



Electronic Communications Committee (ECC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

HIGH CAPACITY DSL-SYSTEMS

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EXECUTIVE SUMMARY

In this report, the main characteristics of high capacity DSL systems are described and some regulatory issues that may arise from their deployment are identified. The new generation of ADSL and VDSL offer the capability of delivering digital television and video-on-demand services over the fixed access network in addition to telephony and high speed internet access. This is often referred to as “triple play”.

So far, the deployment of VDSL in Europe is very low compared to countries such as South-Korea and USA. However, some countries in Europe have held field trials or started limited deployment of new high capacity DSL systems. Other countries are in the planning phase where regulators work very closely with the main network operators. In chapter 3, some information about national activities in selected European countries is provided.

Regulators may be faced with a number of issues related to the introduction of these new systems, especially for VDSL/VDSL2. Such issues include frequency planning, EMC and interference, restrictions on copper pair utilization, unbundling of sub-loops and co-location in outdoor cabinets. Consequently, regulators need a good understanding of the properties of these new DSL systems.

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High capacity DSL systems

1 INTRODUCTION

Over the last few years, ADSL has been the most popular technology for providing broadband access to residential customers via the fixed network. New improved versions of ADSL, called ADSL2 and ADSL2+, providing higher bit rates have now been developed and are gradually being introduced in many networks.

VDSL has so far had a very limited deployment in Europe compared to countries such as South-Korea and USA. VDSL systems can offer a transfer capacity exceeding 20 Mbit/s but only within a relatively short range (about 1 km). Recently, ITU-T approved the new VDSL2 standard, which is the latest in a series of standards for different DSL technologies for broadband communication in the fixed access network. Theoretically, VDSL2 can provide a transmission capacity up to 200 Mbit/s.

If all these systems and different variants are mixed together, signal interference and other compatibility problems may occur unless careful planning is made. Both network operators and regulators therefore need to have a good understanding of the properties of the various DSL technologies.

2 STANDARDS

In this chapter, the main characteristics of the high-speed versions of ADSL and VDSL are summarized.

2.1 ADSL/ADSL2/ADSL2+

ADSL (Asymmetric Digital Subscriber Line, ITU-T Rec. G.992.1) is a well known technology that has been deployed in large numbers over the last years. ADSL has become the standard solution for providing broadband services to residential customers. The basic ADSL version can theoretically provide a downstream capacity up to 8 Mbit/s but commercial services are in most cases limited to 1-2 Mbit/s. ADSL uses bandwidth up to 1.1 MHz.

Network operators with a large deployment of ISDN in their network usually choose the “ADSL over ISDN” option reserving frequencies below 138 kHz. Other network operators usually choose “ADSL over POTS” which allows more use of lower frequencies and thereby provides a higher upstream capacity.

ADSL2 (ITU-T Rec. G.992.3 and G.992.4) adds new features and functionality targeted at improving performance and interoperability, and adds support for new applications, services, and deployment scenarios. Among the changes are improvements in data rate and reach performance, rate adaptation, diagnostics, and stand-by mode.

ADSL2+ (ITU-T Rec. G.992.5) doubles the bandwidth used for downstream transmission from 1.1 Mhz to 2.2 Mhz, achieving (theoretically) data rates up to 20 Mbit/s on short lines. The maximum ADSL2+ upstream data rate is about 1 Mbit/s. ADSL2+ enables service providers to evolve their networks to support services such as digital TV and video-on-demand in a flexible way. It includes all the feature and performance benefits of ADSL2 while maintaining the capability to interoperate with existing equipment.

2.2 VDSL/VDSL2

VDSL (Very high speed Digital Subscriber Line, ITU-T Rec. G.993.1) can provide a downstream capacity of up to 50 Mbit/s. However, the data rate decreases rapidly with distance and at 1 km the maximum rate is about 20 Mbit/s. VDSL uses bandwidth up to 12 Mhz.

VDSL is more complex than ADSL since there are several options for frequency band allocation and modulation techniques. While ADSL is designed for asymmetric transmission only, the VDSL standard includes both asymmetric and symmetric profiles targeted at both residential and business applications. In practice, network operators need to make a choice of which frequency plan to adopt as the different options are not compatible because upstream and downstream bands are overlapping. This is illustrated below showing the frequency plans for asymmetric profile (998) and symmetric profile (997).

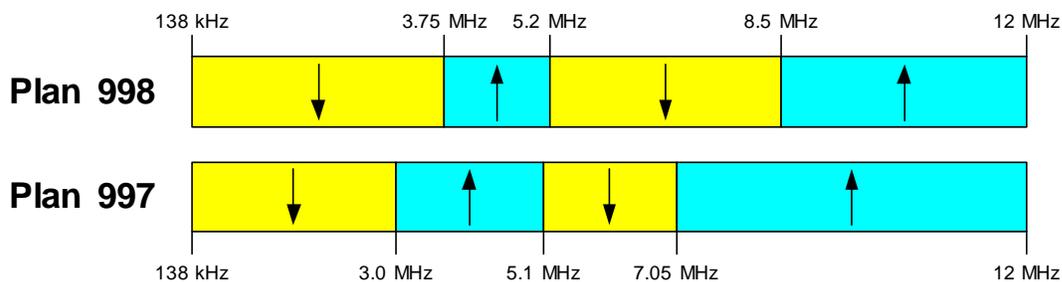


Figure 1: Frequency plans for VDSL

The transmission capacity that can be offered to users will depend on the choice of frequency plan. Typical figures for available capacity is illustrated in the figure below. The upstream capacity decreases rapidly with range since most of the upstream data are carried in the higher frequency bands.

	Range	200 m	500 m	1000 m
Frequency plan 997	Downstream	35 Mb/s	30 Mb/s	20 Mb/s
	Upstream	35 Mb/s	25 Mb/s	8 Mb/s
Frequency plan 998	Downstream	45 Mb/s	40 Mb/s	25 Mb/s
	Upstream	20 Mb/s	15 Mb/s	4 Mb/s

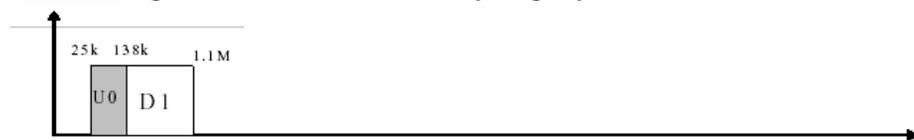
Figure 2: Typical figures for VDSL data rates

The new VDSL2 standard (ITU-T Rec. G.993.2) offers improved performance and range compared to VDSL with data rates up to 100 Mbit/s, or even 200 Mbit/s by using frequencies above 12 MHz. VDSL2 also provides better spectrum compatibility with the ADSL family and better capabilities for subscriber line management and diagnostics. Only DMT modulation (like ADSL) is specified for VDSL2.

According to the VDSL2 standard, frequencies up to 30 MHz can be used. However, in Europe (Annex 2 of G.993.2) the frequencies above 12 MHz are left for further study and the frequency plan for VDSL2 are based on the existing 997 and 998 plans specified for VDSL. For the lower frequency bands, several options exist to accommodate underlying services such as POTS and ISDN.

A comparison of the different frequency band plans for ADSL/ADSL2+ and VDSL/VDSL2 is shown below:

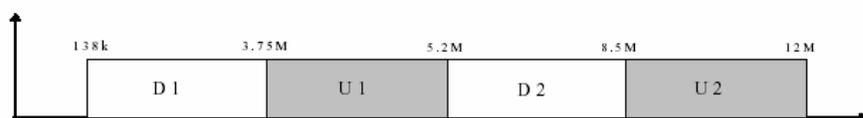
ADSL: Up to 7 Mb/s, most widely deployed



ADSL2plus: Up to 18 Mb/s; advanced line diagnostics



VDSL1: Up to 50 Mb/s, less than 1.2 km loop reach



VDSL2: Greater reach and bit rate than VDSL1, advanced diagnostics from ADSL2plus

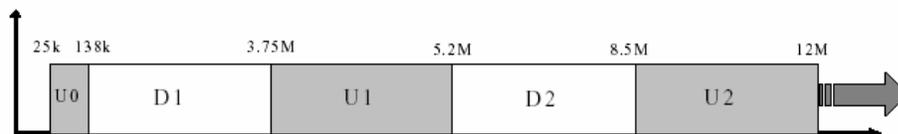


Figure 3: Frequency band plans for ADSL and VDSL families (source: DSL Forum)
U = Upstream D = Downstream

3 NATIONAL ACTIVITIES

In this chapter, some information is given about field trials, pilot services and commercial deployment of high capacity DSL-systems in various European countries.

Note: The information given dates from October 2005.

3.1 Austria

There is no deployment of VDSL technology in Austria so far and there are no signals from the market that VDSL will be introduced in the near future.

A public consultation on the introduction of VDSL from January 2004 showed that although there is a common interest of market players in new access network technologies like VDSL, other technologies were seen to be better suited for meeting customer demands. One argument raised was the data rate / distance trade-off with VDSL is especially designed for short reach deployments. Therefore VDSL has to be seen rather as a supplement to existing technologies such as HDSL, ADSL and SDSL have already been rolled out. Another argument pointed out that VDSL is only a niche solution not justifying the necessary investments in network upgrading. Additionally it was mentioned, that the short reach of VDSL would require a different roll-out strategy using e.g. sub-loop unbundling.

The public consultation from 2004 also resulted in a rather clear opinion agreeing on the necessity of general regulations regarding the frequency plan, the modulation technique and the transmitting power. It was stated that investments in

already deployed technology (HDSL, ADSL, SDSL) must be protected, meaning that new deployments like VDSL must not disturb the transmission systems in operation today.

Regarding the deployment of new technologies in the access network of Austrian incumbent Telekom Austria, this is regulated in the Reference Unbundling Offer (RUO) available on Telekom Austria's website (<http://www.telekom.at/Content.Node/dateien/standardentbundlungsangebot.pdf>, in German only). It mandates Telekom Austria being responsible for the integrity of the access network and new technologies to be introduced following clear procedures of network integrity tests, ensuring the compatibility with already deployed technologies as well as other regulations regarding the access network.

The next access technology to be deployed in Austria will be ADSL2+ according to information from market players. ADSL2+ enables operators to offer products with increased data rates on distances comparable to those available with ADSL. Additionally ADSL2+ has high compatibility with already deployed technologies like ADSL. Roll-Out is expected in the second half of 2005. The newly ITU-T approved VDSL2 standard is compatible with ADSL2+. How this will affect the Austrian market is unclear at the moment.

3.2 France

In France, the Reference Unbundling Offer (RUO) from France Telecom, dated 15 April 2005, specifies the authorized techniques to be used in the local loop in chapter 4.4.2.2. The authorized techniques in France are the standard ETSI and ITU techniques as specified below:

- Analogue telephony (POTS)
- Base band connection
- ISDN and IDSL / 2B1Q
- ADSL/POTS and ADSL Lite ,
- ADSL 2 on analogue base band (ITU G 992.3, annexe A)
- ADSL 2 + on analogue base band (ITU G 992.5, annexe A)
- SDSL ETSI TS 101-524,
- G.SHDSL (ITU G 991.2- annex B),
- HDSL 2 or 3x 2B1Q modulation pairs ,
- HDSL 2x CAP modulation pairs [7].

The following techniques are rejected:

- ADSL/ISDN
- HDSL2
- HDSL on a pair
- SDSL 2B/1Q.

These technologies have lower performance, bring more interference and are outside the French PSD mask. Moreover, RE-ADSL2 (ITU G.992.3 Annex L recommendation) has been authorized by the Committee in the local loop since 17 May 2005. Regarding full access to the sub-local loop, only analogue telephony (POTS) and voice band modems are authorized today.

Regarding the sub-local loop trials, an ADSL 2+ trial has been authorized but is not currently implemented. A VDSL trial is currently under test.

Today there is no commercial VDSL service in the local loop owned by the incumbent operator, as this technique is not authorized yet.

3.3 Norway

In the period 2000 – 2004, Telenor operated a VDSL pilot service in the Stavanger area on the west coast of Norway involving approximately 700 residential customers. This was one of the first VDSL field trials in Europe. The objective of this pilot service was to gain experience with VDSL technology for the distribution of digital TV, high speed internet access and telephony services (“triple play”) via the fixed access network. The asymmetric VDSL frequency plan (998) was selected providing approximately 20 Mbit/s downstream capacity for simultaneous reception of two independent video streams. Even though the pilot service was fairly successful, Telenor has not yet introduced VDSL services in the end user market except in the remote island of Svalbard.

In 2004, Telenor introduced VDSL and ADSL2+ in their RUO (Reference Unbundling Offer) but so far commercial interest from wholesale customers for deploying VDSL has been rather low. Some broadband service providers seem to consider VDSL more suitable for the business market by offering high speed symmetric capacity, e.g. 10/10 Mbit/s. Consequently, the choice of VDSL frequency plan in the RUO was changed from 998 to 997. For the residential market, ADSL2+ now seems to be the preferred choice by most broadband service providers.

3.4 Romania

In Romania, ANRC the National Regulatory Authority issued its first decision concerning local loop unbundling and introduction of xDSL techniques in the local loop in May 2004. ANRC closely followed the European best practice guides in the unbundling sector and in September 2004 started discussions in the industry driven Working Group for frequency management plan in the incumbent's access network. In February 2005 the Working Group presented its report on frequency management plan on local loop in the access network of the incumbent operator.

The DSL transmission techniques accepted in the first phase of ULL for introduction in the access network have been :

Short local loops	Medium local loops	Long local loops
POTS and modems in the vocal band	POTS and modems in vocal band	POTS and modems in vocal band
ISDN-BRA (2B1Q)	ISDN-BRA	ISDN-BRA
HDSL (2B1Q) (1168 kbps)	HDSL (2B1Q) (1168 kbps)	HDSL (2B1Q) (784 kbps)
SDSL-ETSI (G.SHDSL) (max. 2304 kbit/s)	SDSL-ETSI (G.SHDSL) (max. 2048 kbit/s)	SDSL-ETSI (G.SHDSL) (max. 1024 kbit/s)
ADSL.FDD over POTS	ADSL.FDD over POTS	ADSL.FDD over POTS
ADSL2+.FDD over POTS	ADSL2+.FDD over POTS	ADSL2+.FDD over POTS
ADSL.FDD over ISDN		
ADSL2+ over ISDN		

In the final report, reference standards for xDSL systems that can be used in the Romanian distribution network were recommended and some compatibility rules derived for assessing interoperability problems. Romtelecom, the incumbent operator, elaborated its first RUO (Reference Unbundling Offer) in October 2004 and started to offer commercial xDSL services in May 2005 (for the business market) with the intent to start the offer services for residential market in July 2005. The first alternative operator started to offer commercial xDSL services in April 2005 and in conformance with the RUO provisions it targeted the residential and business markets with separate offers. Additional six alternative operators have signed the standard access contract for access to the incumbent distribution network and prepared their commercial offers for xDSL services, especially in urban areas.

VDSL introduction.

Although discussed, the VDSL transmission technique was not initially retained in the list of DSL techniques for introduction in the first phase of the unbundling process, but some alternative operators requested permission to initiate projects and investments with VDSL technique. Neither Romtelecom nor the alternative operators have experience in international standardisation of VDSL (developed in ITU-T and ETSI) and the industry working group created for assessing VDSL issues find that some experiments and test pilots were necessary to develop expertise in this technology. ANRC started a new working group for VDSL issues that includes representatives of industry, LLU operators, incumbent operator and research and development experts.

The target of the working group activity for the introduction of VDSL was to explore the ways of introducing VDSL in the local loop especially concerning compatibility problems that may arise between VDSL and other DSL techniques. The working group for the introduction of VDSL produced a report and proposed to ANRC to draw up a decision which permits studies, laboratory tests, simulations and experiments of VDSL in some controlled operational space (sub-loops or loops).

Sub-loop unbundling

At the start of 2005, the incumbent began a large scale network modernization program that includes deployment of ONUs (Optical Network Units) into the access network and replacement of the portion of copper pair between MDF and ONU with optic fiber. Thus, sub-loop unbundling at the ONU level might become the only available solution for unbundling. On the other hand, these sub-loops do not present the "back-off" power limitation, therefore the introduction of high capacity DSL systems such as VDSL at ONU level do not hinder neither network performance nor the introduction of other DSL systems at the same level.

3.5 Spain

ADSL is the main technology for the provision of broadband access in Spain, with 75 % of the market. There are offers of “double play” and “triple play” based on ADSL that combine Internet access with telephony and TV/Video on demand. In the case of TV and video on demand, only one channel is served at a time.

Both VDSL and ADSL2+ signals may be used in Telefonica’s network, since the revision of the RUO (Reference unbundling Offer) that took place in March 2004. ADSL2+ is used at present by Telefonica for the provision of the same services already provided through ADSL, with the aim of increasing the number of pairs valid for broadband access. Some operators have announced the launch of new ADSL2+ services with bit rates above those of ADSL, for the 3rd quarter 2005.

VDSL is not currently used in Spain. Operators have not shown great interest in launching services based on this technology.

The spectrum management plan included in Telefonica’s RUO is based on a set of rules that states the utilisation rates. These rules are applied to each bundle of pairs in the access network. The bundles have usually 25 copper pairs on the subscriber side. Utilization refers to the maximum number of pairs that may carry a given signal within the same bundle of 25 pairs.

According to the RUO, ADSL2+ signals have the same utilisation rate as ADSL. VDSL signals have a utilisation rate of 2/25.

Utilisation rates depend on the type of pair. The types of pairs are defined according to attenuation values measured in dB. They are called UBC, UBM, UBL and UBmL. The approximate equivalent lengths (L) for these types are the following:

- UBC: L < 1400 m
- UBM: 1400 < L < 2300 m
- UBL: 2300 < L < 3300 m
- UBmL: L > 3300 m

The utilisation rates (over a maximum of 25 pairs) are shown in the following table. The information provided here is a simplification of the real rules. Actually, ADSL and ADSL2 utilization rates also take into account the number of pairs carrying high ADSL speeds (reducing general values in some cases).

	UBC	UBM	UBL	UBmL
ADSL over POTS	25	25	16	16
ADSL over ISDN	4	4	4	4
SDSL	16	16	16	16
HDSL	8	5	2	0
HDB3	2	2	2	0
ADSL2 (Anex A, Anex I)	25	25	16	16
ADSL2 (Anex B, Anex J, Anex L, Anex M)	4	4	4	4
ADSL2+ (Anex A, Anex I)	25	25	16	16
ADSL2+ (Anex B, Anex J, Anex M)	4	4	4	4
VDSL	2	0	0	0

Neither VDSL nor ADSL2+ are used for the provision of commercial services in Spain to date. There are offers in the market combining Internet access with TV/Video on demand and with telephony, but so far based exclusively on ADSL. However, Telefonica has announced an immediate use of ADSL2+ for the same offers already provided through ADSL, with the aim of increasing the rate of pairs valid for high bit rate services. In the case of TV and video on demand, only one channel is served at a time.

In Spain, there has not been any trial or pilot service coordinated by the regulator. Trials, if any, are performed by operators without regulatory intervention.

4 REGULATORY ISSUES

Local loop unbundling (LLU) has now been introduced in most European countries allowing service providers to deploy their own transmission systems in the fixed access network of the incumbent. The reference offer for LLU usually specifies in detail the frequency bands and the DSL technologies that are allowed to be used. In some countries, these specifications are determined by the incumbent alone and the regulator only intervenes if there are complaints from other parties. In other countries, the regulator works very closely together with the incumbent and other service providers to determine the specifications to be included in the reference offer for LLU.

Whatever approach taken by the regulator, several issues may arise from the rapid deployment of different DSL systems that may require close attention of the regulator. Some of these issues are discussed below.

4.1 Frequency planning

In some countries, a frequency plan for the access network has been issued allowing transmission systems that fall within the specified masks to be used. In other countries, a list of specific transmission systems (usually referring to relevant ETSI and ITU-T specifications) are published by the incumbent as part of the reference offer for LLU. This list needs to be continually updated with the introduction of new DSL technology. Transmission systems that are not included on the list are normally not allowed in the network.

If service providers wish to use DSL systems that are not allowed according to the specifications issued for LLU, the regulator may have to deal with complaints from service providers who are rejected by the incumbent. For VDSL in particular, a choice has to be made between frequency plan 997 (symmetric) and 998 (asymmetric) since they are not compatible. Service providers who are planning to use VDSL technology may have different business strategies focusing on either residential or business customers, which influences their choice regarding frequency plan.

4.2 EMC and interference

New DSL systems use higher and higher frequency bands with frequencies ranging from 1.1 MHz (first generation ADSL) to 12 MHz and even 30 MHz now specified for the second generation VDSL. Although international ETSI and ITU-T specifications for DSL systems seek to minimize interference with other systems, regulators need to be aware of any potential EMC issues that may arise from the large deployment of these systems in the access network.

4.3 Copper pair utilization

The characteristics of the cables used in the access network are also a key factor in the deployment of DSL systems. The individual copper pairs are bundled together in groups of different sizes depending on the type of cable. In order to have sufficient margins against crosstalk and interference, network operators usually apply a set of planning rules for how many copper pairs within a certain cable that can be allocated to DSL systems. An example of such rules is given in chapter 3.7 where the copper pair utilization in the access network of Telefonica in Spain is described.

Until now, restrictions in cable utilization have probably not been a major problem in most countries since the overall volume of DSL systems has been relatively low compared to the total number of available copper pairs. However, as the number of DSL systems increases rapidly this situation could change creating “bottlenecks” against further expansion. Regulators therefore need to ensure that dimensioning rules for cable utilization are fair and not discriminating.

4.4 Sub-loops

Initially, local loop unbundling was confined to the premises of the local exchange and the main distribution frame (MDF) giving the service provider access to the entire length of the subscriber line. With the introduction of high speed DSL systems such as VDSL, the transmission range is very limited (approx. 1 km) which may require access to only a section of the subscriber line. This is usually referred to as a “sub-loop”. In this case the transmitted signal level must be lower than at the local exchange in order not to cause harmful interference with other signals. This is called “back-off” power level and is usually specified in the reference offer for “sub-loop” access. However, this limitation is irrelevant in case of ONU deployment into the access network and unbundling at that level.

In the case of ONU deployment, co-location of equipment may have to take place in outdoor cabinets and not within the local exchange. Regulators therefore need to be prepared for co-location issues that are somewhat different in nature from cases experienced within local exchanges and buildings.