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

Scalable Multi-mode xDSL solution covering in a seamless way ADSL, ADSL-Lite and VDSL
VDSDL 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

IEEE 802.3 MAC
Reconciliation

MII

EoVDSL Adaptation

β/γ

PTM-T C

PMS-T C

PMD

from existing IEEE® 802® standards
to be specified by 802.3ah
from G.993.1
from T1E1.4 Trial Use VDSL Standard
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

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

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 ($\Delta f = 4.3125$ kHz) is the same as in ADSL
  - It can fit ADSL frequency allocation and PSD masks

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**Table:**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Power Spectral Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC</td>
<td>300 kHz</td>
</tr>
<tr>
<td>138 kHz</td>
<td>300 kHz</td>
</tr>
<tr>
<td>1.1 MHz</td>
<td>1.1 MHz</td>
</tr>
<tr>
<td>12 MHz</td>
<td>12 MHz</td>
</tr>
</tbody>
</table>

**Diagram:**

- POTS
- ADSL downstream
- ADSL upstream
- NO NEXT introduced by VDSL onto ADSL
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:**
    - Ñ Operates in standard DMT-VDSL mode with other standardized frequency plans and newly defined ones
    - Ñ Frequency plans optimized as a function of the targeted services
      - Ex: 997, Fx, others…

  - **Long range:**
    - Ñ 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


THANK YOU!