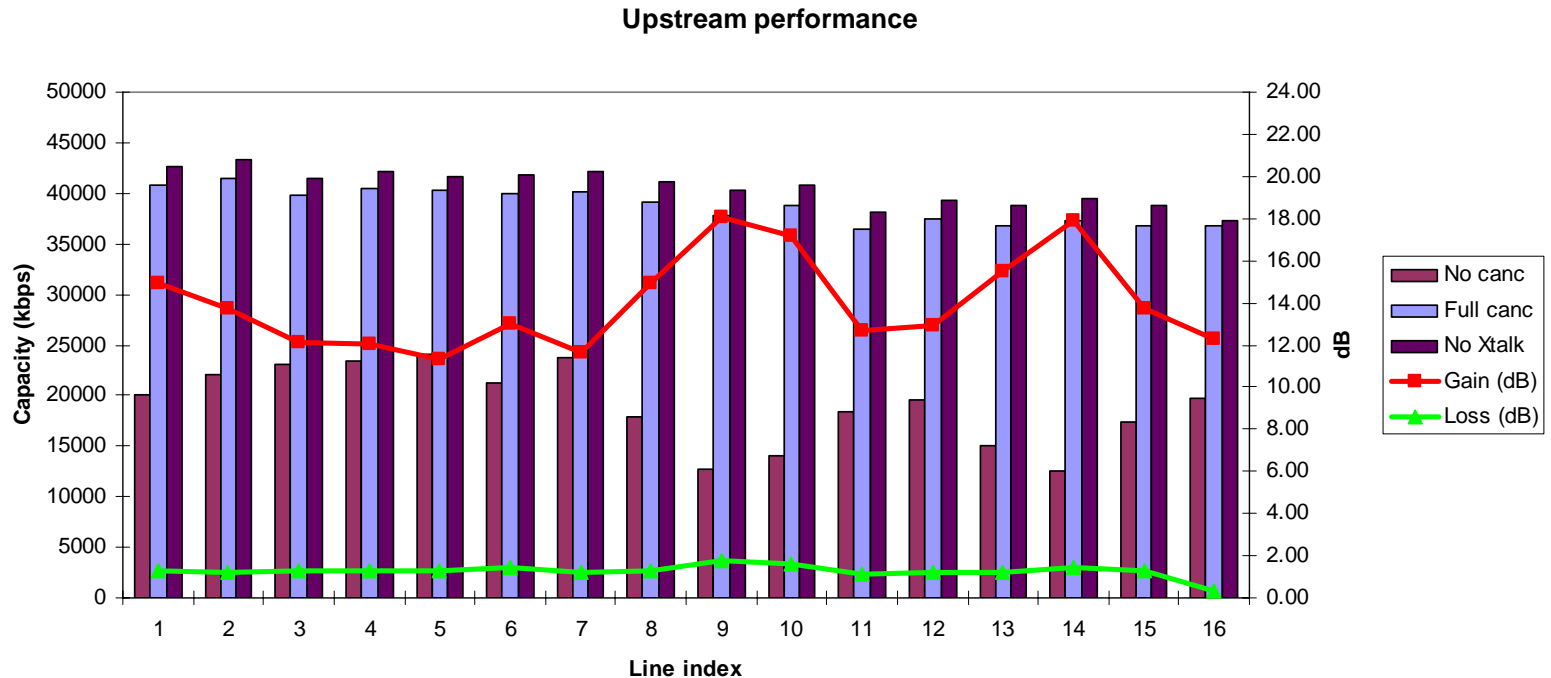
Downstream performances



- Gain (dB) is the mean gain of SNR in dB from no cancelling and to full cancelling on loaded sub-carriers.
- Loss (dB) is the mean loss of SNR in dB from no crosstalk to full cancelling on loaded sub-carriers.

Co-located topology

Upstream performances

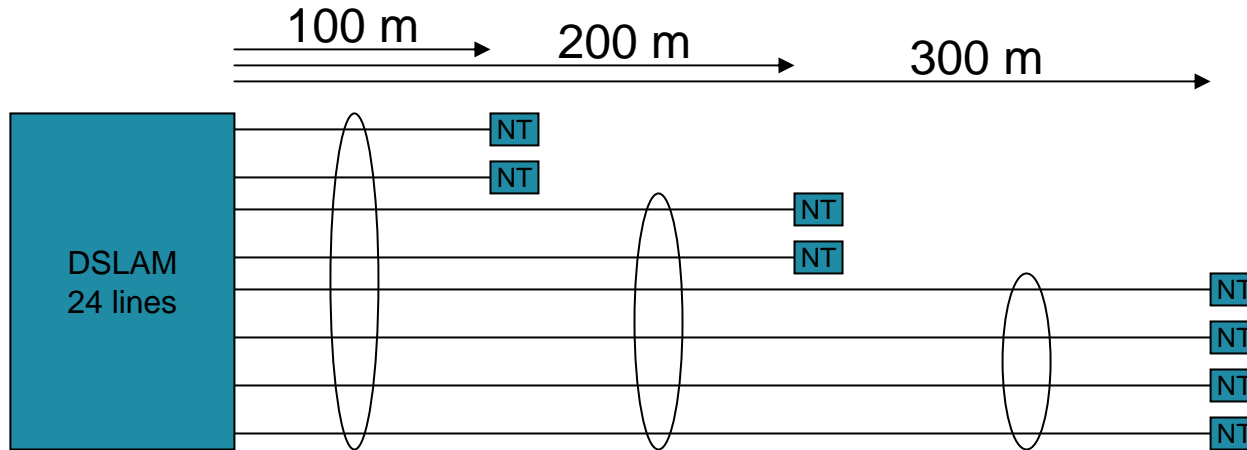


- Performances

- Gain above 10dB and up to 23dB in upstream and downstream directions
- Implementation loss smaller than 2dB (upstream) and 1 dB (downstream).

- Full self-FEXT cancelling at line card level is achievable and very close to theoretical expectations.

Distributed topology



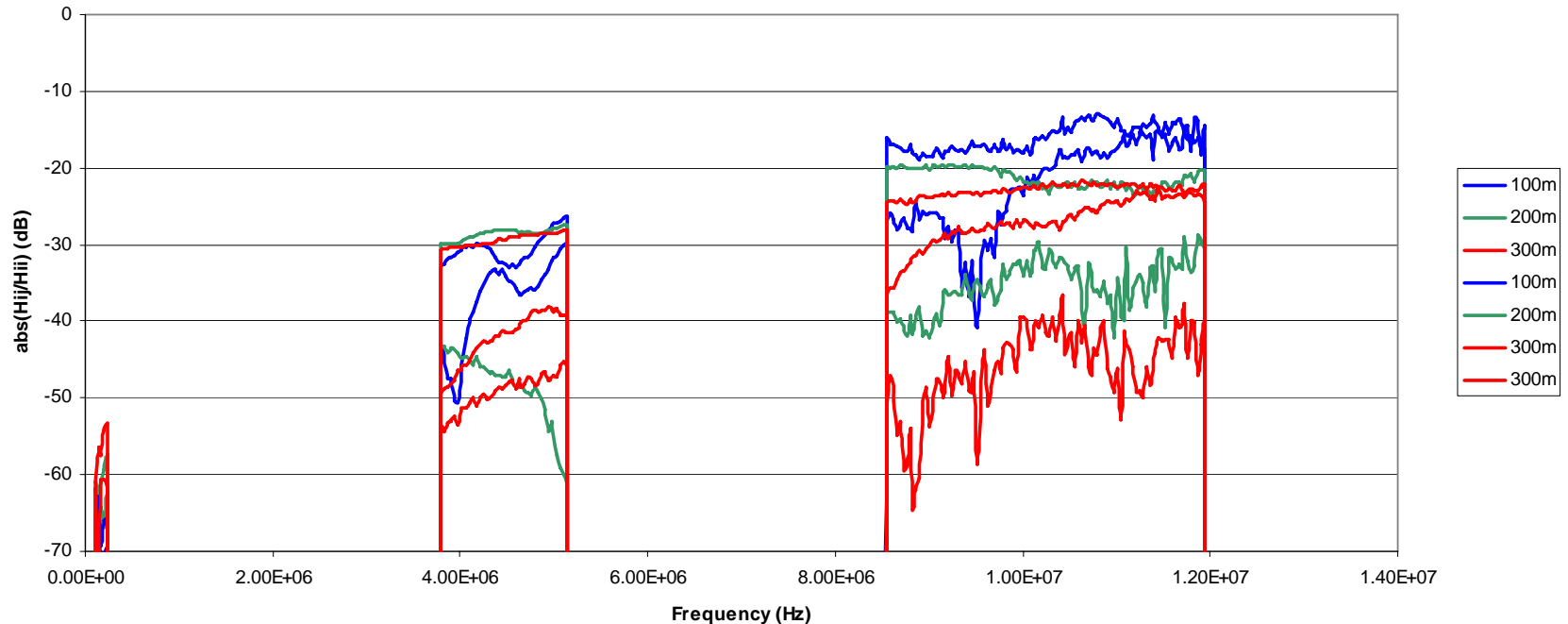
- **Distributed topology**
 - 2 NTs@100m, 2NTs@200m, 4NTs@300m.
 - Commercial PE cable 0.4mm.
- **Configuration**
 - 17a profile, A-EU-32, 6dB margin, concatenated gains
- **Connectors are present in the loop at 100m and 200m.**
 - They generate additional/parasitic crosstalk.

Distributed Topology

Example of upstream crosstalk channel (300m)



Upstream crosstalk channels normalized by direct channel



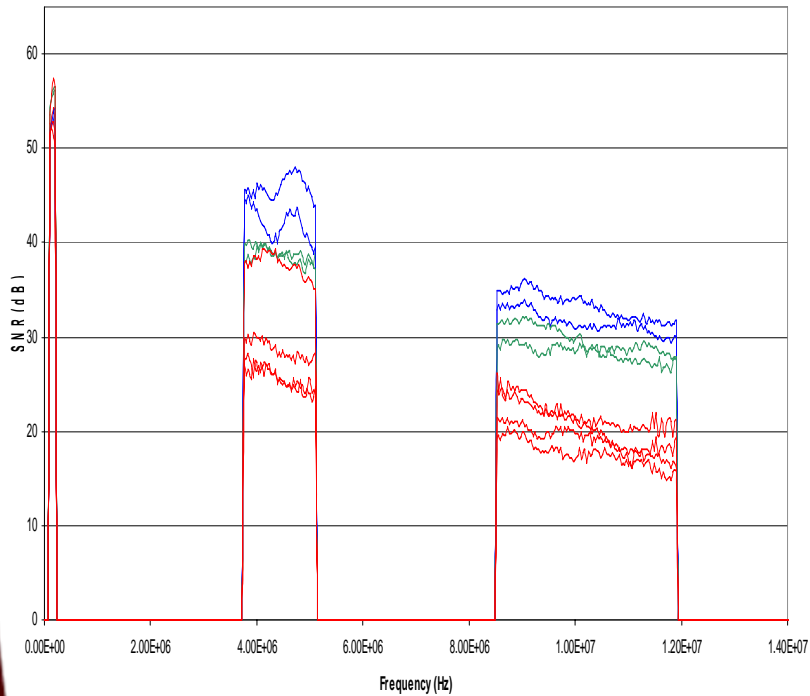
- At high frequency, crosstalk of short lines are significantly higher due to the near-end FEXT effect
- Near-end FEXT effect is usually mitigated by upstream power back-off.

Distributed Topology

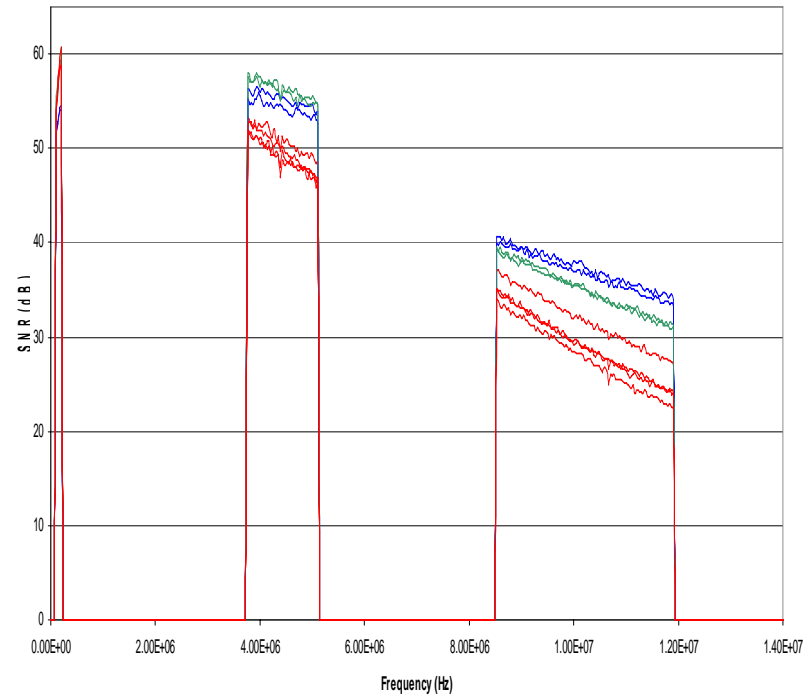
Example of SNR gain in upstream (UPBO)

- SNR approaching no crosstalk limit

Without vectoring

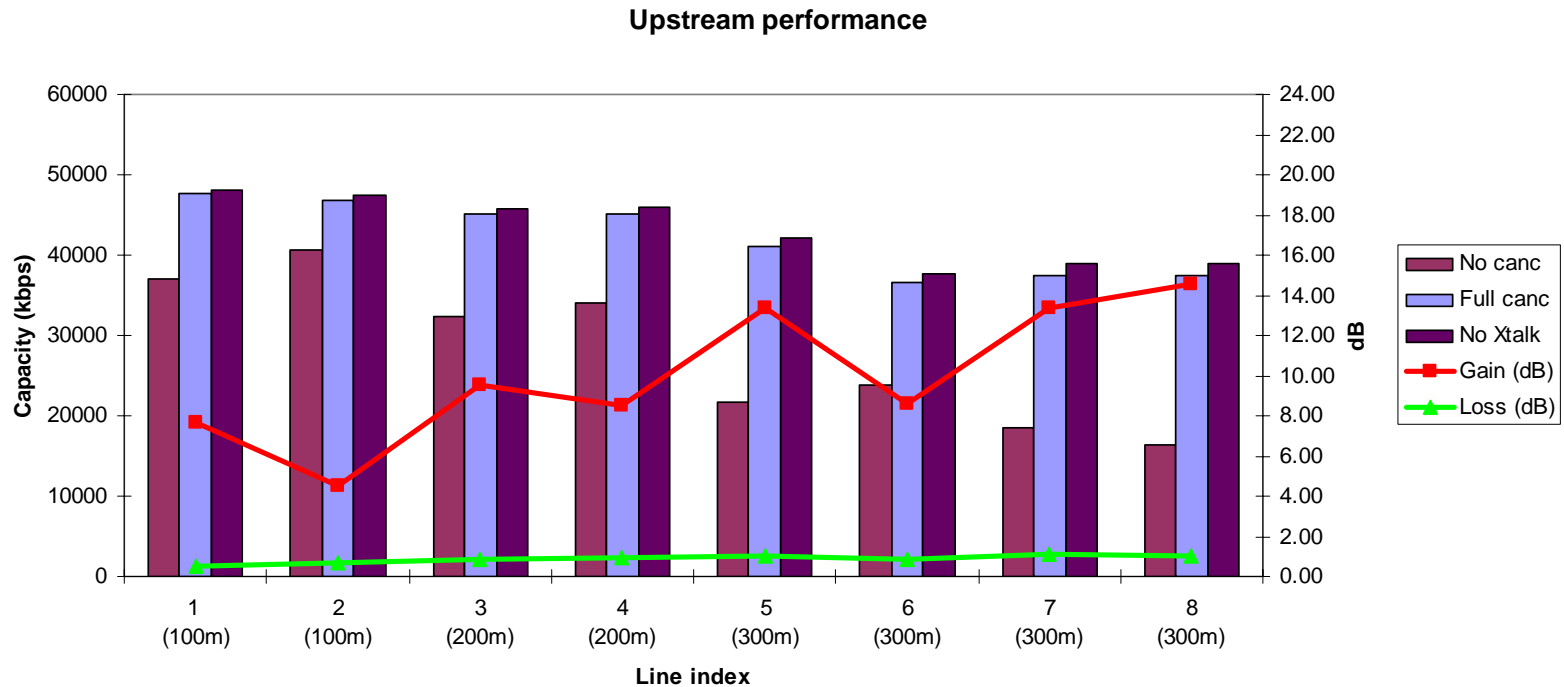


With vectoring



Distributed topology

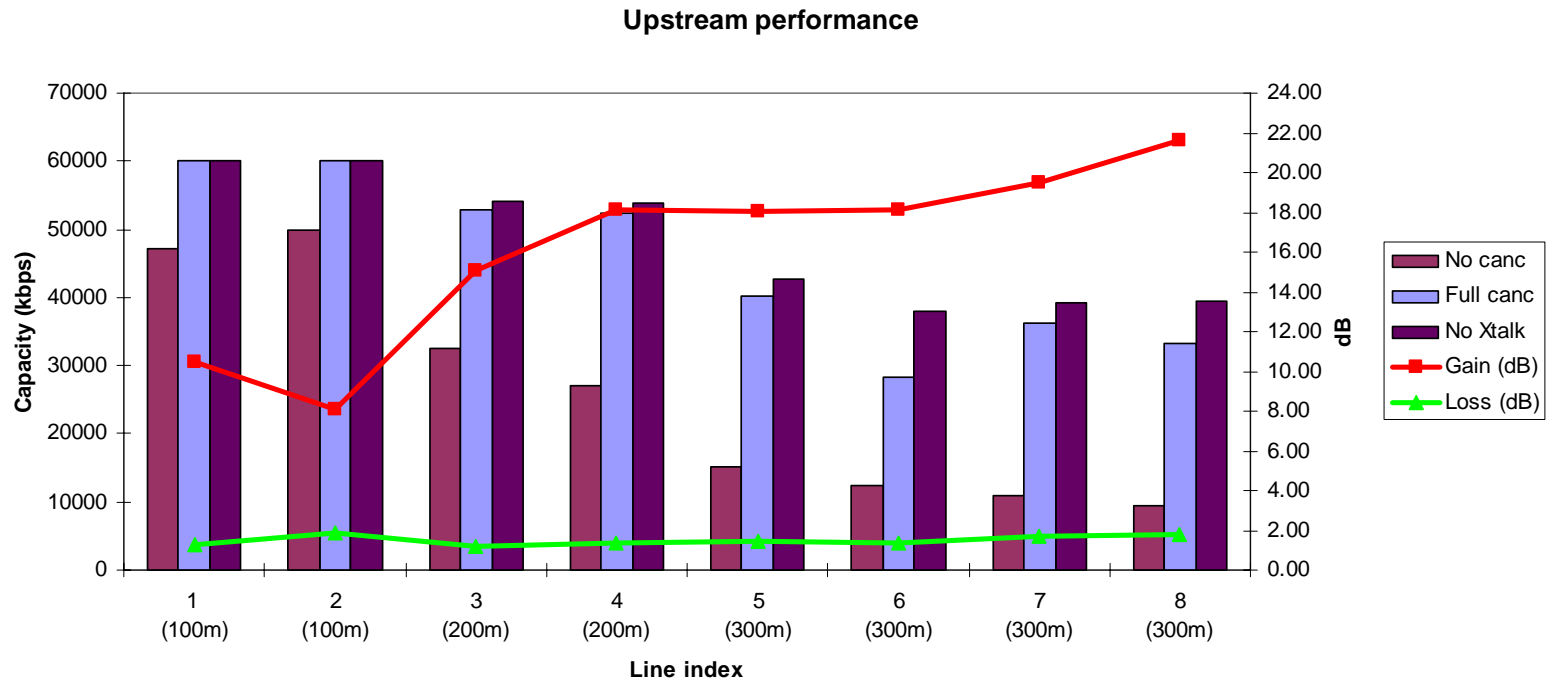
Upstream performance (UPBO)



- Performance similar to the centralized cases.
 - Gains between 6 and 16dB. Higher on longer loops.
 - Implementation loss smaller than 2 dB.

Distributed topology

Upstream performance (No UPBO)



- Gains of Vectoring increases with the loop length
 - Near FEXT effects that are not compensate by the UPBO.
- A large dynamic range between the FEXT and signal must be handled.

System level vectoring

Requirements



- **Definition**

- System level vectoring consists of a DSLAM system where:
 - The binder size is larger than the line density of a single xDSL line card
 - 'Vectoring' can be performed between lines of different xDSL line cards.

- **Potential issues**

- Crosstalk cancellation at system level requires access to all lines
- Very high speed interface are required to exchange data between xDSL line cards of a DSLAM
 - Tens of gbps of data are generated from a typical xDSL line card !
 - Exchange of hundredths of gbps is required to implement NxN cancellation on common FFTC cables (e.g. up to 200 lines per binder)

- **Key question**

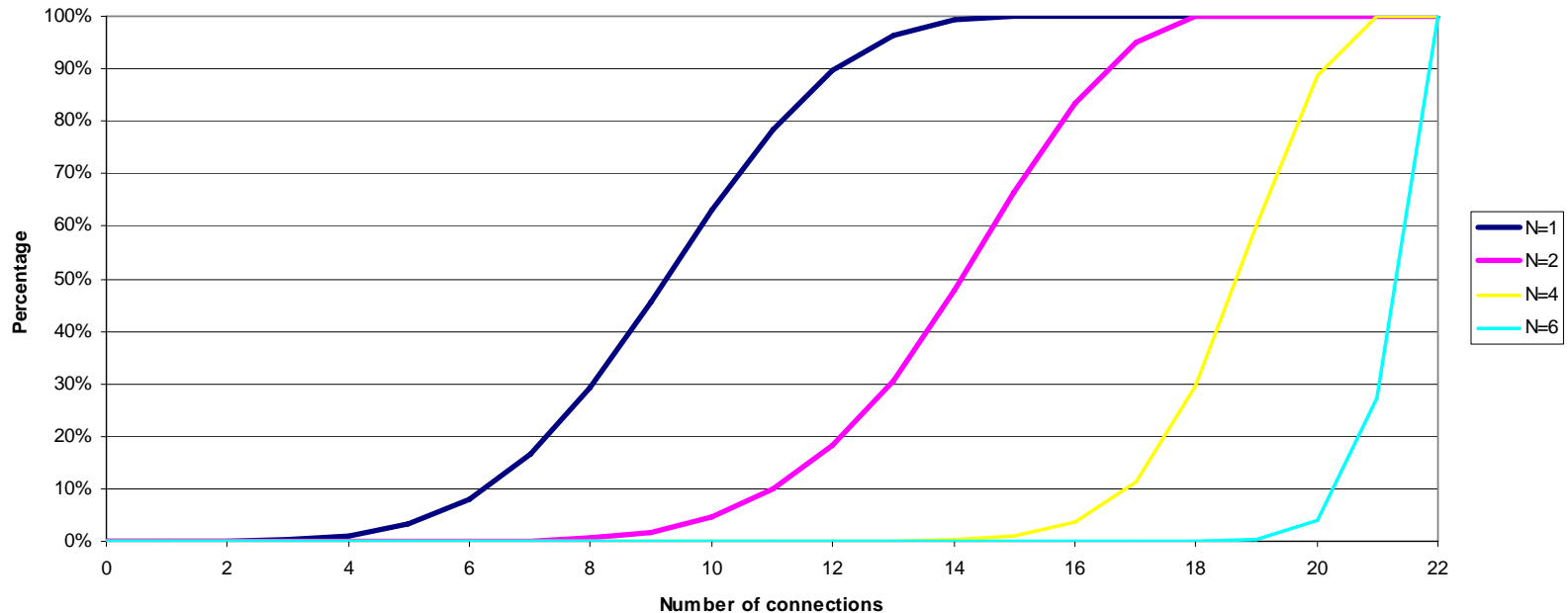
- Assuming each lines of the binder can selectively be routed to a xDSL line card, is it possible to isolate a reduced set of lines causing most of the crosstalk ?

- **If the answer is yes, overall data bandwidth and system complexity can be reduced !**

System level vectoring

Split of 22L system in 2 X 11L

Percentage of combination that requires less than X connections



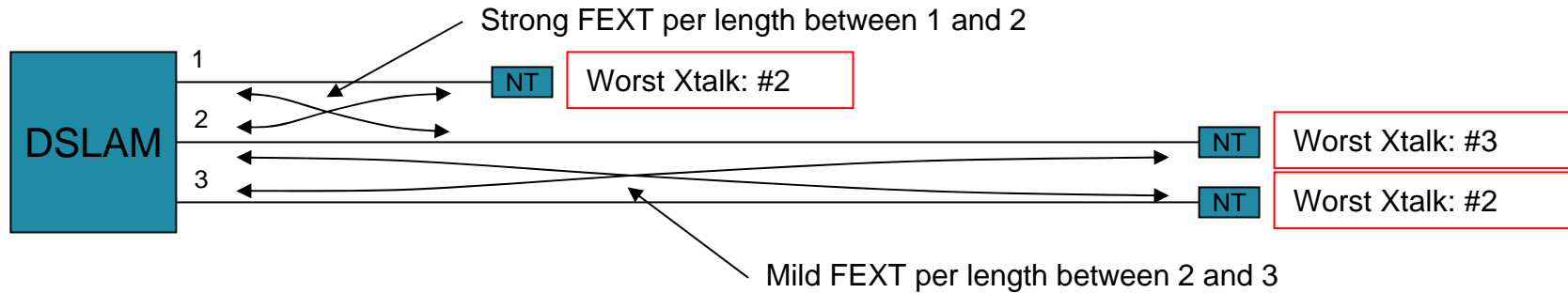
- **Simulations**

- Results based on measurements done on a 500m cable, split in 3 binders.
- An exhaustive search over all combinations of 2 X 11 pairs has been carried over
- For each combination, the number of connection between the two groups has been computed in order to have access to the N worst crosstalkers (N=1, 2, 4, 6).

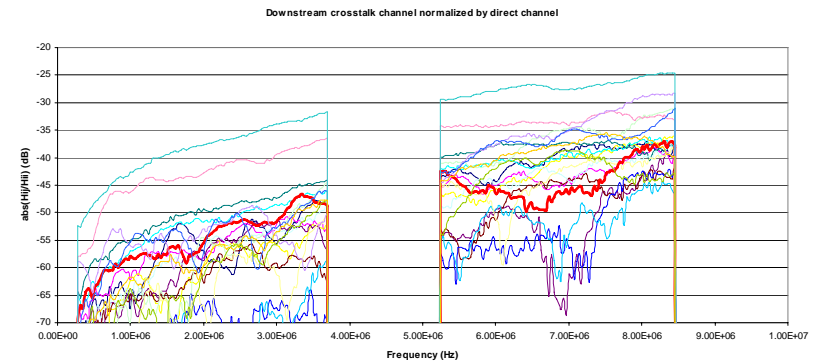
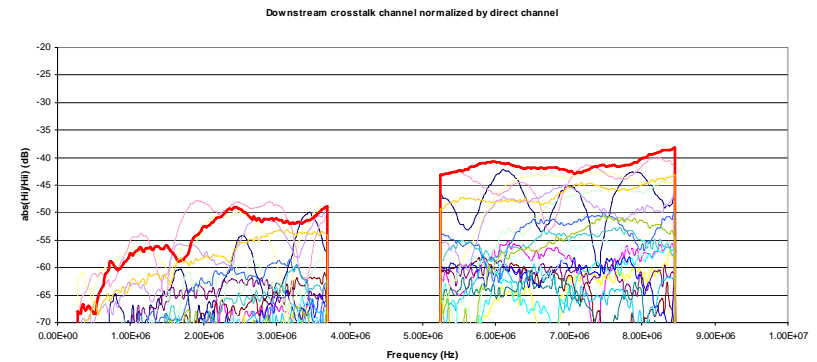
- **Without binder management, all pairs must be accessible by the canceller for each line.**

System level vectoring

Distributed topology



- Crosstalk level is highly impacted by the distribution of loop lengths because the FEXT is coupled on limited segment.
 - The relative ranking of crosstalkers can be highly asymmetrical between two pairs
- Binder management must take this into account in the connections of the pairs.



Conclusions

- **Evaluation of a real vectoring VDSL2 prototype**
 - Near Xtalk-free cancellation is achievable at xDSL Line Card level
 - Loss wrt Xtalk free < 1dB in downstream
 - Loss wrt Xtalk free < 2 dB in upstream
 - Mitigation of upstream crosstalk can lead to no or reduced UPBO requirements
 - Relatively important amount of crosstalkers must be cancelled (more than 8).
- **System level vectoring**
 - Important for high density system > 48L.
 - If binder management is impossible, each lines must have access to all crosstalkers:
 - Requires high speed bus between line cards.
 - Even if binder management is possible, selection of independent subsets is a non-trivial exercise, e.g due to distributed loop length, and probably not realistic