Uni-DSL™: One DSL for Universal Service.

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DSL technology's history of rapid evolution has been rewarded with market success. Yet its greatest challenge lies ahead. New technologies must be developed to handle bandwidth-intensive, next-generation DSL services. The factors shaping new services include high-data-rate video delivery, infrastructure cost considerations, and competing broadband access technologies – especially in light of the triple-play video, data, and voice packages already being offered by some cable TV operators.

To meet the needs of DSL users and operators, TI is developing a next-generation DSL delivery platform called Uni-DSL. This white paper introduces Uni-DSL and its ability to provide one DSL for universal service. The paper has four main objectives:

1. To present the forces driving Uni-DSL development and to define Uni-DSL in terms of higher data rates and universal service.
2. To enumerate the technological advancements enabling Uni-DSL; and, to describe typical system configurations for end-to-end Uni-DSL service delivery.
3. To summarize the benefits to users in terms of new applications and services; and to operators in terms of increased revenue and decreased operating and infrastructure costs.
4. To explain how broadband silicon vendors can differentiate themselves in terms of performance, system integration and value-added applications; and, to show how Texas Instruments is uniquely qualified to deliver complete, best-in-class Uni-DSL silicon and software.

Introduction: The last-mile challenge

Delivering the data rates available within most of the Internet infrastructure to end users has always been hindered by the "last-mile" bottleneck – the connection of homes and businesses to the edge routers that reside in Internet access points or *points of presence* (PoPs). Broadband technologies such as DSL unplug this bottleneck by providing high-speed data connectivity from the PoPs to the customer premises.

Higher connection speeds enable multimedia applications such as listening to real-time Internet audio streaming from remote sources, viewing video news clips and movies, and posting and transferring still images.

Even though broadband has facilitated a wide range of new data services, new and more demanding services are taxing the broadband access infrastructure. Peer-to-peer file sharing, interactive gaming and VoIP telephony are three hot applications today.

In the near future, higher quality audio/video broadcast and conferencing, telecommuting with high-speed graphics transfer and other applications will become mainstream – as soon as they can be enabled.

The primary broadband growth drivers and their impacts are summarized in Texas Instruments' vision is that broadband multimedia – video, audio, voice, and data – will be delivered to and distributed within the home or business to personal endpoint devices. Services will be affordable and easy to use. They will be delivered quickly, securely and reliably. In the future, all things will be connected.

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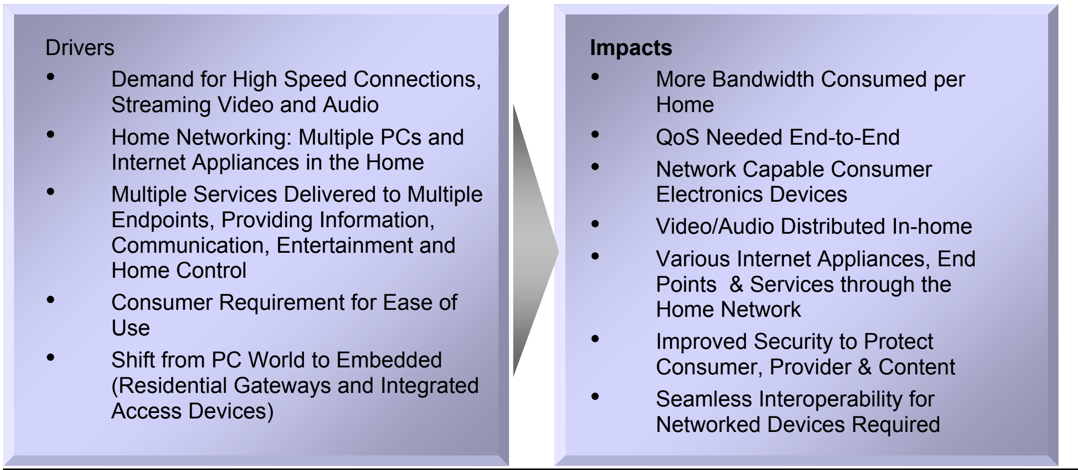

Figure 1: Drivers and Impacts of Broadband Growth

Accelerated evolution needed

DSL technology has evolved rapidly over the years. Present-generation Asymmetric DSL (ADSL) provides up to 8 Mbps from the network to the subscriber (downstream) and 1 Mbps from the subscriber to the network (upstream). The ADSL2 and ADSL2+ standards have been ratified. ADSL2+ enables downstream data rates up to 24 Mbps and upstream data rates up to 3 Mbps by doubling the line bandwidth to 2.2 MHz.

Very-high bit-rate DSL, or VDSL, can support asymmetric data rates of up to 52 Mbps on short (1-2 kft maximum) copper loops. But VSDL has not been widely adopted because of its short-loop limitation. The VDSL2 standard is currently advancing in the standards bodies and is expected to be ratified sometime in 2005.

For additional discussion of DSL evolution, see the sidebar article DSL: A History of Innovation.

Texas Instruments believes none of these developing standards alone will meet the demands of an increasingly competitive environment.

1. Factors driving Uni-DSL development

Uni-DSL – One DSL for Universal Service – is a new DSL delivery platform proposed by TI and enabled by TI's next-generation DSL modem integrated circuits and software.

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Next-generation DSL equipment – and the systems based on this delivery platform – will support aggregate upstream plus downstream data rates up to 200 Mbps, including 100 Mbps symmetric, and will optimize the performance and service delivery for every local loop in the network.

The service is *Universal* because it takes advantage of both ADSL2+ and VDSL2 technology and supports a converged upgrade path that includes both ADSL/ADSL2 and VDSL1.

Specifically, Uni-DSL provides:

- Enriched and reliable service delivery to users – both home and business – including triple play data, voice and video services at data rates up to 200 Mbps aggregate
- Optimal performance and future-proof service delivery for each loop in the network.
- Unified, cost-effective network upgrade path as fiber is deployed further from the central office and closer to end users.
- Unified, cost-effective provisioning and management
- Backward compatibility with current infrastructure

DSL: A History of Innovation

The twisted-pair copper access network has been in place for more than a century and has well served the needs of voice telephony. Over the latter half of that century, however, the network has also evolved to support data communications, driving the development of Digital Subscriber Line (DSL) technology to carry high-speed data over twisted copper pairs.

The earliest type of DSL was basic rate ISDN, deployed in 1986, supporting two 64 kbps B channels and one 16 kbps D channel for a total of 144 kbps. High-data-rate DSL (HDSL), introduced in 1992, offered 1.5 Mbps symmetric service on a single pair to small and medium enterprise customers (SMEs) as a competitive alternative to T1/E1.

Various other forms of non-standard symmetric DSL (SDSL) were deployed by competitive service providers on leased copper pairs. SDSL standardization converged in the development of ITU standard G.991.2, known as G.shdsl, providing for a replacement SDSL service with data rates from 192 kbps to 2.3 Mbps.

These DSL technologies have shown continual growth in total deployment but they are tailored to the limited SME subscriber base and are expensive for residential users. It was not until cost-effective ADSL enabled the web browsing needs of residential users that DSL's explosive growth occurred.

Asymmetric DSL, or ADSL, provides up to 8 Mbps from the network to the subscriber (downstream) and 1 Mbps from the subscriber to the network (upstream). The asymmetry of ADSL has proved ideal for residential users because typical applications like web browsing and media streaming demand much higher data rates downstream than upstream.

Lower system costs

The popularity and standardization of ADSL have driven system costs low enough for the typical residential user to affordably subscribe, facilitating worldwide growth from 18M in 2001 to 110M in 2004, or 83% year-on-year growth. The ADSL2 and ADSL2+ standards have now been ratified, with ADSL2+ enabling downstream data rates up to 24 Mbps and upstream data rates up to 3 Mbps by doubling the line bandwidth to 2.2 MHz.

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Factors driving Uni-DSL development

Uni-DSL development is being driven by many important factors, as listed here and discussed below:

- DSL operators need to support competitive triple-play services, eventually including multiple channels of on-demand HDTV video delivery
- Appealing business case alternative to Fiber to the Home (FTTH)
- Advancements in DSL technology
- VDSL2 standards development
- Unique advantages over cable and other shared medium broadband services

One of the service providers' major concerns is the continuing loss of traditional analog telephony revenue from the copper infrastructure. This threat has two distinct aspects:

- The popularity of wireless phones means many people are substituting their traditional wire line phone service
- Other broadband service providers are adding telephony to their broadband offerings

It is estimated that service providers are losing 1-2 percent of their installed customer base per year to these alternative service options. Given that cable already provides video, telephony and high-speed data in much of its service area, the threat is quite real and the need to enable new services to extract more revenue from the existing copper base is obvious.

Very-high bit-rate DSL, or VDSL, can support asymmetric data rates of up to 52 Mbps on short (1-2 kft maximum) copper loops. However, since the line length (reach) between the central office (CO) or remote terminal (RT) modem and the customer premises equipment (CPE) for most users is greater than 1-2 kft, VDSL is not a viable service for these users.

In addition, VDSL standardization has lagged ADSL and available products are more proprietary and expensive, so at present VDSL service is primarily restricted to select businesses and residential users willing to pay a premium for these rates. The VDSL2 standard is currently advancing in the standards bodies.

Standards development status

The ADSL2+ standard is enabling a new wave of DSL equipment just coming to market to support up to 24 Mbps downstream, and deployment from the RT is expected to ramp over the next several years. The VDSL2 standard, however, is still in development and is expected to be ratified sometime in 2005.

TI is actively involved in the VDSL2 standards process and has already submitted a number of technical contributions. Some operators currently deploy VDSL1, but they are generally concerned with the lack of a unified, widely productized VDSL standard; other operators are simply waiting.

The ratification of VDSL2, with the involvement of operators, equipment vendors and silicon providers, will eliminate these concerns and open the gates for next-generation DSL deployment to proceed.

Fiber's unfulfilled promise

One solution is to overlay or replace the copper physical plant with fiber. Such a FTTH build-out is in the long-term strategic plan of many LECs, but at the same time it is recognized that deploying fiber all the way to every end user typically does not justify the capital cost of the upgrade, especially in developed areas that require significant retrenching and/or running of aerial fiber.

FTTH installations by LECs to date have been primarily in greenfield (new development) locations and in certain generally affluent areas with high expected take rates. The compromise to FTTH for most developed areas is, and will be, to expand fiber out from the central office gradually, stopping at several natural transition points in the copper plant. Mass deployment of FTTH is not envisioned for many years.

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Uni-DSL Deployment Locations and Data Rate Tradeoffs

Possible locations for DSL equipment include the central office (CO), remote terminal (RT), cross-connect box, pedestal, curb, or basements and wiring closets of multi-dwelling units (MDUs) and enterprises.

Figure 2 depicts these locations and their respective upper-range distances from the customer premises as typically found in North America. In many countries loop lengths tend to be shorter, so this diagram somewhat represents worst case. DSL services that can be deployed from each location and the data rates expected from them are noted in the figure.

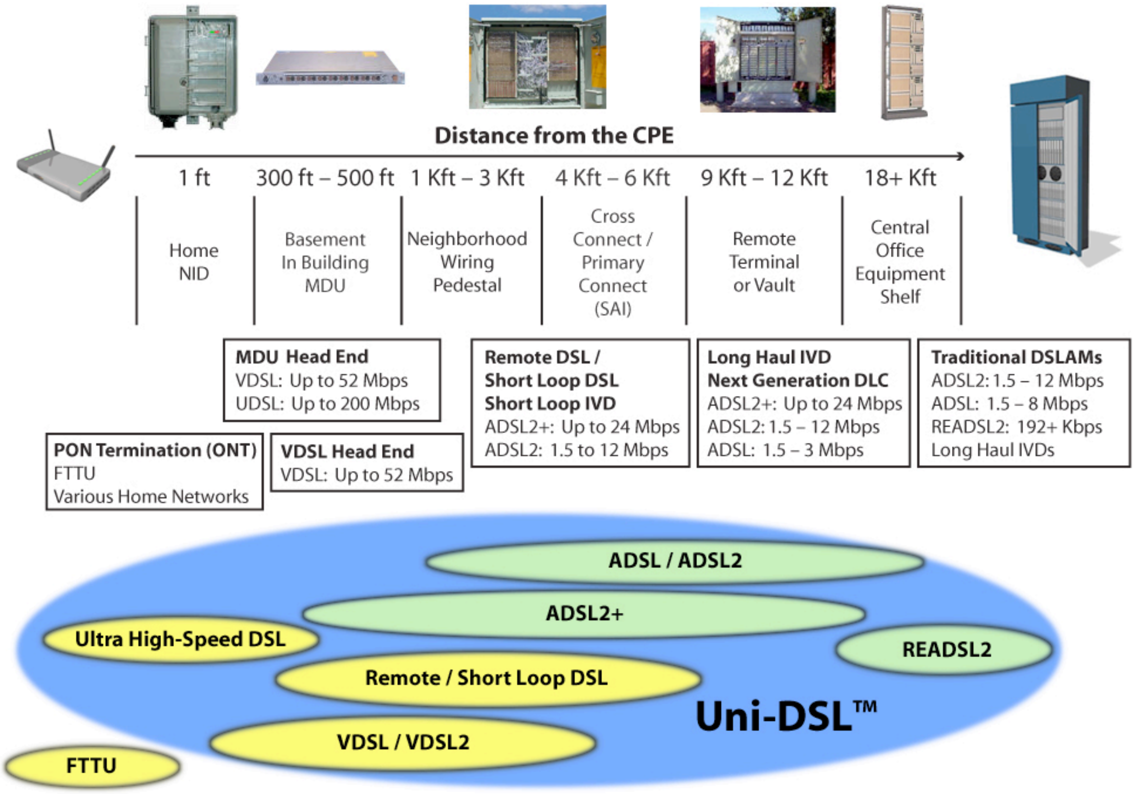

Figure 2: DSL Deployment points within the copper loop plant and the DSL services available from those points.

Most loop lengths from the central office (CO) or remote terminal (RT) are 6 kft or less, but depending on loop plant topology up to 30% are more than 6 kft and some approach the *carrier service area* (CSA) limit of 12 kft of 24 gauge wire or 9 kft of 26 gauge wire.

As shown in a comparison of the rate and reach performance of the various DSL standards, VDSL2 can provide >15 Mbps for those loop lengths in the 5-6 kft or less region. Assuming MPEG4 video at ~6-10 Mbps for HDTV, 2-4 Mbps for SDTV, data service at 1.5-3 Mbps, and voice service at several hundred kbps, this 15 Mbps will accommodate triple-play services to more than 70% of the service area.

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