NEXT GENERATION BROADBAND SYSTEMS DEPLOYMENT IN CUSTOMER CABLING

Introductory Tutorial on C658:2018 Deployment Rules

April 2018

Communications Alliance

Outline:

- Applicability and Overall Objectives
- Key Concepts
  - Subscription and Notification
  - Deployment and Non-Deployment Class Systems
  - Viable Sharing Options
  - Full Coverage
- Priority: The Rule for Determining Sharing Options
  - Exception Cases (Sharing Resolution)
- Processes for Determining and Realizing Sharing
- Example Scenarios
- Conclusions

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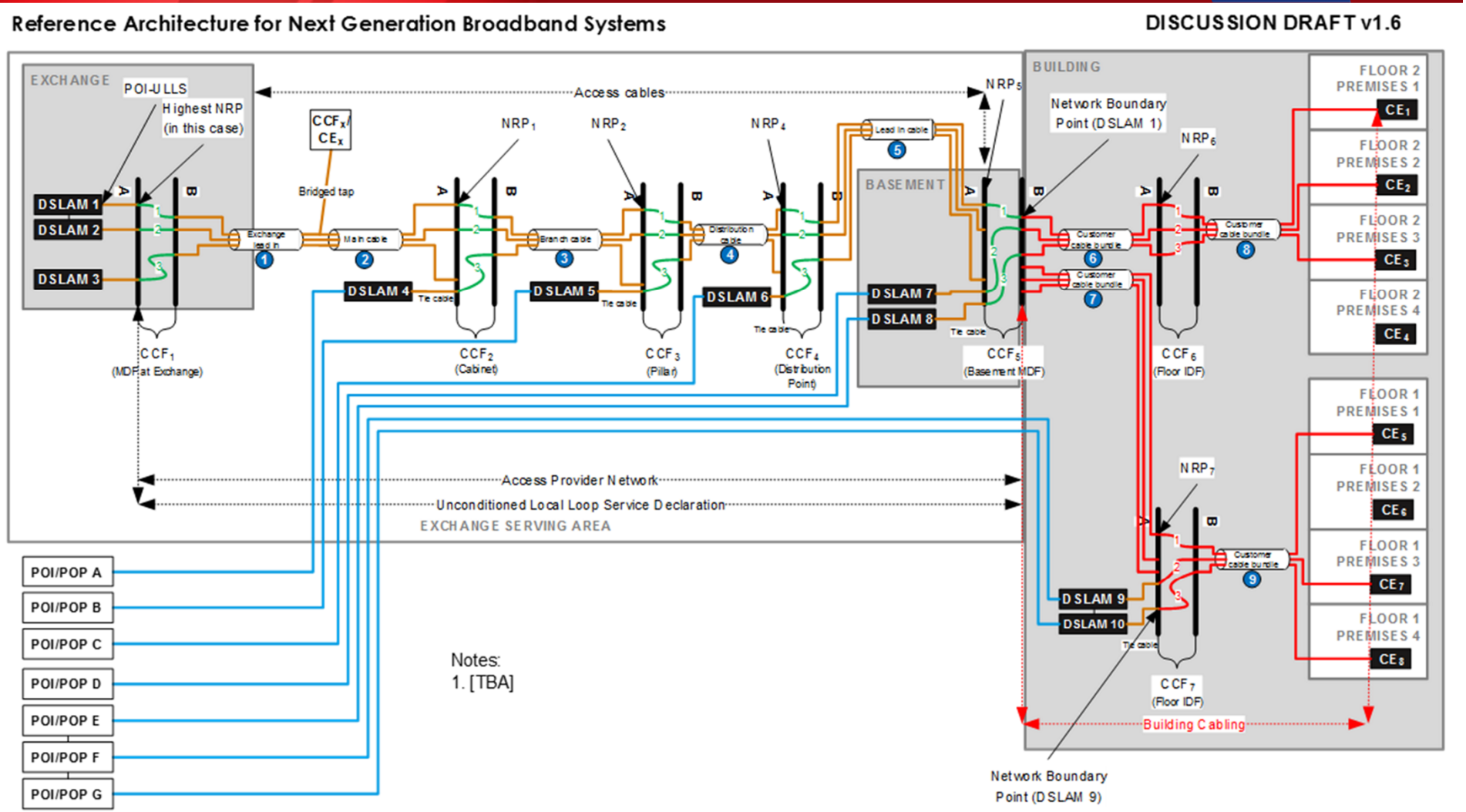
The 5 Main Objectives (1.2/Pt1):

- to **facilitate competition** in the deployment of Next Generation Broadband Systems (NGBS) by carriers and Carriers and Providers;
- to **minimise** the potential for **interference** between telecommunications systems deployed in the same Shared Cable Bundle;
- to **ensure** a minimum level of **performance** for certain Next Generation Broadband Systems;
  - Minimum 25 Mbps download speed (the Code Committee set this as the minimum for network and Campus systems)
  - The Code Committee also set a 50 Mbps minimum for building systems
- to **protect** the performance of certain **Legacy Systems** (e.g. ADSL2+) deployed in the same Shared Cable Bundle as a Next Generation Broadband System;
- to provide flexibility and scope for **technology Upgrades** (e.g. G.Fast)

C658:2018 Applies to:

- All non-Unconditioned Local Loop Services (non-ULLS) systems deployed or to be deployed from either a network node or from an access module installed in a multi-dwelling building or lateral development (1.3.4/Pt1)
  - Includes Network, Building and Campus systems
  - Includes Building and Campus legacy ADSL/ADSL2+ systems
- All NGBS deployed or to be deployed
  - Examples include VDSL2 (vectored and non-vectored) and G.Fast
- Shared Cable Bundles (2.2/Pt1)
  - Any grouping of pairs of conductors where the proximity of the cable sheaths and/or pairs in the grouping has the potential to cause unacceptable Interference between them.
    - This includes groupings of separate cables that run together for some or all of their routes.
    - However a properly earthed screened cable does not become part of such larger cable bundle, but remains as its own separate cable bundle.
    - Does not include exclusive customer (2.2 Pt1) cabling

Reference Architecture (3/Pt1):

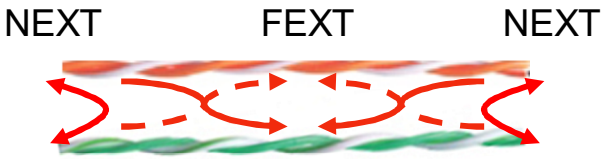


Crosstalk Interference :

- The Code requires that no system cause unacceptable interference to any equal or higher priority Deployment Class NGBS or to any legacy system (4.2-4.3/Pt1)
  - “Priority” and “Deployment Class Systems” are defined in the Code (more later in this tutorial)

- Interference arises from Near End and Far End Crosstalk (NEXT and FEXT) within Shared Cable Bundles
  - Vectored and non-vectored systems (including those that vector only over a limited frequency range) must be considered
  - Frequency separation, Downstream Shaping and Upstream Power Back Off (UPBO) are used to minimise unequal level FEXT impacts

- The Code primarily manages interference by controlling spectrum usage (unlike CA Code C559)
  - This includes defining the direction of transmission (5.3/Pt1)



Protecting Legacy Systems:

- Legacy System Protection (4.3/Pt1)
  - All systems must not cause unacceptable interference to selected ADSL legacy systems (corresponding to ADSL and ADSL2+ basis systems in C559) that are (or may be) deployed in the same Shared Cable Bundle
    - Legacy systems include ULLS systems deployed in accordance with C559, and building systems using a technology that corresponds to an ADSL or ADSL2+ Deployment Class in C559.
  - Hence, existing building/campus systems and NGBS systems are likely to need downstream shaping when a legacy network system may exist in the Shared Cable Bundle.
    - This includes shaping any legacy ADSL/ADSL2+ building or campus systems

- Legacy System Removal (end of co-existence period 4.5/Pt 1)
  - There will be a co-existence period when both the network/building legacy ADSL/ADSL2+ systems and the NGBSs share the cable bundle
  - After the co-existence period, NGBS shaping requirements to protect legacy network systems are removed which will typically improve the performance of the NGBS
  - Legacy ADSL/ADSL2+ systems must be removed if they interfere with a NGBS

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Subscription and Notification (7/Pt1):

- Subscription
  - Means a Carriage Service Provider (CSP) of a next-generation broadband system has lodged all necessary details in the Provider List maintained by CA (7.3/Pt1)
    - Provider Register contains provider email addresses and notification web pages
- Notification
  - Means a Provider of a System has informed all relevant CSPs on the Provider List details of the proposed/deployed system (7.3/Pt1)
- What happens if not Subscription and/or Notified?
  - A CSP that has not Subscribed with CA or has not Notified other registered CSPs of their deployment to the shared cable bundle shall be placed at the lowest priority and hence must defer to other CSPs that have Registered and Notified. That includes not operating the system if it fails to meet the technical requirements 4.2 to 4.4 of the Code.
- Why Subscribe and Notify?
  - Provides a priority date, the potential to be protected, and the ability to be informed and respond to any (future) notifications from other providers
  - Non-subscribed CSPs or non-notified systems must comply with the non-interference requirements when a subscribed/notified deployment class system is operating into a shared cable bundle. The Providers of such systems can only respond as a subsequent system and would be given a later priority date.

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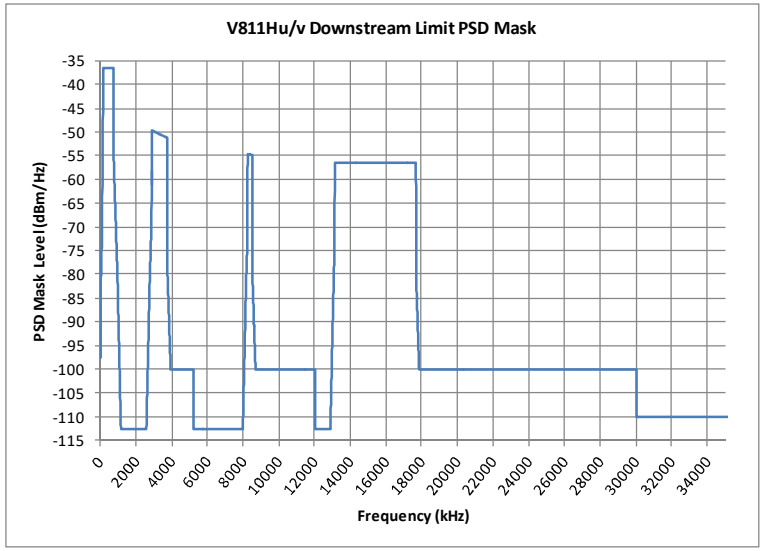
Deployment Class Systems (DCS):

- Six VDSL2 DCSs are defined in the Code (including co-existence masks)
  - Three spectra which may be vectored or non-vectored
- UPBO values are specifically defined when multiple non-vectored DCSs share common spectrum in order to ensure upstream FEXT compatibility
- Must satisfy the legacy system shaping requirements during co-existence
- May have viable co-existing Deployment Class Systems (Deemed Compliance)
- Note: Low and High split DCSs are defined which use different portions of the spectrum where FEXT is an issue and can therefore co-exist
  - A portion of the low frequency region is shared when FEXT is relatively small
  - The intention is for high split systems to be used at the lower Network Reference Point

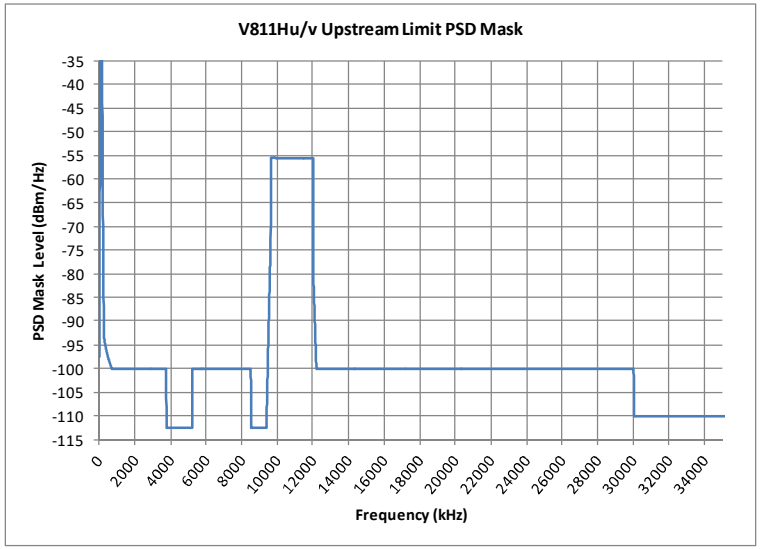
Deployment Class (Vectored or Non-Vectored)	International Standard
VDSL2 17.6 MHz	G.993.2 17a
VDSL2 Low Split 17.6 MHz	G.993.2 17a
VDSL2 High Split 17.6 MHz	G.993.2 17a

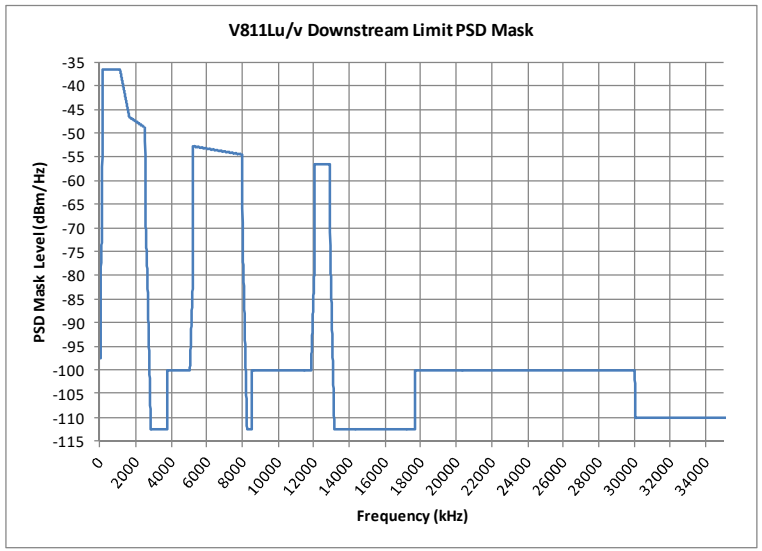
Table1/Pt1

High and Low Split DCS Power Spectral Density Masks:

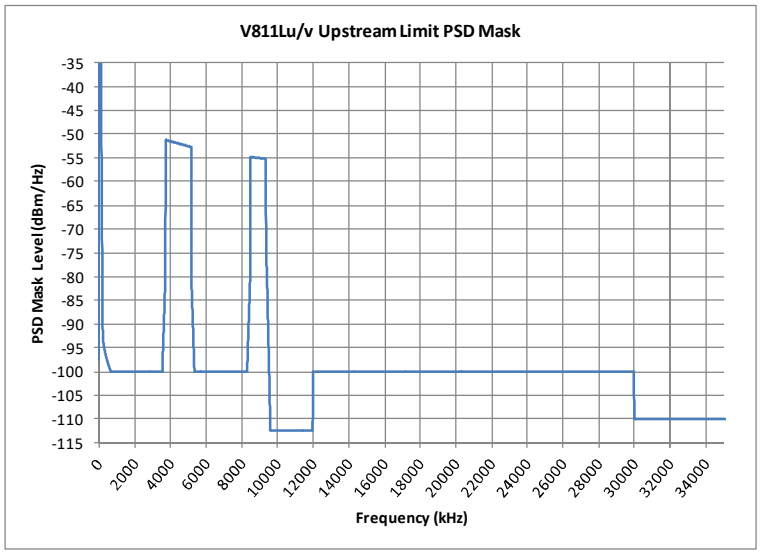


High Split





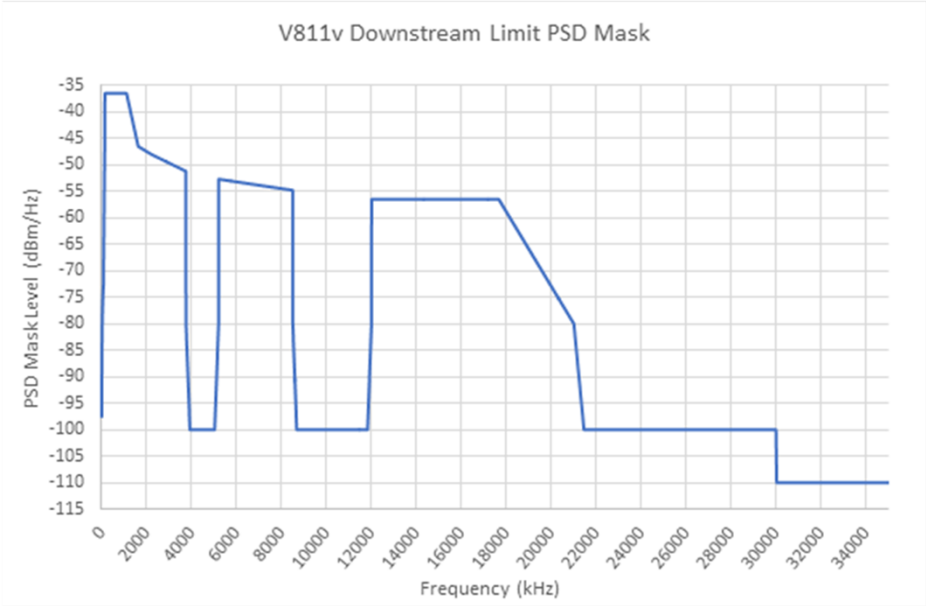
Low Split



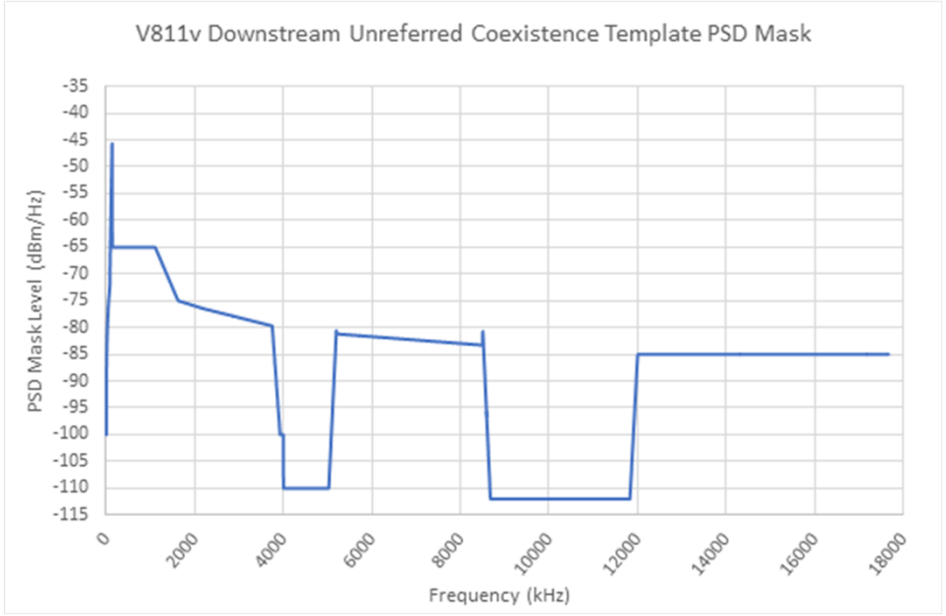
Example of a Co-existence Mask: Vectored VDSL2 17.6MHz DCS

Example: A vectored VDSL2 17.6MHz DCS (at the downstream transmitter output)

Transmit PSD for 17.6MHz DCS



Co-existence mask for vectored 17.6MHz DCS



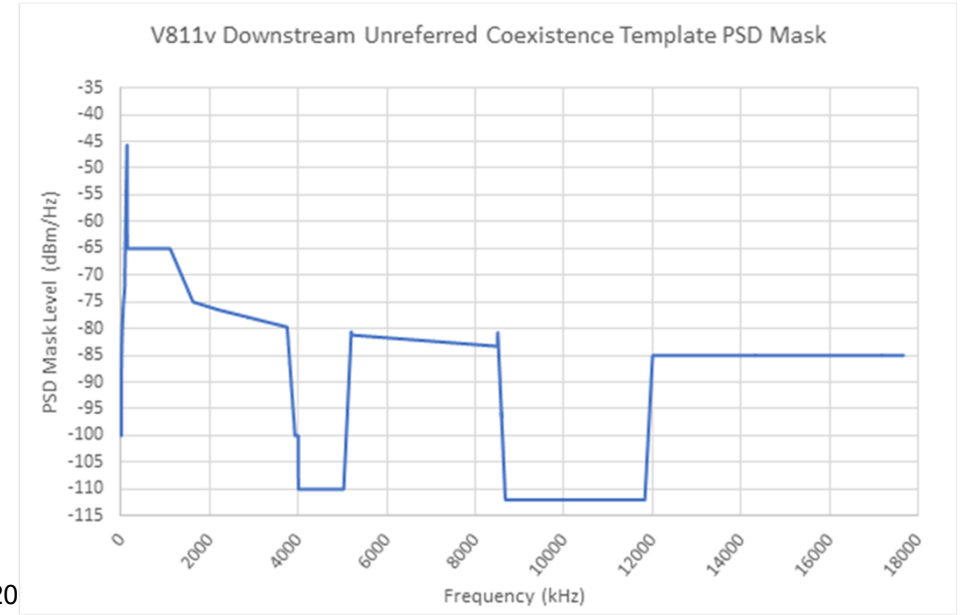
In-band transmit PSD reduced by 25dB to take into account vectoring gain

Non Deployment Class Systems (NDCS):

- Not fully defined in the code
- Must satisfy the legacy system shaping requirements
- Must satisfy the co-existence masks of any DCSs in the shared cable bundle
- An analysis of interference must be undertaken

Example: An NDCS satisfying the mask of a vectored VDSL2 17.6MHz DCS

Co-existence mask for vectored 17.6MHz DCS



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Viable Sharing Options

1. Use of a Deemed Compliant Deployment Class Systems
   - Some combinations of Deployment Class Systems can co-exist with minimal interference and so are deemed to be compliant
   - These system combinations give Carriage Service Providers a simple approach to co-existence
   - Different combinations exist when the DCSs are at the same or different locations (see Tables 2 and 3/Pt1)
   - Example: A lower priority vectored or non-vectored VDSL2 17a DCS can co-exist with a higher priority non-vectored VDSL2 17a DCS when they are at the same location provided same UPBO settings
   - Example: A lower priority low split VDSL2 17.6MHz DCS can co-exist with a higher priority high split VDSL2 17a DCS

2. Non-Deployment Class Systems conforming to any DCS co-existence masks (previous slide)

3. Any other solution agreeable to all parties while meeting any legacy system protection requirements

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Full Coverage:

- Full Coverage is determined only for Deployment Class Systems using the Maximum Inline Attenuation (eg longest loop length) and a look up table in the Code giving the maximum attenuation to qualify for Full Coverage (Table 4 Part 1)
  - Determined using a computer model of the Deployment Class System assuming no legacy systems
- The Maximum Inline Attenuation in the look-up table is given for the following access payload throughput speed targets:
  - For a Network or Campus System, 25 Mbps downstream; or
  - For a Building system, 50 Mbps downstream
  - Note that all target download payload rates are determined assuming legacy system removal
- Maximum Inline Attenuation (2.2/Pt1)
  - means the maximum over all potential end user Customer Equipment connections of the sum of the inline attenuations at 3.75 MHz of all cable segments in the path connecting the DSLAM to the end user via the Tail Cable, Shared Cable Bundle and Drop Cable.

Full Coverage (cont.):

- Full coverage is designated when the Maximum Inline Attenuation does not exceed the attenuation given in the table below, using the relevant speed target, and Deployment Class
  - For a Network or Campus Systems, 25 Mbps downstream; or
  - For a building system, 50 Mbps downstream

- Note that any NDCS or non notified system cannot have Full Coverage status

Target Minimum Layer 2 Rate	25 Mbps	50 Mbps
VDSL2 17.6 MHz Non-Vectored	37.6	8.7
VDSL2 17.6 MHz low split Non-Vectored	25.4	1.69
VDSL2 17.6 MHz high split Non-Vectored	6.8	1.12
VDSL2 17.6 MHz Vectored	54.9	30.2
VDSL2 17.6 MHz low split Vectored	42.8	16.0
VDSL2 17.6 MHz high split Vectored	22.15	4.4

Maximum Attenuation in dB at 3.75MHz for Full Coverage Table4/Pt1

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Priority:

- In general, the Code protects higher priority systems against unacceptable interference from lower priority systems

- Priority is determined by:
  - Whether the system has Full Coverage (Full Coverage systems have higher priority than systems that do not achieve Full Coverage)
  - NGBS System type (Deployment Class Systems have higher priority than Non Deployment Class Systems)
  - Priority Date (where systems belong to the same priority level, systems with an earlier Priority Date have priority)

- A system must be Notified to be given a Priority Date
  - Note that a priority date can be lost if the provider fails to operate a notified system (7/Pt1)

- Note - the Code provides for two specific **exception** cases where higher priority systems must change into order to allow competitive access (**Sharing Resolution – Exceptions 6.3/Pt1**)

System Priority Order (4.4/Pt1):

- Notified Full Coverage Deployment Class Systems (DCS) – a Notified DCS that meets the Codes minimum speed expectation (network/campus 25Mbps, building 50Mbps)
  - Has the highest priority (ordered by Priority Date in respect to other full coverage DCSs)
  - Full Coverage is determined from the actual maximum cable attenuation of lines connected to the shared cable bundle and using the full coverage look-up table in the code for the DCS (Table 4/Pt.1)
  - A system with full coverage cannot lose full coverage status unless the provider chooses not to upgrade when a full coverage option exists when a lower priority system is notified

- Notified Deployment Class Systems (DCS)
  - A Notified DCS (without full coverage) with priority ordered by Priority Date
  - All DCSs must be defined in the code

- Non Deployment Class Systems (NDCS) and Non-Notified Systems
  - Lowest priority - The code cannot offer any protection to these systems from interference
  - All systems have equal priority but NDCSs that are notified have a priority date and can retain this date if upgraded to a DCS
  - Non-Notified Systems have no priority date
  - Cannot be given full coverage status
  - An NDCS can only become a DCS by inclusion into the code through a CA technical committee

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Sharing Resolution - Exceptions (6.3/Pt1):

- Sharing resolution is motivated by the concern that a higher priority provider's choice of DCS can prevent another provider from deploying a DCS from its NRP when alternate viable options are available

- There are two specific exceptions cases to the Priority ordering when a notified lower priority DCS provider can potentially force a change to a higher priority provider (specified by a Sharing Resolution Process)
  - The sharing resolution process will enable sharing where possible by forcing a change of DCS on the higher priority provider. The lower priority provider would then be able to deploy a complementary DCS that can coexist with that higher priority provider's new DCS.

- The two specific cases are:
  - Case 1 – Two systems at the same NRP (Likely Solution: Shared full spectrum VDSL2)
  - Case 2 – Two systems at separated NRPs (Likely Solution: Lower NRP takes high split VDSL2, higher NRP takes low split VDSL2)

- Conditions that block sharing resolution:
  - Where an existing (higher priority) DCS which has full coverage would no longer have full coverage with the proposed DCS
  - Where forcing a change would require a provider with an existing higher priority DCS to physically reconfigure ports or to deploy a second DSLAM ("an unacceptable operational impost")

Exception Case 1: Two providers are at the same NRP (6.3/Pt1)

- A higher priority notified vectored VDSL2 Deployment Class exists
- The code allows a lower priority provider to deploy a vectored or non-vectored VDSL2 DCS provided:
  - If the higher priority system has full coverage then the full coverage is maintained with non-vectored VDSL2
  - Tie cable attenuations can be equalised
  - Uses the non-vectored UPBO settings
- The code forces the higher priority provider to re-notify a non-vectored DCS and use its specified UPBO settings
  - Note the provider may still use a vectored DCS (with the non-vectored UPBO settings) but will be treated as if it were non-vectored.
- (An alternative is that the two providers may agree to use low and high split DCS systems)

Exception Case 2: Two providers at separated NRPs (6.3/Pt1)

- A higher priority provider's choice of DCS is preventing a lower priority provider from deploying any defined DCS from its chosen NRP

- The providers could use the High Split VDSL2 DCS from the lower NRP and the Low Split VDSL2 DCS from the higher NRP provided:
  - If the higher priority system has full coverage then the full coverage is maintained with the change in DCS
  - the higher priority provider would not suffer operational impost as a result of having to operate both split and full spectrum VDSL2 from the same DSLAM.

- Note: When the higher priority system is at a higher NRP then generally changing to a low split would fail the operational impost criterion since the system is likely to feed multiple shared cable bundles that can have other systems present

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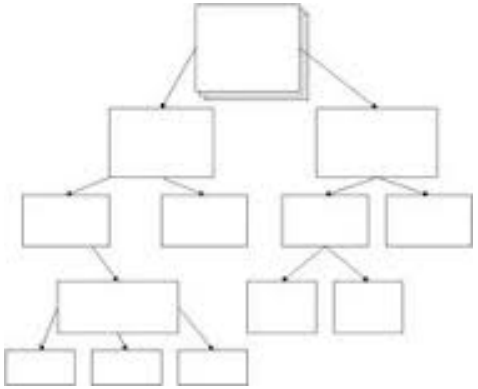
Code Processes(7/Pt1)

- Notification and Upgrade Process
- Compliance Process for a system to deploy
  - Sharing Resolution Process
- Code Start-up Process
- Non Compliance with Processes
- Non Compliant Interference

Note: Flowcharts of each of the processes is included in an Appendix to Part 1 which are designed to assist code users. However, it should be noted that the code text is definitive.



Overall Processes: The code makes provision for (7/Pt1):

- An **Initiator** to notify a new system or an upgrade to a system
- A **Responder to notify a new system** in response to another provider's notification (the initiator) and receive this latter notification date as its priority date
- A **Responder (or incumbent) to upgrade an existing (notified) system** and retain the previously allocated notification date as its priority date
- **Time limits are imposed** on the responder and subsequent initiator actions
- **Loss of Priority Date** should any responder that has previously **reneged** on an opportunity to make the same upgrade to a DCS or to propose the same new DCS.
- **Loss of Priority Date** should any CSP **fail to operate** a compliant system in a reasonable timeframe
- Resolution of **Equal Priority Cases**

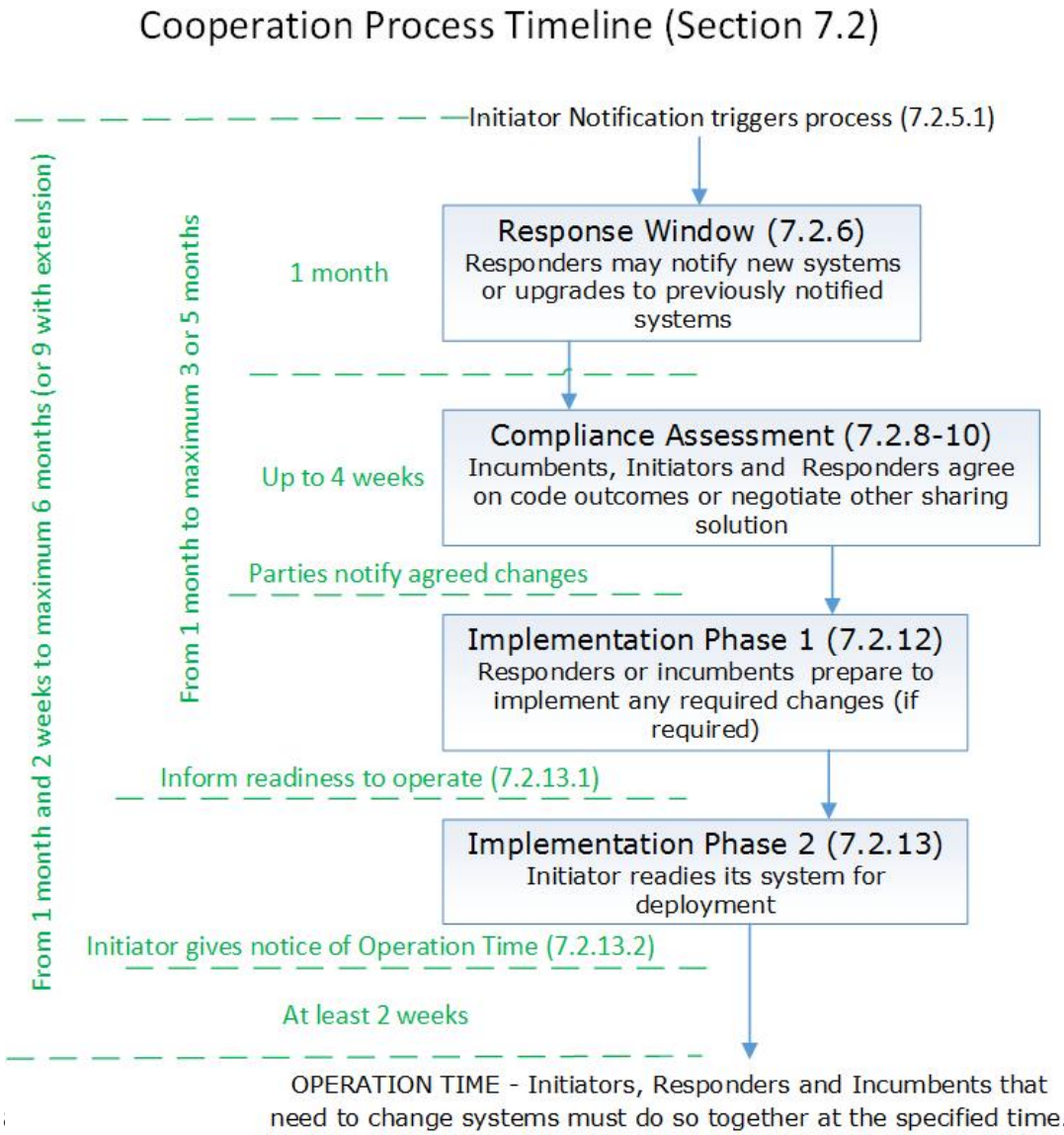
Co-Operation Process (7.2/Pt1) - 1

- An Initiator who notifies a new system or system upgrade must wait 1 month (the Response Window) to allow for any Responders (7.2.6.1)
  - The Co-Operation process commences (7.2.5.1)
- Only one Co-operation Process can be in progress for any shared cable bundle(s) (7.2.5.1)
  - Consists of Compliance Assessment and Implementation
- The Co-operation Process ends when (7.2.5.2):
  - The Initiator's and Responder's/incumbent's operation time is reached (whichever is later), or, the initiator retracts the notification
- Late Responders (responding after the 1 month Response Window and before the Operation Date)
  - May not participate in compliance assessment but must comply with the outcomes (7.2.11)

Co-Operation Process (7.2/Pt1) - 2

- Within 1 week after the Response Window, Initiator and Responders indicate their interpretation of the code outcome to all notified providers in the shared cable bundle (7.2.8.6)
- Within 2 weeks after the Response window, all notified incumbents can indicate their desire to commence a negotiation (7.2.8.8)
- Within 3 weeks after the Response Window, negotiate for an acceptable outcome (7.2.8.10)
- Within 4 weeks after the Response Window, update notifications with the outcomes (7.2.8.14)
- Within 6 months of the Initiator's notification (or 9 months with an accepted extension), the Initiator must operate the system (7.2.12)
- Within 3 months of the Initiator's notification, Responders proposing new systems must be ready to operate (7.2.12.5) – upgrades have 5 months (7.2.12.8)
- Initiator notifications must be updated at least 2 weeks before the Operation Date (Must have a co-ordinated operation of new systems)

Co-Operation Process (7.2/Pt1) - 3



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Scenario Examples:

- The code allows for sharing solutions for many different scenarios

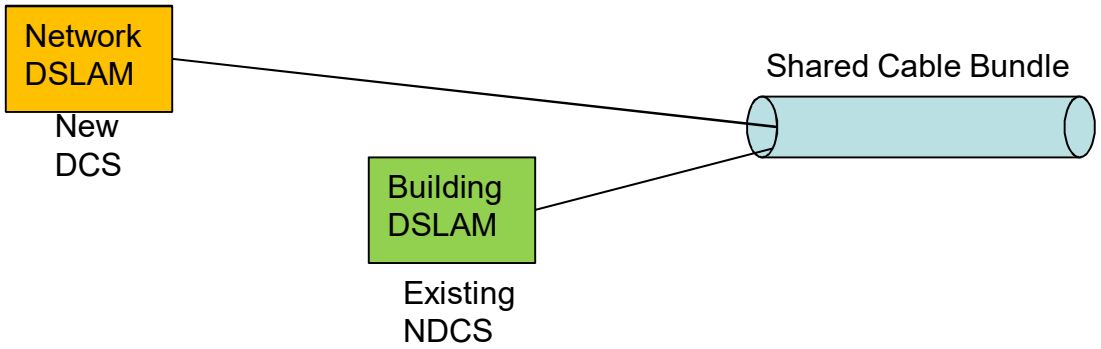
- The following three specific scenarios are merely illustrative of situations that may exist and some specific responses/outcomes to these situations
  - Note that the outcomes are not necessarily comprehensive and there may be other responses not described in the examples

Scenario Example 1:

- Scenario: Existing (notified) building VDSL2 NDCS and a new network DCS Notification is received (at different NRPs) by an Initiator

- Some Possible Outcomes if the Building system provider responds:
  - The Building System is able to achieve Full Coverage using the vectored VDSL2 high split DCS and the network system uses the low split VDSL2 17.6MHz DCS (Exception Case 2)
  - The Building System is only able to achieve Full Coverage with full spectrum VDSL2 and so the network system provider must seek an alternative approach (e.g. use a co-located DSLAM if the existing system can still achieve full coverage with a non-vectored full spectrum VDSL2)

- If the Building system provider does not respond:
  - The building system must comply with the co-existence mask of the new network DCS or remove its system from operation

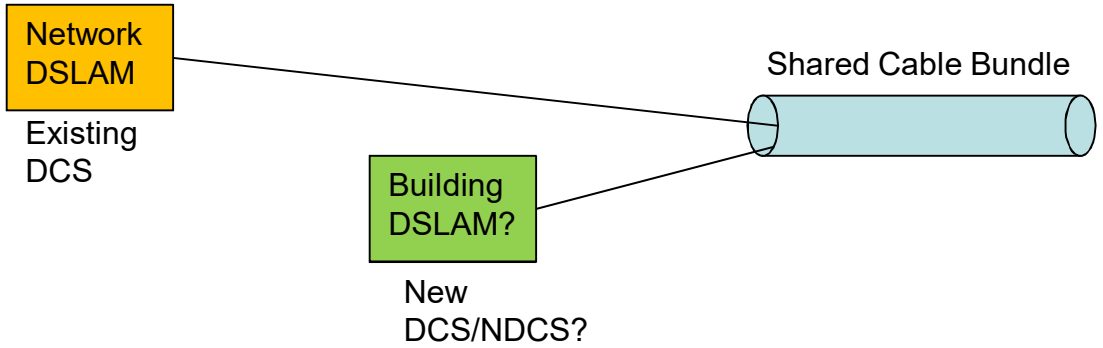


Scenario Example 2:

- Scenario: Existing (notified) network full spectrum full coverage vectored VDSL2 DCS and a new building VDSL2 DCS Notification is received (at different NRPs)

- The Outcome:
  - The network system provider would not be required to change due to the operational impost of configuring only those lines into the proposed building
  - The building system provider must seek an alternative approach (e.g. an NDCS satisfying the co-existence mask of the network DCS)

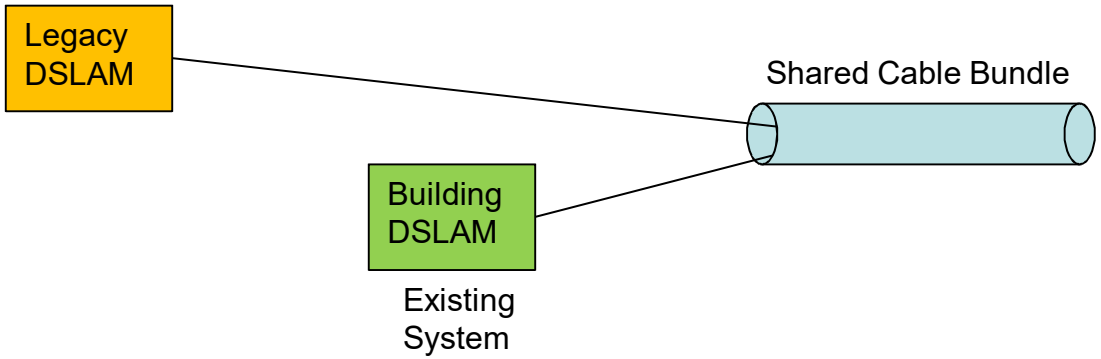
- Note: In reality the Building system provider would likely recognise this outcome before notifying and hence notify an NDCS



Scenario Example 3:

- Scenario: Existing building (NDCS) VDSL2 system and the code comes into effect. No network NGBS has been notified within the initial code registration window but legacy ADSL2+ network systems are present

- Likely Outcome:
  - Building system shapes spectrum below 2.208Mhz because a legacy ADSL/ADSL2+ system is present
  - Building system provider notifies the system as a NDCS to obtain a priority date
  - The Building system provider may also see an advantage in upgrading to a DCS to achieve higher priority – this may include the determination of the full coverage status. However they do not need to perform this until a DCS is notified since they can retain their priority date



Conclusions: General

- The Code applies to all non-Unconditioned Local Loop Service (non-ULLS) systems deployed from either a network node or from an access module installed in a multi-dwelling building or lateral development
  - Where a legacy ADSL/ADSL2+ system may exist in a shared cable bundle, all network, campus and building systems must shape to avoid unequal level FEXT
- Systems can come under the protection offered by the code if the Carriage Service Provider is Subscribed and the system Notified
- While the Code is complex in order to cover all possible scenarios, the majority of sharing solutions should be straightforward

Conclusions: Suggestions

- Gain an understanding of the Code
- Subscribe as a Service Provider under the Code
- Develop systems and processes to notify, gather and process Notifications
- Notify existing systems within the first two months of the code's release to obtain the earliest possible priority date
- Be prepared to shape existing building systems to protect legacy ADSL/ADSL2+ systems
- Where a legacy ADSL/ADSL2+ building system exists with a NGBS, develop an approach for when the co-existence period ends (these legacy systems exceed co-existence masks)
- Consider upgrading existing systems to one of the Deployment Class Systems to increase priority (although it can be done as a Responder)
- Bring alternate systems into the Working Committee for consideration as Deployment Class Systems (e.g. G.Fast)

Thank You

John Stanton, CEO
Communications Alliance

Appendix: Additional Material

John Stanton, CEO
Communications Alliance

Three Parts to the Code:

- Part 1: Performance Requirements
  - Contains the overall objectives, terminology definitions, and the processes for resolving use of the available spectrum where a shared cable bundle is shared by more than one carrier.
- Part 2- Methods for Determining Compliance
  - Contains the full detail of the technical approach to spectrum management that will protect Next Generation Broadband Systems and Legacy Systems that use shared cable bundles in buildings or campuses from unacceptable interference. The two key aspects covered are:
    - Code compliance calculations, and
    - The process for developing the Code to include newer technologies as they evolve.
- Part 3 – Requirements for Deployment Class Systems
  - Contains details of the current Deployment Class Systems and their co-existence masks

Cooperation in Good Faith (4.1/Pt1):

- CSPs shall cooperate in good faith to enable any viable sharing of the cable bundle

- A CSP is taken to have cooperated in good faith if the provider complies with the technical requirements in 4.2 to 4.4 of Part1 of the code

Direction of Transmission:

- In systems that have separate spectral frequencies for upstream and downstream transmission, conflicts in the transmission direction has the potential to cause unacceptable interference

- The transmission direction is determined as follows:
  - Any shared cable bundle that is currently or has been used for delivery of telephone or ADSL or VDSL2 services from the customer access network shall retain the direction used for those services,
  - For an interconnection cable between buildings, direction in any shared cable bundle it traverses is defined by the highest priority system that has been deployed to that cable bundle.

Deemed Compliance (6 & 8/Pt1):

- Some combinations of Deployment Class Systems are designed to co-exist with minimal interference and so are deemed to be compliant
- These system combinations give two competing carriage service providers a simple approach to co-existence
- Different combinations exist when the DCSs are at the same or different locations

For DCSs at same location

Higher Priority Deployment Class System	Deployment Class System deemed to coexist (May be vectored or non-vectored)	Parameters that must match Deployment Class System
Non-vectored VDSL2 17a	VDSL 2 17a	UPBO a, b, AELE-MODE, DPBO
	VDSL2 17a High Split	UPBO a, b, AELE-MODE, DPBO
	VDSL2 17a Low Split	UPBO a, b, AELE-MODE, DPBO
Non Vectored VDSL2 High Split	VDSL 2 17a	UPBO a, b, AELE-MODE, DPBO
	VDSL2 17a High Split	UPBO a, b, AELE-MODE, DPBO
	VDSL2 17a Low Split	UPBO a, b, AELE-MODE, DPBO
Non Vectored VDSL2 Low Split	VDSL 2 17a	UPBO a, b, AELE-MODE, DPBO
	VDSL2 17a High Split	UPBO a, b, AELE-MODE, DPBO
	VDSL2 17a Low Split	UPBO a, b, AELE-MODE, DPBO

Deemed Compliance (cont):

Co-existence scenarios (at same or another location)

Higher Priority Deployment Class System Vectored or non-Vectored	System that is deemed or permitted to coexist (May be vectored or non-Vectored)	Parameters that must match Deployment Class System
VDSL2 17a	{G.fast >17.6 MHz}	Coexisting System PSD Masks must satisfy Higher Priority Deployment Class System Coexistence Masks.
	{VDSL2 >17.6 MHz}	Coexisting System PSD Masks must satisfy Higher Priority Deployment Class System Coexistence Masks.
VDSL2 17a High Split **(Note 1)**	VDSL2 17a Low Split,	DPBO masks must be used below 2.208 MHz to adjust for separation
	{VDSL2 >17.6 MHz}	Coexisting System PSD Masks must satisfy Higher Priority Deployment Class System Coexistence Masks.
	{G.fast >17.6 MHz}	Coexisting System PSD Masks must satisfy Higher Priority Deployment Class System Coexistence Masks.
VDSL2 17a Low Split **(Note 2)**	VDSL2 17a High Split,	DPBO masks must be used below 2.208 MHz to adjust for separation
	{VDSL2 >17.6 MHz}	Coexisting System PSD Masks must satisfy Higher Priority Deployment Class System Coexistence Masks.
	{G.fast >17.6 MHz}	Coexisting System PSD masks must satisfy Higher Priority Deployment Class System Coexistence Masks.

Table3/Pt1

Bracketed systems are informative only; as NDCSs they must meet the required coexistence masks for the listed DCS.

Upgrade Definition

Means any:

- replacement or modification to a System that results in a change to the Notified System type (including from Non-Deployment Class System to a Deployment Class System or vice versa) or of the parameters that describe that System implementation; or
- software or firmware change that alters the ability of the system to achieve full coverage.