Committee T1 - Telecommunications **T1E1.4/2003-131**
Working Group T1E1.4 (DSL Access)
New Orleans, Louisiana, May 19 - 23, 2003

Contribution

Title: **M2DSL Defined as an Enabling Technology Applicable to Existing DSL Systems**

Source: **Texas Instruments**

Project: **M2DSL**

Abstract

In this contribution M2DSL is proposed as a specification of a set of technologies that can be applied to any existing DSL system to make it M2DSL enabled. Included in the set of technologies are flexible PSDs, aggregation of multiple lines, and hooks for DSM. Likely candidate DSL systems for M2DSL enhancement include ADSL, SHDSL and VDSL.

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Notice

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1 Introduction

Recent DSL development has coalesced around 3 standards: ADSL (with DMT modulation), SHDSL (with PAM modulation) and VDSL (with DMT or QAM modulation, still TBD). Each of these standards has been demonstrated in large deployments to provide reasonable performance under various circumstances.

Proposals related to ADSL, SHDSL and VDSL indicate an interest in addressing some or all of the M2DSL goals (the primary being high speed symmetric rates with graceful degradation, the secondary being high speed asymmetric rates) with each of the standards. For example, in ADSL2+, proposed Annexes J and L allow for higher upstream data rates using spectrally flexible PSD masks [8]. In SHDSL, recent work has centered on increasing the constellation size, bandwidth, and bonding to achieve higher symmetric data rates [2], [3]. And in VDSL, various flexible PSD's have been proposed to allow for graceful degradation of the upstream data rate [4], [6].

The question then arises at to what is the best or most appropriate way to address the goals of M2DSL. Some possibilities include:

1. Developing a new standard specifically for M2DSL. Since no new modulation methods have been championed recently and a completely new standard would take a longer time to develop, this appears less advantageous.
2. Building M2DSL on top of a single DSL standard. The benefit of this is that (likely) only some aspects of a standard would need to be modified for M2DSL. The drawback is in determining what standard gets to evolve to M2DSL, especially since each of the previously mentioned standards has shown it's usefulness is certain deployments.
3. Defining M2DSL as a set of technologies and specifications that can be used to enhance an existing DSL standard (including ADSL, SHDSL and VDSL). The benefits of this include the ability to bring higher data rates to more systems, and the ability to sidestep a debate in determining what standard becomes M2DSL.

This contribution proposes that option 3, defining M2DSL as a set of technologies and specifications that can be used to enhance an existing DSL system, is the appropriate way to proceed with the M2DSL project. The result would be ADSL that is M2DSL enabled, or M2DSL enabled SHDSL (or a similar naming convention for VDSL). Note that within the guidelines of the M2DSL specification, each of M2DSL components can be optimized to suit the particular standard to which it is applied.

In some sense, this is already occurring. As noted above, most standards are already looking at methods for increasing data rates. By making M2DSL a specification that could be applied to all standards, this would serve to formalize the process and allow for consistent decisions to be applied across standards (also potentially diffusing some existing controversy on PSD selection).

The following sections describe the core components of the M2DSL project, and provide some examples of it's application to ADSL, SHDSL and VDSL.

2 Components of a M2DSL System

This section describes the core components of a M2DSL system.

2.1 Flexible PSDs

To achieve graceful degradation of data rate as the loop length increases in the presence of various noise sources, flexibility in the PSD is required. ADSL, SHDSL and VDSL all currently provide mechanisms for modifying the PSD bandwidth and/or level. These capabilities would be enhanced in a M2DSL system.

The flexible PSD component of the M2DSL specification would be used to determine the type of spectrum that can be used to M2DSL enhance a given standard. The following constraints (or some variation of) would be included:

1. Either upstream or overlapped to f_1, $f_1 < 1104$ kHz.
2. Follow band plan 997 or 998 (depending on the region) to 12000 kHz.
3. Spectrally compatible according to T1.417 and/or other appropriate standards.

It is important to note that ADSL, SHDSL, and VDSL all currently fit under this band plan (as it is not necessary to use all of the bands for a given system). Additionally, recently proposed enhancements also fit under this band plan (e.g., [2], [4], [8]). For example (using the notation of figure **1** and table **1**):

- ADSL2+ Annex J/L: The first band is configured as 0U with f_0 set to 0/25 kHz and f_1 is set to 256 kHz. Band 1D is only used to 2208 kHz, and bands 1U, 2D and 2U are not used.
- Enhanced SHDSL: The first band is configured as 0UD, with f_0 set to 0 kHz and f_1 set to the upper limit of the ESHDSL spectrum.

Additionally, note that the "flexibility" in the PSD has been introduced in the lower frequencies. This was done intentionally to minimize the impact of crosstalk on existing systems such as VDSL (taking into account the increase in crosstalk with frequency).

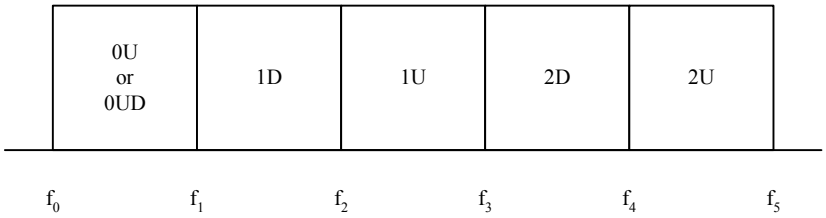


Figure 1: A flexible band plan for M2DSL. U indicates upstream, D indicates downstream, and UD indicates overlapped (upstream and downstream).

Band Plan	f_0	f_1	f_2	f_3	f_4	f_5
Flexible 997	> 0	f_0 - 1104	3000	5100	7050	12000
Flexible 998	> 0	f_0 - 1104	3750	5200	8500	12000

Table 1: Flexible band plan frequencies (in kHz). f_1 is allowed to take on values from f_0 to 1104 kHz.

2.2 Aggregation of Multiple Lines

The aggregation of multiple lines to increase data rates is already an active topic within multiple standards bodies. For examples, methods of bonding G.shdsl are being considered, and the ITU created a G.bond to address to issues for all DSL's [7]. It seems likely that this capability, either at the physical layer with coordination (vectoring, likely related to sections 2.1 and 2.3) or at a higher layer (bonding) will be a part of M2DSL. As such, it is proposed to follow the lead of the ITU, and work towards a set of aggregation specifications that can be applied to all DSL standards.

2.3 DSM

In a similar manner in which the ITU is working on bonding for all DSL's, T1E1's DSM project is also applicable to multiple DSL systems [1]. As such, it is proposed to determine the set of DSM technologies applicable to M2DSL and ready for implementation (e.g., iterative waterfilling) and make them a part of the DSM specification.

3 Example

As an example of applying a set of M2DSL specifications to an existing DSL system, consider the proposal in [5] for increasing the upstream data rate of ADSL (this was originally done in the context of 10MDSL). The basic idea in the contribution was to estimate the loop length, then determine a set of points (f_1, S_x) where S_x is a parameterized description of the PSD, which are spectrally compatible to the estimated loop length. The CO and CPE would then determine which point (f_1, S_x) from the set best approximates the target data rate requirements.

Figure **2** shows how the spectrally compatible PSD level is a function of the choice of f_1 and the loop length. Figure **3** shows the resulting data rates which could be achieved on an AWGN channel using this approach.

Note that these results are for illustration purposes only (i.e., we are not proposing on the agreement of a method simply based on it's AWGN performance), and only consider one aspect of M2DSL (the flexible PSD component). Higher data rates can be achieved with aggregation and by applying DSM concepts (for the community of users).

However, the important point to recognize is that the approach of defining M2DSL as a set of technologies that can be applied to an existing standard provides a great deal of flexibility for the improvement of existing standards.

Similar examples can be shown for recent work in enhanced SHDSL and VDSL with a more symmetric upstream.

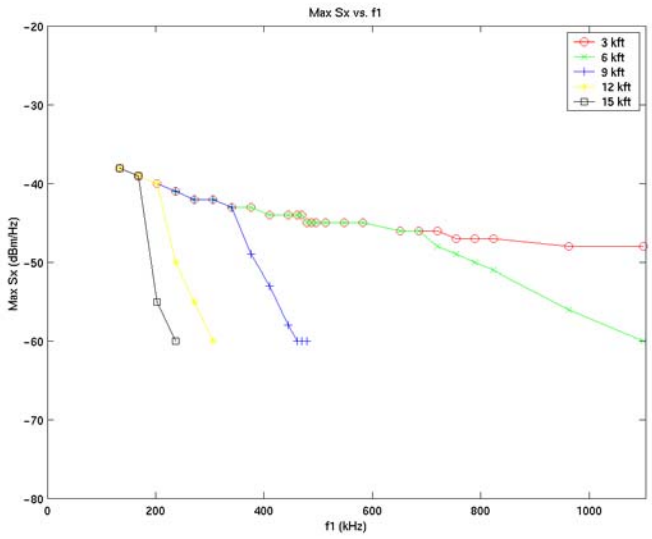


Figure 2: An example of the application of M2DSL to ADSL2+. This figure shows the limits on the flexibility of the selection of the upstream and downstream split for maintaining spectral compatibility with ADSL. The maximum PSD level for a given upstream/downstream crossover point is shown.

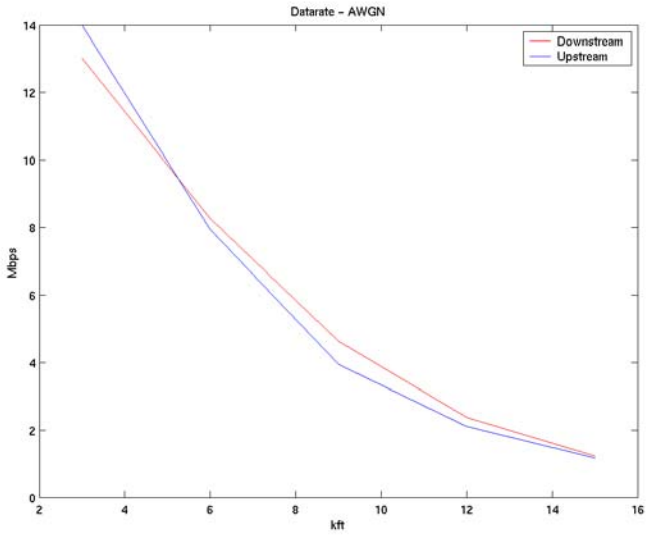


Figure 3: The resulting data rate for the example application of M2DSL to ADSL2+ with a single line and AWGN.

4 Proposal

The following agreements are proposed:

1. M2DSL should not take the form of a new standalone standard.
2. M2DSL should take the form of a set of agreed to technologies/specifications that can be applied to existing DSL standards to make them M2DSL enabled.
3. The proposed set of technologies should include flexible PSDs, aggregation of multiple lines, and DSM.

5 References

[1] J. Cioffi, "Dynamic spectrum management report," T1E1.4/2003-018R1, Feb. 2003.

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