EFM-Copper: Operators' Perspective

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Introduction

- To have **broad market potential**, EFM-copper should address the need for both business and residential markets
- Consequently, it should support both symmetric and asymmetric services
- We propose to modify the rate/reach objective to cover both markets

EFM-Cu for Residential Customers

- Should be optimized for broadcast video with support for voice and data
- Should be optimized for asymmetric data-rate transmissions
- Should be compliant with the current issue of T1.417 and Band Plan 998

EFM-Cu for Business Customers

- Should be optimized for data only
- Should be optimized for symmetric data-rate transmissions
- Should be compliant with the current issue of T1.417

Two Solutions Needed

- Both markets are important for the success of EFM-Cu
- The two markets demand different sets of applications
- Therefore, two distinct technical solutions are required for asymmetric and symmetric services, respectively

A Classic Ethernet Perspective

- Ethernet is inherently and traditionally a symmetric technology
- Many PHYs for symmetric transmissions have been developed
- EFM-Cu deserves to have a PHY suitable for symmetric transmissions

VDSL for EFM-Cu

- Can achieve high data rates on shorter loops (< 5 kft)
- Not suitable for longer loops (> 5kft): data rate drops rapidly
- Need to choose one line code from QAM and DMT, which has been a very difficult problem for many years

VDSL for Asymmetric Services

- As an FDD technology, VDSL is appropriate for asymmetric services
- Band Plan 998 is designed in favor of asymmetric services
  - 2-3 digital video channels
  - high-quality audio
  - high-speed data

VDSL for Symmetric Services

- Achievable data rates are highly asymmetric between upstream and downstream
- Supporting symmetric transmissions wastes significant amount of bandwidth
- Achievable symmetric data rates are far below capacities

VDSL Performance

The table below is based on contribution T1E1.4/2002-125

Loop Length (kft)	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
US Rate (Mbps)	14.2	13.0	12.1	9.2	5.5	3.7	1.7	0.4
DS Rate (Mbps)	44.5	40.9	38.2	34.9	29.1	23.3	19.7	16.2

This is Not New

- The highly asymmetric capacity has been recognized
  – mizrahi_1_0501.pdf
  – oksman_1_0701.pdf
  – penazzi_1_0701.pdf
  – oksman_1_0901.pdf

SHDSL for Symmetric Services

- SHDSL = Symmetric High Bit-rate DSL
- Theoretically, echo-cancellation (EC) systems are appropriate for symmetric transmissions: offering symmetric data rates independent of loop conditions
- EC DSL systems have been successfully deployed for business market (e.g., SDSL, HDSL/HDSL2/HDSL4, G.shdsl)

How About G.shdsl (G.991.2)?

- The leading DSL technology primarily designed for symmetric services on medium and long loops
- It utilizes bandwidth for symmetric transmission in a highly efficient way compared with other DSL technologies
- Data rate decreases gracefully as loop length increases

Two Limitations of G.shdsl

- Not optimized for short loops: the maximum data rate on a single pair is about 2.3 Mbps
- Support aggregate operation over at most two pairs

Enhancing G.shdsl

- To increase the rate/reach capabilities of G.shdsl, the following issues are under study at ITU-T and T1E1.4
  - using larger constellations on shorter loops
  - support an aggregation mode for more than two pairs
  - others

Performance of Enhanced G.shdsl

- Simulation model:
  - 32 TC-PAM
  - 5 dB coding gain
  - 6 dB noise margin
  - 24 self-NEXT/FEXT plus -140 dBm/Hz background noise

Performance of Enhanced G.shdsl

- Achievable data rates per pair
  - 5 Mbps at 3.6 kft or 1.2 km (26 AWG)
  - 3.33 Mbps at 5.0 kft or 1.6 km (26 AWG)
- A true "First Mile" technology!
- Achieve longer reaches than VDSL

Why Go Farther

- Borrowed from Howard (frazier_1_0901.pdf)
  - 750 m reach covers < 40% of DLC-fed loops
  - 3600 m reach covers 95% of DLC-fed loops
  - 750 m reach covers about 20% of business and residential loops
  - 3600 m reach covers > 85% of business and residential loops

Other Advantages

- No line code war is needed for enhanced G.shdsl
- If we cannot resolve the VDSL line code issue, Ethernet-over-SHDSL can save the EFM-Cu standard
- Since it is a short-term project in T1E1.4, it will be available very soon

The Problem of the Current Rate/Reach Objective

- Among existing DSL technologies, it allows only VDSL as a PHY
- This symmetric objective is only met by a highly asymmetric transmission technology
- The reach in the objective (750 m) is less than half a mile - way too short

The Problem of the Current Rate/Reach Objective

- It severely limits the reach of EFM-Cu
  - even with a reasonable number of pairs, VDSL cannot offer high-speed symmetric services on loops that are a mile long
- It severely limits the applicability of EFM-Cu
- It fails to meet the criterion of "**Broad Market Potential**"

Proposal 1

- Replace the current rate/reach objective with the following two
  - objective for asymmetric services: PHY for single pair non-loaded voice-grade copper with distance >= 1200 m (26 AWG) and speed >= 20 Mbps aggregate
  - objective for symmetric services: PHY for single pair non-loaded voice-grade copper with distance >= 1200 m (26 AWG) and speed >= 5 Mbps full-duplex

Proposal 2

- Adopt VDSL as the PHY for asymmetric services
  - ANSI VDSL Trial-Use Standard is a good starting point

Proposal 3

- Adopt enhanced G.shdsl as the PHY for symmetric services
  - Copper Sub-TF should work closely with ITU-T Q4/15 and T1E1.4
  - there should be only one standard for enhanced G.shdsl

Proposal 4

- Develop a generic Ethernet-over-xDSL Adaptation Layer that fits on the Gamma-interface and rides on the top of either PHY