Standard compliant VDSL : a flexible and efficient solution for EFM over Copper

Christophe Del-Toso, **Raffaele Penazzi**, Mounir El-Amrani, Denis Mestdagh, Srikanth Gopalan

ST Microelectronics

Contacts: christophe.del-toso@st.com, raffaele.penazzi@st.com

Supporter : Alcatel

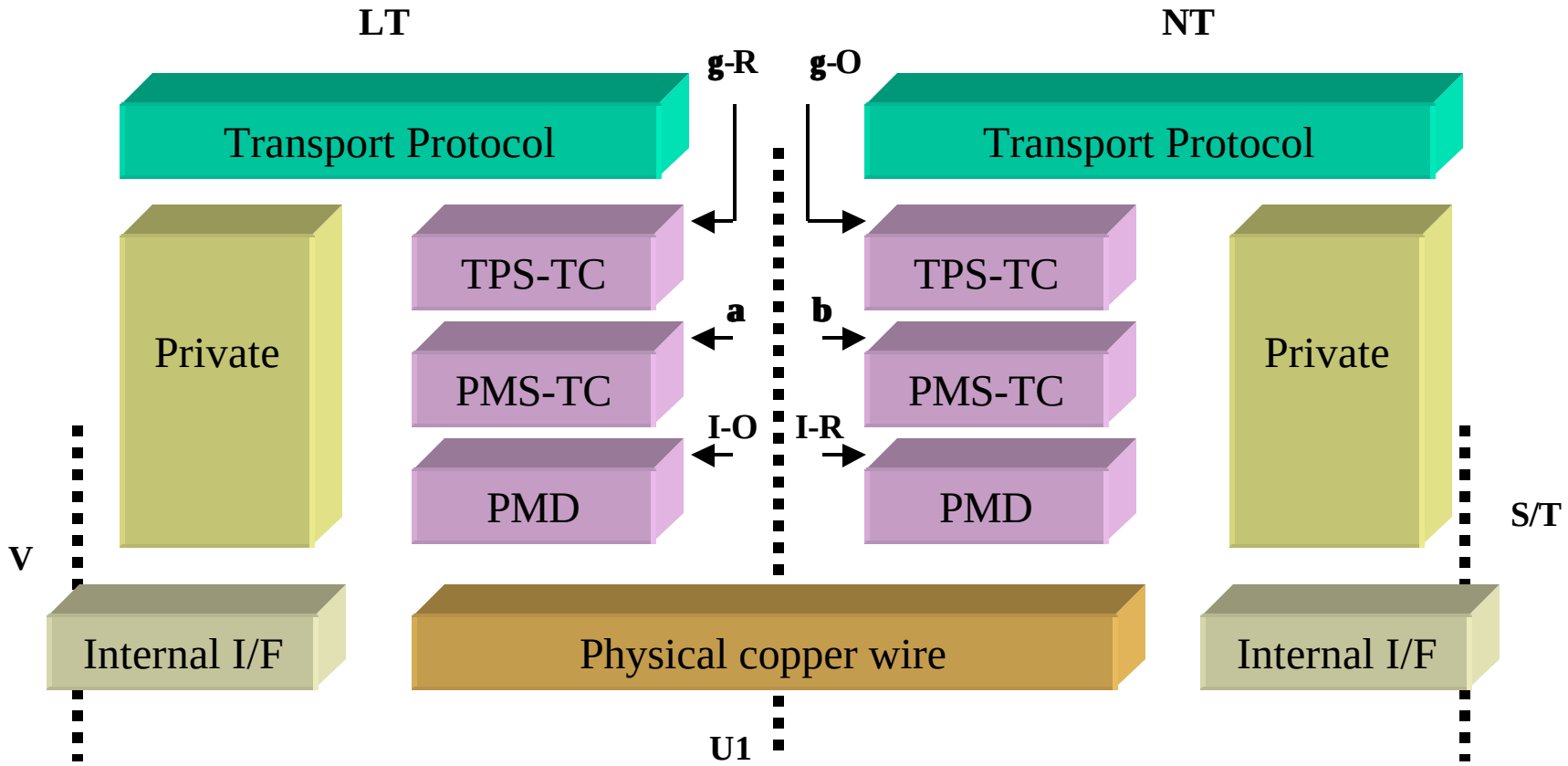
Scope

- Make a clear distinction between PHYsical and Transport Protocol Specific layers
- Present advantages of standard compliant VDSL PHYsical layer
- Present examples of achievable bit-rates obtained with standard compliant VDSL (simulation results)
- Conclusion

EFM over Copper: PHY or Protocol centric ?

- So far, the Protocol reference architecture for EFM has not yet been specified
- Physical layer should be (is) Protocol independent and vice versa *(see EFM contributions, March 2001, Beck_1_0301, Barrass_1_0301, Mizrahi_1_0501)*
- Standard VDSL (ITU-T, ANSI, ETSI) is already a layered model with distinct PHY and Transport Protocol Specific layers
- Standard VDSL can support different Transport Protocol Specific – Transmission Convergence (TPS-TC) layers
  - ATM-TC, STM-TC already specified in ETSI, ANSI and ITU-T
  - Packet-oriented TPS-TC called PoV-TC is under specification in ITU-T

VDSL protocol layer model



PMD is line code dependent, PMS-TC and TPS-TC are not
VDSL TPS-TC could be either ATM or PoV(Ethernet)

EFM over Copper & VDSL (1)

- No need to define a new PHYsical layer in EFMC
  - VDSL Transport Protocol Specific layer can support Ethernet
    - Ethernet over VDSL is included in PoV
    - PoV specification should be approved in ITU-T in October 2001
    - Ethernet frames are encapsulated into HDLC frames
    - No need for SAR engine, no impact on Ethernet MAC
  - VDSL PHY fulfills requirements of EFMC
    - Two modulation techniques are specified for the PMD sublayer:
      - Multi-Carrier Modulation line code (MCM or DMT)
      - Single Carrier Modulation line code (SCM)
    - Both are compliant to standards ETSI, ANSI
    - Both support standard frequency plans (998, 997)
    - Both ensure spectral compatibility with other legacy DSL services
    - Full duplex transmission ensured by Frequency Division Duplexing (FDD)
      => This is not half-duplex TDD which has been rejected by FSAN
    - *FDD better than TDD in unbundled Local Loop*
    - Symmetry and Frequency agile
    - Robust against RFI, bridged-taps, impulsive noise
    - PSD level management and RF egress control

EFM over Copper & VDSL (2)

- EFMC work on PHY layer should line up with work on VDSL standardisation
  - Functionnal requirements (e.g. spectral compatibility, service types) are already specified in ANSI, ETSI and soon in ITU-T
    - A Foundation recommendation G.vdsl.f should be adpoted in ITU-T in October 2001 meeting
    - G.vdsl.f will specify functional requirements for both SCM and MCM VDSL PHY layers
    - G.vdsl.f will be in line with ANSI and ETSI requirements
    - G.vdsl.f will include functional specification of PoV
  - Strong involvment and support of Chipset vendors, System & Equipment manufacturers, Telecom Operators (FSAN)
  - Cost benefit: Unique PHY layer for both VDSL and EFMC
  - Speed-up process for EFMC PHY layer definition
  - Liaisons to ANSI, ETSI should be set-up to line up proposals
- In parallel, IEEE should specify complementary requirements:
  - Bit-rates and service types specific to EFMC
  - Network topologies and noise models specific to EFMC

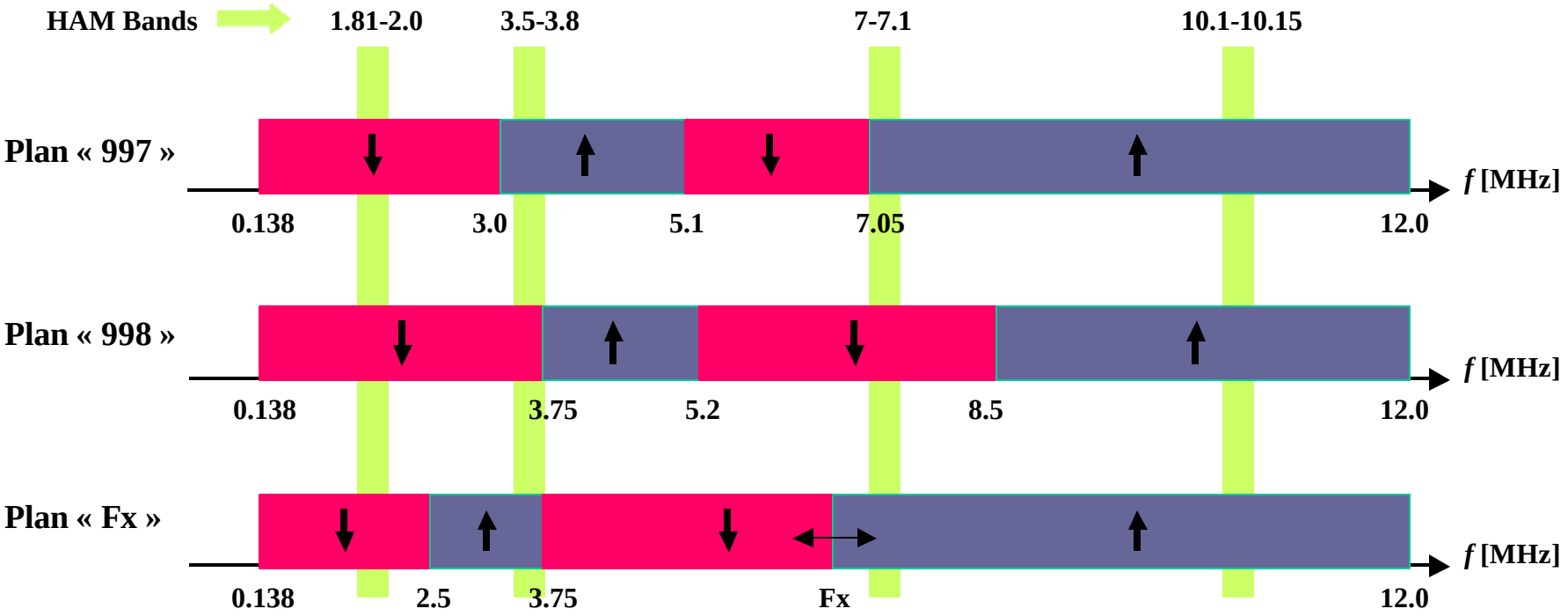
EFM over Copper & VDSL (3)

- Guarantees services and spectral compatibility for deployment in environments subject to regulatory regimes (e.g. Public Network)
  - Fall-back mode of operation which guarantees spectral compatibility with internationally approved frequency plans (998, 997) and spectral masks
  - Compliancy to ETSI, ANSI standards

- Can provide complementary services for deployment in non-regulated environments (e.g. Private Networks)
  - Services optimization based on user needs
  - Services optimization is possible thanks to new frequency plans different from standard frequency plans
  - Noise sources are less important than in the Public Network (less legacy xDSL services) => *Capacity can be maximized !*
  - Deployment in Private Networks shall not disturb the Public Network

Standard VDSL PHY can offer both !
But need to define clear FRONTIER between PUBLIC and PRIVATE networks for spectral compatibility issues

Frequency plans specified for VDSL



- Plans 998 approved for ANSI T1 (North America, Japan)
- Plans 997, 998 approved for ETSI (Europe)
- Plans 997, 998, Fx accepted in ITU-T

Services requirements specified for VDSL

Services specified in ETSI

Service type	Up (Mbps)	Down (Mbps)
A1	2.048	6.4
A2	2.048	8.576
A3	3.072	14.464
A4	4.096	23.168
S1	6.4	6.4
S2	8.576	8.576
S3	14.464	14.464
S4	23.168	23.168
S4	28.288	28.288

Services specified in ANSI

Service type	Up (Mbps)	Down (Mbps)
Asymmetric	3	22
Symmetric	6	6
Symmetric	13	13

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
  - 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 should be approved in October 2001

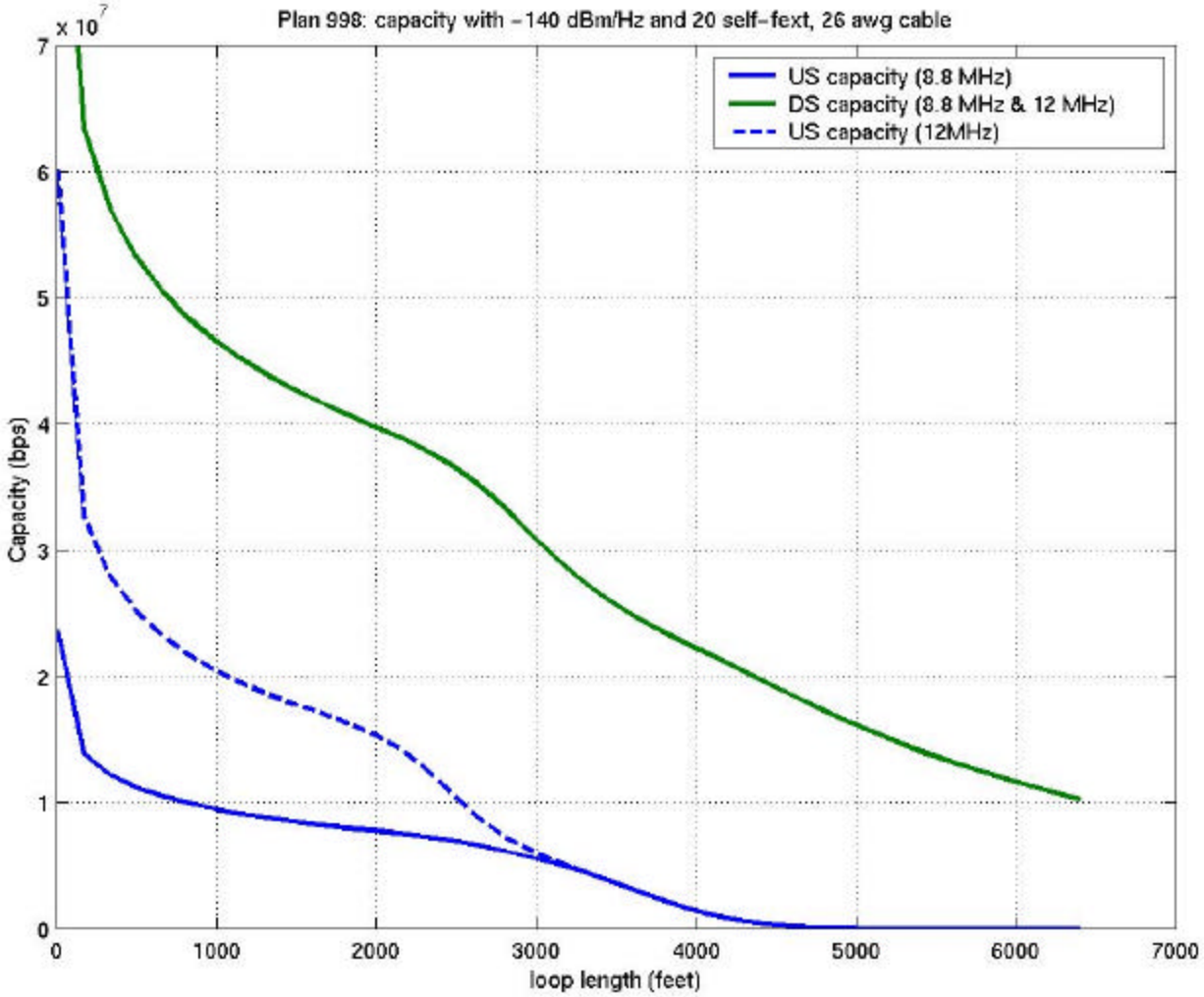
Example of services supported by VDSL (1)

- Bandwidth considered = [25 kHz, 12 MHz]
- Frequency plans 998, 997 and Fx
- Targeted services : symmetric and asymmetric
- Constant power sent on the line P_{dBm} = 14 dBm
- Spectral and PSD Management capabilities
  - Spectral and PSD Management done by Software
  - Takes into account cable attenuation, loop length
  - PSD notching in HAM bands to control RF egress
  - Dynamic PSD level management provides automatic Upstream Power Back Off

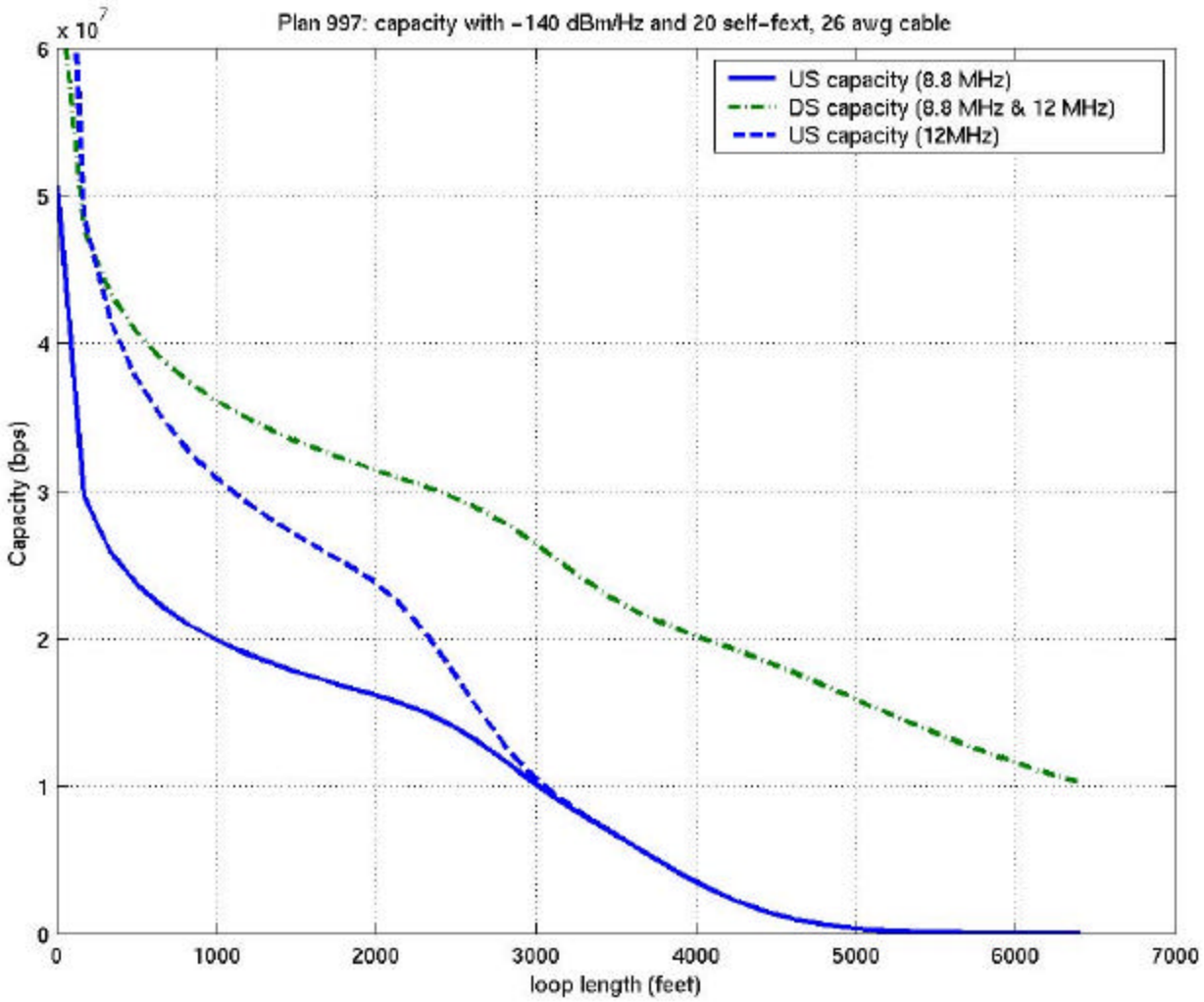
Simulation Conditions

- Performances in terms of bit-rates and loop reach
  - Frequency Plan 998
  - Frequency Plan 997
- Conditions of simulation
  - 26awg twisted pair
  - Background noise @ -140 dBm/Hz
  - 20 VDSL crosstalkers
  - Bandwidth up to 12 MHz
  - Coding gain = 3.5 dB
  - System margin = 6 dB

Simulation Results: Plan 998



Simulation Results: Plan 997



Further improvements…

- Standard VDSL is flexible and evolutive enough to be easily upgraded

- Performances improvements can be obtained by:
  - Adding extra bands to the existing standard plans in order to increase the bandwidth up to 15 or 17 MHz
  - Defining new frequency plans and spectral masks
  - Increasing the coding gain by using advanced coding schemes:
    - Turbo-Codes (TC)
    - LDPC codes
    - Higher coding gain (6 to 7 dB)
    - TC and LDPC are currently discussed in ITU-T for both ADSL and VDSL

- Target bit-rates should be > 100 Mbps aggregate on short loops (< 1.5 kft)

Conclusion

- EFMC does not need to define a new PHY layer but shall use ANSI and ETSI specification of VDSL PHY layer
- Adaptation to Ethernet protocol will be ensured by PoV-TC sublayer functionalities with MII interface
- VDSL PHY used in EFMC should provide
  - A compatible mode of operation when operating in regulated environments (e.g. Public Networks)
    - VDSL configured in 998, 997 or Fx spectral plans
    - Compliancy with VDSL standards ensured
    - Spectral compatibility with other legacy DSL services ensured
  - Complementary modes of operation can be supported when operating in non-regulated environments (e.g. Private Networks)
    - Frequency allocation optimized for Symmetric and Asymmetric services
    - Spectrum and PSD management are required
    - Further improvements should guarantee up to 100 Mbps aggregate on 1.5 kft