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Aspects of VDSL Evolution

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Abstract:
This document provides a framework for VDSL study within the DSL Forum. It points to the standards which define VDSL requirements and interfaces. It also identifies deployment scenarios that are expected to be implemented and characterizes the service evolution from other DSL technologies to those based on VDSL. Additionally, challenges to deployment are considered.

1   Introduction

This document provides a framework for VDSL study within the DSL Forum. It points to the standards which define VDSL requirements and interfaces. It also identifies deployment scenarios, utilizing the public network, that are expected to be implemented and characterizes the service evolution from other DSL technologies to those based on VDSL. Additionally, challenges to deployment are considered. VDSL applications utilizing private networks are outside the scope of this document.

2   References

At the time of publication, the editions indicated were valid. All references are subject to revision.

[1] Committee T1 Working Group Contribution T1E1.4/2000-009R3 (LB941) "Very-high-bit-rate Digital Subscriber Line (VDSL) Metallic Interface, Part 1: Functional Requirements and Common Specification", November 2000

[2] Committee T1 Working Group Contribution T1E1.4/2000-011R3 (LB941) "VDSL Technical Specification, Part 2: Technical Specification for a Single-Carrier Modulation (SCM) Transceiver", November 2000

[3] Committee T1 Working Group Contribution T1E1.4/2000-013R4 (LB941) "Very-high bit-rate Digital Subscriber Lines (VDSL) Metallic Interface, Part 3: Technical Specification of a Multi-Carrier Modulation (MCM) Transceiver", November 2000

[4] ETSI TS 101 270-1 Ver. 1.2.1 "Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Very high speed Digital Subscriber Line (VDSL); Part 1: Functional requirements", 1999-10

[5] ETSI TS 101 270-2 Ver. 1.1.1 "Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Very high speed Digital Subscriber Line (VDSL); Part 2: Transceiver specification", 2001-02

[6] FSAN Full Services Access Network Requirements Specification Issue 3, 1998-08-18

[7] Radiocommunications Agency draft MPT 1570 "Radiation Limits and Measurement Standard, Electromagnetic radiation from telecommunications systems operating over material substances in the frequency range 9 kHz to 300 MHz", April 2000

[8] Federal Communications Commission, Code of Federal Regulations, Title 47 Telecommunications Part 15, "Radio Frequency Devices"

[9] Federal Communications Commission, Code of Federal Regulations, Title 47 Telecommunication Part 68, "Connection of terminal equipment to the telephone network"

[10] CENELEC, EN55022, "Information Technology Equipment – Radio disturbance characteristics - Limits and methods of measurement"

[11] Committee T1, T1.417-2001, "Spectrum Management For Loop Transmissions Systems"

3   Glossary

The following definitions/abbreviations apply for the purposes of this document:

ANSI	American National Standards Institute
CENELEC	European Committee for Electrotechnical Standardization
CO	Central Office
CLEC	Competitive Local Exchange Carrier
CPE	Customer Premises Equipment
DAVIC	Digital Audio Video Council
DLC	Digital Loop Carrier
DSL	Digital Subscriber Line
DSLAM	DSL Access Multiplexer
ETSI	European Telecommunications Standards Institute
FSAN	Full Service Access Network
FS-VDSL	Full Service VDSL
FTTB	Fiber-to-the-business

FTTC   Fiber-to-the-curb
FTTCab   Fiber-to-the-Cabinet
FTTH   Fiber-to-the-home
G.pnt   The working title given to the family of phone line networking recommendations being
                  developed by the ITU-T. The first recommendation to be published, G.989.1 Phoneline
                  Networking Transceivers - Foundation, specifies the basic characteristics of devices
                  designed for the transmission of data over in-premises phoneline networks
G.vdsl   The working title given to the VDSL recommendation being developed by the ITU-T
ILEC   Incumbent Local Exchange Carrier
ISO/IEC   In the field of information technology, ISO (the International Organization for
JTC   Standardization) and IEC (the International Electrotechnical Commission) have established
                  a joint technical committee, ISO/IEC JTC
ITU-T   International Telecommunication Union, Telecommunication Standardization Sector
NGDLC   Next-Generation DLC
MCM   Multi-Carrier Modulation – a candidate line code for VDSL employing multiple carriers
                  (i.e. DMT)
MDU   Multi-Dwelling Unit (typically a residence)
MPEG   Motion Pictures Expert Group
MTU   Multi-Tenant Unit (typically a business)
ONU   Optical Networking Unit
PON   Passive Optical Network
POTS   Plain Old Telephone Service
SCM   Single-Carrier Modulation – a candidate line code for VDSL employing a single carrier
                  (i.e. CAP/QAM)
SG15/Q4   Study Group 15 / Question 4 – The working group of ITU-T responsible for Transport
                  networks, systems and equipment specifically addressing transceivers for subscriber access
                  systems (eg. VDSL standards)
SME   Small / Medium Enterprise
T1E1.4   Committee T1, technical subcommittee E1, working group 4 – The working group of
                  Committee T1 responsible for Digital Subscriber Loop Access (eg. VDSL standards)
TM6   Transmission & Multiplexing 6 – The working group of ETSI responsible for Access
                  Networks (eg. VDSL standards)
VDSL   Very High Speed DSL or Very-high-bit-rate DSL
VoDSL   Voice over DSL
VoIP   Voice over IP

4   What is VDSL

VDSL is a digital data transport technology which uses a copper wire pair as the physical medium and as
such is bounded by that medium. Both symmetric and asymmetric data flows are supported providing
increased flexibility in meeting specific applications. (See section 6 for general characteristics of VDSL.)

4.1   Where will VDSL be used

Traditionally, VDSL has been viewed as providing the "last mile" access to the home. Since VDSL enables
much higher bandwidths than established mass market DSL technologies like ISDN and ADSL it is usually
associated with the delivery of a bundle of services. Like existing xDSLs, VDSL can provide the familiar
high speed internet access as well as voice services. Due to increased bandwidth availability VDSL can,
however, provide higher speed internet access, more simultaneous voice channels and perhaps unique to
VDSL, digitally encoded video. These video services typically consist of multiple channels of MPEG
encoded data, today requiring from 6 to 8 Mbps for sequences with fast movements and good picture
quality. At least two simultaneous video streams must be delivered in order to compete with the near video
on demand systems currently offered by cable TV Operators. This bundle of services drives the bandwidth
requirements for asymmetric VDSL to deliver at least 13 Mbps downstream and 1 Mbps upstream.

Several business applications are also possible and promise additional evolutionary growth where copper
can provide high speed pipes for access in a campus or high rise building environment. The re-use of

copper in business parks, campuses, multi-tenant buildings, etc enables VDSL to cost effectively serve growing bandwidth needs where cable lengths fit VDSL topology. One significant symmetrical application is the extension of corporate ethernets which drives the requirement for symmetrical bandwidth of at least 10 Mbps.

4.2   Why will VDSL be used

As an "access technology" VDSL must be viewed in the context of other competing technologies such as Fiber-to-the-Home(FTTH), Wireless local loop and even Power Line telecom. Viewed in this manner, the viability of VDSL is closely related to the following drivers:

−   The commitment of the incumbent service provider (ILEC) to use the existing copper plant for applications requiring VDSL bandwidths.
−   The competitive service provider (CLEC) commitment to the same thing in an unbundled loop environment.
−   The cost/benefit trade-offs of using a FTTCab technology such as VDSL over existing copper plant versus construction of an overlay architecture e.g., FTTH.

The primary driver for VDSL technology today is for residential access with a secondary goal of providing a business overlay. Much attention has been focused upon FTTH replacing copper-based technologies in these applications. From a "bandwidth delivered" point of view fiber offers virtually unlimited bandwidth however installation costs currently favor architectures which reuse the existing copper plant. In the near-term a hybrid approach which pushes fiber closer to the customer (FTTCab or FTTC) which requires less of the existing copper plant is most likely to prevail. VDSL offers data rates in excess of other DSLs and is sufficient to address current broadband service requirements and therefore is likely to be the "last-mile" DSL of choice. This hybrid fiber-copper approach best satisfies the need for higher bandwidth services while minimizing expensive plant upgrades. As compression technologies progress over time the "limited" bandwidth of VDSL will not necessarily be a significant limitation versus fiber for many applications.

Another advantage of the VDSL architecture is the security benefit provided by point to point links. This is a significant advantage over technologies which rely upon a bus architecture, e.g. HFC networks.

5   VDSL Standardization

There are currently three organizations developing VDSL transceiver standards; ITU-T, ETSI and ANSI (FSAN acts through contributions to these organizations).There are agreements between all of them to promote cooperation and to work towards the final standards with as few differences as possible. There are some important differences in the goals between the different bodies, which results in differences between them in focus and output (see 5.2 Background).

ITU (International Telecommunication Union) is the United Nations Specialized Agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the ITU. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis. ITU-T Recommendation G.vdsl is being developed by Study Group 15 (Question 4).

ETSI (European Telecommunications Standards Institute) is a non-profit making organization whose mission is to produce the telecommunications standards that will be used for decades to come throughout Europe and beyond. ETSI TM6 is responsible for VDSL.

ANSI (American National Standards Institute) has accredited Committee T1 to create network interconnections and interoperability standards for the United States. Committee T1, technical subcommittee E1, working group 4 is responsible for VDSL.

5.1   Status

5.1.1 Technology

This section provides a snapshot in time of the current status of the VDSL standardization effort within the respective standards organizations. The following information is believed to be accurate as of March 2001. A dual line code standard has been agreed for publishing by ETSI. Committee T1 is in the process of resolving letter ballot comments for its dual line code trial use standard. ITU-T Study Group 15 continues to progress its work towards publishing a VDSL recommendation.

5.1.1.1 ETSI

ETSI TM6 is in the process of developing a European VDSL specification which is currently composed of two parts;
"Part 1: Functional requirements" is available in a second revision as ETSI Technical Specification TS 101 270-1 ver 1.2.1.
"Part 2: Transceiver specification" has been published as TS 101 270-2 ver 1.1.1.

The **ETSI**Transceiver specification contains the description of two different Physical Media Dependent (PMD) layers, one based on Single-carrier Modulation and one based on Multi-carrier Modulation. Both line codes use Frequency Division Duplexing (FDD) and a common set of frequency plans; frequency band plan 997 and 998. The specified spectrums for use in this first version of the Transceiver specification is from 138kHz up to 12 MHz, with the use of the spectrum below and above for further study.

Outstanding issues associated with this specification include:
-   disposition of additional frequency band plans such as the Fx plan
-   specification of Upstream Power Back-Off (UPBO)

ETSI has started the following two new work items to address these issues and others;
1.   A revision of the VDSL Part 2 document.
2.   A study of VDSL services and assessment of the need for more bandwidth allocation.

5.1.1.2 ANSI

ANSI Accredited Standards Committee T1 T1E1 is in the process of developing a North American VDSL specification which is currently composed of three parts;
Part 1: which defines the VDSL functional requirements and specifications that are common to both Single-Carrier Modulation (SCM) and Multi-Carrier Modulation (MCM) based VDSL transceivers.
Part 2: Technical Specification of a Single-Carrier Modulation (SCM) Transceiver.
Part 3: Technical Specification of a Multi-Carrier Modulation (MCM) Transceiver.

Since consensus was not achieved on a single line code ANSI has decided to publish this draft Standard for trial use, comment and criticism. It has been published in order to obtain those comments that will occur as a result of its use. When sufficient time has elapsed for the trial use of the Standard and subsequent receipt of comments (two years from the date of publication by Accredited Standards Committee T1), the draft standard will be amended as needed, and a revised text will be submitted for approval as an American National Standard.

Part 1, Part 2 and Part 3 documents were agreed to be sent out for letter ballot from the November 2000 meeting. The process of balloting and resolving letter ballot comments is now being performed before the documents can be officially published.

 The **T1E1.4** draft Trial Use Standard documents describe two different standard PMD layers and a third one is included in an informative Annex. One document is based on Single-carrier Modulation and the other one is based on Multi-carrier Modulation. The Multi-carrier document contains an informative Annex describing another Multi-carrier technology called Filtered Multi-tone (FMT).

All three line codes use FDD and a common frequency band plan, plan 998. Additionally, the use of the band between 25kHz and 138kHz is optional.

Outstanding issues associated with this specification include:
-    specification of Upstream Power Back-Off (UPBO)

5.1.1.3 ITU-T

ITU-T SG15/Q4 is in the process of developing an international VDSL Recommendation. The group's stated target is to develop a single interoperable worldwide VDSL recommendation. Due primarily to a lack of consensus on the line code issue, progress so far has been slow and little text has been produced for the recommendation.

The following points highlight the status of agreements achieved by this group with respect to the VDSL recommendation:
-    Both Single and Multi carrier line codes have been proposed but neither has achieved consensus.
-    Frequency Division Duplexing (FDD) will be used.
-    Three frequency band plans will be specified. Plan 997 and 998 are on equal footing while a third plan called the Fx plan is "intended for use in Sweden only". The use of the frequency band between 25kHz and 138kHz is also under study.
-    Upstream Power Back-Off (UPBO) method has been agreed. The agreement calls for the upstream transmitter to limit its transmit power below a frequency dependent transmit mask. The shape of the mask depends on the electrical length of the line over which the VDSL modem pair operates. Further details remain outstanding to completely specify UPBO.

5.1.2 Regulatory

This section identifies the status of regulatory requirements that are known to apply to VDSL and are believed to be accurate as of December 2000. Service regulations are not currently addressed by this document.

5.1.2.1 European Community

EN55022 (www.cenelec.org) [10] is expected to be used by European regulators as guidelines for regulatory requirements. The intention of this standard is to establish uniform requirements for the radio disturbance level of the equipment contained in the scope, to fix limits of disturbance, to describe methods of measurement and to standardize operating conditions and interpretation of results. See section 9 for issues related to the application of this requirement.

A joint ETSI-CENELEC working group has been set up to look into in-situ measurements for radiated emissions from installations.

At least two countries propose additional national regulations :

5.1.2.1.1   UK

MPT 1570 Radiation Limits and Measurement Standard [7] (http://www.radio.gov.uk/document/ra_info/ra107.htm) is expected to apply. It intends to afford general protection to licensed and license exempt radio communications services. Limits are defined for equipment which operate over material substances (including metallic cable) in the frequency range from 9 kHz to 300 MHz. These frequency ranges clearly overlap those used by VDSL systems. See section 9 for issues related to the application of this requirement.

5.1.2.1.2   Germany

RegTP documents (http://www.regtp.de/en/index.html) are expected to apply. The functions of the RegTP include ensuring efficient, interference-free use of frequencies while accommodating broadcasting requirements. See section 9 for issues related to the application of this requirement.

5.1.2.2 United States

FCC Part 68 (http://www.access.gpo.gov/nara/cfr/waisidx_98/47cfr68_98.html) [9] is expected to be amended for applicability as the attachment requirements. The purpose of the rules and regulations in this part is to provide for uniform standards for the protection of the telephone network from harms caused by the connection of terminal equipment and associated wiring thereto.

FCC Part 15 (http://www.access.gpo.gov/nara/cfr/waisidx_98/47cfr15_98.html) [8] is expected to apply for EMI. This part sets out the regulations under which an intentional, unintentional, or incidental radiator may be operated without an individual license.

See section 9 for issues related to the application of this requirement.

5.1.3 Interoperability

It is not necessary for modems to implement both line codes to be compliant with the dual line code standards. Interoperability is expected between implementations of the same line code of each standard. It is expected that the differences between the T1 and ETSI transceiver specifications for the same line code will be minor facilitating multi-standard compliance by the same transceiver. Although unlike line codes are not expected to interoperate, compliance with the same frequency band plan is expected to enable coexistence within the same cable plant of VDSL systems of different line codes.

5.2 Background to Standardization Efforts

ITU started their VDSL project later than the other bodies. An outspoken goal has been to make a hard line code decision choosing only one line code. While this is a desirable goal from an interoperability point of view, it has delayed the progress relative to ETSI and T1 which have adopted dual line codes.
http://www.itu.int

ETSI published revision 2 with updates of "Part 1: Functional requirements" in October 1999. In parallel with the definition of the requirements, and as the main focus after the publication of the revision 2, TM6 has been working with their "Part 2: Transceiver requirements". This document is a dual line code specification containing some parts that are common to both the Single-carrier and Multi-carrier proposals, in areas were the technology differ there are dual sections with line code dependent descriptions. The main reason for developing a dual line code standard was that none of the groups could prove their technology to be superior in all aspects. The goal of this decision was to speed up the development of the recommendation.
http://www.etsi.org

Committee T1 was, similarly to ETSI, developing a Functional Requirement document as a basis for their VDSL project and also discussed how to progress the work on the Transceiver specification. As a result of the start of the ITU VDSL project, T1E1.4 reorganized their VDSL project to mainly focus on North American input to the ITU and stopped the development of their own standard document. Due to the slow progress on the ITU project, the ANSI VDSL project was reopened within T1E1.4. At the February 2000 meeting it was decided to develop three "Trial Use Standard" documents: one for the Common parts, one describing the Single-carrier modulation specific parts and one describing the Multi-carrier modulation specific parts. The goal was to be ready for ballot at the end of the November 2000 meeting or earlier if unanimously agreed. It was also stated to be highly desirable to complete the documents by the end of the August 2000 T1E1.4 meeting.
The Trial Use Period for the standard will be two years from the publication date.
http://www.t1.org

FSAN - The worlds major telephone companies including BT, BellSouth, France Telecom, Deutsche Telekom, GTE, NTT, Swiss Telecom, Telecom Italia, Telefonica, Telstra and U S West have founded the FSAN (Full Service Access Network) initiative to define standards for the delivery of broadband digital services over fiber and fiber/copper hybrid networks. The primary focus of the group has been on the specification of a Passive Optical Network or PON and defining common telco requirements for VDSL

systems. The group has issued specifications covering PONs resulting in an ITU-T recommendation G.983 and has deferred to ANSI and ETSI for recommendations on specifications for VDSL. Figure 1 shows the FSAN reference architecture as an example.

http://www.fsanet.net
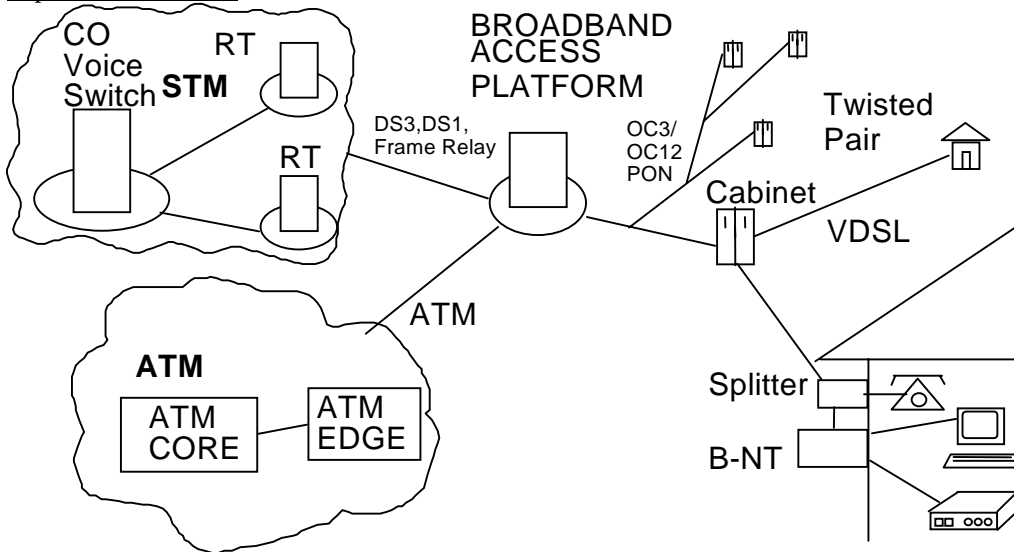
Figure 1 FSAN Reference Architecture

FS-VDSL Committee

A group created in August 2000 to accelerate standardization, implementation and deployment of a VDSL based network optimized for delivery of a full set of integrated services, including entertainment video, high speed data, and voice utilizing existing copper twisted pair loop infrastructure.

The Committee is open for operators, service providers and manufacturers, focusing on delivery of integrated services based on the more asymmetric (video friendly) '998' VDSL frequency band plan. The Committee will feed input into the international standards process and where standards are absent define new ones.

http://www.fs-vdsl.net

DAVIC

DAVIC was a non-profit Association based in Switzerland, with a membership which culminated at 222 companies from more than 25 countries. It represented all sectors of the audio-visual industry: manufacturing (computer, consumer electronics and telecommunications equipment) and service (broadcasting, telecommunications and CATV), as well as a number of government agencies and research organizations. The association was closed, according to its statutes, after 5 years of activity and remains only active through its website.

DAVIC created and published a set of specifications to enable the delivery of broadband services focused on digital audio-visual systems. An end-to-end all layer solution was enumerated which provides architectural and other information for the server, the delivery system, and the service consumer systems.

DAVIC developed a specification for a fiber to the curb point to multipoint access solution which included "Short-Range Baseband Asymmetrical PHY on copper and coax". This specification is NOT discussed within this document as a VDSL standard.

The DAVIC Publicly Available Specification was forwarded to ISO/IEC JTC for transposition into an international standard. Parts of DAVIC work are also documented as ISO/IEC JTC Technical Reports.

http://www.davic.org

VDSL Alliance

An interest group created to promote Multi-Carrier Modulation (DMT and FMT) as the preferred line code for VDSL standardization. The group develops text proposals for Multi-Carrier Modulation VDSL and feeds it into the various standards processes.
The organization is open for all with an interest in Multi-Carrier Modulation for VDSL.
http://www.vdslalliance.com

VDSL Coalition
An interest group created to promote Single Carrier Modulation (CAP / QAM) as the preferred line code for VDSL standardization. The group develops text proposals for Single Carrier Modulation VDSL and feeds it into the various standards processes.
The organization is open for all with an interest in Single Carrier Modulation for VDSL.
http://www.vdsl.org

6   VDSL Service Characteristics

6.1   VDSL Requirements

The basic service requirements for VDSL are set out in the relevant ETSI, T1and FSAN publications. For a more complete description, the reader should refer to these documents (see references [1], [4] and [6]).

6.2   VDSL Characteristics

This section contains a summary of the service characteristics provided by the proposed VDSL standards. Differences by standards organization are outlined where applicable.

6.2.1   Rate versus Reach

ETSI has defined two classes of operation for VDSL, Class I covering asymmetrical use and Class II covering symmetrical use; the performance objectives for these various service types are as follows:

Service Type	Downstream Rate (Mbps)	Upstream Rate (Mbps)	Best/worst case Reach (m) [PSD mask 1]	Best/worst case Reach (m) [PSD mask 2]
Asymmetric (A4)	23.268	4.096	896/453	995/534
Asymmetric (A3)	14.464	3.072	1,294/729	1,344/820
Asymmetric (A2)	8.576	2.048	1,592/789	1,691/882
Asymmetric (A1)	6.4	2.048	1,689/843	1,791/936
Symmetric (S5)	28.288	28.288	N/A	298/212
Symmetric (S4)	23.168	23.168	N/A	397/261
Symmetric (S3)	14.464	14.464	796/580	845/575
Symmetric (S2)	8.576	8.576	1,245/820	1,294/820
Symmetric (S1)	6.4	6.4	1,392/881	1,444/876

Table 1 ETSI Rate vs. Reach

Committee T1 has proposed a set of data rates for VDSL based on short, medium and long lines as well as predicted loop lengths – see Table 2:

Service Type	Downstream Rate (Mbps)	Upstream Rate (Mbps)	Reach (m)

Asymmetric Short	52	6.4	300
Asymmetric Short	38.2	4.3	300
Asymmetric Short	34	4.3	300
Asymmetric Medium	26	3.2	1000
Asymmetric Medium	19	2.3	1000
Asymmetric Long	13	1.6	1500
Asymmetric Long	6.5	1.6	2000
Asymmetric Long	6.5	0.8	2000
Symmetric Short	34	34	300
Symmetric Short	26	26	300
Symmetric Short	19	19	300
Symmetric Medium	13	13	1000
Symmetric Long	6.5	6.5	1500
Symmetric Long	4.3	4.3	1500
Symmetric Long	2.3	2.3	1500

Table 2 Committee T1 Rate vs. Reach

The rate and reach values in Tables 1 and 2 assume .4mm (or equivalent) wire gauge. See the relevant standard for the conditions under which these performance objectives are achieved, including PSD mask, BER, noise model, test loop, etc..

6.2.2 Bit Error Ratio

These rate/reach requirements are defined so that a 6 dB noise margin degradation would yield a bit error ratio under the test conditions of less than 1 in 10^7. This procedure is defined so that testing can be accomplished within reasonable time periods. In normal operation the modems are expected to operate nominally error-free under these conditions. In practice error performance requirements may depend on the type of service and would be determined by the network operator.

6.2.3 Latency

The standards define both single and dual latency modes.

In single latency mode, all the system data payload capacity is dedicated to one channel. This mode provides programmable burst error protection. The latency of this path is a function of the data rate and the amount of burst error protection. The latency is programmable by the network management system.

In dual latency mode two channels are provided, a "low latency" fast channel and "higher latency" slow channel. The slow channel provides programmable burst error protection as described above. The allocation of capacity between the two channels is performed according to parameters provided by the network management element manager.

6.2.4 Spectral Compatibility

Ensuring spectral compatibility with existing and future DSL transmission systems is of paramount importance to Network Operators. The following VDSL spectral characteristics are separated into those which apply to adjacent wire-pairs, and the same wire-pair, which may be used as transmission bearers for other forms of service (e.g. POTS, ISDN, etc.). As an example, working group T1E1.4 has approved a draft standard to address the spectral compatibility between CO based DSLs and network legacy systems.

Designated T1.417, this standard does not address the issue of compatibility between DSL transmissions starting from different points in the network, e.g., CO and cabinet. Guidelines covering this and network repeaters are expected to be included in the second version.

6.2.4.1 Adjacent Wire-pairs

VDSL systems have been designed to operate with a number of different DSL systems operating on adjacent wire-pairs in a multi-pair cable. Each of the other systems will generate crosstalk which will appear as unwanted noise at the front-end of a VDSL receiver. Both Asymmetric and Symmetric VDSL systems may be operated on different wire-pairs within a multi-pair cable provided that they use the same frequency band plan. No special arrangements are required for pair selection.

All VDSL standards provide for co-existence with an installed base of xDSL systems (e.g. HDSL, ADSL, ISDN, etc.) and other systems operating in the same multi-pair cable.

6.2.4.2 Same Wire-pair

VDSL has also been designed to co-exist with some narrowband services that may be carried on the same wire-pair. This is to ensure that the VDSL system can provide a broadband overlay capability. In particular, VDSL is able to operate at frequencies above POTS and both 2B1Q and 4B3T forms of ISDN-Basic Access.

A splitter filter is used to achieve frequency separation of the VDSL signals from the POTS or ISDN signals.

7   Service Evolution to VDSL

7.1   Service Migration

The migration of services from ADSL to VDSL based services is driven by the value added higher rate services enabled by VDSL. The factors determining the pace of service evolution however are different for Green Field versus existing plant deployments.

7.2   Service Evolution on Green Field Sites

In the Green Field case, new customers receive a broadband connection upon initial service installation. The hub is fed by optical fiber and the Network Access Provider has a choice of ADSL or, when available, VDSL based service delivery. New Housing and Business Park developments today are typically built out of City Centers and close to main Autoroutes. Many of these Green Field developments are often beyond the reach of an ADSL based Central Office DSLAM. Consequently many such sites are connected by fiber optic (NGDLC or PON) back to a Central Office in the City Center.

 Examples of Green Field Deployments include:
- New Residential Developments
- New Business Park Developments
- First access to Multi Tenant Units
- New extensions to existing Campus Networks
- Newer fiber fed NGDLC deployments

In this Green Field case the complexity of infrastructure required for VDSL and ADSL Service is similar. For deployment scenarios see section 8. In a simple choice of ADSL versus VDSL, VDSL is very attractive, offering faster service rates and providing a seamless evolution path to VDSL enabled Premium services. VDSL provides the Network Access Provider additional revenue streams for no additional investment and future proofs the customer.
In this way Green Field deployment of VDSL can provide early access to advanced services. For this strategy to work however the VTU-R must provide access to current broadband services as well as access

to VDSL enabled services when available. It must also support a range of legacy CPE equipment by appropriate choice of user interface.
Where VDSL is not available ADSL and SDSL based service modules can be changed later with compatible VDSL modules to provide access to VDSL enabled services. This requires a Common Access Architecture supporting SDSL, ADSL and VDSL.

European PTTs face strong competition from Cable operators on residential sites. By bundling television services with telephony, cable operators take a significant percentage of new lines. In countries where PTTs are allowed a Broadcast License, VDSL provides a route for incumbents to exploit the opportunity for video and data services on Green Field sites, providing a competitive service offering and at the same time developing the infrastructure for future deployment of Fiber to the Home.

7.2.1   Factors enabling VDSL Service on Green Field Sites

- Compatibility with the DSL Forum Network Architecture allows support for ADSL based Services over VDSL and by appropriate choice of user interface, compatibility with ADSL based CPE.
- The length of copper loops, from DSLAM to customer on Green Field sites is typically less than 500 meters. VDSL can provide greater capacity than ADSL on such short lines.
- The additional capacity of VDSL provides a route to upgrade to faster VDSL enabled services later without additional infrastructure and without the need for a site visit.
- VDSL offers ease of upgrade as services evolve, reducing churn for VDSL based customers.
- The lack of existing Broadband services on Green Field sites minimizes the risk of cross talk.
- Green Field deployment offers ILECs with a Broadcast License the opportunity to compete more effectively with Cable Operators.

7.2.2   *Challenges to VDSL Service on Green Field Sites*

- Availability of Standardized Product solutions for VDSL based Services
- Interoperability of VDSL based CPE
- Electromagnetic compatibility with Amateur band radio broadcast.

7.3   Service evolution on Existing Plant

In the case of existing plant, broadband services are already available from other service platforms. In this case, upgrade to a VDSL based service requires additional infrastructure that must be justified solely by the demand for VDSL enabled services. Examples of existing plant deployment include:
- Public Broadband Access Networks
- Campus Environment
- Multi-tenant Environment

In existing plant deployments the time to deploy a VDSL based Service platform restricts the rate of VDSL deployment. The need to obtain planning permission for Street cabinets and the civil works required to run fiber to the curb or building restrict market growth and constitute a barrier to deployment.

In this existing plant case, VDSL must be spectrally compatible with other broadband services. This includes ADSL and SHDSL based services from Central Office based DSLAMs.

VDSL has the ability to overlay a number of existing services (POTS, ISDN, ADSL). If different Network Access Providers provide these services, several broadband service platforms share the local loop in a Line sharing arrangement. This creates demarcation issues in Fault Management and Service Management.

Line Sharing can be avoided if a single VTU-R displaces existing broadband NTs. This requires that the VDSL based service platform support ADSL based services in the near term, alongside VDSL enabled Premium services. An appropriate choice of user interface is also required to provide compatibility with a range of legacy CPE equipment. A Common Access Architecture supporting both ADSL and VDSL is also required.

7.3.1 Factors enabling VDSL Service on Existing Plant

- Compatibility with the DSL Forum Network Architecture allows support for ADSL based Services.
- VDSL is spectrally compatible with a range of Central Office based Service platforms and allows Line Sharing with services including POTS, voiceband services (V.90) and ISDN BRI.
- VDSL can potentially displace existing service platforms with a single VTU-R supporting existing services and CPE equipment alongside VDSL enabled services.

7.3.2 Challenges to VDSL Service on Existing Plant

- Availability of Standardized Product solutions for VDSL based Services
- Interoperability of VDSL based CPE
- Electromagnetic compatibility with Amateur band radio broadcast.
- Complexity of service management and fault management associated with Line Sharing.
- The time and resources required in deploying VDSL services from street cabinet sites.
- Whether the plant construction enables VDSL to meet minimum service coverage requirements

7.4 Two stage Evolution of VDSL Services

The compelling case for VDSL Service on Green Field sites will ensure early evolution to a VDSL enabled Service Platform.

The deployment of ADSL based service Platforms will capture the majority of customers in close proximity to the City Center based Central Office. Deployment will then migrate to smaller offices and Remote Concentrator sites served by an optical fiber link back to the central office. As deployment continues the Service Node will get smaller and closer to the customer. Where small sites have short loops, new opportunities for Green Field Deployment will be created. Existing plant deployment will follow as Services demand exceeds the available capacity of ADSL lines. This is likely to happen first on longer loops, which support only the lower ADSL service rates. The success of early deployment of services to Green Field sites will be a key driver in creating demand for VDSL enabled services in existing plant deployment.

7.5 VDSL Enabled Services

The tables below identify typical sets of VDSL enabled services for Residential and SME customers. Approximate Service rates are identified along with the need for a Guaranteed Service Rate and Service Protection. The service rates indicated are approximate and provided to assist in mapping a given set of services to actual bearer rates defined in section 6. The Service Set for Residential customers has a high video content and is suited to Asymmetric bearer rates. The video service rates in the residential case assume 3 simultaneous MPEG2 video channels (including audio) of at least 5 Mbps per channel. The Service Set for SME customers requires roughly equal upstream and downstream rates and is therefore suited to symmetric bearer rates.

Service Type *(Asymmetric-Residential)*	Downstream Rate (Mbps)	Upstream Rate (Mbps)	Service Guarantee	Service Protection
Video Services (3 Channels)				
-Switched Video Broadcast	>15	<0.2	Yes	No
-Stagger Cast	>15	<0.2	Yes	No
-Video on Demand	>15	<0.2	Yes	No
Audio Services				
-Hifi Audio on Demand	>1	<0.1	Yes	No
-Online radio	>1	<0.1	Yes	No
Internet/Intranet				
-Download Multimedia	>10	<0.1	Best Effort	No
-Download Applications	>10	<0.1	Best Effort	No
-Virtual Reality Gaming	>10	<1	Best Effort	No
-Online shopping	>10	<0.1	Best Effort	No

(Download of Soft goods)				
-Website Hosting	>0.4	>2	Best Effort	No
Derived Voice				
-VoDSL (ATM) (< 4 channel)	<0.32	<0.32	Yes	No
-VoIP (< 4 channel)	<0.32	<0.32	Best Effort	No

Table 3 Residential Service Set

Service Type (Symmetric SME)	Downstream Rate (Mbps)	Upstream Rate (Mbps)	Service Guarantee	Service Protection
Office Communications				
-Derived Voice (>16 channel PCM @ 64Kbps)	<2	<2	Yes	Yes
-High Quality Video Conferencing	<8	<8	Yes	Yes
Internet/Intranet				
-Large File transfer	>10	>10	Best Effort	Yes
-Application download	>10	<2	Best Effort	Yes
-Access Virtual Reality Websites	>10	<2	Best Effort	Yes
-Media hosting (Webcast)	<2	>10	Best Effort	Yes
-Website Hosting	<2	>10	Best Effort	Yes
-Remote Learning Applications	>10	<2	Best Effort	Yes

Table 4 SME Service Set

Some operators will offer different combinations of these services.

8   Deployment Scenarios

8.1   Example Deployments

8.1.1   Public Broadband Access Networks

The ultimate goal for access network operators is to deliver high bandwidth services to their customers exploiting fiber all the way to the premises. Today's fiber to the home (FTTH) networks are not economical, because of the high infrastructure costs to deploy optical fibers within the last mile to the customer.

Hybrid fiber-copper systems deploying VDSL in the last mile to the customer offers sufficient bandwidth and is more economical than pure fiber networks, therefore Fiber to the Curb/Cabinet (FTTC/FTTCab) solutions are regarded as an intermediate step towards the ultimate goal.

In residential applications where the bandwidth needs are asymmetric, approx 15 Mbps downstream and 1 Mbps upstream, VDSL will reach about 1 km. For the SME, bandwidth needs are typically symmetric, approx 10 Mbps, and VDSL will reach about 0.7 km. The rates and reach depend upon the existing copper infrastructure and other deployed services.

Like ADSL, VDSL systems also offer the possibility to transport POTS or ISDN baseband signals over the same line. VDSL splitters may be electrically different than their ADSL equivalent due to the higher frequencies used for VDSL systems.

Due to a different access network structure, fiber to the cabinet, there is a significant cost associated with the deployment transition from ADSL to VDSL. When an optical fiber is used to transport broadband signals to a curb/cabinet, new broadband services (e.g. Switched Digital Video, faster / symmetrical

Internet access) utilizing VDSL technology can be offered to customers. Utilizing existing CO equipment (DSLAMs) in a curb/cabinet may not be possible due to different environmental conditions. While it may be desirable to re-use existing CPE equipment this may not be possible due to higher data rates and different service delivery architectures.

8.1.2 Campus Environment

VDSL has particular relevance to the Campus environment when used in its Symmetrical form.

With the concept of a fiber fed ONU placed reasonably centrally within the campus, symmetrical VDSL at speeds up to 10 Mbps may be used to connect all the campus locations within a radius of some 700 metres from the hub. For either an existing or new campus, twisted pair copper wire may be used for the final drop from the ONU to the user terminal. Provided the radial distances fall within those accessible using VDSL, this will provide a comparatively cheap and easy to install and provision method of providing high-speed access throughout a typical campus development.

There are a number of advantages from using VDSL for such campus installations:

- Ease of installation;
- Cost of installation;
- Speed/bandwidth available;
- Dependence on a standard.

8.1.2.1 Ease of Installation

Existing copper pairs may be used where these are available or new copper may be easily installed at comparatively low cost. In practice, most campus environments will be built with twisted copper wiring installed and available and this may be then used for VDSL.

8.1.2.2 Cost of Installation

With wiring already available, no major engineering work will be required to provision the physical network on the campus site. New terminal equipment will be required but this will be needed in some form whatever high speed access solution is chosen.

It is envisioned that a VDSL hub will be centrally located in the campus. This may either be fiber fed from some remote location to provide wide area connectivity or possibly could be stand-alone simply to serve the campus. In the latter case, all connection to locations within the campus site could be provided using twisted copper pairs and no fiber feed would be needed.

8.1.2.3 Speed/Bandwidth Available

Using VDSL, a 10 Mbps symmetrical service could be provided throughout the campus. Traditionally, this would have required fiber to every user, probably on some form of SONET/SDH ring. With VDSL, such a sophisticated delivery mechanism would not be required and additional bandwidth could be provided by the simple use of additional copper pairs, assuming that these were available.

8.1.2.4 Dependence on a Standard

Since it is envisioned that any campus site would be under the control of a single organization, be that a site management company or a singe company/organization, standards would not be needed. The site managers could purchase all the necessary VDSL equipment from a single supplier. Even with an off-campus fiber feed, there would be no need for a specific VDSL standard.

Even without a formal standard for VDSL, never the less, any implementation will need to adhere to certain rules:

- It must be spectrally compatible with other services in any binder group;

- All VDSL services in a cable or binder group must use the same up and downstream frequencies;
- All VDSL services must fit within the same frequency band plan, 997, 998 or Fx.

8.1.2.5 Typical Deployment Scenarios

Typical scenarios include:

- Hospital sites;
- Company campuses;
- Business Parks;
- "Vertical" campuses;
- Universities/Colleges;
- Factories.

8.1.2.5.1   Hospital Site

For a hospital campus with many separate buildings, VDSL provides an excellent means to build and extend PACS type radiological image distribution. Here, the radiological images are of a very dense nature requiring very high bandwidth for rapid transmission – VDSL is ideal.

8.1.2.5.2   Company Campuses

With a typical company site, with many separated buildings, VDSL offers a cheap and fast to install high bandwidth communication solution. All buildings may be connected using existing copper pairs providing the necessary path for VDSL speed data transmission.

8.1.2.5.3   Business Parks

The typical business park is envisioned as a campus with many separate commercial tenants. The Park management company may use VDSL – in this case probably with an off-site fiber feed, to provide each separate business unit with broadband communications.

8.1.2.5.4   Vertical Campuses

A vertical campus is seen as a large MTU with separate tenants on each floor or even several tenants on one floor. In all other respects, it is seen as equivalent to a special case of a business park.

8.1.2.5.5   Universities/Colleges

Universities and colleges are similar in some ways to hospitals. There is a single overall controlling organization with many separate buildings with a growing need for high bandwidth communications.

8.1.2.5.6   Factories

Not often talked about in the context of VDSL, large factory sites are another possible location for the use of VDSL, particularly those needing to communicate dense information such as detailed designs and engineering specifications around the site. Typically, even the largest factories will be less than 2,000 metres from end to end so allowing the use of VDSL over the existing twisted copper pair communication infrastructure.

8.1.3 Multi-tenant Environment

The VDSL multi-tenant environment consists of service delivery to both business and residential subscribers. Business subscribers are typically small-to-medium enterprises leasing office space in Multi-tenant Units (MTU) such as office parks and strip malls. Residential subscribers are typically consumers renting living space in Multi-dwelling Units (MDU) such as apartments and town homes. Figure 2 illustrates typical Fiber-to-the-Building (FTTB) and Fiber-to-the-Cabinet (FTTCab) MDU/MTU architectures that are ideal for VDSL deployments. For FTTB the VTU-O is located in the basement or wiring closet. For FTTCab the VTU-O is co-located with the existing POTS junction wiring interface or DLC, or can be integrated in a new NGDLC.
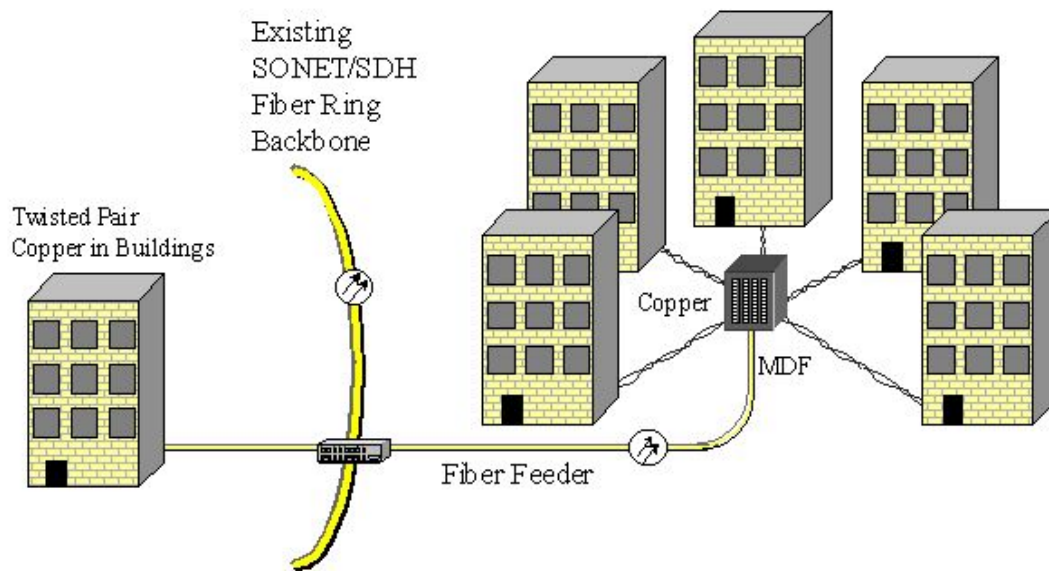
Figure 2 VDSL MDU/MTU FITL Architecture

8.1.3.1 MTU Environment

The MTU environment to serve SMEs requires symmetric rates from 1.5 Mbps to greater than 10 Mbps. Example services to be carried by VDSL to this environment include multi-megabit Internet access, LAN extensions and dedicated data services; telephony services including multi-port derived telephony (VoDSL, VoIP) and T1/E1 replacement; and video services including digital broadcast, video-on demand, surveillance and video teleconferencing. The ability of the service provider to support guaranteed bandwidth via Service Level Agreements is likely to be important.

8.1.3.2 MDU Environment

The MDU environment to serve consumers requires asymmetric rates in excess of 15 Mbps downstream and 1 Mbps upstream to support up to three simultaneous digital video streams plus multi-megabit Internet access, lifeline telephony and two or three lines of derived telephony (VoDSL, VoIP). This is required to effectively compete with emerging digital CATV technologies and service offerings. Quality of service for video entertainment and telephony services is critical, while best effort is sufficient for Internet service.

8.1.3.3 Ease of Installation

Most, if not all, MTU/MDU environments have existing copper pairs to each unit from a common distribution point. These pairs can be easily utilized to deliver VDSL-based services, which means no new wiring. VDSL splitters would need to be used to maintain lifeline POTS services where required.

8.1.3.4 Cost of Installation

With wiring already available, no major engineering work will be required to provision the physical network in the MTU/MDU site. New terminal equipment will be required but this will be needed in some form whatever high speed access solution is chosen.

It is envisioned that a VDSL access switch or concentrator will be located in the basement or wiring closet of the MTU/MDU. This will likely be fiber fed from some remote location (e.g. CO or other VDSL node) to provide high bandwidth for backhaul to the core network.

8.1.3.5 Speed/Bandwidth Available

Using VDSL, as much as 52 Mbps could be provided throughout MTU/MDU buildings. Available line rates will depend upon copper loop lengths and the adoption of VDSL standards. Typically, residential services to MDUs would be 22/3 Mbps downstream/upstream and business services to MTUs would be 13 Mbps symmetrical.

8.1.3.6 Dependence on a Standard

Communication services to MTUs and MDUs are typically under the control of the building owner or Real Estate Investment Trust, and the building management company. Because the copper infrastructure inside the building is not part of the public network, there is central control by the owner or manager over the services distributed over this infrastructure. This central control reduces the need for VDSL standards compliance since the site managers could purchase all the necessary VDSL equipment from a single supplier. Therefore, early VDSL deployments could begin in these markets segments. Note that compliance to other existing standards, such as SONET/SDH and SNMP, is highly desirable for any installations as backhaul to the core network will be required.

Even without a formal standard for VDSL, any implementation will need to adhere to certain rules:

- It must be spectrally compatible with other services in any binder group;
- All VDSL services in a cable or binder group must use the same up and downstream frequencies;
- All VDSL services in a cable or binder group must fit within the same frequency band plan, 997, 998 or Fx.

8.1.3.7 Typical Deployment Scenarios

Typical scenarios include:
- High rise apartments
- Condominiums and townhomes
- High rise commercial buildings
- Strip malls
- SME office parks
- Hospitals
- Dormitories
- Hotels and motels

8.1.4 Home Networking

The use of VDSL as a home networking vehicle is beyond the scope of this document and from recent advancements in Home Networking technologies it appears that VDSL will not be an approach selected. However, VDSL will terminate in the home on a device that provides the connection to the services offered within the home. This device is often called the Residential Gateway (RG).

Since the RG is the connection between the Access Network and the In-Home local area network (being called a RAN – Residential Area Network by some), it will become a critical piece of the network. It will have a direct impact on the success of VDSL as one of the possible access technologies available.

8.2 Network Topologies

VDSL as defined by ETSI, T1& ITU-T is a point to point transmission technique across the U reference point as defined in TR-001 and TR-012. However VDSL may be used to realize different end-to-end network topologies as described below. The operator of the VDSL network will determine depending on the applications running on top of his networks which VDSL service profile (asymmetric / symmetric, data rates, transport protocols) will be chosen.
It should be noted that VDSL as defined above is always directional with a well defined head end (VTU-C) and remote end (VTU-R) functionality, even if the service profile is symmetric. The concept of VDSL

using FDD to avoid near end crosstalk (NEXT) requires that VTU-Cs are not collocated with VTU-Rs at one end of a shared cable in order to guarantee proper operation.

8.2.1   Star Networks

The most common topology for DSLs is a star network. The purpose of the network is to interconnect multiple endpoints located at various customer premises with one centrally located endpoint.

Typically multiple VDSL endpoints at the central location are realized as multiple VDSL port devices (line cards) using the same housing (DSLAM, ONU,....) whereas VDSL endpoints at the customer premises are usually single VDSL port devices (Set Top box, Residential Gateway, PC card, ...). Within these topologies the head end functionality (VTU-C) of each VDSL link is always located in the central location. The clear structure of a star network requires minimal network engineering, even if an operator of the star network chooses different service profiles for each VDSL connection.

8.2.2   Point-to-Point

Because of the point to point nature of VDSL, Point to point networks utilizing the benefits of VDSL are of particular interest. Some common applications for VDSL point to point networks include the provision of an individual high speed connection or to multiplex a number of lower speed connections onto a single high speed VDSL connection. In this scenario a symmetric service profile would likely be chosen. Due to the individual requirements in terms of required bandwidth, distance and transport each VDSL connection may have a specific profile. Operating a higher number of point to point VDSL connections within a cable plant may require a certain level of network engineering.

8.2.3   Mesh Networks

Using VDSL to realize meshed networks, a combination of many point-to-point VDSL connections and/or star networks, seems to be very attractive due to the high number of possible service profiles (symmetric / asymmetric, big variety of datarates). However realizing meshed networks with VDSL requires a high level of network engineering to respect the requirements of VDSL at the physical layer.

9   Regulatory barriers and related issues

9.1   Unbundling

VDSL from the exchange is governed by the same unbundling rules as other DSLs. Both loop and spectral unbundling is required. Subloop unbundling, access to the final drop, is also required.

The selection of allowable frequency band plan for any particular element of copper plant may be in the domain of the incumbent operator, or may be a subject for national regulation.
A firm regulatory basis is essential for mass deployment of VDSL by network operators, for a number of reasons.

There can only be one frequency band plan but this may be contentious since it has a major impact on the kind of service that may be provided. Also, the specific connection rules have an important bearing on the location and method of connection to the installed plant impacting both incumbent and competitive operators.

Since VDSL may use frequencies below 1 MHz, the spectrum management regulations applicable to other DSLs and ADSL in particular will need to consider VDSL.

9.2   EMC

Current EMC regulations have not proven to be a serious impediment to DSL deployments in general. These requirements were considered in defining the Power Spectral Density limits for VDSL. Further limitations were adopted to reduce potential interference to radio amateur installations in the vicinity of VDSL deployments.

However, spectrum regulators in Germany and the UK have recently become concerned that the existing EMC limits are not sufficient to prevent significant interference being experienced by licensed spectrum users. This is despite the development of recent standards that allow much higher levels of emissions from high efficiency lighting systems.

These regulators plan to put in place regulatory instruments providing limits applicable to resolution of interference complaints. They have a general power to shut down any source of interference. This power is not constrained by any lower limit to the enforcement threshold.

However, RegTP in Germany, and the Radio Communications Agency in the UK, are developing regulations for resolution of interference complaints that provide a measurement method and intervention threshold to be applied to systems in service. These provide guidance to equipment and system developers, and prevent further dispute in most cases. Nevertheless, in particularly sensitive cases systems may be shut down even if their emissions are below these levels.

The current RegTP specification (Usage Provision NB30) covers frequencies from 9 kHz to 3 GHz. The RA specification (MPT1570) covers 9 kHz to 300 MHz. The RegTP specification has been approved covering only the bands up to 1.6 MHz. However, work has started to extend the provisions to include the whole range of frequencies used by VDSL.

There is currently controversy regarding these regulations arising from the contradictory interests of RF spectrum users and the telecommunications industry. At present the most vocal spectrum users are the AM broadcasters and civil aviation authorities, but considering VDSL, the defense community will set stringent objectives.

The levels proposed by the UK radio communications agency in particular (April 2000), is so low as to make deployment of ADSL highly risky for network operators. Indications are that when VDSL is considered the network operator risk may be the same or worse.

9.3   RF Ingress and Egress from Unshielded Wire

Unshielded wire pairs tend to act as radio frequency antennas, allowing both ingress of broadcast and other radio signals that represent noise to a DSL system, and egress of broadband noise that can interfere with reception in radio receivers. Other ingress noise sources include electrical equipment and machinery.

Emissions from DSL systems at frequencies below 1 MHz have been shown to be close to, but potentially higher, than levels deemed acceptable by radio spectrum regulatory authorities. However, the 'antenna' efficiency of premises wiring, and in particular overhead drop wires, increases markedly at frequencies in the range 1 MHz to 20 MHz that may be occupied by VDSL. Work in ETSI and ANSI has previously demonstrated that significantly lower power spectral density must be used at VDSL frequencies to make the emissions acceptable to the regulatory agencies.
There are two modes of emission that are significant for unshielded wire pairs: direct magnetic coupling from differential mode signals on untwisted or poorly twisted wires, and electromagnetic coupling from common mode signals on all kinds of exposed wiring.

A critical issue controlling emissions from common mode signals is system balance. The balance of the cable itself is important, but other factors may dominate. These include: the balance of the multi-pair distribution plant to which the cable is attached, terminal equipment balance, and point disturbances such as cable securing methods in overhead plant.

It is often assumed that shielding or burying the cable is sufficient to overcome ingress and egress problems. However, poor grounding of cable shields can negate the effects of shielding, and it has been reported by some workers that common mode signals found on underground wiring can in some circumstances be as high as on overhead drops.

Emissions can impact domestic short wave radio receivers as well amateur radio receivers that are close to VDSL installations. However a potentially more serious problem exists in the ensemble effects of potentially millions of lines. The spectrum between 1 MHz and 20 MHz is allocated to a large number of spectrum uses. Some of these are high priority, including military, security, diplomatic, aviation and seafaring, life critical services.

As well as degrading performance, ingress from licensed radio spectrum usage can cause legal and personal disputes. In particular, amateur radio transmitters may cause complete disruption to service if modems have inadequate immunity to common-mode interference-signals. Neighbor - neighbor disputes are often difficult to resolve for network operators and EMC enforcement agencies.

9.4   Unregulated interference issues

VDSL may suffer interference from other systems using spectrum shared with VDSL. This interference may arise directly from signals that are intended to be confined to in-premises telephony wiring, or indirectly from signals on other media that couple into telephony wiring.

The class of direct interference sources includes the HomePNA and related ITU G.pnt transmission systems. It has been demonstrated that these systems do in fact interact - even if they are used by different customers served by loops in the same cable. In an ideal world, whenever G.pnt is deployed, there should be a filter to isolate VDSL on the loop plant from in-premises wiring carrying G.pnt signals. However since G.pnt is user-installed, this is hard to ensure, even if unbundling regulations theoretically control equipment that can be connected to the loop plant.

Indirect interference can arise from signals carried on other media such as electrical power supply cables both outside and inside the home. These are relatively large signals on wiring that may be installed close to telephony cables carrying VDSL, that may cause interference by electromagnetic coupling. From a consideration of likely worst-case coupling, the existing EMC regulations may not be sufficient to prevent significant performance impairment to VDSL. However in some countries the new EMI emissions regulations discussed above may have the side effect of limiting deployment of the sources in question.

Editors Note: this page will not form part of the final technical report.

<div align="center">**<u>Contributory Material to this Technical Report</u>**</div>

The following DSL Forum contributions have been made on this technical report and their comments incorporated:

1. 99-344, Minutes of Emerging DSLs Study Group Meeting – Nov 17th & 19th. David J K Greggains, Gorham & Partners Ltd, Paris meeting, February 2000.
2. 00-029, Service evolution and Deployment scenarios for Working Text 99-047 "Aspects for VDSL Evolution". Wolfgang Kluge, Marconi Communications GmbH, Paris meeting, February 2000.
3. 00-225, WT-047 Section 5.3.1 Draft. David J K Greggains, Gorham & Partners Ltd, Dublin Meeting, August 2000
4. 00-245, WT-047 Appendix A-1. Chuck Van Dusen, VideoTele.com, Dublin Meeting, August 2000
5. 00-254, VDSL Standardization status update. Piotr Korolkiewicz & Jan Boström, Ericsson, Dublin Meeting, August 2000
6. 00-403, Service Evolution to VDSL, Robert Daley, Fujitsu Telecommunications Europe Ltd, Portland Meeting, December 2000
7. 01-078, Vote and Comments to Straw Ballot WT-047, Sabit Say-Otun, Next Level Communications, Vancouver Meeting, March 2001

<div align="center">**<u>WT-047 Revision History</u>**</div>

Revision	Date Issued	Editor	Comments
1	April, 2000	Chuck Storry	Initial strawman of WT-047 incorporating comments from 99-344 and 00-029
2	May, 2000	Chuck Storry	Initial review in Orlando
3	May, 2000	Chuck Storry	Output of Orlando meeting
4	August, 2000	Chuck Storry	Working text with contributions merged
5	August, 2000	Chuck Storry	Output of Dublin meeting
6	November, 2000	Chuck Storry	Included interm input from mailing list
7	December, 2000	Chuck Storry	Included text from Portland Contributions
8	March, 2001	Chuck Storry	Incorporated Straw Ballot comments