G.993.2

WHITE PAPER

video

higher data rates

advanced diagnostics

VDSL2

The Ideal Access Technology for Delivering Video Services

Revision 2

impulse noise protection

pre-emption

30 MHz bandwidth

AWARE

IPTV

VDSL2 was approved by the ITU in May 2006 and is designed to increase both rate and reach over the copper network, achieving data rates in excess of 25 Mbps over long loops (4-6 kft) and symmetrical data rates of 100 Mbps over short loops (<1kft). The VDSL2 standard includes many of the features and functionality contained in the ADSL2+ standard, including advanced diagnostics, a common management interface and the ability to maximize the use of bandwidth and bit rate, making it an ideal access technology for delivering video.

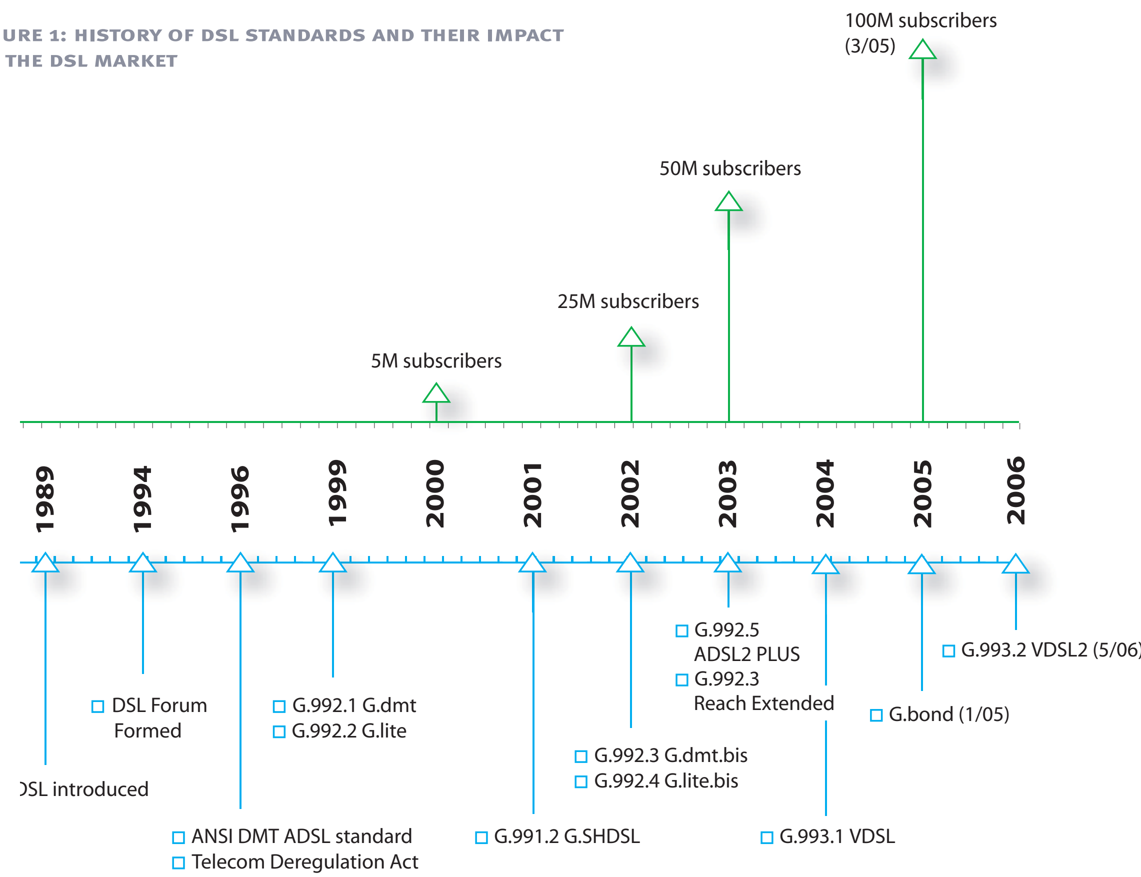
VDSL2 (G.993.2) is one of the most highly anticipated standards to emerge from the International Telecommunications Union (ITU-T). It is also one of the most complex, with numerous profiles and bandplans detailing everything from geographic-specific requirements to variations of reach and bandwidth. This white paper will offer insight into the history of the standard, its bandplans, profiles, architectures, and new features.

The major driving force behind VDSL2's success is video. Telcos see a tremendous revenue-generating opportunity to deliver video to customers. This is not a new idea. When DSL was developed in the late 1980s, its original function was to delivery video over copper. However, the bandwidth required was more than early generations of ADSL could offer, so the emphasis was put on data communications over DSL. High-speed Internet access was a "killer app" for several years. Now we have moved into the next phase of broadband: video. The reality is that competitive services, such as cable and satellite, are rolling out advanced video packages, including Video on Demand (VoD) and High Definition TV (HDTV), to subscribers and are making tremendous profits off of the new services offered. Carriers realized years ago that in order to effectively compete in this market, they must not only include video in their service offering, but also make the package more attractive to subscribers in order to attain video market domination. With the introduction of VDSL2, there is finally a standardized way to make this a reality for service providers.

HISTORY OF DSL STANDARDS

In order to understand VDSL2's place in the industry, it is important to follow the history of the ITU standard. In June 1999, the industry cheered as ADSL was standardized by the ITU-T. According to many experts, G.992.1 (G.dmt) and G.992.2, (G.lite) were the standards the industry needed to set the stage for worldwide mass-market deployment of broadband Internet services via copper. Rollouts began, and by 2000, there were 5 million ADSL subscribers. Shortly after launching ADSL, the ITU-T committee realized that, while the standard was a great starting point, it needed still improvements in several areas, and they set to work on ADSL2. By 2002, the ADSL2 standard was approved and the industry hailed the extended rate and reach as the defining technologies needed

FIGURE 1: HISTORY OF DSL STANDARDS AND THEIR IMPACT ON THE DSL MARKET



to effectively compete with the burgeoning cable modem market, especially in the United States. With the introduction of ADSL2+, also known as ADSL2plus, in 2003, carriers and service providers began to see the magic bandwidth numbers needed to effectively deliver video-over-DSL.

The ITU standard, G.bond, also known as "Bonded ADSL2+," was introduced in early 2005 as a way to double the downstream data rate of copper pairs. It was most effective for customers 6 Kft or more from the central office, so it lacked the short distance and high data rates that video demands. VDSL was ratified in 2003, but service providers concluded that more work was needed on the standard and the new standard, VDSL2, showed the potential of much higher data rates, so the ITU-T continued to hammer out the details for the next-generation of the standard. Shortly after the world celebrated the milestone of 100 million DSL subscribers globally, VDSL2 (G.993.2) was consented in May 2005, and officially approved in May 2006.

With the introduction of VDSL2, the industry will see a major transition from high-speed Internet, which is primarily a data-only service (e.g. websurfing and email), to broadband triple play: voice, video and data. Triple-play service is necessary to offer subscribers all of the essential blocks of communication and information in the same service. This will move customers beyond the PC into other realms of entertainment and non-traditional web interfaces, opening new lines of revenue and unlimited opportunity for carriers and service providers. The addition of video will also help to level the playing field, allowing carriers and service providers to compete with the cable companies who recently began offering voice services.

VDSL

Efforts to standardize VDSL began in 1995 with several simultaneous projects initiated in the ETSI, ITU and T1E1.4 organizations. In 1997, a group of service providers from around the world joined together in an organization known as the Full Service Access Network, or FSAN. This group, which was led by British Telecom, developed the first VDSL end–to-end requirements specification. However, the industry was not able to capitalize on FSAN architecture due to on-going debate of which VDSL modulation code (QAM or DMT) should be used. Separate camps from QAM and DMT proponents limited VDSL's standardization. Therefore, VDSL had limited deployment in Korea and Japan – primarily in multiple-dwelling unit (MDU) applications.

Then in 2003, eleven major silicon suppliers collectively announced support for the DMT line coding for standards-based VDSL, and the ITU finally ratified G.993.1, which is known as "VDSL" or "VDSL1". The standard was unique in that it supported DMT in the main body of the specification and QAM in a normative annex. It was also agreed that any new features and functionality to VDSL1 would be added to a second-generation standard, VDSL2, and that VDSL2 would only contain the DMT linecode.

VDSL2

The VDSL2 standard (G.993.2) was initiated in by the ITU in January 2004, with input from the North American ANSI and ETSI standards. It reached consent at the Geneva meeting in May 2005 and was approved in May 2006. The underlying DMT modulation code is the same as ADSL and ADSL2+, providing spectral compatibility with existing services and enabling backward-interoperability with ADSL.

Annexes

As in legacy ADSL and ADSL2+, VDSL2 includes regional bandplan annexes that specify PSD Mask for numerous regional bandplans and are designed to provide coexistence with other services. Annex A specifies bandplans for the North American region and enables VDSL2 to be deployed with traditional POTS telephony or in an all-digital mode (similar to Annex J in ADSL2). Annex B specifies bandplans for Europe and enables VDSL2 deployment with underlying POTS and ISDN services. Annex C allows VDSL2 to coexist with TCM-ISDN services, found primarily in Japan.

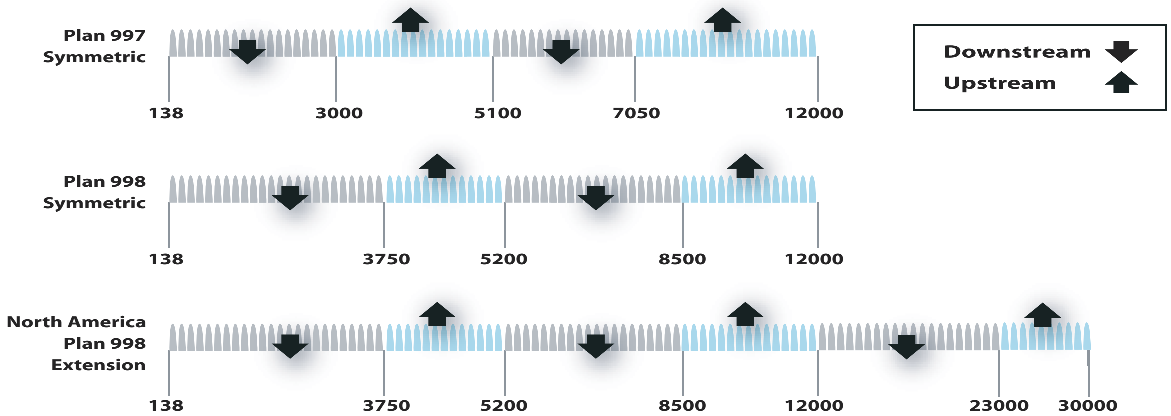
Bandplans

VDSL2 is a true worldwide standard which has been developed to support the next generation of advanced services. VDSL2 has numerous configuration profiles and bandplans to meet regional service provider requirements. The frequency bandwidth has increased to 30 MHz, with configuration options at 8.5 MHz, 12 MHz, 17.7 MHz and 30 MHz. VDSL2 also defines asymmetric (Plan 998) and symmetric (Plan 997) bandplans for the transmission of upstream and downstream signals. The next revision of the ITU G.992.3 standard is expected to extend the North American bandplan from 12 MHz to 30 MHz frequency range (Figure 2).

Profiles

To simplify the task of configuring network equipment, the VDSL2 standard defines profiles tailored for different regional deployment architectures such as central office, remote DSLAMs, digital loop carriers and multi-dwelling units. There are eight profiles which define power options from 11.5 dBm to 20.5 dBm, bandwidth up to 30 MHz and a minimum data rate for each profile (Figure 3).

FIGURE 2: BANDPLANS

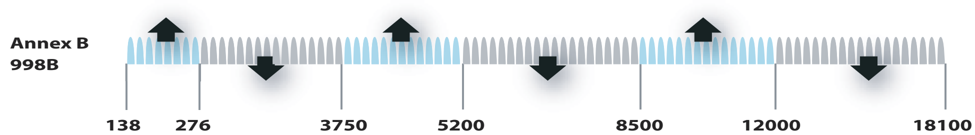


Note: US0 band can vary from 138 to 276 KHz

FIGURE 3: VDSL2 PROFILES

Parameter	Parameter value per profile							
	8a	8b	8c	8d	12a	12b	17a	30a
Bandwidth MHz	8.5	8.5	8.5	8.5	12	12	17.7	30
Tones D/S	1,971	1,971	1,971	1,971	2,770	2,770	4,095	2,098
Spacing KHz	4.312	4.312	4.312	4.312	4.312	4.312	4.312	8.625
TX Power D/S dBm	+17.5	+20.5	+11.5	+14.5	+14.5	+14.5	+14.5	+14.5
Min net Data Rate Mbps	50	50	50	50	68	68	100	200

FIGURE 4: DEUTSCHE TELEKOM VDSL2 DEPLOYMENT



Deutsche Telekom

Deutsche Telekom has announced plans to deploy advance IPTV services based on VDSL2. VDSL2 will be deployed in a fiber-to-the-cabinet architecture and support rates up to 50 Mbps downstream and 10 Mbps upstream. Deutsche Telekom has selected the 17a and 8b profiles which are best suited for their loop plant and deployment architecture. Figure 4 defines the upstream and downstream bandplan for the 17a, plan 998 asymmetric profile.

PEFORMANCE

The rate and reach charts in Figure 5 shows the expected downstream and upstream performance of VDSL2 using the 30a, 17a and 8b configuration profiles. The rates are in the presence of crosstalk over 26 AWG Gauge wire. Figure 5A shows the VDSL2 (30MHz) configuration, which achieves data rates up to 100 Mbps over very short loops. Because the rate declines rapidly, this configuration is ideally suited for MDU and fiber-to-the-home applications. Figure 5B defines the expected performance for a 17a configuration which is ideally suited for a fiber-to-the-curb or fiber-to-the-cabinet applications. Figure 5C shows the data rate for the 8b profile, which is ideally suited for longer reach applications such as a remote DSLAMs or fiber-to-the-cabinet deployments.

FIGURE 5A: PROFILE 30A

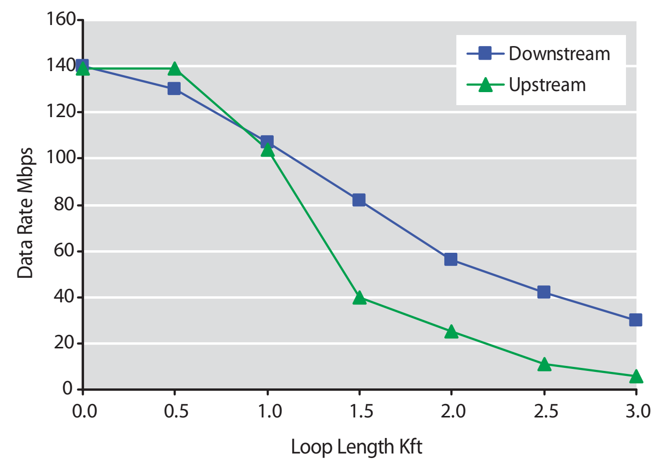


FIGURE 5B: PROFILE 17A

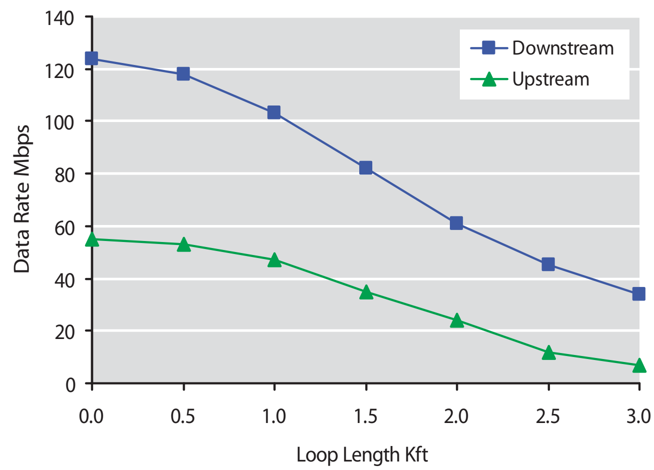
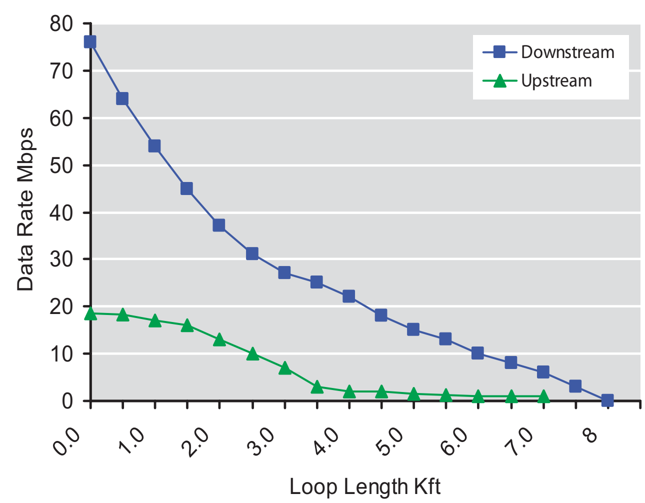


FIGURE 5C: PROFILE 8B



VDSL2 FEATURES

Improved rate and reach using Upstream "0" Band

Whereas VDSL1 systems typically operate to approximately 3 Kft, the goal of VDSL2 was to provide loop reach out to 9 Kft. In order to achieve this, VDSL2 had to be redesigned with certain features from ADSL systems, which provide service over very long loops.

Traditionally, VDSL1 systems use a technique called digital duplexing for maximizing bandwidth utilization in the upstream and downstream directions. But, digital duplexing only works well on shorter loops and does not work well when the first "Upstream 0" (US0) Band between 20 and 138 kHz is used.

As a result, the VDSL1 initialization procedure had to be completely redesigned for VDSL2 to include new Channel Discovery and Transceiver Training phases. The Channel Discovery phase enables the VDSL2 transceivers to identify the loop conditions (e.g. loop length and noise) and select the best mode of operation (e.g. US0 enabled, FFT size, etc). The Transceiver Training Phase enables the transceiver to train echo cancellers and equalizers when operating over long loops with US0 enabled.

Impulse Noise Protection (INP)

The copper loop plant is suseptable to short impulses caused by external sources. These impulses cause large bursts of errors, which could have a significant impact on the video picture quality. In order to remove errors, VDSL2 has an impulse noise immunity (INP) capability. INP provides the ability to correct any impulse noise less than 250 microseconds (INP=2, 8 milliseconds latency). VDSL2 can even provide impulse noise protection values up to INP=16, which corresponds to the ability to correct any impulse noise that is less than 3.75 milliseconds.

Packet Transfer Mode – Transmission Convergence PTM-TC

In addition to classical ATM transport, VDSL2 supports the transport of packet-based services (e.g. Ethernet packets, IP packets, etc.) In particular, VDSL2 specifies a Packet Transfer Mode – Transmission Convergence (PTM-TC) function that is based on the Ethernet in the First Mile (EFM) IEEE802.3ah standard. The PTM-TC specified in VDSL2 was extended to provide two features that are not contained in the IEEE standard: Pre-emption and Short Packet Support.

Pre-emption is a new feature that enables the VDSL2 system to efficiently transport high- and low-priority packets through a single bearer channel. Pre-emption improves traffic management by pausing the transmission of a low-priority packet (e.g. data packet) when a high-priority packet (e.g. voice packet) needs to be transmitted. After transmitting the high-priority packet, the pre-emption function resumes the transmission of the low-priority packet. This way, high-priority packets experience a minimum amount of packet insertion delay.

The Short Packet Support feature enables a VDSL2 system to transport packets that contain less than 64 bytes. While IEEE802.3 was designed exclusively for the transport of Ethernet packets greater than 64 bytes, VDSL2 transports of any packet type, including those that can have less than 64 bytes (such as IP packets).

Common Management Interface with ADSL2/2+

For many service providers, VDSL2 is expected to be the next-generation technology offering after ADSL2/2+ systems. As a result, it is predicted that many of the VDSL2 devices sold will be capable of operating in an ADSL2/2+ mode. For this reason, VDSL2 was designed to provide a management interface that is virtually identical to that of currently deployed ADSL2 systems.

Dual Latency for improved QOS

It is well known that different user applications have different physical layer QoS requirements with regard to data rate, latency, bit error rate and INP. Since VDSL2 is specifically targeting to triple-play services, the ITU standard specifies a Dual Latency operation mode. Dual Latency provides improved QoS features by enabling simultaneous transport of applications with different physical layer requirements. For example, Dual Latency can be used to transport a video channel with a high INP while simultaneously transporting a voice channel with very low latency.

Loop Diagnostics Modes based on ADSL2/2+

After years of ADSL deployments, service providers have learned that DSL fault identification is challenging. To tackle the problem, ADSL2/2+ transceivers were enhanced with extensive diagnostic capabilities that solved many of the operator deployment problems. As a result, when the VDSL2 specification was initiated, service providers required that the VDSL2 standard contain the same diagnostic capabilities as in ADSL2/2+. These diagnostic capabilities provide tools for trouble resolution during and after installation, performance monitoring while in service, and upgrade qualification. In order to diagnose and fix problems, VDSL2 transceivers provide for measurements such as line noise, loop attenuation, and signal-to-noise ratio (SNR) at both ends of the line. These measurements can be collected using a special diagnostic testing mode even when line quality is too poor to actually complete the VDSL connection.

ADSL-Backward Compatibility

VDSL2 solutions will most commonly be multi-modal, interoperating with ADSL, ADSL2+ as well as VDSL2 chipsets. This will allow service providers the flexibility to evolve their networks to support advanced services such as IP Video using a single customer premises solution.

ACCESS NETWORK DEPLOYMENT SCENARIOS

To accommodate the bandwidth requirements of triple-play and interactive services, service providers are extending fiber deeper into the access network. Typically, this is not fiber-to-the-home, but a hybrid approach whereby fiber is fed to a remote DSLAM or remote node, shortening the copper connection to the home to under 5 Kft. As shown in Figure 6, this approach leverages the existing copper infrastructure and bridges the bandwidth gap between fiber and copper while avoiding the cost and time of deploying fiber all the way to the premises. It is anticipated that remote DSLAMs will support multimode operation which requires central office equipment to be backward compatible and interoperateable with ADSL, ADSL2+ and VDSL2 customer premises equipment. This will enable service providers to segment advanced services into a Next Generation Service Area (NGSA) located between 1,000 and 5,000 feet from a remote DSLAM (Figure 7). Beyond 5,000 feet, ADSL2+ and Bonded ADSL2+ can be deployed to support advanced services.

FIGURE 6: TYPICAL ACCESS NETWORK SCENARIOS

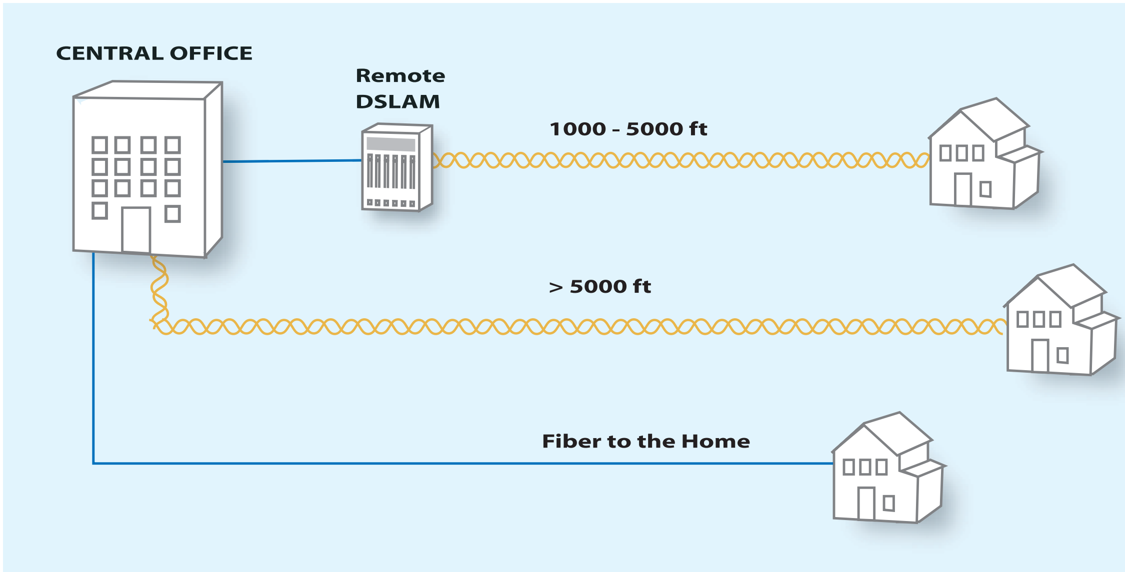


FIGURE 7: NEXT GENERATION SERVICE AREA (NGSA)

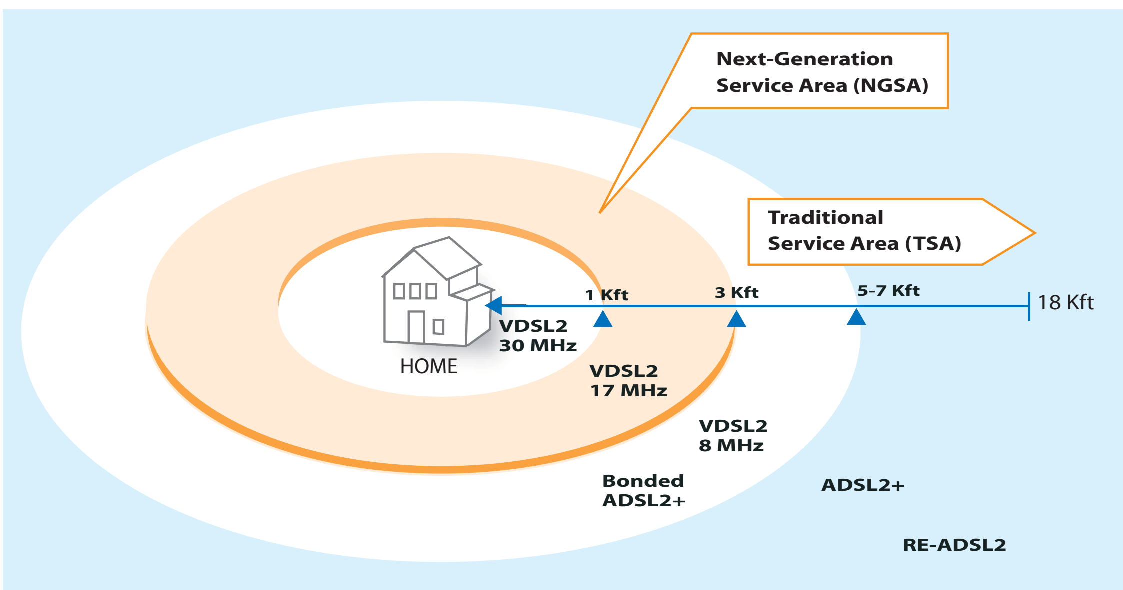


Figure 8 shows a comparison of downstream data rates for ADSL2+, versus VDSL2 profile 8b for a service area between 1,000 and 6,000 feet. For customers beyond 5,000 feet the data rates for ADSL2+ are superior to VDSL2. Figure 9 highlights the difference between a Bonded ADSL2+ and VDSL2 8b downstream service area.

FIGURE 8: ADSL2+ VS VDSL2 PROFILE 8B

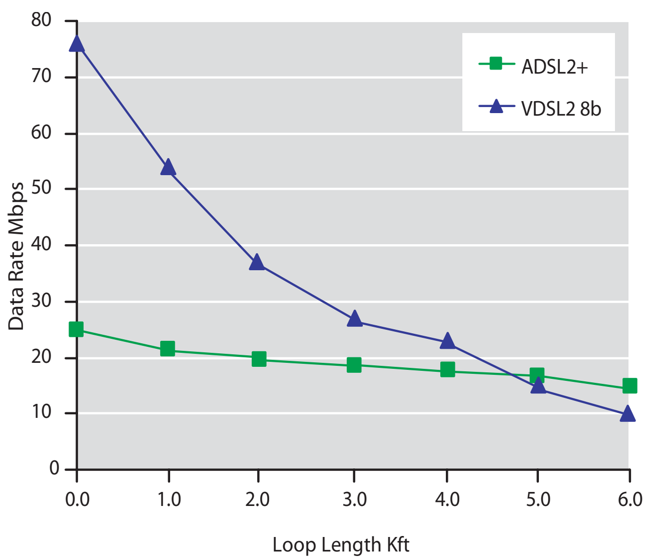
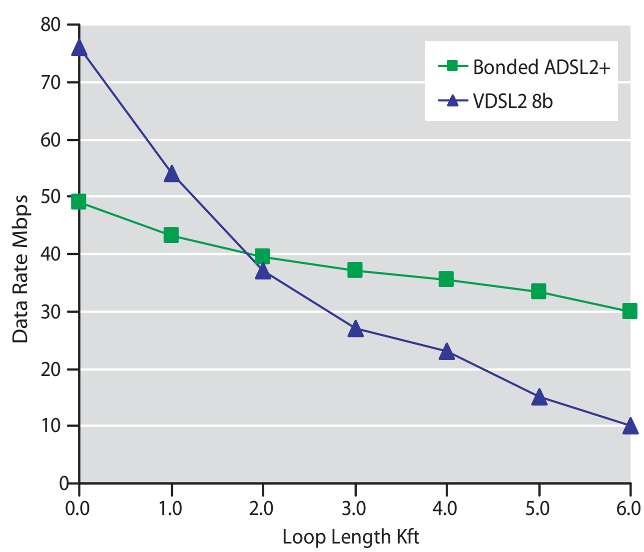


FIGURE 9: BONDED ADSL2+ VS VDSL2 PROFILE 8B



CONCLUSION

In summary, the VDSL2 standard holds the promise of the next generation of broadband services over DSL. By maximizing bandwidth and utilizing its new features and functionality, it is an ideal access technology for delivering video. Carriers and service providers will now have a true competitive advantage in the broadband triple-play space when video is combined with their extensive knowledge of the voice and data space. Carriers realized years ago that in order to effectively compete in this market, they must not only include video in their service offering, but also make the package more attractive to subscribers in order to attain video market domination, maximize revenues and reduce churn through service bundles. Particularly in the United States, video is the crucial piece of the puzzle and VDSL2 will help to level the playing field with cable companies now offering voice.

STRATIPHY DSL PLATFORMS

The StratiPHY™ family of high-performance DSL platforms contains all the requisite technology for semiconductor and vertically integrated system vendors to rapidly incorporate DSL into their central office or customer premises product offerings. StratiPHY2+™ is a complete instantiation of Aware's intellectual property supporting ADSL, ADSL2 and ADSL2+. StratiPHY3™ combines all the features of StratiPHY2+ along with complete support for VDSL1 and VDSL2 and can be configured to operate as an ATU-C or ATU-R.

The StratiPHY platforms allow silicon providers to combine Aware's field-proven intellectual property with the strength and diversity of their existing silicon product offerings to dramatically expand their revenue opportunities for CPEs, such as DSL modems, gateways, routers and set-top-boxes, or multi-port CO chipsets for DSLAM or RT applications, including line cards, ONUs and cabinet-based solutions.

Aware, Inc. is a worldwide leader in the development and marketing of semiconductor intellectual property (IP) for broadband communications. Our focus is DSL technology which enables high-speed data, voice and video over telephone lines. We deliver complete IP platforms which our customers can easily integrate into system-on-chip solutions. Our technology offerings consist of complete RTL, software, and reference designs. Aware is headquartered in Bedford, Massachusetts, and has approximately 125 employees. Aware is a publicly traded company on the NASDAQ Stock Exchange (symbol: AWRE).

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