Scalable Multi-mode VDSL (DMT option) for EFM-Cu

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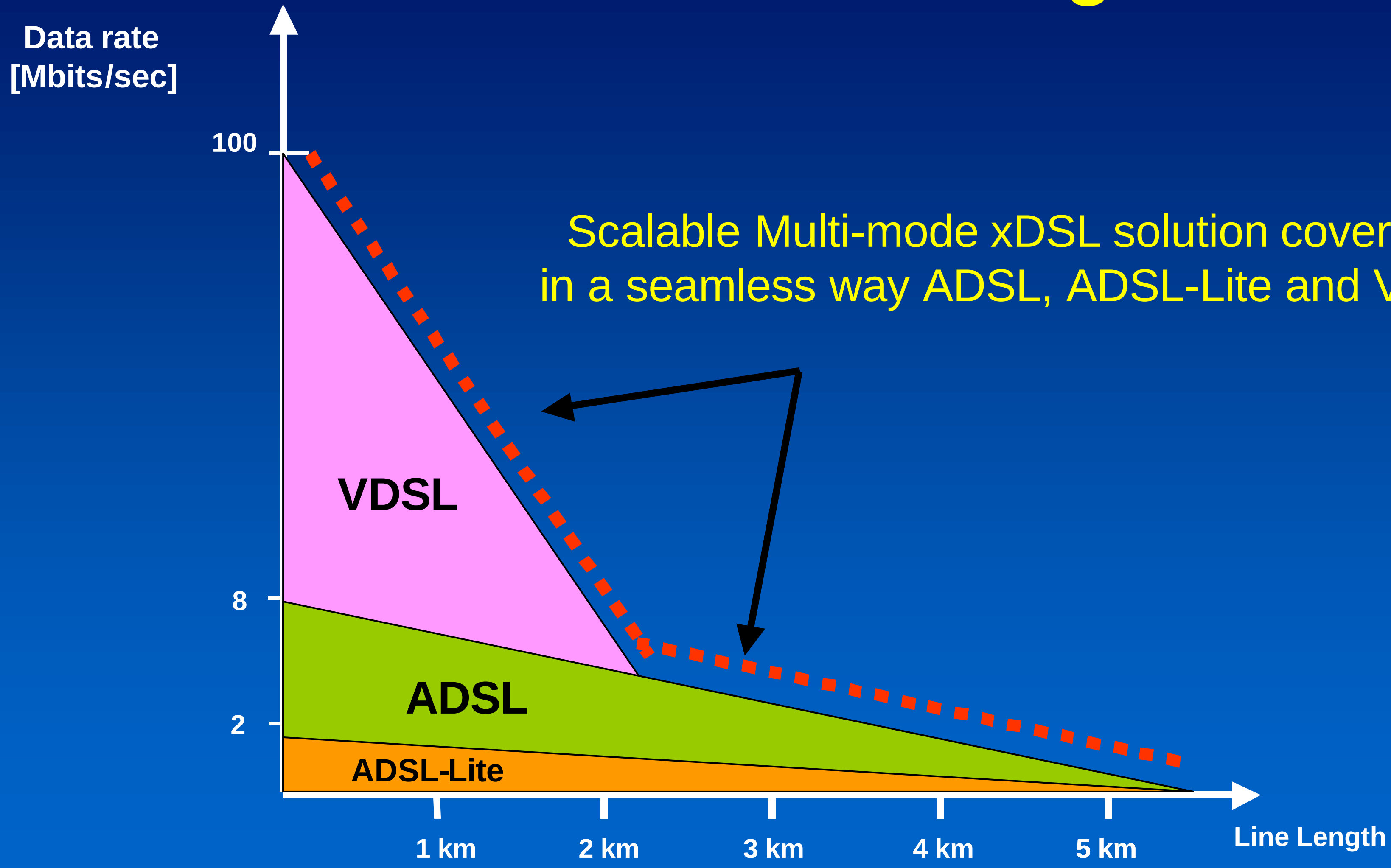
Scope

- Propose a PHY layer solution based on FDD DMT-VDSL concepts
- This solution supports the ANSI, ETSI, ITU-T specifications and is candidate for the future EFM-Cu standard
- This solution is scalable, flexible and is compatible/interoperable with ADSL, ADSL-Lite and DMT-VDSL systems
- This solution is suitable for both Public and Private Networks deployments
- Conclusion

Overview of ADSL, ADSL-Lite and VDSL technologies



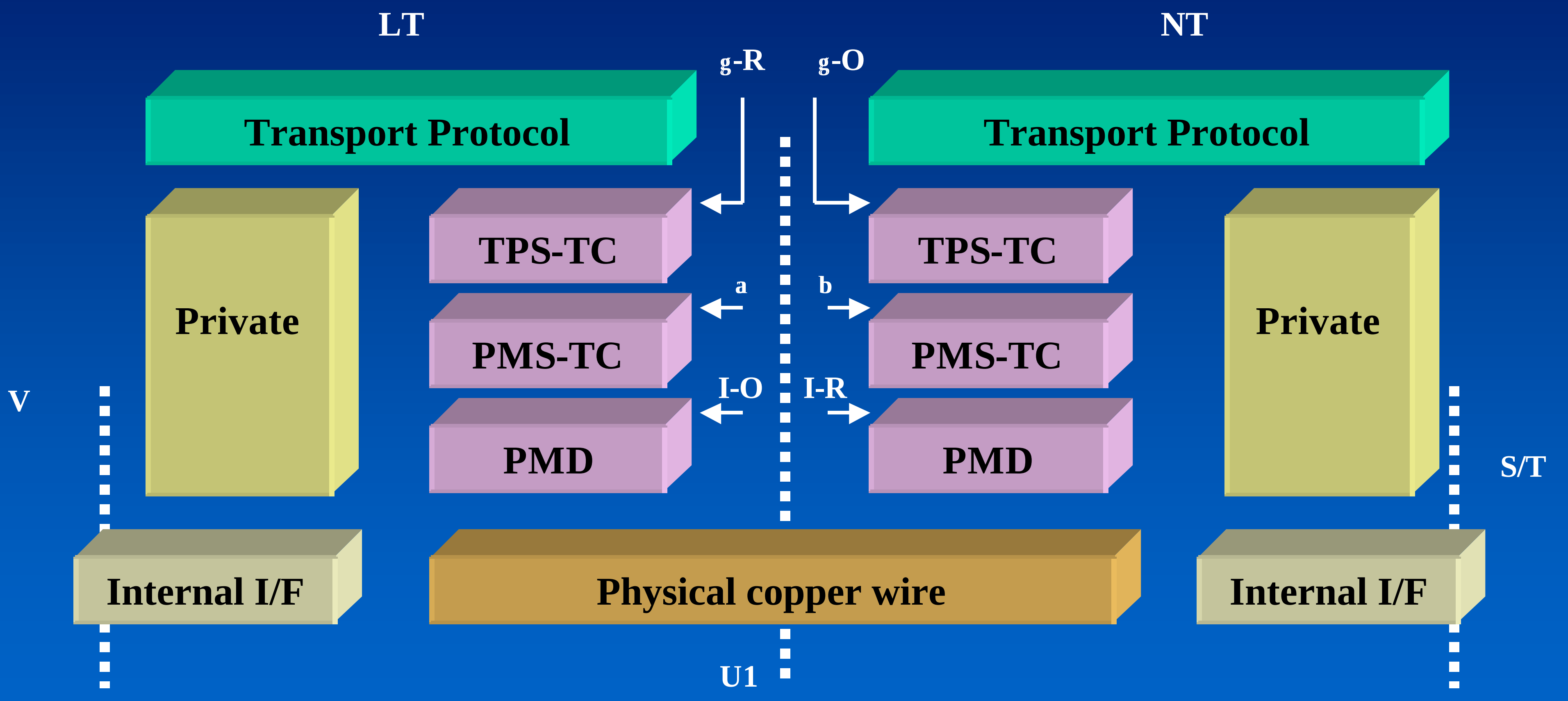
VDSL Standardization status

- ETSI TM6
  - Functional requirements, ref: TS 101270-1 approved
  - Spec document approved in Nov.2000, ref. TS 101270-2 contains:
    - System specification of Multi-Carrier Modulation (MCM) VDSL
    - System specification of Single-Carrier-Modulation (SCM) VDSL

- ANSI T1.E1.4
  - Draft Trial use standard in comment resolution
  - After publication, this document will be valid for a period of 2 years
    => *Trial use standard for a period of two years*
  - Document contains:
    - Common Functional requirements
    - System specification of Multi-Carrier Modulation (MCM) VDSL
    - System specification of Single-Carrier-Modulation (SCM) VDSL

- ITU-T SG15/Q4
  - Foundation document G.vdsl.f specifying functional requirements approved in ITU-T plenary meeting in October 2001 (**G.993.1**)
    => This document specifies the « Packet Transfer Mode » (PTM-TC) layer and the encapsulation method to handle the transport of generic packets

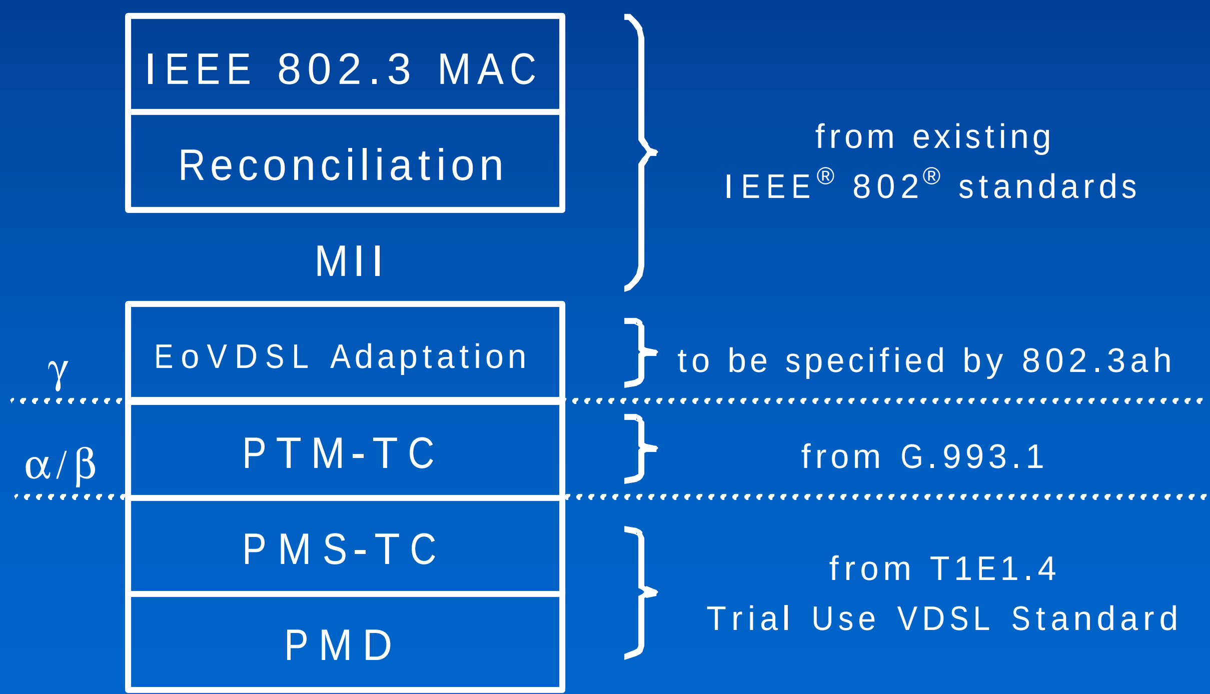
The VDSL protocol layer model, as reminder



A Standard Based Ethernet-over-VDSL Model

The Ethernet-over-VDSL model shown here follows the ideas put forward by ITU-T SG15 during the specification of the “Packet Transfer Mode”.

IEEE P802.3ah



A Standard Based Ethernet-over-VDSL Model (cont'd)

- The **PTM-TC Layer of G.993.1** (G.vdsl.f) specifies the use of HDLC encapsulation (ISO 3309) for the transport of generic packets over VDSL (or other ITU-T xDSL flavors).
- Any protocol-specific operations are moved to the "**Adaptation Layer**" just above the PTM-TC layer, and outside the scope of the ITU-T Recommendation.
- **IEEE 802.3ah** could take advantage of the EoVDSL Adaptation Layer to address buffering requirements, flow control, preamble removal, link aggregation, …

FDD DMT-VDSL at a glance (1)

- FDD DMT-VDSL is one of the VDSL PHY layer specified in ANSI and ETSI VDSL standards [1], [2] and is proposed in ITU-T
  - It offers flexibility in the frequency allocation and PSD masks... [3], [4]
  - It is symmetry agile
  - It is robust against bridged-taps, RFI, impulsive noise
  - It implements Power Back Off, PSD management and Egress control
  - It is a Full-duplex FDD scheme
    - It does not require synchronisation of the lines in the same cable bundle
  - It supports both ATM and PTM Transport Protocol Specific Transmission Convergence sublayers
    - ATM is the most popular protocol used in network backbones
      - Guarantees interoperability with legacy ADSL, ADSL-Lite and VDSL-ATM services
    - PTM is a generic « Packet Transfer Mode » which includes EoVDSL
      - Supports HDLC encapsulation, byte stuffing, rate decoupling
      - Can provide MII, RMII and SMII interfaces

FDD DMT-VDSL at a glance (2)

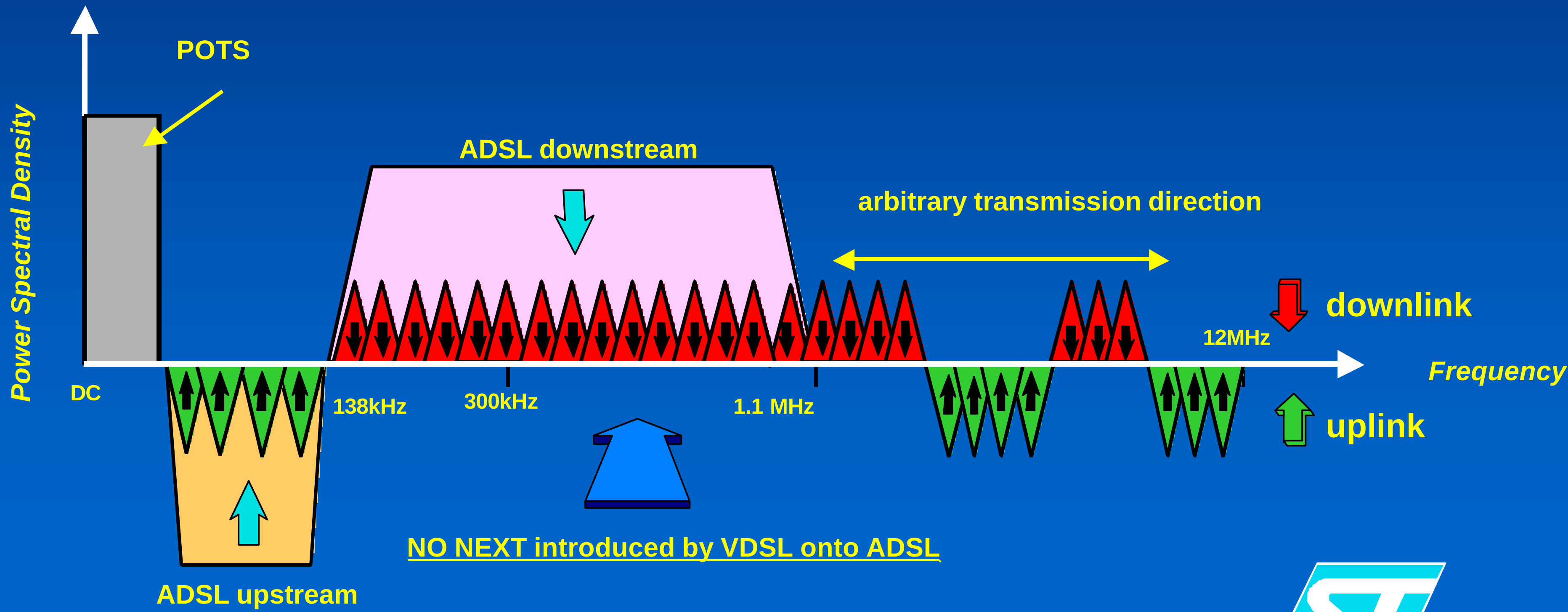
- FDD DMT-VDSL as per specified in ANSI and ETSI documents and proposed in ITU-T is a scalable system [1], [2]
  - It supports all FFT/IFFT lengths from 256 to 4096 points
  - Each FFT/IFFT size corresponds to a certain bandwidth and consequently to a certain achievable bitrate/loop reach
  - System bandwidth can be scaled as a function of the loop length and the targeted service

FFT length	Bandwidth (MHz)	Ex of targeted aggregate bitrate (Mbps)	Max asymmetric services Us/Ds (Mbps)	Ex of targeted reach on 26 AWG cable (kft)
256	1.1	1.5	0.3 /1.2	10
512	2.2	12	5/7	6
1024	4.4	25	5/20	4
2048	8.8	40	10/30	3
4096	12 (17.6 max)	70	25/45	2

Conditions: 26 AWG, 998 frequency plan, -140 dBm/Hz thermal noise + 20 VDSL self-FEXT, extended US bans up to 500 kHz, 6 dB margin, 5.5 dB coding, 14 bits/s/Hz max

FDD DMT-VDSL at a glance (3)

- FDD DMT-VDSL is by nature spectrally compatible and backward interoperable with ADSL and ADSL-lite
  - It is a DMT-based system like ADSL and supports 256-FFT size
  - The tone spacing (Δf= 4.3125 kHz) is the same as in ADSL
  - It can fit ADSL frequency allocation and PSD masks



Deployments scenarios (1)

❑ In the Public Network (1) : Asymmetric Services

- Short/medium range:
  - Operates in standard 998-VDSL mode (ANSI T1.E1)
    - Use of standard PSD masks
    - Offers Asymmetric service 22/3
- Long range:
  - Operates in G.dmt or G.lite ADSL modes (G.dmt/G.lite)
    - Use of ADSL PSD masks
    - Offers classical ADSL or ADSL-Lite services

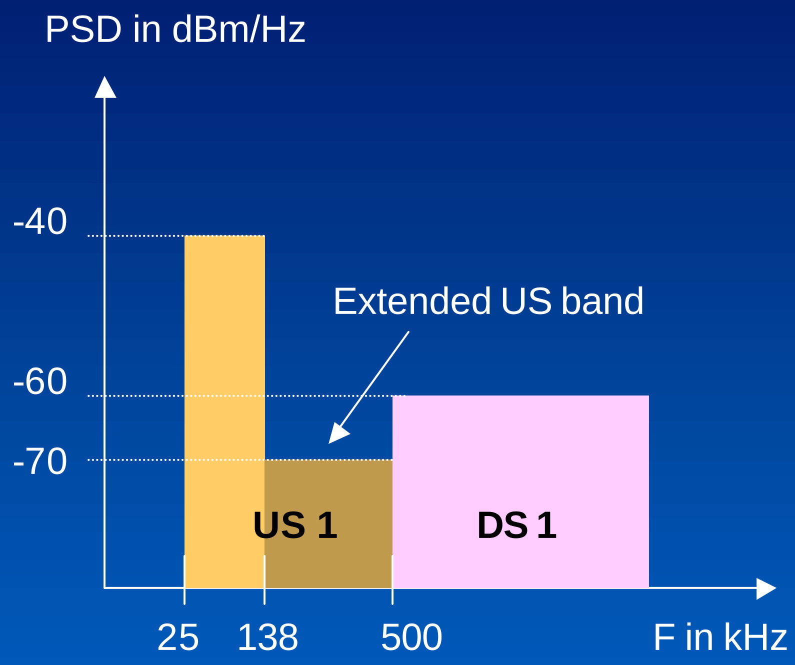
Deployments scenarios (2)

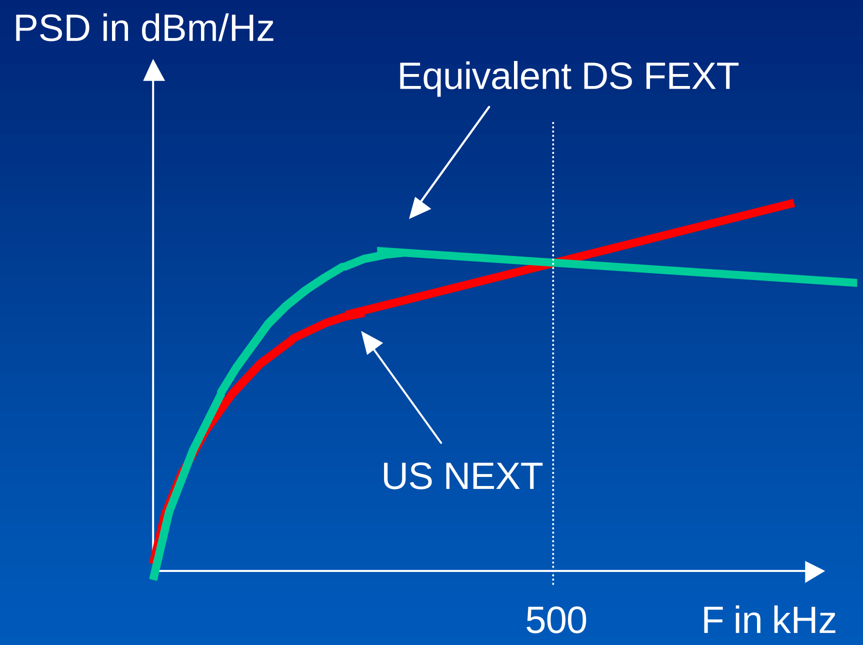
❑ In the Public Network (2): Symmetric Services

- Short/medium range:
  - Operates in standard 998-VDSL mode with extended Upstream mode *(see contribution to ANSI T1.E1, T1E1-238 from B.Rezvani and J. Cioffi, Ottawa, Canada, Aug.2001 [5])*
    - Use of extended US band from 25 up to 500 kHz
    - Reduced transmit PSD at –70 dBm/Hz in the band [138, 500 KHz]
    - Spectrum overlapping but still compliancy with T1.417 Spectrum Management Rules is guaranted

- Long range:
  - Operate in scaled 998-VDSL mode (FFT length = 256) with extended Upstream mode
    - Use of extended US band from 25 up to 276 kHz
    - Use of DS band from 276 to 1.1 MHz

Extended US mode with Standard 998-VDSL thanks to smart PSD management





Below 500 kHz, the NEXT induced by US signal transmitted in the DS band remains below the equivalent DS FEXT

⇒ Spectrum overlapping is possible without violation of T1.417 SM Rules

Deployments scenarios (3)

- In the Private Networks: Asymmetric & Symmetric

  - Short/medium range:
    - Operates in standard DMT-VDSL mode with other standardized frequency plans and newly defined ones
    - Frequency plans optimized as a function of the targeted services
      - Ex: 997, Fx, others…

  - Long range:
    - Operates in scaled DMT-VDSL with other standardized frequency plans and newly defined ones
      - FFT length = 256, 512,…
      - Reduced bandwidth, reduced power dissipation

Conclusion

- ADSL, ADSL-Lite and scalable DMT-VDSL specifications can be factorized in a unique architecture
  - Common hardware, differentiation is done by mode specific application software programs (e.g., ADSL Sw, VDSL Sw, EFM-Cu Sw)
  - Scalable multi-mode devices can be obtained at no extra cost compared to a classical DMT-VDSL implementation
- Mode and/or FFT length is selectable, in a seamless way, by the universal ITU-T G.994.1 G.hs protocol
- Scalable Multi-mode devices cope with a broad range of deployment scenarios and service offerings
  - Minimum guaranteed bitrate -> Reduced bandwidth, Long Reach
  - High bitrate -> Full-bandwidth, Short reach
- Ease Fast-deployment and roll-out
  - Cheaper multi-mode line cards
  - Fit with existing Access Multiplexer Equipments at CO, MxU

References

[1] Very-High speed Digital Subscriber Lines (VDSL) Metallic Interface, Part 2: Technical specification of Multi-Carrier Modulation (MCM) Transceiver, ANSI, T1E1.4/00-011, Draft Specification.

[2] Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Very High speed Digital Subscriber Line (VDSL); Part 2: Transceiver specification, ref : ETSI, TS 101 270-2.

[3] “Standard compliant VDSL : a flexible and efficient solution for EFM over Copper”, C. Del-Toso et al., ST Micro, IEEE EFM-C working group meeting, July’01.

[4] “EFM data rate analysis, Part II: low-bound channel capacity without bridge taps”, B. Rezvani et al. Ikanos, IEEE EFM-C interim meeting, October’01.

[5] “New NEXT results for Extended-Upstream Operation”, B. Rezvani, J. Cioffi, contribution T1E, Part II: low-bound channel capacity without bridge taps”, .4/2001-238, T1.E1 meeting, Ottawa, Canada, August’01.

THANK YOU !