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

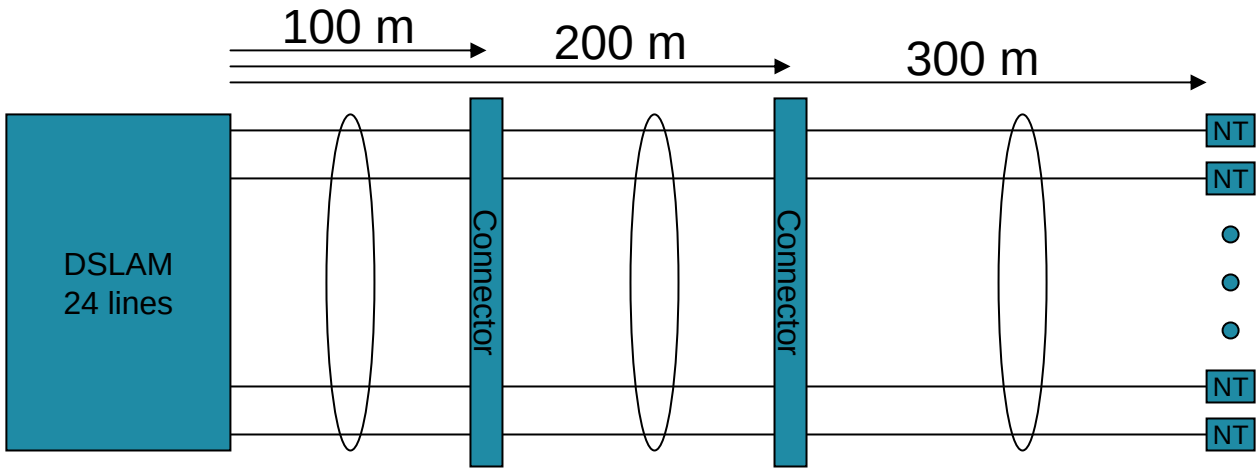
Vectoring
Definitions

- 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

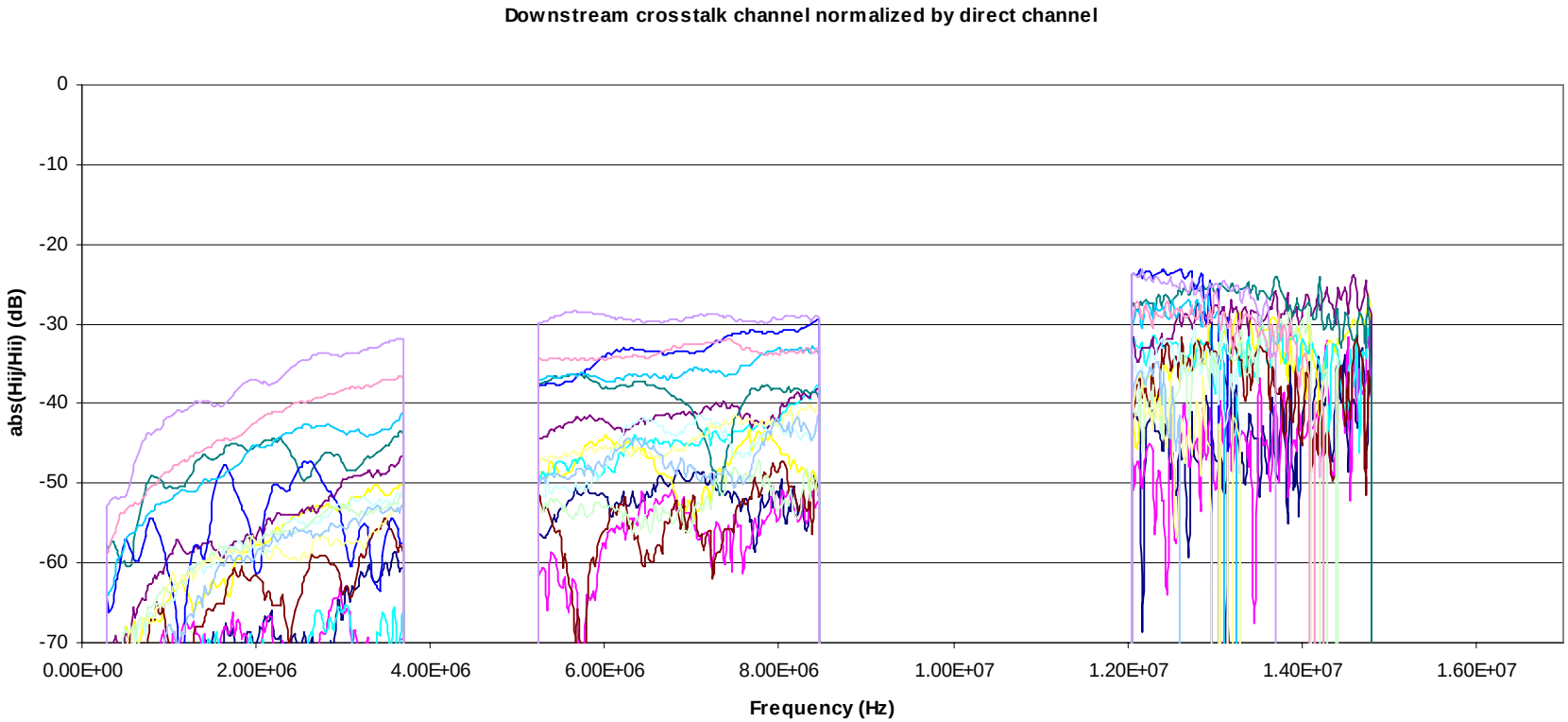
- Based on a standard VDSL2 profile 17a reference design
- Up to 24 Self-FEXT cancelled
  - Simultaneously in both upstream and downstream directions.
- Implemented protocol was close to ITU G.vector definition
  - Sync symbols modulated with pilot sequence in upstream and downstream direction.
  - Back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

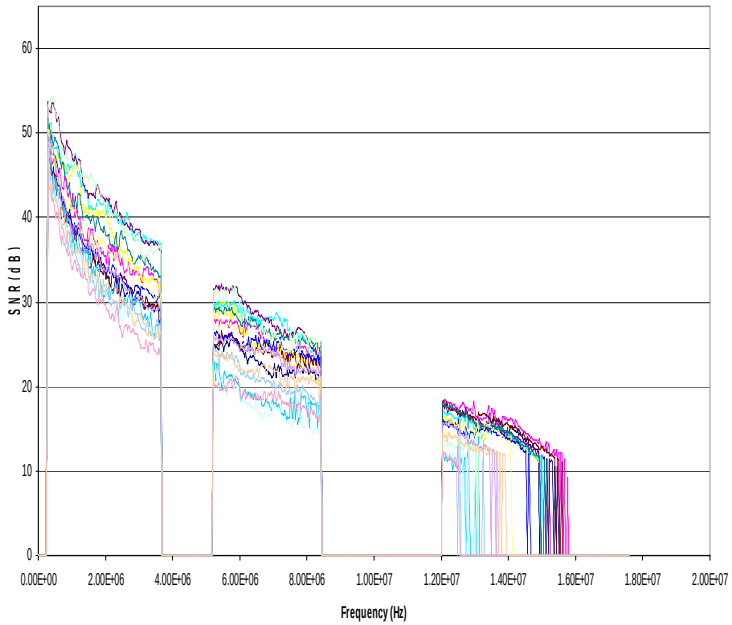


- Observations
  - Set of dominant crosstalkers varies with frequency …
  - Need 8 or more lines to reduce crosstalk significantly …
  - Lines with smaller crosstalk levels have a significant contribution once summed together ...

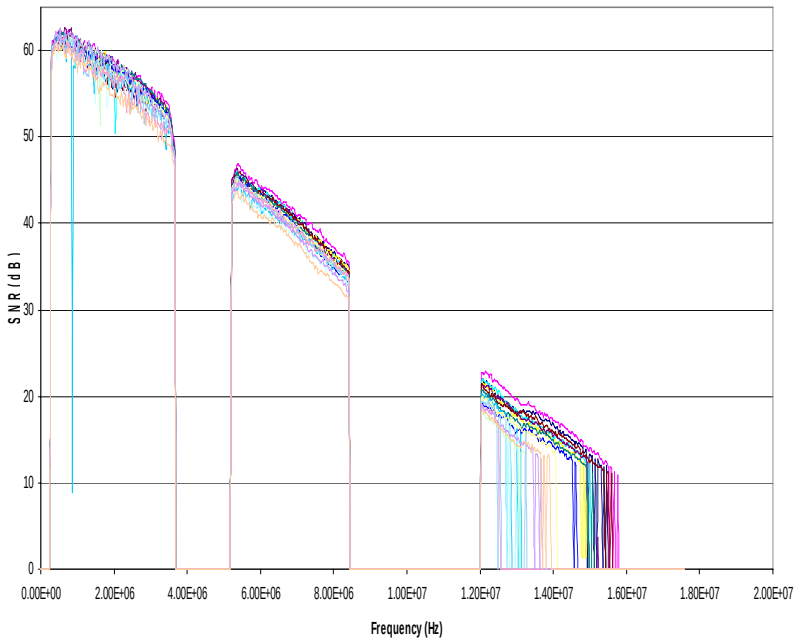
Co-located topology
Example of SNR gain

- SNR approaching no crosstalk limit

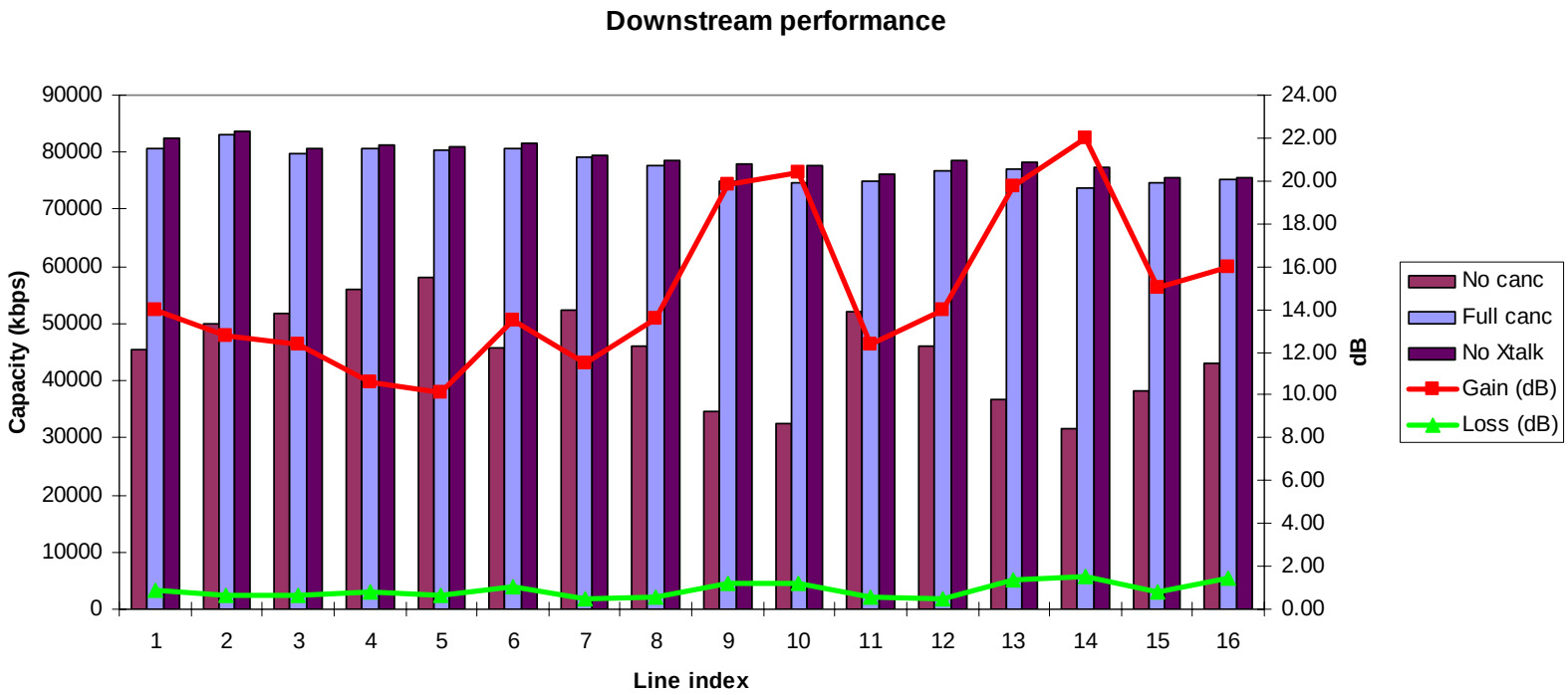
Without crosstalk cancelling



With crosstalk cancelling

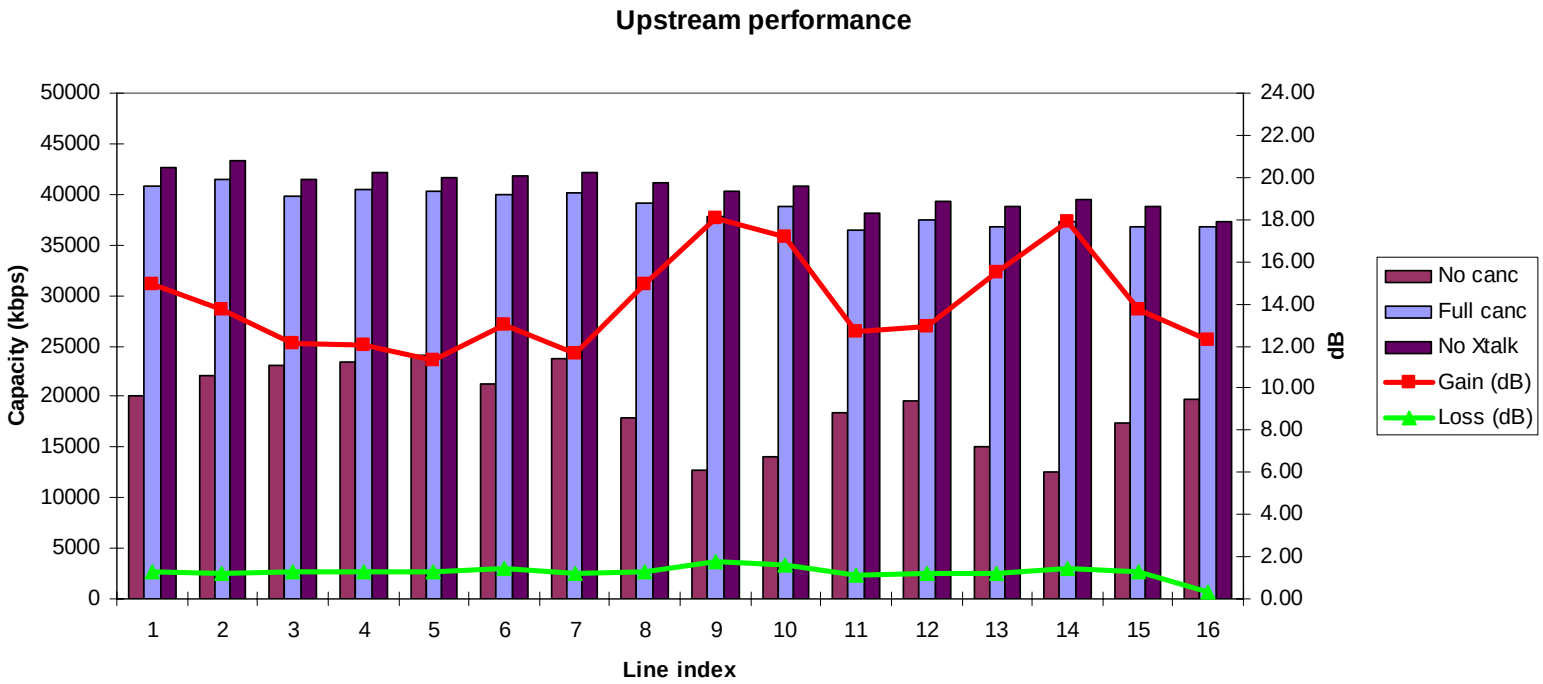


Co-located topology
Downstream performances



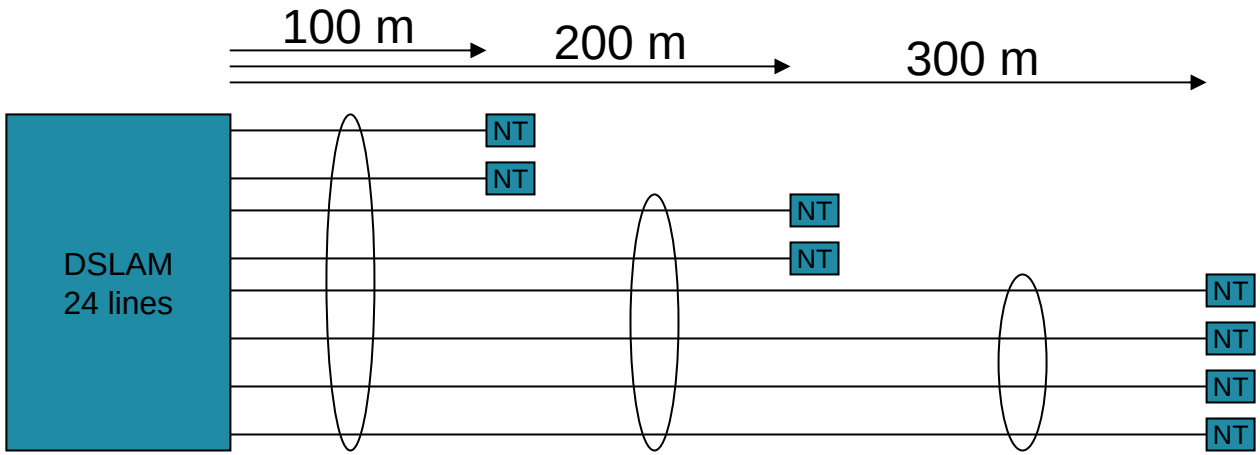
- Gain (dB) is the mean gain of SNR in dB from no cancelling and to full cancelling on loaded sub-carriers.
- Loss (dB) is the mean loss of SNR in dB from no crosstalk to full cancelling on loaded sub-carriers.

Co-located topology
Upstream performances



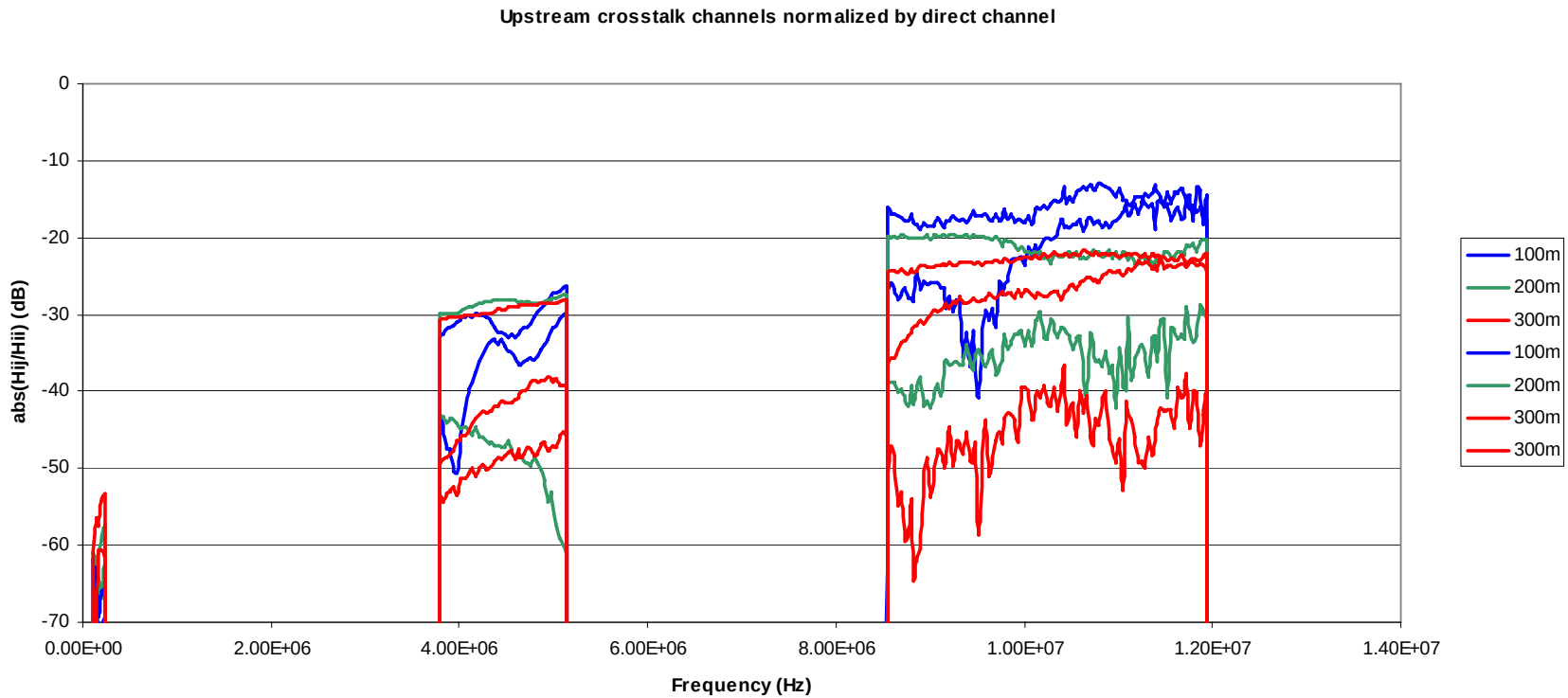
- Performances
  - Gain above 10dB and up to 23dB in upstream and downstream directions
  - Implementation loss smaller than 2dB (upstream) and 1 dB (downstream).
- Full self-FEXT cancelling at line card level is achievable and very close to theoretical expectations.

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)

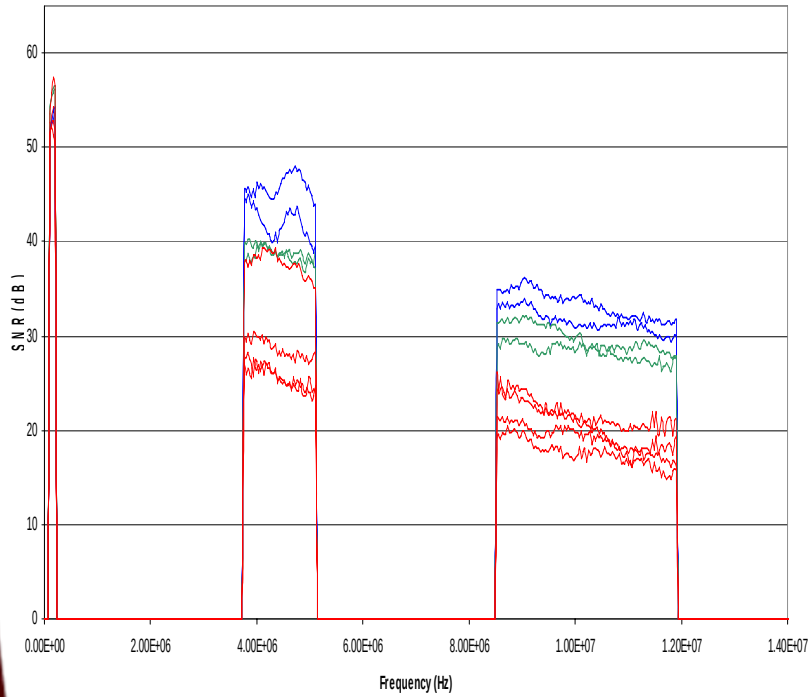


- At high frequency, crosstalk of short lines are significantly higher due to the near-end FEXT effect
- Near-end FEXT effect is usually mitigated by upstream power back-off.

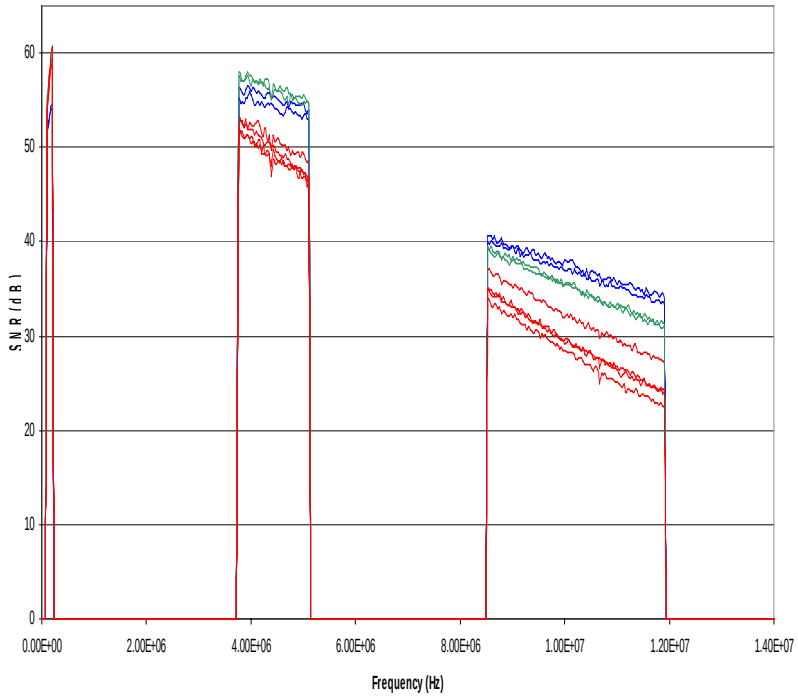
Distributed Topology
Example of SNR gain in upstream (UPBO)

- SNR approaching no crosstalk limit

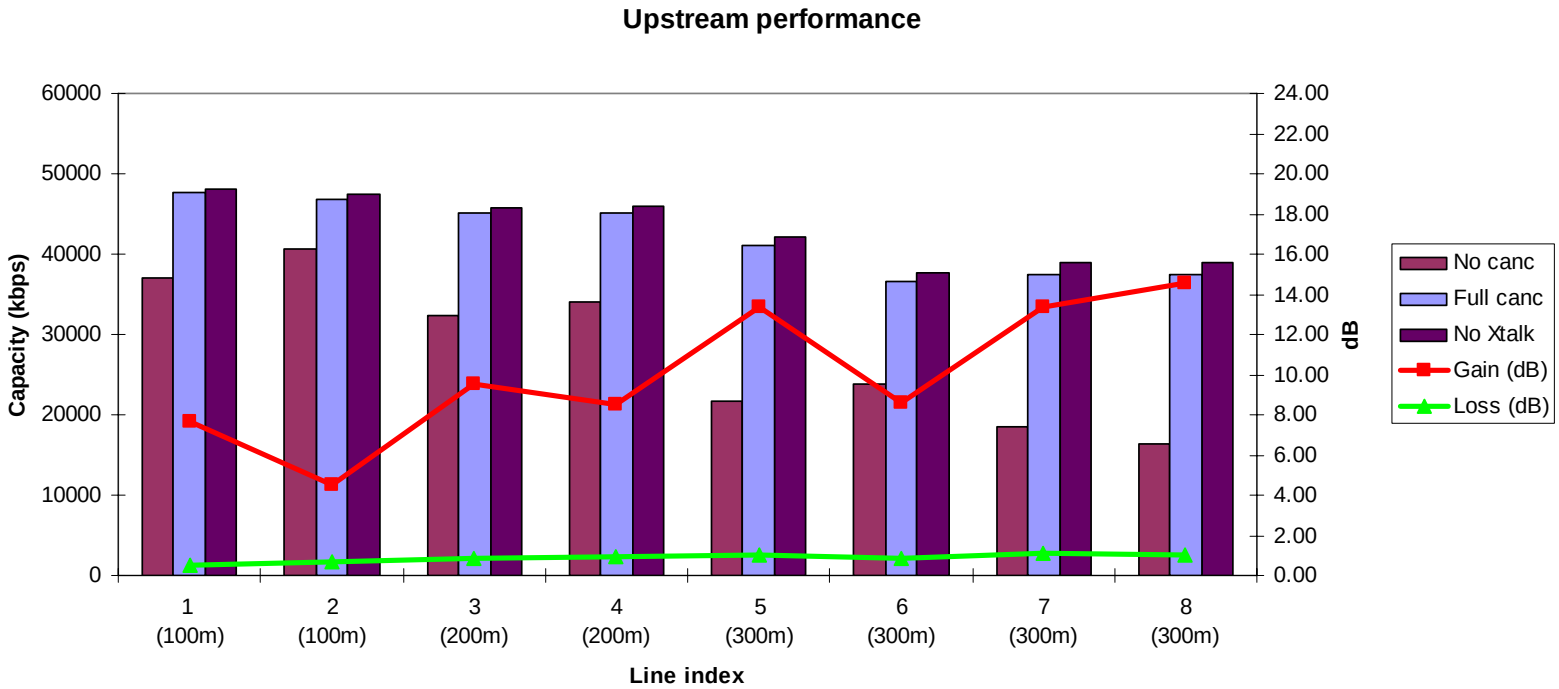
Without vectoring



With vectoring

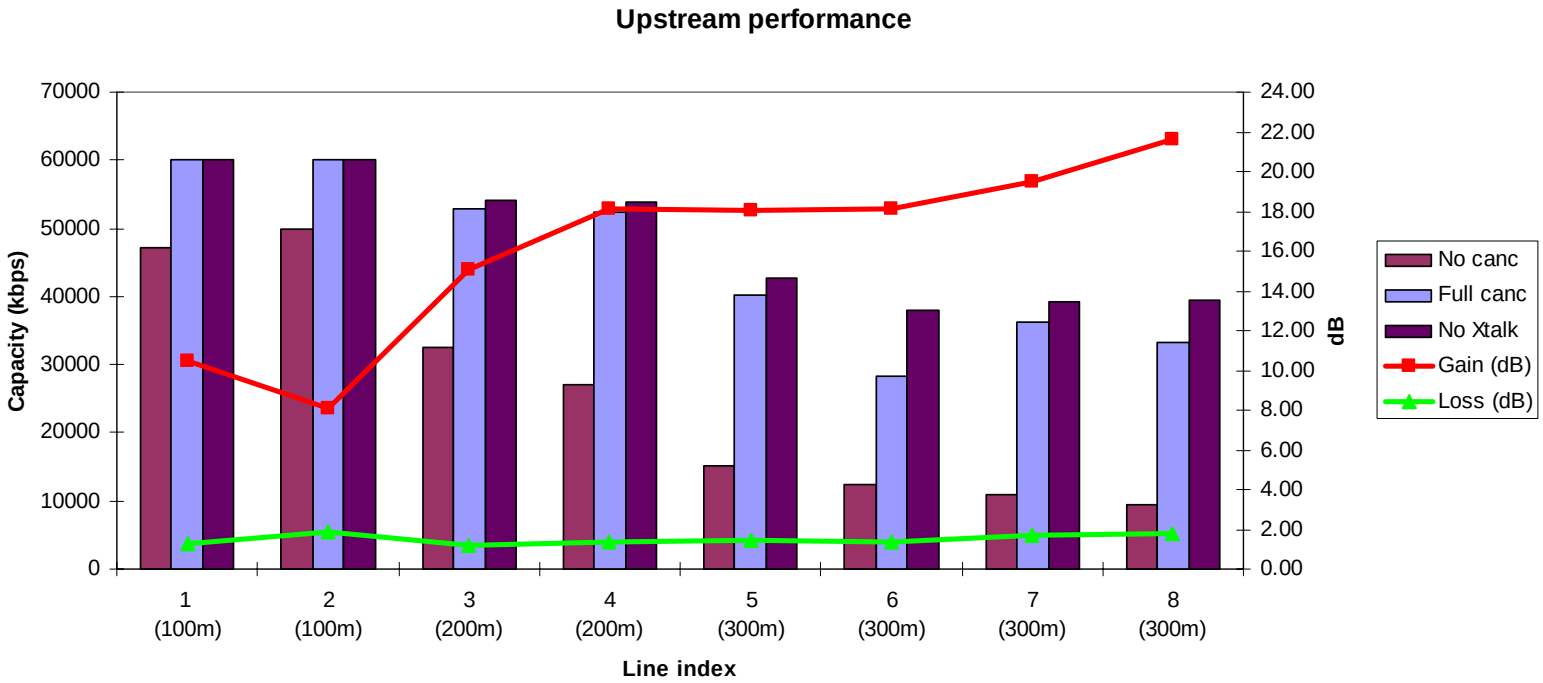


Distributed topology
Upstream performance (UPBO)



- 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)

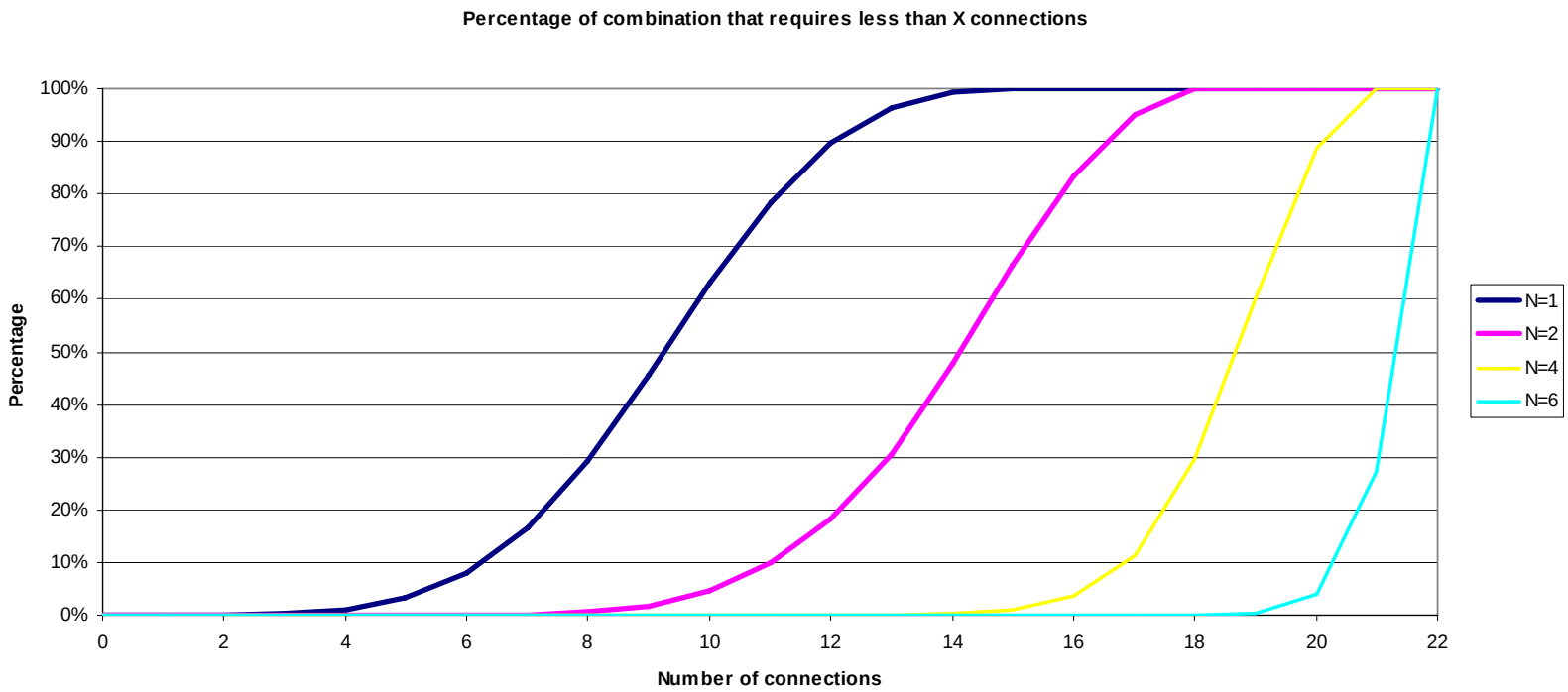


- Gains of Vectoring increases with the loop length
  - Near FEXT effects that are not compensate by the UPBO.
- A large dynamic range between the FEXT and signal must be handled.

System level vectoring
Requirements

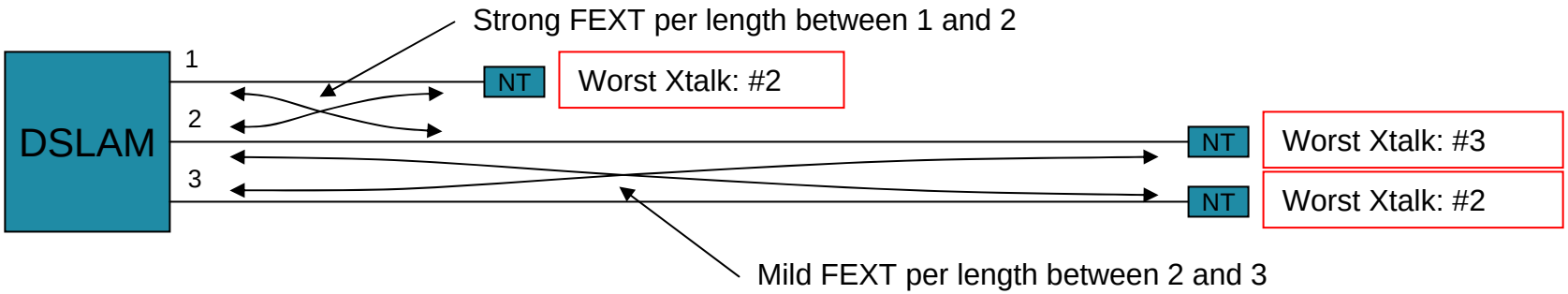
- Definition
  - System level vectoring consists of a DSLAM system where:
    - The binder size is larger than the line density of a single xDSL line card
    - ‘Vectoring’ can be performed between lines of different xDSL line cards.
- Potential issues
  - Crosstalk cancellation at system level requires 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

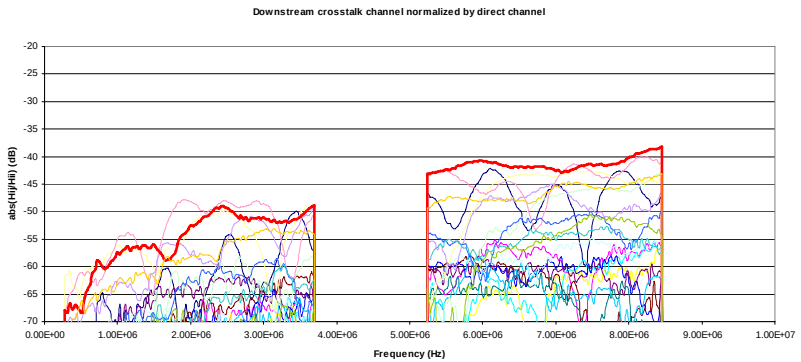


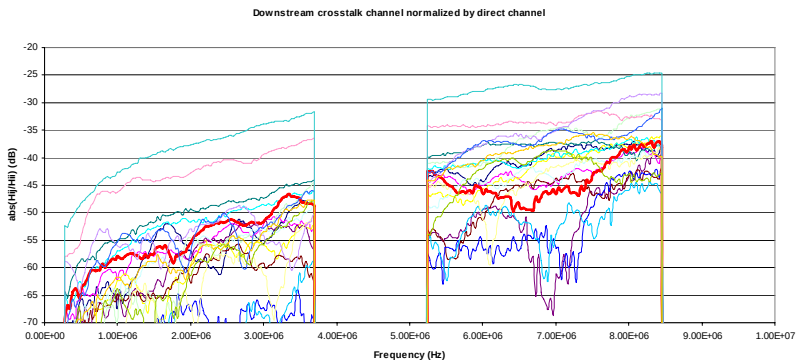
- Simulations
  - Results based on measurements done on a 500m cable, split in 3 binders.
  - An exhaustive search over all combinations of 2 X 11 pairs has been carried over
  - For each combination, the number of connection between the two groups has been computed in order to have access to the N worst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