

## **Report on the Technical Feasibility of Deployment Options for VDSL from the Exchange**

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## Foreword

This NICC Document (ND) has been produced by the NICC DSL TG.

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## 1 Scope

This report provides a technical exposition on VDSL2 from the exchange and is provided to help determine whether to move forward with new actions such as creating or changing any documents or instructions (including the ANFP). It highlights the technical considerations associated with moving forward with any specific potential recommendation, but it does not present an agreed technical solution nor does it recommend (i.e. prioritise) one approach over another.

This report provides an industry view on the issues associated with VDSL2 from the exchange due primarily to anticipated interference between exchange and cabinet based DSL deployments.

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## 2 References

- [1] *Specification of the Access Network Frequency Plan applicable to transmission systems connected to the BT Access Network*, NICC Standard ND 1602 V5.1.1 (2011-09).
- [2] *Report on Dynamic Spectrum Management (DSM) Methods in the UK Access Network*, NICC ND 1513, January 2010.
- [3] *Dynamic Spectrum Management Technical Report, Issue 2*, ATIS-0900007, 2012.
- [4] *Physical layer management for digital subscriber line (DSL) transceivers*, ITU-T G.997.1,
- [5] *Asymmetric digital subscriber line transceivers 2 (ADSL2)*, ITU-T G.992.3.
- [6] *Asymmetric Digital Subscriber Line (ADSL) transceivers – Extended bandwidth ADSL2 (ADSL2plus)*, ITU-T G.992.5.
- [7] *Techniques to Mitigate Uncancelled Crosstalk on Vectored VDSL2 Lines*, Broadband Forum TR-320, 2014.
- [8] *Data Sharing for DSM*, NICC document ND 1518 (Note: at the time of writing this is being drafted and not available publicly).

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## 3 Definitions, Symbols and Abbreviations

### 3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

**Binder:** A group of twisted wire pairs in a multi-pair cable that form their own twist bound group. This grouping is typically 10 or 25 pairs depending on the cable size.

**Equivalent Electrical Length:** Equivalent Electrical Length is the insertion loss at a given frequency for a physical length of cable and will vary with the cable gauge and material used.

**Exchange VDSL:** VDSL that is deployed from a DSLAM located within or near an exchange and connected to an MDF in an exchange.

**Cabinet VDSL:** VDSL that is deployed from a DSLAM located at or close to a Sub-loop Distribution Frame (SDF), typically at a street cabinet.

**D-Side Electrical Length (DSEL):** Equivalent electrical length from the SLCP to NTE.

**E-Side Electrical Length (ESEL):** Equivalent electrical length from exchange MDF to SLCP.

**CAL:** CAL is the “Cabinet Assigned Loss” and is a value determined by the MPF provider for each SLCP.

**Pure EO line:** Shown in Figure 1, Case 1- pure EO line, no shared binder.

**Shared binder:** Two or more twisted wire pairs that are in the same physical binder group of lines.

### 3.2 Abbreviations

ADSL	Asymmetric Digital Subscriber Line
AELEM	Alternative Electrical Length Estimation Method
ALA	Active Line Access
ANFP	Access Network Frequency Plan (BT or KCH)
ATIS	Alliance for Telecommunications Industry Solutions
AWGN	Additive White Gaussian Noise
CAL	Cabinet Assigned Loss
CP	Communications Provider(s)
CPE	Customer Premises Equipment
DP	Distribution Point
DPBO	Downstream Power Back Off

DSEL	D-Side Electrical Length
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
DSM	Dynamic Spectrum Management
FEXT	Far End Cross Talk
FTTC	Fibre To The Cabinet
Mbps	Megabits per second
MDF	Main Distribution Frame
MIMO	Multiple Input, Multiple Output
MPF	Metallic Path Facility
NGA	Next Generation Access
NTE	Network Termination Equipment
NTP	Network Termination Point
OAM	Operations Administration and Maintenance
PCP	Primary Connection Point
PSD	Power Spectral Density
SCP	Secondary Cross-connect Point.
SHDSL	Single-pair High-speed Digital Subscriber Line
SIN	Supplier Information Note
SLCP	Sub Loop Connection Point (See ND1602 [1])
SRA	Seamless Rate Adaption
SSM	Static Spectrum Management
UNI	User Network interface
UPBO	Upstream Power Back-Off
USn	Upstream Band n, where, n refers to upstream bands 0,1,2 allowed in band plan 998 ADE17
VDSL	Very high speed Digital Subscriber Line (refers to any VDSL type including VDSL1, VDSL2, and vectored VDSL)
VDSL2	Very High Speed Digital Subscriber Line version 2

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## 4 Summary of Findings

When deployed from the exchange, VDSL will be compatible with all current DSL services with one exception, which is VDSL deployed from a cabinet. This document explores potential crosstalk impacts in terms of line speed between exchange VDSL and cabinet VDSL. VDSL from the exchange may degrade VDSL from a cabinet, and VDSL from the cabinet may also degrade VDSL from the exchange, if they share the same cables, and if there is high crosstalk. These interactions can depend on loop lengths, numbers of lines, crosstalk couplings, cable layouts, and transmission parameters. The DSL Task Group study into exchange VDSL feasibility has followed two main themes of discussion:

- 1) a discussion of cable-plant, and whether some exchange lines can be identified as being isolated from cabinet lines;
- 2) an investigation into crosstalk between exchange VDSL and cabinet VDSL. Some techniques to mitigate these have been considered and analysed.

There are technical issues with both of these that require further work to resolve and gain agreement upon a solution. This document explores some potential compromises and solutions.

Speeds provided by exchange VDSL vary depending on loop length, restrictions for compatibility with overlapping cabinet VDSL, and typical copper variations. Downstream speeds of 30 to 100 Mbps and upstream speeds from 3 to 25 Mbps are possible depending upon the location of the DSLAMs and the restrictions placed upon them.

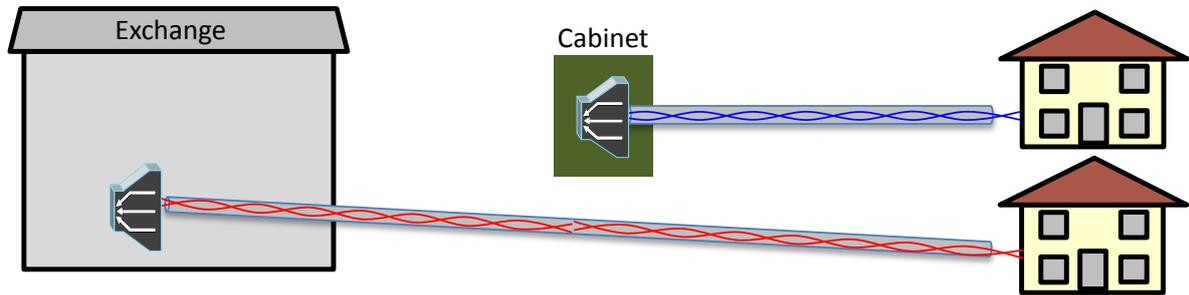
The group also reviewed examples of mixed cabinet/exchange deployments from other European jurisdictions as part of the study. Some information on deployments in various European countries has been contributed to the DSL TG . The examples uncovered a number of current approaches, which ensure compatibility by using simple rules:

- Deploy from the exchange, but migrate lines to cabinet as and when a cabinet is installed that overlaps the exchange lines.
- Deploy from the exchange, but enforce a minimum cable length or insertion loss between exchange and cabinet to prevent crosstalk issues.
- Deploy either exchange or cabinet VDSL in a cable sheath, but not both.

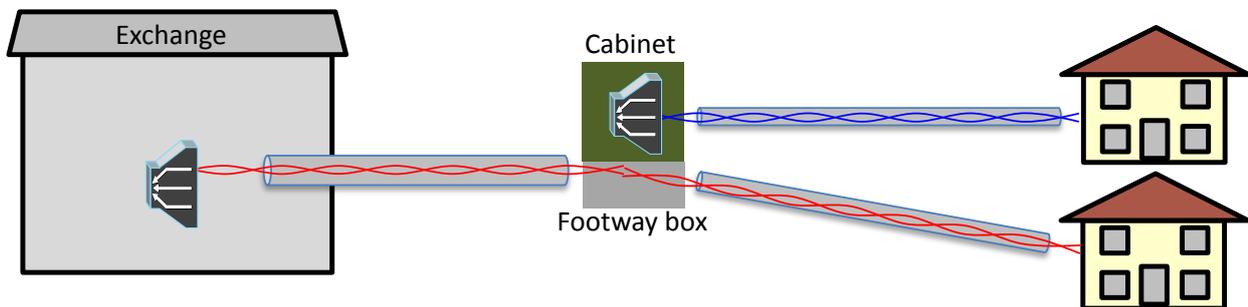
### 4.1 Cable-plant topologies relevant to VDSL from the exchange investigations

Some basic topologies for the copper network have been identified, illustrating a few scenarios where binders in cables may be shared between cabinet and exchange lines (shared binder) and scenarios where exchange lines did not share binders with cabinet lines (exchange outlet).

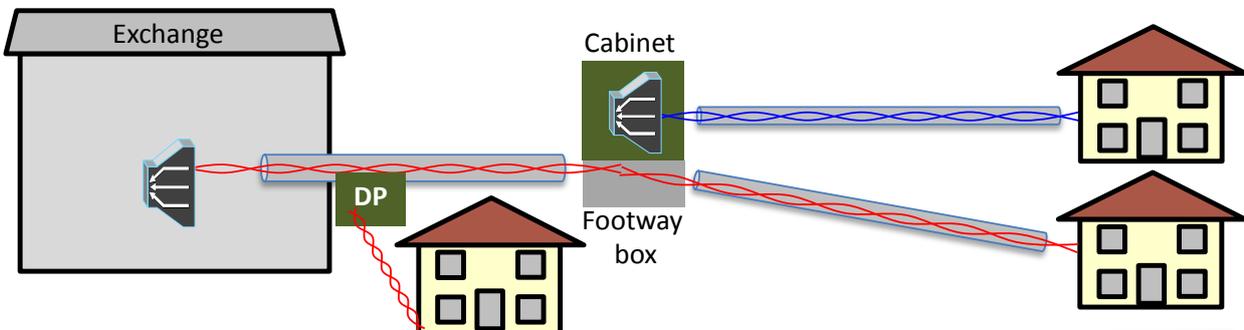
### Case 1 – pure EO line, no shared binder



### Case 2a – shared E-side binder



### Case 2b – shared E-side binder



### Case 3 – shared D-side binder

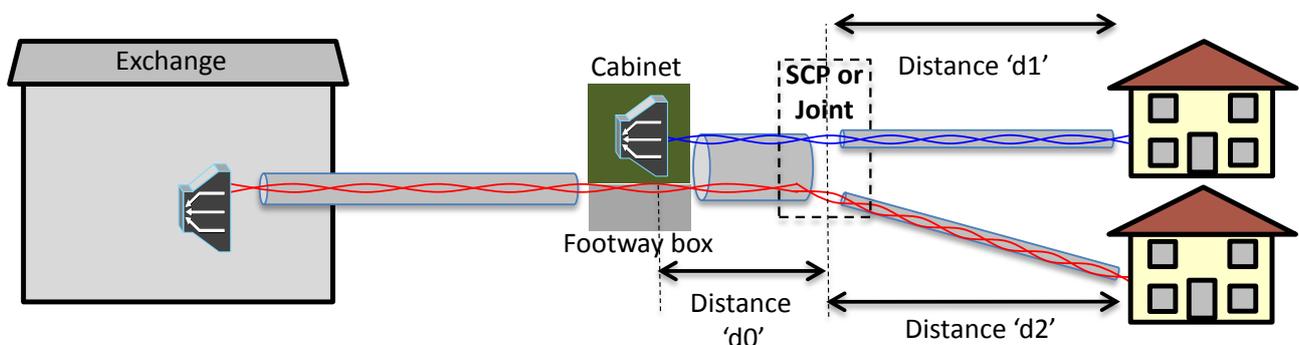


Figure 1. VDSL deployment scenarios.

NOTE: Copper pairs may share the same cabling between the exchange and cabinet in Cases 2a, 2b and 3.

All the topologies presented in Figure 1 do exist and have to be accommodated in a solution. Currently the ANFP only has a placeholder for Case 1 (pure EO in Part D).

Inputs to this study have stated that the physical plans for the network are not in a sufficiently accessible format to identify which lines are shared binder, and which are exchange outlet (EO). Loop records may lack the necessary data and accuracy to identify EO lines with certainty. Network re-configuration and new cabinet installations can change current EO lines into non-EO lines. So a current EO line may not be an EO line in the future.

Because of the age of the network in many areas and the levels of intervention over the years other, more complex, topologies were introduced in discussions. In these topologies cables are split and joined at various points, potentially downstream of a cabinet. Although an end to end pair may not be recorded as passing through a D-side cable shared with cabinet fed lines this may well be the case. Such “straps” may cause exchange lines to be in the same cable as cabinet lines in some cases. Although a line may be “EO” in the sense that there is no recorded cabinet, this does not provide certainty that the binder is not at some point shared with cabinet served lines. The scale of this issue is not known and is outside the scope of this report.

The infrastructure networks where these solutions are to be implemented are not static in structural layout and will evolve over time as the required engineering works for best practise take place. The architecture of plant built under Sub Loop Unbundling regulation, in particular, will have an impact on solution availability and deployment. The long term viability of solutions needs to be taken into account when implementing solutions.

The static nature of network equipment insertion under LLU and SLU created fixed points of connection. The possible complications of implementation of the solutions described here should have a formal method of resolution available to manage disputes. This should be included in design and implementation discussions and documentation.

Exchange tie cable loss from LLU CP HDF to MDF may provide significant extra loss which has not been catered for in the report (may increase overall cable lengths by 50-100m in extreme cases). This will impact speed and addressable market for Exchange based VDSL2. Technical issues over allowable PSD limits may also exist, and this subject may require further study by the DSL TG.

## 4.2 Potential Interactions Between Exchange and Cabinet-based VDSL and Requirements for Mitigation

In NICC contributions, possible impacts of crosstalk from exchange lines on cabinet lines were identified, for the two separate cases of non-vectorized cabinet lines and vectorized cabinet lines:

Non-vectorized cabinet lines

- Additional exchange lines will not cause any more crosstalk (than the self-crosstalk due to additional cabinet lines) to non-vectorized cabinet lines downstream.
- Exchange lines will in some cases cause damaging crosstalk to non-vectorized cabinet lines upstream, and therefore need some restrictions in some cases. This is because the longer exchange

lines can have less UPBO than the cabinet lines. There is no such impact if DSEL > 0.8 km or if ESEL > 1.3 km.

#### Vectored cabinet lines

- Exchange lines degrade the downstream bit rates of vectored cabinet lines up to about 25% if the cabling from the exchange to the cabinet (the E-side electrical length, or ESEL) is less than about 400m. If ESEL is greater than 400m, then there can be up to about a 10% decrease in the vectored cabinet lines' downstream bit rates .
- Exchange lines will in some cases cause damaging upstream crosstalk to vectored cabinet lines, and therefore need some restrictions in some cases.

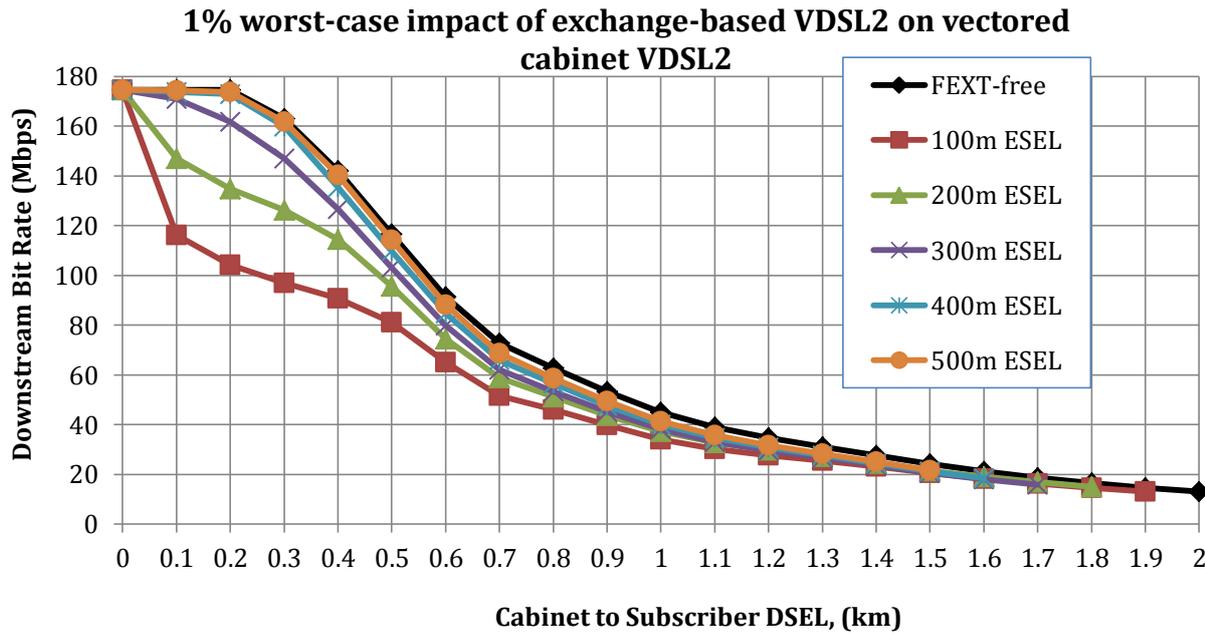
### 4.3 Spectrum Management Techniques to Mitigate Interactions Between Exchange-based and Cabinet-based VDSL

Spectrum management refers to processes that are intended to minimize the potential for interference and maximize the utility of the frequency spectrum of metallic line cables. Static Spectrum Management (SSM) [1] applies a static set of rules to ensure spectral compatibility, while Dynamic Spectrum Management (DSM) [2] is more flexible and incorporates time or situation-dependent variations in the subscriber line environment and line transmission systems.

NICC DSL TG contributions have suggested and analysed some techniques for managing transmit spectra to achieve spectral compatibility. Case 3 in Figure 1 is analyzed, since this is the most technically challenging. The techniques include Static Spectrum Management (SSM) and Dynamic Spectrum Management (DSM) that can be implemented with a limited knowledge of the cable plant, or an overall management system common to the exchange and cabinet lines which can obtain good speed from the exchange with very little sacrifice in terms of cabinet speeds. These techniques are outlined here. At the time of this writing, there is no agreed mechanism to embed these techniques in the ANFP and no agreed policing regime, but this may be surmountable with further work.

#### 4.3.1 Static Downstream Crosstalk Management

Vectored VDSL originating from a cabinet with ESEL less than 500m can be impacted by the exchange VDSL. In the absence of dynamic management of downstream crosstalk, one solution discussed was to use a simple rule to not deploy exchange VDSL for lines which go through a cabinet that's within a fixed copper distance of the DSLAM. Simulations here (using 0.4mm copper cable) suggest a distance of 400-500m depending on the speed harm allowed to cabinet based systems.



**Figure 2. Impact on downstream vectored cabinet VDSL with 12 exchange VDSL and 12 cabinet VDSL and 1% worst-case FEXT.**

Another approach could be to use the CAL value assigned to cabinets within 400m of the exchange to set a limit on downstream signal spectrum transmitted by the exchange equipment.

A further static approach is to define a new type of DPBO for VDSL at a cabinet, using a wider-bandwidth than is currently defined for protecting ADSL from an exchange; this would further restrict the transmit PSD of the cabinet VDSL.

Openreach has provided the statistics of exchange loops in Market 2 and Market 3 with E-side length plus D-side length  $\leq 1300\text{m}$ , and these are shown in Table 1. These statistics are for loop lengths, not electrical lengths. Also, note that the previous Market categorisations no longer exist and these have been replaced with Market A and B. About 25% of this population are EO lines, the remainder pass through a PCP. Removing the EO lines, the population is further restricted and the remaining percentages correspondingly increase in Table 2.

Some EO lines are being migrated to cabinets close to the exchange, and Table 3 shows the statistics of the limiting case where all EO lines are moved to cabinets within 100m of the exchange.

The size of the sample population, or equivalently the probability that E-side length + D-side length  $\leq 1300\text{m}$ ; has not been released.

**Table 1:** Percentage of loops at each E-side length and D-side length, given that E-side length + D-side length  $\leq 1.3$  km.

D-side length	EO	E-side length												
		0m to 100m	100m to 200m	200m to 300m	300m to 400m	400m to 500m	500m to 600m	600m to 700m	700m to 800m	800m to 900m	900m to 1000m	1000m to 1100m	1100m to 1200m	1200m to 1300m
0m to 100m	1.2%	0.1%	0.3%	0.5%	0.7%	0.8%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.8%	0.8%
100m to 200m	2.1%	0.2%	0.7%	1.1%	1.5%	1.7%	1.9%	2.1%	2.1%	2.1%	2.1%	2.3%	2.1%	
200m to 300m	2.6%	0.2%	0.6%	1.0%	1.3%	1.6%	1.9%	1.9%	2.0%	2.2%	2.1%	2.3%		
300m to 400m	2.8%	0.1%	0.5%	0.7%	1.0%	1.2%	1.5%	1.5%	1.6%	1.8%	1.8%			
400m to 500m	2.7%	0.1%	0.3%	0.5%	0.8%	0.9%	1.1%	1.2%	1.2%	1.3%				
500m to 600m	2.5%	0.1%	0.2%	0.4%	0.5%	0.7%	0.8%	0.8%	0.9%					
600m to 700m	2.2%	0.0%	0.2%	0.3%	0.4%	0.5%	0.5%	0.6%						
700m to 800m	2.0%	0.0%	0.1%	0.2%	0.3%	0.3%	0.4%							
800m to 900m	1.8%	0.0%	0.1%	0.1%	0.2%	0.2%								
900m to 1000m	1.5%	0.0%	0.1%	0.1%	0.1%									
1000m to 1100m	1.4%	0.0%	0.0%	0.1%										
1100m to 1200m	1.2%	0.0%	0.0%											
1200m to 1300m	1.1%	0.0%												

**Table 2:** Percentage of loops at each E-side length and D-side length, given that E-side length + D-side length  $\leq 1.3$  km and that the lines are routed via a PCP (excluding EO lines).

D-side length	E-side length												
	0m to 100m	100m to 200m	200m to 300m	300m to 400m	400m to 500m	500m to 600m	600m to 700m	700m to 800m	800m to 900m	900m to 1000m	1000m to 1100m	1100m to 1200m	1200m to 1300m
0m to 100m	0.1%	0.4%	0.7%	0.9%	1.0%	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%	1.1%	1.1%
100m to 200m	0.2%	0.9%	1.5%	2.1%	2.3%	2.6%	2.8%	2.8%	2.9%	2.8%	3.0%	2.8%	
200m to 300m	0.2%	0.8%	1.3%	1.8%	2.1%	2.5%	2.6%	2.7%	2.9%	2.8%	3.1%		
300m to 400m	0.2%	0.6%	1.0%	1.4%	1.6%	2.0%	2.0%	2.2%	2.4%	2.4%			
400m to 500m	0.1%	0.4%	0.7%	1.0%	1.2%	1.5%	1.5%	1.6%	1.8%				
500m to 600m	0.1%	0.3%	0.5%	0.7%	0.9%	1.1%	1.1%	1.1%					
600m to 700m	0.1%	0.2%	0.3%	0.5%	0.6%	0.7%	0.8%						
700m to 800m	0.0%	0.1%	0.2%	0.3%	0.4%	0.5%							
800m to 900m	0.0%	0.1%	0.2%	0.2%	0.3%								
900m to 1000m	0.0%	0.1%	0.1%	0.2%									
1000m to 1100m	0.0%	0.1%	0.1%										
1100m to 1200m	0.0%	0.0%											
1200m to 1300m	0.0%												

**Table 3:** Percentage of loops at each E-side length and D-side length, given that E-side length + D-side length  $\leq 1.3$  km and that all EO lines were converted to cabinet lines with E-side length  $< 100$ m.

D-side length	E-side length												
	0m to 100m	100m to 200m	200m to 300m	300m to 400m	400m to 500m	500m to 600m	600m to 700m	700m to 800m	800m to 900m	900m to 1000m	1000m to 1100m	1100m to 1200m	1200m to 1300m
0m to 100m	1.2%	0.3%	0.5%	0.7%	0.8%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.8%	0.8%
100m to 200m	2.3%	0.7%	1.1%	1.5%	1.7%	1.9%	2.1%	2.1%	2.1%	2.1%	2.3%	2.1%	
200m to 300m	2.8%	0.6%	1.0%	1.3%	1.6%	1.9%	1.9%	2.0%	2.2%	2.1%	2.3%		
300m to 400m	3.0%	0.5%	0.7%	1.0%	1.2%	1.5%	1.5%	1.6%	1.8%	1.8%			
400m to 500m	2.8%	0.3%	0.5%	0.8%	0.9%	1.1%	1.2%	1.2%	1.3%				
500m to 600m	2.5%	0.2%	0.4%	0.5%	0.7%	0.8%	0.8%	0.9%					
600m to 700m	2.3%	0.2%	0.3%	0.4%	0.5%	0.5%	0.6%						
700m to 800m	2.0%	0.1%	0.2%	0.3%	0.3%	0.4%							
800m to 900m	1.8%	0.1%	0.1%	0.2%	0.2%								
900m to 1000m	1.6%	0.1%	0.1%	0.1%									
1000m to 1100m	1.4%	0.0%	0.1%										
1100m to 1200m	1.3%	0.0%											
1200m to 1300m	1.1%												

An analysis was performed to determine the downstream speed degradation that may be caused on vectored cabinet lines by exchange VDSL. In these cases the exchange VDSL is not spectrally shaped for compatibility with the cabinet lines, and instead transmits maximum power and PSD. Vectoring is assumed to lower the cancellable FEXT between cabinet-based lines by 25 dB. Broadband Forum TR-320 [7] described “cancellable” FEXT with vectoring.

Results here are based on a number of simulation assumptions. The analysis assumes that six exchange VDSLs share the same 25-pair distribution cable binder with six vectored cabinet VDSL, as in Case 3 of Figure 1. All subscribers (TU-Rs) are collocated, but some are served by the exchange and some by a cabinet. The transmit PSD is the maximum PSD as allowed by the ANFP (nominally 3.5 dB below the PSD mask) using the VDSL profile 998ADE17-M2x-A PSD. The margin is 6 dB and the total coding gain is 3 dB. Loops are all 0.4 mm, and AWGN at -140 dBm/Hz is added to each receiver.

The following analyses assume that statistics on loop length and electrical length are equivalent. It is assumed that exchange VDSL is not deployed on loops with electrical/loop length greater than 1.3 km, so for DSEL+ESEL  $> 1.3$  km it is assumed that there is zero percent degradation. It is also assumed that vectored line speeds need be no higher than 111 Mbps; giving 100 Mbps user data rate if there is 10% overhead, in some cases, and that vectored line speeds are unlimited in other cases. With “unlimited vectored line speed” the vectored lines are rate adaptive and achieve the highest bit rate possible with 6 dB margin; this speed varies with loop length.

The following levels of “harm” are defined:

- More than 25% reduction of speed
- Between 25% and 10% reduction of speed
- Between 10% and 2% reduction of speed
- No more than 2% reduction of speed.

In previous NICC documents, cabinet VDSL was allowed to cause up to 2% reduction in exchange ADSL speed, however SHDSL can cause greater reductions in exchange ADSL speed.

For each combination of ESEL and DSEL, 50,000 different cases of randomly chosen same-binder FEXT couplings between the 12 simulated lines were simulated using the ATIS MIMO FEXT model, and the impact on the vectored cabinet lines is calculated. The ATIS model was developed based on American cable measurements. The percent speed degradation on the vectored cabinet lines was calculated for each loop length combination, multiplied by the loop statistics in Table 2 and Table 3, and summed to determine the statistics in Table 4-Table 7. Since the data in Table 1 and Table 2 only have one decimal place of precision, the statistics in Table 4 to Table 7 do not exactly sum to 100%.

**Table 4.** Percentage of PCP lines / vectored cabinet VDSL experiencing downstream speed reduction levels due to maximum power exchange VDSL crosstalk within the population that have DSEL + ESEL  $\leq$  1.3 km, pass through a PCP, and have a vectored VDSL DSLAM at the PCP. Maximum vectored line speed expectation = 111 Mbps.

Category	Percentage of loops within the population that have DSEL + ESEL $\leq$ 1.3 km, pass through a PCP, and have a vectored VDSL DSLAM at the PCP.
More than 25% reduction of speed	0.0008%
Between 25% and 10% reduction of speed	0.15%
Between 10% and 2% reduction of speed	1.8%
No more than 2% reduction of speed	97.6%

**Table 5.** Percentage of PCP lines / vectored cabinet VDSL experiencing downstream speed reduction levels due to maximum power exchange VDSL crosstalk within the population that have DSEL + ESEL  $\leq$  1.3 km, pass through a PCP, with a vectored VDSL DSLAM at the PCP, assuming every EO line has been moved to a PCP within 100m of the exchange. Maximum vectored line speed expectation = 111 Mbps.

Category	Percentage of loops within the population that have DSEL + ESEL $\leq$ 1.3 km, pass through a PCP, and have a vectored VDSL DSLAM at the PCP; after every EO line has been moved to a PCP within 100m of the exchange.
More than 25% reduction of speed	0.057%
Between 25% and 10% reduction of speed	4.65%
Between 10% and 2% reduction of speed	9.80%
No more than 2% reduction of speed	85.49%

**Table 6.** Percentage of PCP lines / vectored cabinet VDSL experiencing downstream speed reduction levels due to maximum power exchange VDSL crosstalk within the population that have DSEL + ESEL  $\leq$  1.3 km, pass through a PCP, and have a vectored VDSL DSLAM at the PCP. Unlimited vectored line speed.

Category	Percentage of loops within the population that have DSEL + ESEL $\leq$ 1.3 km, pass through a PCP, and have a vectored VDSL DSLAM at the PCP.
More than 25% reduction of speed	0.038%
Between 25% and 10% reduction of speed	0.64%
Between 10% and 2% reduction of speed	3.9%
No more than 2% reduction of speed	94.9%

**Table 7.** Percentage of PCP lines / vectored cabinet VDSL experiencing downstream speed reduction levels due to maximum power exchange VDSL crosstalk within the population that have DSEL + ESEL  $\leq$  1.3 km, pass through a PCP, with a vectored VDSL DSLAM at the PCP, assuming every EO line has been moved to a PCP within 100m of the exchange. Unlimited vectored line speed.

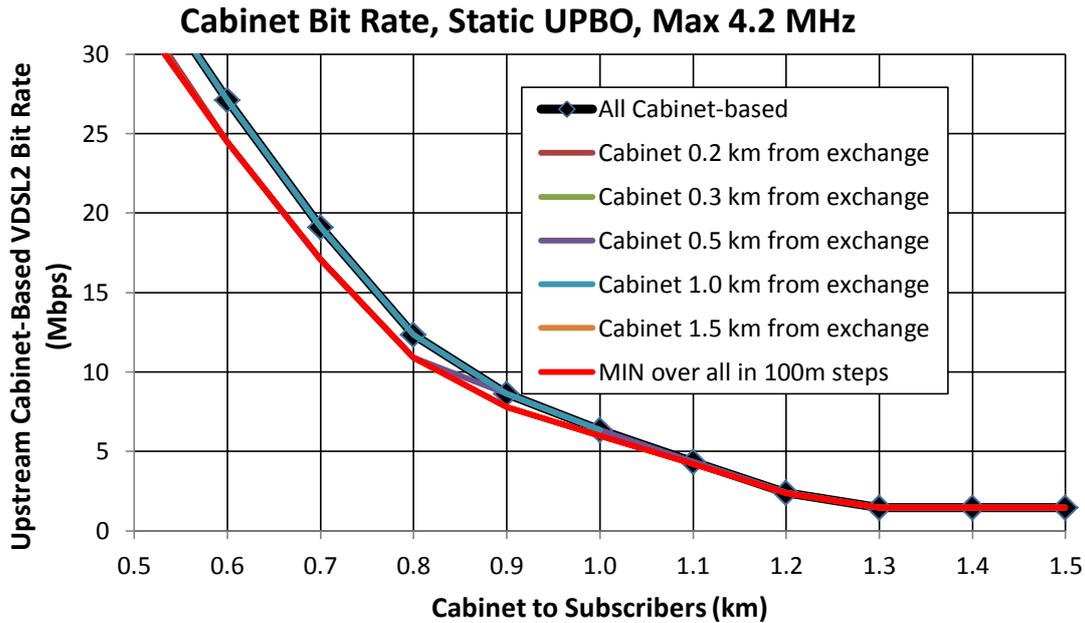
Category	Percentage of loops within the population that have DSEL + ESEL $\leq$ 1.3 km, pass through a PCP, and have a vectored VDSL DSLAM at the PCP; after every EO line has been moved to a PCP within 100m of the exchange.
More than 25% reduction of speed	0.63%
Between 25% and 10% reduction of speed	10.9%
Between 10% and 2% reduction of speed	15.2%
No more than 2% reduction of speed	73.3%

The probability of exchange VDSL causing high speed reduction on downstream vectored cabinet VDSL is generally low. However, individual cases, particularly with cabinets very close to the exchange, have significant speed impact. The operational likelihood of these risks is outside the scope of this document, but this analysis does highlight that there should be mechanisms to identify and manage such interactions.

### 4.3.2 Static Upstream Crosstalk Management

Within the impacted loop lengths, exchange lines can cause damaging crosstalk to cabinet lines in the upstream direction. A simple but effective solution to this would be to use only the US0 band for exchange lines (US0 frequencies do not need crosstalk management like US1 and US2 do). An extension of this thinking may be to use extended US0 with extension as per Annex-M of ITU-T G.992.3 [5] and ITU-T G.992.5 [6], allowing higher upstream data rates. US0, however, only provides about 1 Mbps upstream.

Upstream exchange lines may be restricted for the purpose of compatibility with cabinet lines so they are only allowed to use US0 and also a small portion of the US1 band. Use of only the lower few hundred kHz of US1 by exchange lines has at worst only a small impact on cabinet lines while increasing exchange VDSL upstream to roughly 2 to 3 Mbps. Any part of the band can be selected for transmission by setting the standard VDSL-CARMASK parameter [4]. This is not currently considered in the ANFP. While this is well below the maximum achievable upstream VDSL speed, such a modest upstream rate may be sufficient for residential service. Although this semi-static rule is technically possible the ability to police it has not been considered as part of this study.



**Figure 3. Impact on upstream vectored cabinet VDSL from exchange VDSL limited to frequencies below 4.2 MHz. With this restriction the exchange lines transmit above 3 Mbps on loops up to 1 km.**

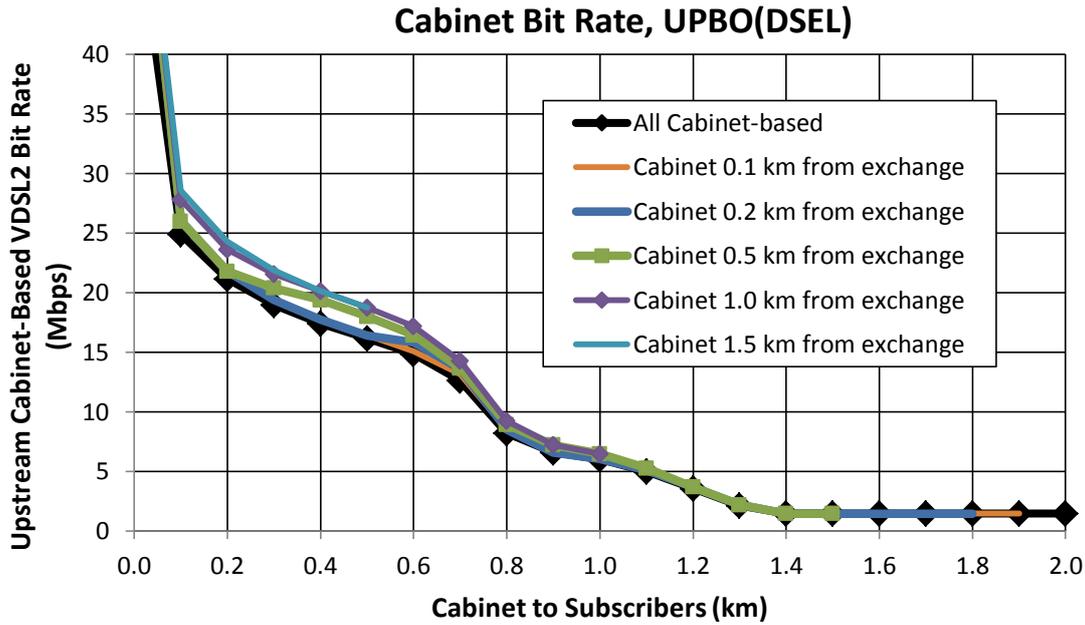
### 4.3.3 Semi-Static Crosstalk Management

Simulations were run that showed the impact of upstream exchange VDSL on upstream cabinet VDSL. Static UPBO with A and B parameters as defined in the ANFP [1] was assumed. Loops are 0.4 mm, and Case 3 of Figure 1 is assumed with collocated subscribers. 1% worst-case FEXT is assumed. There are 12 exchange VDSL and 12 cabinet VDSL in the same 25-pair binder, except the “All cabinet-based” case has 24 cabinet-based lines.

“Semi-static” approaches have static PSD mask specifications that vary only according to electrical loop lengths. For example, exchange VDSL has negligible impact on non-vectored cabinet VDSL with long ESEL and exchange VDSL has no impact on non-vectored or vectored cabinet VDSL upstream if only US0 is used. So, further PSD restrictions on exchange lines are not necessary in these cases if they are correctly identified.

Another semi-static rule is to vary the US1 bandwidth to be used by exchange lines. The lower frequencies of US1 were shown to have negligible effect on cabinet lines in Figure 3, particularly if some simple rule was used to select stop-frequency values in US1. This can increase exchange VDSL upstream to roughly 3 to 4 Mbps without impacting cabinet lines.

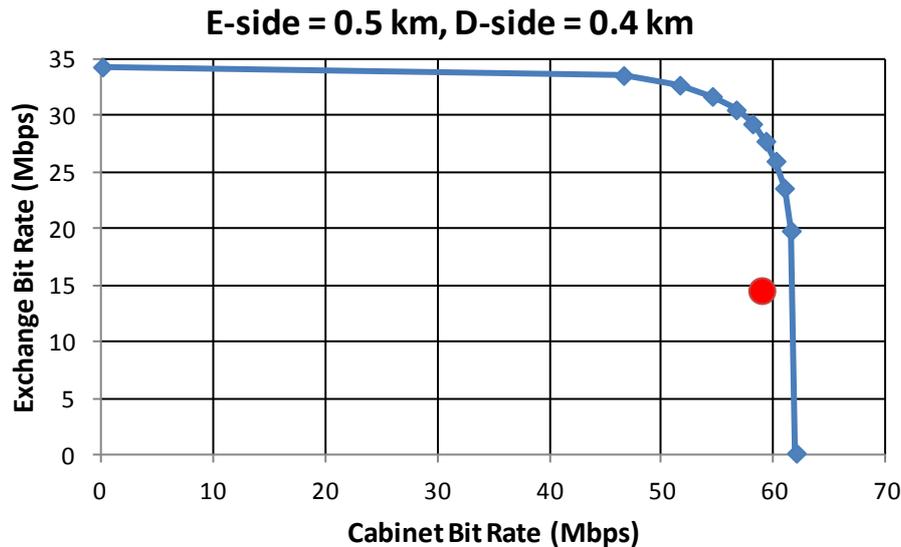
Another semi-static rule is to make upstream power backoff (UPBO) of exchange lines be a function of DSEL of the impacted cabinet VDSL. The values of DSEL used here will generally be different for each exchange line. This is called UPBO(DSEL) and has been shown in Figure 4 to be compatible with non-vectored cabinet lines, provided that DSEL is known. However, this semi-static rule may not recover a significant percentage of the vectoring gain for vectored cabinet lines.



**Figure 4. Bit rate of non-vectored cabinet lines, with UPBO(DSEL) on the exchange lines.**

#### 4.3.4 Dynamic Spectrum Management (DSM)

Any one of the many available DSM methods [2][3] can adapt both the cabinet VDSL and the exchange VDSL to optimise compatibility, ensuring that line speeds of all systems improve. DSM, however, requires some knowledge of the particular situation. For example, in cases where all lines are collocated or all lines are vectored, then static UPBO is sub-optimal and a DSM solution can provide higher bit rates on both exchange lines and cabinet lines than static UPBO, as shown in Figure 5. The static point in Figure 5 simply transmits the maximum PSD level allowed by the ANFP on all cabinet and exchange lines.



**Figure 5. Achievable downstream non-vectorized VDSL bit rates using Optimal Spectral Balancing (OSB) transmit PSDs with 12 cabinet VDSL and 12 exchange VDSL 1% worst-case FEXT. E-side = 0.5 km, D-side = 0.4 km. Red dot = static ANFP PSDs.**

There are many different ways of implementing DSM, and many tradeoffs involved with these implementations. An example is shown in Figure 5, and more examples are shown in Broadband Forum TR-320 [7]. DSM can be implemented with varying levels of information, with higher levels of information allowing more complex solutions with more degrees of freedom:

- A. No information – the most restricted (static).
- B. Identification of loop topologies, and services sharing cables such as exchange lines and cabinet lines (semi-static).
- C. Identification of pertinent transmit settings and performance levels.
- D. Distributed DSM with a shared database for exchanging network information between operators.
- E. Full centralized DSM, overseeing all lines.

An increasingly important aspect of these solutions is information and objective function sharing between participants. This could be implemented by posting such information in a shared database, facilitated through specified management interfaces. However, the details of such information sharing have not been agreed; at the time of writing work is continuing in the NICC DSL TG to identify requirements and feasibility [8].

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## 5 Conclusions

The NICC DSL Task Group has investigated the technical feasibility of VDSL from the exchange in the UK access network. At the time of writing several possible solutions have emerged but no single one has been identified as a preferred option. Each of these options is viable.

Cable plant records of ‘pure EO lines’ have the potential to provide the most rapid opportunity for exchange deployment, but there are issues to resolve in cases where such data is unavailable, and so other approaches may be sought.

Static Spectrum Management (SSM) rules can be implemented to allow VDSL from the exchange, but designing these rules for the worst-case scenario will generally result in relatively poor performance. The worst case here not only involves a worst-case number of crosstalkers and worst-case crosstalk couplings, but also worst-case VDSL cabinet locations and line lengths.

Semi-static approaches improve on the static approach and have static PSD mask specifications that vary only with electrical length and require knowledge of both the exchange line length as well as potentially the impacted cabinet's electrical line length.

Dynamic Spectrum Management (DSM) has been shown to be able to offer the best rates, but DSM implementation can require new management paradigms. Fully centralised DSM would require a level of cross-platform and inter-CP cooperation that may not emerge in the UK environment. It is more reasonable to allow DSM to be implemented to the extent that there is information allowing it. The capability of spectrum management is impacted by the information available; e.g. knowledge of ESEL, DSEL, topology of physical network, technology deployments, crosstalk couplings, impact of one line on nearby lines, etc.

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## 6 Technical Options Regarding VDSL from the Exchange

The tradeoff between complexity and performance offered by solutions presented here need to be evaluated by CPs in light of the potential gains offered by exchange VDSL. Each of the solutions is considered in terms of the technical work required to achieve them and the impact of implementing them on existing DSL deployments. In those cases when the deployment of exchange VDSL may impact existing deployments, the possible degradation to existing deployments is identified.

An alternative to exchange VDSL deployment is a continuation of the status quo - the ANFP is not updated and VDSL2 signals cannot be inserted at the MDF or NTE for exchange lines, and some number of UK residences continue to be excluded from VDSL2 service availability. Other methods and access technologies may be available (e.g. fibre). Due to the nature of DSL, the customers best served by exchange based ADSL will also be best served by exchange based VDSL.

### 6.1 Exchange VDSL on Pure EO Lines

This approach would allow exchange VDSL on lines identified as pure EO. It would require a technically simple modification to the ANFP. To progress this approach, a definition of a pure EO line would be needed, which could be: any line which does not share any binder with lines routed via a PCP; or could be any line which does not share any binder with lines carrying cabinet VDSL.

In the former case, the MPF provider would need to identify loops as pure EO and share this information with their CPs. In the latter case, some agreement will be necessary on how to handle exchange VDSL2 lines in the event that cabinet VDSL2 is deployed into shared binders downstream of the EO lines in the future.

### 6.2 Allow Exchange VDSL with Restrictions to Protect Cabinet VDSL

This approach requires consideration of the downstream and upstream signals in order that cabinet lines are not degraded by exchange deployments. It requires changes to the ANFP.

## 6.2.1 Downstream

Downstream signals from cabinet deployments could be protected by using a simple rule, such as ensuring exchange VDSL signals traverse at least 400m of copper before sharing binder with vectored cabinet lines. This may affect, or be affected by, installation of new VDSL DSLAMs within 400m of the exchange and impacts on exchange VDSL performance or cessation of any VDSL from the exchange would need a resolution process. Such an arrangement requires knowledge of the minimum E-side electrical length (the length between MDFs and cabinets), and that the cabinet data (including E-side electrical length) is available.

In the above scenario, although cabinet lines are protected from interference the reverse is not true – cabinet lines can cause strong and damaging interference to exchange lines, although this is mitigated somewhat by the ANFP shaping on the cabinet lines for compatibility with exchange ADSL. An exchange VDSL operator would have to be prepared to deal with this situation (perhaps by accepting some decrease in bit rate).

## 6.2.2 Upstream

Two simple solutions exist for protecting upstream signals of cabinet lines: use only the first upstream signal band (US0) as per ADSL; or, use the first upstream band (US0) and a small slice of the second upstream band (US1).

The second approach will involve accepting an impact on the upstream performance of a few vectored cabinet lines.

A somewhat more complex solution is to apply UPBO on the exchange lines defined by DSEL instead of being defined by total exchange line electrical length (ESEL + DSEL) as usual. In this case knowledge of the ESEL of cabinet lines sharing the cable would need to be known and made accessible, then DSEL could be estimated by subtracting ESEL from the total exchange line electrical length.

## 6.3 Use DSM to Manage Crosstalk

The investigations undertaken by the DSL TG have shown use of DSM to be a technically feasible solution for the physical layer – exchange and cabinet lines can coexist without causing incompatibility in the network, and rates can be managed across all lines.

In order to effectively support DSM, the following are required:

- A DSM system that can span the exchange and cabinet lines. This could be implemented in a single, centralized system, or it could be implemented in distributed systems by exchanging the necessary data.
- Some agreement as to what degree exchange and cabinet lines may be allowed to affect each other's performance (e.g. 5% reduction in cabinet bitrate for 50% improvement in exchange bitrate)
- A new section of the ANFP with well-defined, enforceable, rules for DSM.

The above requirements also imply a level of agreement and cooperation between CPs, in order to agree on operation and use of the shared DSM platform.

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## 7 History

<b>Document history</b>		
V1.1.1	13 <sup>th</sup> October 2014	Initial publication