Future Proof Telecommunications Networks with VDSL2

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VINAX™, Infineon's new VDSL2 chip solution, enables Triple Play and HDTV services over existing telephone lines by combining the best of VDSL and ADSL2+

VDSL2 (Very-High-Bit-Rate Digital Subscriber Line 2), G.993.2, is the newest and most advanced standard of xDSL broadband wireline communications. Designed to support the wide deployment of Triple Play services such as voice, video, data, high definition television (HDTV) and interactive gaming, VDSL2 enables operators and carriers to gradually, flexibly, and cost efficiently upgrade existing xDSL-infrastructure. Infineon Technologies, a leading supplier of communication ICs, introduced the industry's first fully standard compliant VDSL2 chip set dubbed VINAX™. Allowing symmetric data rates of up to 100Mbits/s over short distances and ADSL-like long reach performance, VINAX does not just meet today's requirements for high speed telecommunication networks, but offers a future proof technology that will allow carriers to deliver more services to a growing number of subscribers for years to come.

Why we need VDSL2

Looking at today's xDSL infrastructure the access technologies are still the bottleneck between CO (Central Office) and subscriber. Central Office and Remote DSLAMs (Digital Subscriber Line Access Multiplexer) are supplied with Gigabit Ethernet links and even faster technologies while on the subscriber side we find 54Mbit/s and 100Mbit/s wired and wireless Local Area Networks (LAN/WLAN). But the link in between with either ADSL, ADSL2/2+ or VDSL still limits the rate. Furthermore, the combination of video/HDTV, data, and voice on a single medium, dubbed "Triple Play", requires more sophisticated QoS (Quality of Service) features than are available in either VDSL1 or ADSL. Lastly, Triple Play services, with a minimum of three TV channels, several VoIP connections, and sufficient speed for Internet access, require high data rates of at least 30 – 40 Mbit/s, about twice of what can be achieved under real field conditions with today's ADSL2+ solutions.

VDSL2 was developed and standardized in record time to address the shortcomings of existing access technologies. It serves as the ideal xDSL technology for eliminating last-mile bottlenecks and to enable global mass deployment of advanced Triple Play services.

Key drivers for end-users to implement VDSL2 for broadband services are: Availability of multi-channel video, HDTV educational and entertainment services; Reduced telephony toll charges through the use of VoIP; Increased speed of basic Internet data access; and competitive pricing in regions where VDSL services are sold for the same price as ADSL with increased bandwidth (mainly Korea and Japan).

Telecom carriers will benefit from offering bundled services that can successfully compete with anything cable operators have to offer. In addition, with the migration towards combined ADSL2+/VDSL2 networks (see below), a single network can be maintained to provide the entire xDSL services portfolio while reducing deployment, operating and maintenance costs.

Last but not least VDSL2 efficiently solves the last mile problem with cost efficient hybrid FTTH (Fiber-to-the-Home) networks: by bringing a fiber connection as close as possible to the home, to the DSLAM or DLC via existing tubes deployed in the groundwork and by connecting to high speed VDSL2 to bridge over the last few hundred meters.

Growing Demand for ever faster xDSL Broadband Access

By the end of March 2005 the worldwide number of xDSL subscribers reached 107 million, representing more than 60% of all broadband users worldwide (DSL Forum). The majority of these DSL deployments are ADSL that can carry data with rates of 6-8 Mbit/s downstream and up to 640kbit/s upstream while ADSL2 and ADSL2+ start gaining traction. ADSL2, standardized in 2002, provides numerous improvements compared to ADSL, including line diagnostics, power management, power cutback, reduced framing, and on-line reconfiguration which will be explained later. ADSL2+ standardized in 2004, builds upon ADSL2 and further increases data rates up to 24Mbit/s downstream on phone lines in the lab, and about 16Mbit/s under real-life conditions.

To make way for high speed services at least in the short-reach (400m) at the end of 2003 the VDSL standard (now referred to as “VDSL1”) was defined, offering up to 70Mbit/s down- and 30 Mbit/supstream.

Work on the VDSL2 standard began shortly after with the intention of enabling Triple Play services, including multi-channel HDTV and the VDSL2 standard, G.993.2, was approved and announced by the ITU-T on May 27, 2005. A fully compliant VDSL2 solution, such as the Infineon VINAX, provides ultra high symmetric data rates up 100Mbit/s over 4-5kft (1.2-1.5 km) and ADSL-like bit-rates at distances of more than16kf (4-5 km), thus covering over 90 percent of the households within a Telco network and in some countries 100 percent. Figure 1 shows VDSL2 downstream rate/reach performance in comparison with VDSL1 and ADSL2+.

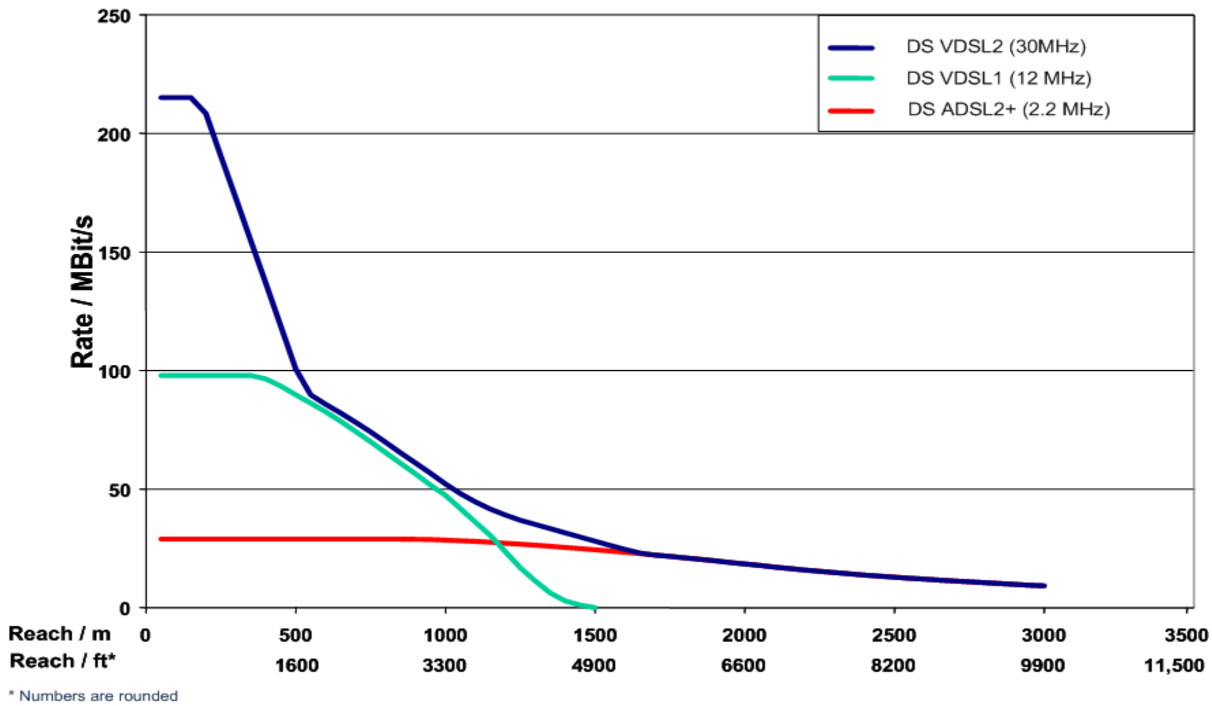

Figure 1: Comparison VDSL2, VDSL1 and ADSL2+, Downstream rate/reach performance

VDSL2 Band Plan and Profiles

Unlike its predecessor, which allowed choosing either DMT (Discrete Multitone) or QAM (Quadrature Amplitude Modulation) technology, VDSL2 only uses the DMT line-code. DMT is a method of separating a DSL signal so that the usable frequency range is separated into multiple small frequency bands, or tones. It uses up to 4096 tones which are spaced 4kHz or 8kHz apart. Each tone can be used for either downstream or upstream however the VDSL2 standard has defined upstream and downstream bands as well as eight different profiles for several application areas.

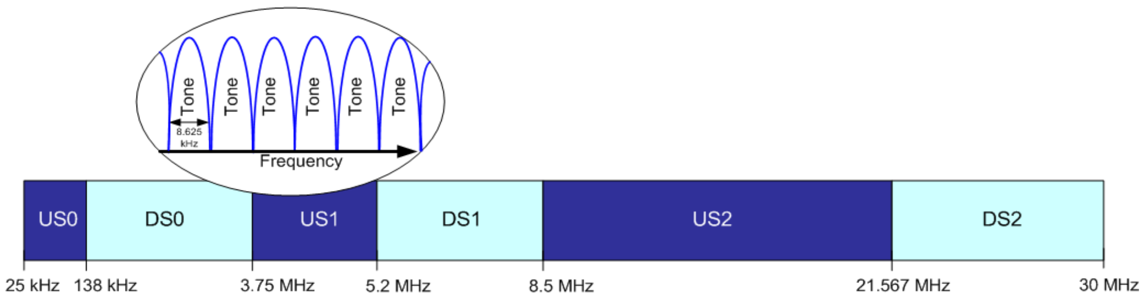

Figure 2: An exemplary VDSL2 band plan – profile 30a (30MHz bandwidth, 8.625 kHz tone-spacing)

Table 1 lists all the standardized VDSL2 profiles tailored for the different regional market applications including CO, Remote DSLAM, DLC (Digital Loop Carrier) and MDU/MXU (Multi Dwelling Unit) switch.

Profile	**8a**	**8b**	**8c**	**8d**	**12a**	**12b**	**17a**	**30a**
Bandwidth (MHz)	8.832	8.832	8.5	8.832	12.	12.	17.664	30.
Tones	2048	2048	1972	2048	2783	2783	4096	3479
Tone Spacing (kHz)	4.3125	4.3125	4.3125	4.3125	4.3125	4.3125	4.3125	8.625
Line Power (dBm)	+17.5	+ 20.5	+ 11.5	+14.5	+14.5	+14.5	+14.5	+14.5

Table 1: Eight VDSL2 Profiles

A chip solution matching only one of these eight profiles is already allowed to claim “standard compliancy”. But in order to provide a true added value for system vendors and to enable the design of a single, universal VDSL2 system that fits all deployment scenarios, the VDSL2 chip solution should support all profiles. For example, European and US carriers require transmit power of 20dBm or 17.5dBm (Profiles 8a and 8b). A chip solution that only features 2048 tones, 17MHz bandwidth, and 14.5dBm transmit power (Profiles 8c and 8d), like a number of pre-standard chip sets do, does not meet requirements of either of these markets. Furthermore, it’s too early to determine the exact regional requirements as many carriers are still evaluating their future networks.

In a nutshell: only a VDSL2 chip solution featuring up to 30MHz bandwidth capability, up to 20dBm transmit power, and up to 4095 tones can provide the required flexibility and enable system manufacturers and service providers to address all regional market applications with a single hardware platform :

DSL1 in comparison to VDSL2

The new VDSL2 standard offers, compared to VDSL1, several new features. These added functionalities explained below enhance bit-rate and service coverage while ensuring high levels of QoS for voice and video transmission - hence facilitating the convergence of all broadband services onto a single network.

- **Higher bit-rates**: A frequency spectrum of up to 30 MHz as opposed to 12MHz with VDSL1 and 17MHz in pre-standard solutions results in 100 Mbit/s symmetric data-rates - much higher than the maximum of 70/30 Mbit/s in early VDSL1 solutions. In addition, on-chip bonding which means using two separate channels for one connection (also referred to as channel-bundling) increases loop reach performance and even supports VDSL2 bit rates for longer loops. Unlike the shared medium cable modem, VDSL2 provides a point-to-point connection which keeps the data rates per subscriber stable.
- **ADSL-like long reach (LR) performance:** ADSL-like long reach performance is one of the key advantages of VDSL2. LR-VDSL2 enabled systems are capable of supporting speeds of around 1-4 Mbit/s (downstream) over distances of 4 to 5 km, gradually increasing the bit rate up to symmetric 100Mbit/s as loop-length shortens. This means that VDSL2-based systems, unlike VDSL1 systems, are not limited to short loops or MTU/MDUs only, but can also be used for medium range applications.

  LR-VDSL2 is implemented by using frequencies down to 25kHz in combination with the ADSL PSD mask supporting 20dBm transmit power. The upstream band in this case is allocated up to 138kHz/276kHz, also referred to as “Upstream Band-0” or “Extended Upstream Band-0”. The VDSL2 downstream band DS0 operates as an extended ADSL band, reaching as high as 3.75MHz as opposed to 1.1MHz and 2.2MHz used in ADSL and ADSL2+ respectively. An example of a VDSL2 band-plan is shown in figure 2.

  LR-VDSL functionality is ensured using **Echo Cancellation** and **Time Domain Equalization.** VDSL1 systems currently use digital duplexing as a method to compensate delay effects for longer subscriber loops. However this technique is limited by loop reach, has no effect above 3kft (about 1km) and would lead to a connection loss. Standard compliant VDSL2 systems therefore must implement Echo Cancellation and Time Domain Equalization to reach required performance for medium and long loop applications above 3-4kft (1-1.2km).

- **Advanced QoS for delay-critical applications:** QoS is of particular concern for the continuous transmission of video and voice. Therefore the VDSL2 standard defines an inherent **Pre-emption** mechanism giving higher priority to the delay-critical voice and video packets over other data packets such as email messages, web-pages etc.

  Pre-emption essentially means that a high priority packet (such as voice) will always have a "right of way" over lower priority packets. Pre-emption can be explained using the example in figure 3: data packets with different priority (voice, data, video, gaming) have to be transmitted through the VDSL2 chip. In order to provide the desired quality (no echo, no delay for on-line gaming) certain delay requirements have to be met. In example A, where a 100Mbit/s connection is assumed, there is no delay interference between the red high priority voice packets and the yellow low priority data packets. In example B however, where a lower speed 1Mbit/s link is assumed, delay becomes an issue as the packet transmit time increases due to the lower speed. The transmit time of packet #2 violates the timing requirements of the voice packet and would therefore cause jitter in the voice

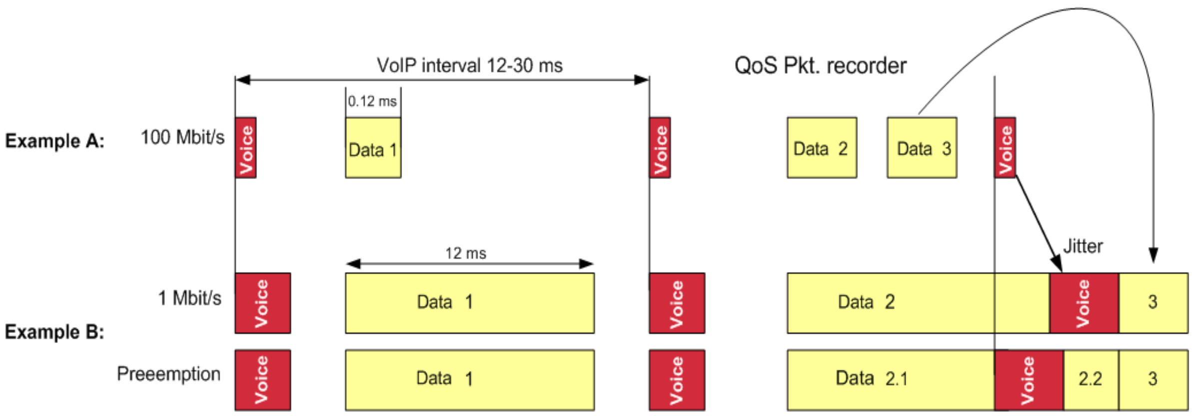

Figure 3: Motivation for packet pre-emption

  packet transmission which means echo in a voice link. This will be the case with any regular system using first-in-first-out (FIFO) technique.

  A Pre-Emption enabled system however will stop the transmission of the low priority data packet until the transmission of the high priority voice packet is completed. Through this feature disturbing echo in a voice call can be avoided.

- **High quality Triple Play services support: Dual latency** (two independent latency paths), **dual interleaving** (better noise protection and higher security) and **2 bearer channels** (for transport of user information) improve the efficient and reliable handling of different data rates which is a key for high quality Triple Play applications.

  Data interleaving and reed-solomon coding protect the signal against burst noise, i.e. noise with the length of approx. 500µs which is often caused by power line interference. This burst noise protection however comes with the penalty of a higher latency, or delay. While video traffic is not affected by high latency, this is not true for voice. Therefore by implementing two independent latency paths the interleaving and reed-solomon coding can be independently selected to provide the optimum of burst noise protection as well as latency for each traffic class.

- **Optimised network utilization:** Through the implementation of powerful **Trellis/Viterbi coding** - not available in VDSL1 - and flexible ADSL-like framing, VDSL2 provides efficient utilisation of line-rate, especially in the downstream mid-range and long reach. Trellis/Viterbi coding gives an improved coding gain of 2dB. Therefore VDSL2 achieves a higher bit-rate compared to VDSL1 under equal signal-to-noise conditions.
- **ADSL backwards compatibility and interoperability:** Due to its DMT nature and ADSL-like functionalities mentioned above, including Framing, Interleaving, and Trellis/Viterbi coding, VDSL2 includes all technical prerequisites to address the ADSL backwards compatibility issues ideally. A fully VDSL2 standard compatible chip solution would be able to perform as both a VDSL2 as well as an ADSL/2/2+ device. This enables operators a smooth, gradual and efficient network transition towards VDSL2 with only a single technology and allows them to cover all xDSL service applications with a single network. At the same time subscribers can still use their ADSL modems as long as they wish to and receive advanced Triple Play services by simply upgrading their CPEs (Customer Premises Equipment). This results in lower infrastructure and maintenance costs and a seamless upgrade to VDSL2.

  However, technical functionality is only one part of the equation. The other important and difficult factor is interoperability with the installed ADSL infrastructure. This is not provided by the standard but is mostly determined by the ADSL know-how and field experience of the particular silicon vendor. Major ADSL players have invested years of effort into interoperability and only continuous participation at interoperability events and partnerships between industry leaders ensure that end customers can use any equipment without worrying about technical compatibility. Therefore, only the combination of technical backwards compatibility and interoperability to ADSL, ADSL2, and ADSL2+ will allow service providers to install VDSL2 as the ultimate DSL technology and utilise the financial advantages through lower operating and maintenance costs.

Feature	VDSL1	VDSL2	VDSL2 Benefit
Bandwidth	12MHz	30MHz	Enables 100MBit/s applications with maximum reach
Trellis/Viterbi Coding	n.a.	Mandatory	Higher Rate/Reach Performance
LR-VDSL	optional	Mandatory	Built-in options for ADSL2 like long-reach performance
Echo Cancellation	n.a.	Yes	ADSL-like long reach
ADSL backwards compatibility	n.a.	Yes	Enables smooth network transition towards VDSL2
Downstream line-power	14.5dBm	20dBm	Maximum performance with co-located ADSL / same binder, ADSL/2/2+ compliance
Interleaving	Triangular Convolutional	General Convolutional	Precise and seamless selection of Impulse-noise protection
EOC, Management	Register based EOC	Message based	Powerful far-end management, unified OAM model like ADSL2
On-Line Reconfiguration	n.a.	SRA, DRR	Most efficient spectrum usage, based on application needs
Diagnostic Mode	n.a.	Yes	Troubleshooting for large scale deployments as in ADSL2

Table 2: Comparison VDSL1 and VDSL2

VINAX - the industry's first VDSL2-compliant chipset

The VDSL2 standard, G.993.2, was approved and announced by the ITU-T on May 27, 2005. That same day Infineon Technologies introduced VINAX, the industry's first chip-set fully compliant to the new xDSLstandard. As a leading supplier of xDSL ICs and with its abundant experience in both VDSL and ADSL chip design, Infineon was a major contributor in the definition process of the new standard.

VINAX leverages the full VDSL2 frequency spectrum of up to 30 MHz and therefore provides symmetric data rates of 100Mbit/s over copper wires at distances greater than 1150 ft (350 meters). This is twice the loop reach performance of existing VDSL solutions, either VDSL1 or pre-standard chip-sets .

Due to its 20dBm transmit power and its Echo Cancellation, Time Domaine Equalization and Trellis/Viterbi coding features, VINAX assures outstanding Long-Reach VDSL2 performance, meaning speeds of around 1-4 Mbit/s downstream over 16kf (4-5km). Infineon also benefits from its year long experience and expertise in the design and manufacturing of voice ICs and therefore achieved best-in-class products features for its new VDSL2 chipset by including Pre-emption, Dual Latency and Dual Interleaving capabilities.

Being capable to support all the eight different profiles is a major advantage of VINAX as it meets the various regional requirements and allows system manufacturers to address the different worldwide markets with a single hardware platform.

Last but not least, being a major player in the ADSL market ensures optimized ADSL backwards compatibility and enables flexible VDSL2/ ADSL2+ architectures.

An end-to-end solution, VINAX includes a multi-channel central office chip-set, the VINAX-CO, and a single-chip device targeting customer premises equipment, the VINAX-CPE. More information is available at www.infineon.com/vdsl2.

Conclusion

VDSL2 was developed and standardized in record time to address the shortcomings of existing access technologies. It serves as the ideal x DSL technology for eliminating last-mile bottlenecks, enabling global mass deployement of Triple Play services and allows carriers to efficiently compete with cable providers. VDSL2 provides ultra high data rates of up to symmetric 100Mbit/s that are already a mandatory requirement in regions like Korea and Japan for service upgrade. Additionally, with its enhanced long-reach capabilities, a VDSL2 system can provide ADSL-like bit-rates at distances over 16kf (4-5 km) hence covering more than 90% of the households within a Telco network and in some countries even 100 percent. Thanks to its ADSL2+ backwards compatibility VDSL2 enables a smooth, gradual and flexible upgrade of existing networks according to market demand and various regional network requirements.

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