G.Lite:

Making the Internet Fast Enough for Consumers

AWARE

Executive Summary

This white paper describes a new high-speed Internet access technology called G.Lite, a variant of ADSL technology designed for easy, low-cost deployment in the home. With G.Lite technology, no special equipment or wiring is required. Using existing phone lines and ordinary phone jacks, G.Lite modems are as easy to use as traditional analog modems, but deliver transmission speeds over 27 times faster than today's top-of-the-line 56 kbps modems. Aware, Inc. pioneered the splitterless DMT technology that came to be known as G.Lite. This technology meets all of the requirements for widespread consumer deployment: it is compliant with industry-endorsed standards, PC-compatible, available today, and splitterless - that is, it requires no change to existing in-home wiring, allowing consumers and phone companies alike to leverage their technology investments. With G.Lite, the Internet can be the rich multimedia experience consumers have come to expect.

G.Lite: Making the Internet Fast Enough for Consumers

"Bandwidth bottleneck. No question, that's the biggest obstacle."

Bill Gates, Microsoft (Fortune Magazine, June 1996)

Introduction

The Internet has become part of the fabric of everyday life. The number of Internet users around the world is expected to soar from 110 million today to a projected 478 million by 2005, according to the industry analyst Ovum. Consumers are hungering for sophisticated Web applications, such as online shopping, distance learning, push technology, multi-casting, video-on-demand and telecommuting.

These applications all require high-speed Internet access, placing an unprecedented burden on the existing telephone network. The 50-year-old copper wires that were originally designed for dial-up voice traffic are now struggling with the teeming traffic of the Internet Age. Phone companies have faced the daunting challenge of rewiring the world for a new delivery system. A decade ago, phone companies envisioned running optical fiber into every home. However, because of the magnitude of the task and the associated cost - over $1,000 per home - it may be decades before every home has fiber optics. Instead, phone companies have built fiber optic networks over much of the country, leaving the copper wiring in place for the "last mile" from the service provider to the home.

Could cable modems be the answer to this problem? Over 90% of U.S. homes have access to cable, with over 60% subscribing to some CATV service. However, most of the current plant cannot support reliable two-way communications. Subscribers must share the available bandwidth with other subscribers; as the number of subscribers increase, the available bandwidth to each decreases. Currently, cable modems are offered to only a handful of subscribers. Additionally, the very nature of cable as a shared medium makes security problematic.

For now, the single best hope for widespread consumer access to the Internet lies in the twisted copper wires that enter every home and every business in the land. There are more than 750 million of these copper wires in place worldwide, of which 170 million are in the U.S. This represents a $100 billion undepreciated investment, waiting to be tapped.

The Need for Speed

Today, the average home accesses the Internet at a sluggish 28.8 kbps. That's fast enough for e-mail, but not for the rich multimedia experience that consumers have come to expect. Even ISDN's 128 kbps rate is barely sufficient for today's multimedia content. What consumers have needed - and lacked - is a widely available and affordable technology that can deliver multimedia Web applications at a speed that makes them meaningful.

Simply put, consumers need more bandwidth.

Consumer Requirements

However, there is a limit to what the consumer is willing to do and pay for fast Internet access. Here are the basic requirements for a high-speed Internet access technology that makes sense for consumers:

- No special equipment to install - and no need for a second phone line. For every home to install a second phone line for Internet access would be an unreasonable expense for the consumer, and a huge burden for the phone system. An ideal solution would allow use of the same line for voice and Internet access simultaneously.
- Compatibility with existing PCs.
- Compatibility with the existing phone network; that is, no rewiring necessary.
- Low cost. Consumer price points should be comparable to existing analog modems.
- Available ASAP!

Once affordable bandwidth is available, it will unleash the floodgates of Internet commerce and spark a renaissance of Web innovation. The Internet Age will have finally arrived.

Enter DSL

Imagine if the modems in today's personal computers were over 100 times faster. Opening the most complex Web page would be instantaneous. Downloading images and even full-motion video would be a matter of split seconds, not several minutes.

Impossible? That's what Digital Subscriber Line (DSL) technology is all about. DSL is a recent innovation that maximizes the existing copper wire network by taking advantage of unused bandwidth. Aware, Inc. developed full-rate ADSL technology that enables speeds up to 140 times faster than 56 kbps modems, 50 times faster than ISDN, and even five times faster than dedicated T1 lines - all on existing copper phone wires, while maintaining normal voice service.

DSL technology works differently from the technology in traditional analog modems. When a POTS (Plain Old Telephone Service) analog modem connects to an Internet Service Provider or ISP, it connects through the telephone voice network. The modem's analog signal is digitized using 8-bit samples, 8,000 times per second, resulting in the ubiquitous 64 kbps data stream.

Over time, the availability of low-cost processing power has enabled higher and higher speed voiceband modems. These improvements have also led to more complex and advanced modulation algorithms in low-cost devices. With all these advances in analog modem technology, the current state-of-the-art is 56 kbps. Standard analog modems operate in the voiceband spectrum, from 0 Hz to 4 kHz, and the 4 kHz limitation is near exhaustion. DSL modems can utilize bandwidth well beyond 4 kHz - up to 1.1 Mhz of spectrum. However, current central office (CO) voice equipment does not know to "look for" information and signals outside the 4 kHz voiceband. Thus, for any DSL service, the local exchange carrier (LEC) must install new equipment to allow the subscriber to use this capacity for faster communications. Because DSL modems can utilize up to 1.1 Mhz of spectrum, this opens the prospect for an exponential jump in speed over today's 28.8 and 56 kbps modems. Speeds of up to 10 Mbps are not unimaginable.

Variants of DSL

The many variants of DSL have been widely tested in hundreds of trials both in the U.S. and abroad. Each has its unique requirements and limitations. For purposes of this paper, we will focus primarily on Asymmetric DSL, or ADSL. ADSL comes in two strengths: the industrial strength version, called full-rate ADSL; and a consumer version known as G.Lite that trades off speed for ease of installation. In one version of DSL, the telephone company installs a special kind of modem in the telephone central office and one in the subscriber's home or business. These two modems utilize up to 500 kHz of bandwidth and communicate 784 kbps bi-directionally over a single twisted copper pair. Utilizing two twisted pairs, this technology, called high bit rate digital subscriber line, or HDSL, is used for new T1 lines in the United States (or E1 lines in Europe). HDSL is a sound technology, but it is not well suited for consumer Internet access. It is a baseband technology, meaning that it requires all of the bandwidth up to 500 kHz, including the 0 to 4 kHz needed for voice traffic. It therefore cannot support simultaneous telephone service and high-speed digital communications over the same telephone line - a key requirement for widespread consumer deployment.

Advantages of Full-Rate ADSL

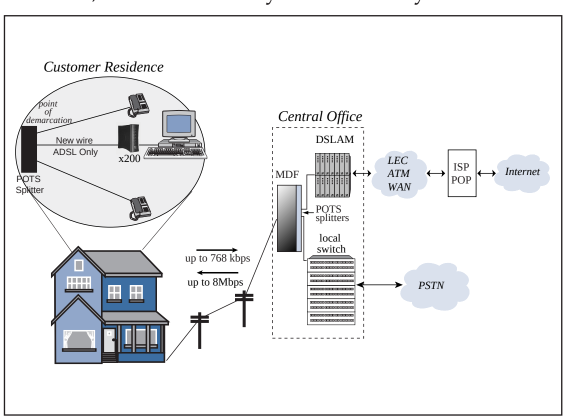
ADSL, or Asymmetric DSL, allows for simultaneous voice and Internet traffic on the same phone line. This feat is achieved by a bandpass technique that avoids the bottom 4 kHz utilized by ordinary voice traffic. By reserving the low end of the spectrum for voice traffic, the same phone line can support both voice and high-speed Internet access at the same time.

Filters are used at each end of the twisted copper pair to split the frequency bands. The low frequencies are sent to the telephone switch in the central office and to the telephone in the home. The high frequencies are sent to the ADSL modems. These filters are known as "splitters," because they split the voice-data spectrum.

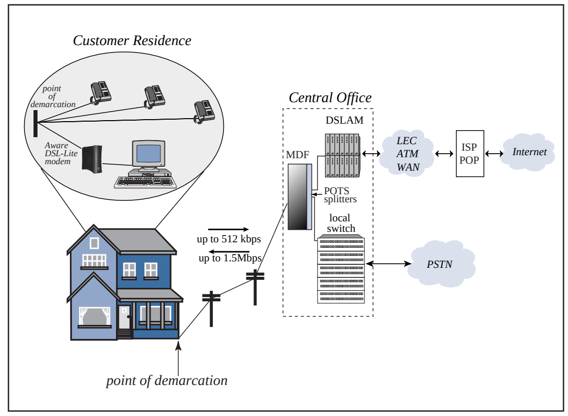
These splitters require that the service provider dispatch a technician to install the device and to wire the ADSL modem. This deployment scenario has many pitfalls. A "truck roll" is expensive, costing at least $200 per dispatch. Additionally, truck rolls limit the rate of service adoption, since each installer can only physically install the devices in so many homes per day. The truck roll model could mandate that the DSL modem be external to the PC to avoid any liability when opening the consumers PC. This would keep the price of DSL modems artificially high by limiting volume and the use of internal PCI adapters.

Splitterless ADSL, or G.Lite

For any new high-bandwidth residential service to succeed, it must be easily installable by both the



Typical ADSL configuration



Typical DSL Lite splitterless configuration

service provider and the consumer. This has led to the development of a new form of DSL, called G.Lite. The key feature of G.Lite is that it does not require the use of a splitter at every home.

Instead of requiring a field technician to install a splitter at the home, G.Lite technology may be embedded in the PC modem. These DSL modems are priced comparably with traditional analog modems, and work with existing phone jacks.

Though G.Lite technology trades off speed for ease of installation, it still represents a measurable improvement over 56k modems - the fastest analog modems available today.

Another great benefit of DSL technology is that the existing phone service is unaffected by adding DSL. The phone signal gets split and continues on its way to the local digital switching system. The DSL signal then terminates on the DSL concentration equipment and is groomed on a larger circuit. The service is then transported via the local carrier's frame relay or ATM backbone network, where it is delivered to the ISP's POP. The DSL data never traverses the public switched telephone network (PSTN) switches. Innovation in the Internet and Web markets is occurring at a rapid pace. New applications such as push technologies and IP multicasting create compelling content for consumers. By providing data simultaneous with voice, G.Lite enables the PC modem to operate in an "always on" mode. Thus, emails can get delivered as they are sent, and the requirement for dial-in access is removed.

DMT and the Importance of Standards

Standards are important. It is because of standards that a consumer can buy a modem from any store, dial an Internet service provider (ISP), and be confident of getting a connection, without ever needing to worry about whether the equipment is compatible with the ISP's.

The standards process works through consensus. Experts from across an industry meet, debate, and share opinions and research in order to arrive at a solution that is "greater than the sum of its parts." The disadvantage is that the process can be time-consuming. A consensus-based solution will arrive on the market later than an in-house approach that need pay no heed to the requests of others.

However, there are massive benefits when a standards-based solution does arrive. Not only is it supported by a wide base of manufacturers, but it also fuels healthy competition among them. Furthermore, the process of different experts from a variety of companies working together and discussing the technology almost always leads to a solution significantly better than any one company could develop on its own; the classic example being the analog or V.34 modem.

This was the process that in 1993 led to the selection of Discrete Multitone (DMT) as the full-rate ADSL line code standard. There was strong debate at the time among three contending camps: DMT, CAP (Carrierless Amplitude and Phase) and QAM (Quadrature Amplitude Modulation). So the impartial Bellcore, along with Bell Atlantic and NYNEX, organized the "ADSL Olympics" to evaluate and compare three line code contenders.

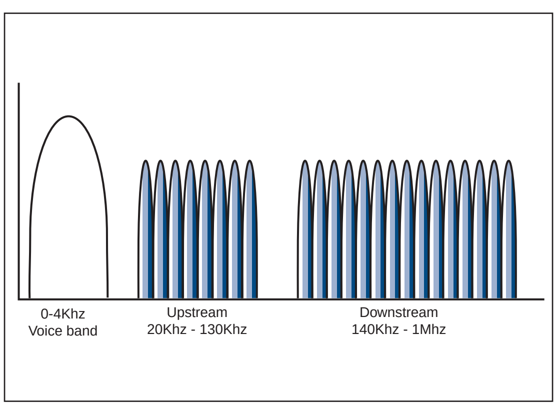
The trial results conclusively indicated that DMT had performed better than CAP and QAM. Consequently, two major standards bodies - the American National Standards Institute (ANSI) and the European Telecommunications Standards Institute (ETSI) adopted DMT as the standard. As a result, the ANSI T1.413 standard was born. Furthermore, in 1998 the International Standards Union (ITU) determined the G.Lite standard, G.992.2, based on DMT technology. Meanwhile, companies like Aware, which pioneered DMT technology, are well along in trialing or demonstrating both splitterless and full-rate ADSL technology based on the industry-endorsed standard.

How DMT Works

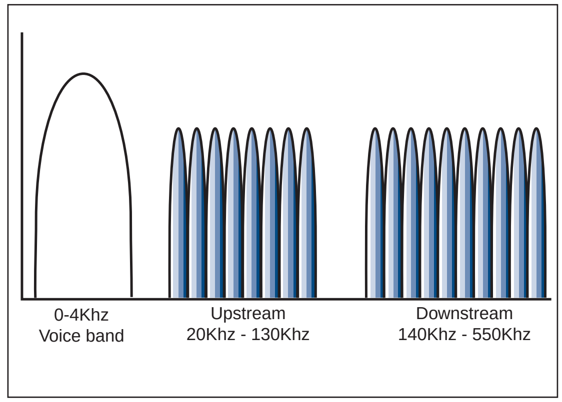
DMT uses many narrow-band carriers, all transmitting at once in parallel, and each carrying a small fraction of the total information. The many discrete bands, or sub-channels, are independently modulated with a carrier frequency corresponding to the center frequency of the bin and processed in parallel. Multicarrier modulation requires orthogonality between all the sub-carriers; a Fast Fourier Transform (FFT) is convenient for achieving this (although other sophisticated transforms have been developed recently).

Multi-carrier techniques require much digital processing, and were not commercially feasible until recently, when IC technology could implement them economically and reliably in mass-market silicon processes. DMT is closely related to OFDM orthogonal frequency division multiplexing, or coded OFDM (C-OFDM), which has just been selected for Europe's Digital Audio Broadcast (DAB) to broadcast CD quality sound and multimedia over the airwaves for in-car and mobile applications.

DMT's ANSI T1.413 standard specifies 256 subcarriers, each with a 4 kHz bandwidth. They can be independently modulated from zero to a maximum of 15 bits/sec/Hz. This allows up to 60 kbps per tone (some implementations support 16, giving rates of 64 kbps per tone). At low frequencies, where copper wire attenuation is low and signal to noise ratio (SNR) is good, it's common to use a very dense constellation; greater than 10 bits per subcarrier/Hz is typical. In unfavorable line conditions, modulation can be relaxed to accommodate lower SNR-usually 4 bits per subcarrier/Hz or less, and deliver the necessary noise immunity. Furthermore, as the system measures line integrity, it can avoid or compensate for cross-talk or interference. This is particularly useful, for example, when reducing modulation in a band where an AM station is causing radio frequency interference (RFI).



ANSI T1.413 DMT spectrum



Proposed UADSL, G.Lite DMT spectrum

Why Deployment Has Been Stalled

Despite the incredible growth in Internet access over the last couple of years, universal consumer acceptance of modems, and vocal demand for higher speeds, ADSL deployment has been slow. The industry fragmentation into distinct and incompatible technologies has meant slower adoption and greater consumer resistance.

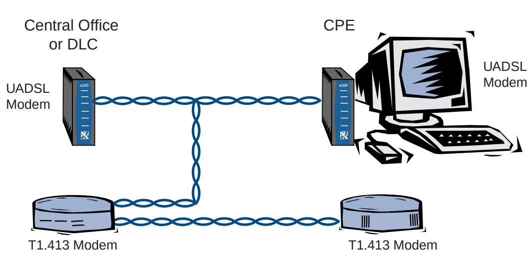
To make ADSL possible, the Incumbent Local Exchange Carriers (ILECs) had to prepare for a considerable investment in upgrading central office technology. Before doing so, there had to be industry agreement on standards to ensure interoperability between multiple equipment vendors. ILECs also had to be certain that the technology may be deployed universally, reliably, and affordably to all phone customers.

The Aware Solution

To jumpstart widespread deployment of ADSL, the "Universal ADSL Working Group" (UAWG) was created by an unprecedented partnership among PC, telecommunications, and networking industry leaders. Led by PC industry giants Microsoft, Intel and Compaq, the UAWG included leading service providers Ameritech, Bell Atlantic, Bell South, GTE, SBC, Sprint and U.S. West; semiconductor networking and telecommunciations equipment suppliers such as Alcatel, Analog Devices, DSC Communications, Ericsson, Lucent, Nortel, Rockwell, Siemens and Texas Instruments; and core technology provider Aware, Inc.

Formally announced on January 26, 1998, Universal ADSL was a proposed specification intended as an interoperable extension of the ANSI standard T1.413 ADSL, based on DMT, which was designed to ensure global acceptance of ADSL and leverage current deployment of T1.413-based equipment around the world. Universal ADSL promises a single standard supported by a cross-industry alliance, accelerating the development of chipsets, software and equipment.

What was Aware's role in this working group's solution? Aware was the first to demonstrate splitterless ADSL technology. There is no need for special installation services or in-home wiring. Aware's G.Lite technology can deliver high-speed Internet access over standard phone lines at speeds up to 1.5 Mbps, more than 27 times faster than 56 kbps analog modems, with no interference from voice, fax and other phone line activity. In addition, Aware's core technology satisfies the need for rapid access to the Internet - in less than 5 seconds - and lets consumers take advantage of new services made possible by always-on connections. Special provisions have been to ensure the security of this always-on connection. Aware's splitterless technology is designed for PC modem applications and is as easy to use as current modems. Most importantly, it is available today!



UADSL Interoperability

Conclusion

The advent of splitterless ADSL, or G.Lite, does not eliminate the need for full-rate ADSL. Rather, G.Lite offers a logical stepping stone between the analog modems available today and the industrial strength solution of full-rate ADSL.

Consumer demand for high-speed Internet access has motivated local exchange carriers to install central office equipment that can handle both full-rate ADSL and the new splitterless version, thus protecting customer and phone carrier investment, and reducing the threat of a fractured xDSL industry. In recent months, telephone companies around the world including Bell Atlantic, SBC Communications, USWest, BellSouth, British Columbia Telephone, Deutsche Telekom, and Telecom New Zealand have begun rolling out DSL services to their customers. These worldwide service offerings are expected to make DSL services available to well over 25 million subscribers by the end of 1999.

Moreover, as momentum in the DSL space builds, ISPs like America Online will increasingly forge strategic alliances with phone companies such as Bell Atlantic and SBC Communications to ensure the availability of a critical high-speed Internet access path for their original Web content.

Most importantly, the accelerated deployment of ultrafast Internet access will unleash a tidal wave of innovative new Web applications, incorporating CD-quality audio and DVD-quality video. The result will be unlimited possibilities for learning, communicating, working and conducting business on the Internet.

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