DSL: An Overview

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ABSTRACT

Today, high-speed Internet access has become quite a necessity, not only in the advanced nations but also in many of the third world countries. Thanks to the fast growing economies, technologies have opened up many of the homes and offices to a new realm of possibilities for network connectivity and applications. Video on demand, Multi-media conferencing and on-line gaming are just a few examples of the services on the Internet that have become quite common these days.

Even though analog modems routinely offer 28.8 kbps, 33.6 kbps or 56 kbps, they have practically reached the limits, thereby leaving no choice but to resort to digital systems. ISDN stretches this up to 128 kbps, but it is still slow compared to the growing needs of the customers, who practically want everything on the Internet. Broadband Communication, in all forms, not only provides high-speed Internet access, but also provides the necessary framework for a variety of value-added services.

DSL and Cable Modem are two parallel technologies in broadband communications, each having its own pros and cons. This article provides an overview of DSL, the associated devices, technologies and its applications. For the benefit of the readers, it also provides a simple comparison with Cable Modem.

ABOUT THE AUTHOR

MultiTech Software Systems India Pvt. Ltd., established in 1990, is one of the leading software development services company, offering services and solutions in the areas of Broadband Networking, Data Communications, Embedded Systems and Voice over Packet communications, to its clients worldwide. MultiTech offers specialized offshore development services for the system integration, testing, design and development of CPE products including DSL Routers, VPN Gateways, VoIP Gateways and IP Phones.

The author is a co-founder and Vice President, Operations of MultiTech. He holds a Masters Degree in Computer Science from I.I.T. Kanpur and a Bachelor's Degree in Computer Science from Andhra University; and has around 18 years of experience in Software Project Implementation (Data communications and Networking), Quality Management, Competency Development and Human Resource Management.

1 HISTORY OF DSL

MODEM (Modulator-Demodulator) used for communication between any two computers through a PSTN line uses Modulation and Demodulation techniques for Digital-Analog and Analog-Digital conversion, respectively.

In 1969, AT&T revised the tariffs to allow customer-provided devices (modems) to be connected to PSTN lines for transferring data, with the following conditions:

- Restriction in output power and energy levels
- Connection to the PSTN thru the telephone company-provided protective devices (Data Access Arrangement)
- All the network-control signalling (Dialling, Busy signals, etc.) performed with the telephone company-provided equipment at the connection point.

Under these conditions, modem technology had to come up with the following new techniques, in order to achieve higher data rates (from 19.2 Kbps thru 56 Kbps):

- Compression
- Error Correction
- Echo Cancellation
- Trellis Encoding

Modem data rates are calculated using Claude Shannon's formula:

$$C = B * \log_2 (1+ S/N)$$

where,

C = Channel Capacity (2400 to 2800 Hz)

B = Bandwidth (24000 bps)

S/N = Signal-to-Noise Ratio (24 to 30 dBs)

The limitations in achieving higher data rates thru these voice band lines are mainly due to the core network and not the bandwidth availability of the copper wire of the telephone network. Filters at the core of the network limit the voice-grade bandwidth to approximately 3.3 KHz. In the absence of these filters, the copper wires can frequencies up to a few MHz.

It is precisely this aspect that is made use of in the DSL technology, which came into existence in the late 1980s.

2 WHAT IS DSL?

Digital Subscriber Line (DSL) is a broadband high-speed Internet technology that brings high-bandwidth information to home and offices over ordinary copper telephone lines. It assumes that digital data does not require changing into analog form and back to digital form. Digital data is transmitted directly to the computer, as is, exploiting the maximum bandwidth and the wide range of unused frequencies available in the existing copper wire of telephone networks for high-speed broadband communication. Moreover, the signal can also be separated, if one chooses, so that some of the bandwidth is used to transmit an analog signal for simultaneously using the telephone line for voice.

Following are some of the key features of DSL:

- Distance-sensitive technology
- Internet connection is always ON
- Simultaneous use of the phone line for voice as well as data traffic
- Internet Connection is highly reliable and secure
- High Speed (Mbps), vis-à-vis a regular modem (56 Kbps max)

3 ADVENT OF DSL

1985 – 1990	Bell Labs discovers a new way to support Digital Services on traditional copper wires.
	Phone companies start deploying High Speed DSL (HDSL) to offer T1 service on copper lines, without installing repeaters.
1990 – 1995	Phone Companies begin to promote DSL as a way to enter video market.
	Innovative companies begin to see DSL as a way to meet the growing need for faster Internet access.
1995+	DSL fully deployed for fast Internet access in the USA and many other advanced nations across the globe.
2000+	DSL enters Indian market in a big way.

4 TYPES OF DSL

ADSL **Asymmetric DSL**. Greater bandwidth downstream from the network than to the network. Perfectly meets the Internet users' requirement that users typically download more than what they upload.

RADSL **Rate Adaptive DSL**. Non-standard version of ADSL. When connected, RADSL adjusts the upstream bandwidth to allow for a wider downstream bandwidth. Connections are more tolerant to errors caused by line noise.

VDSL **Very high bit-rate DSL**. Up to 26 Mbps over distances up to 50 meters on short loops. In most cases, VDSL lines are served up to CO via optical fibre. Useful for campus environments, universities and business parks to provide video services over existing phone lines.

HDSL **High bit-rate DSL**. Delivers symmetric service at speeds up to 2.3 Mbps, both ways. It does not provide the standard telephone service over the same line. Seen more as an economical replacement to T1 or E1.

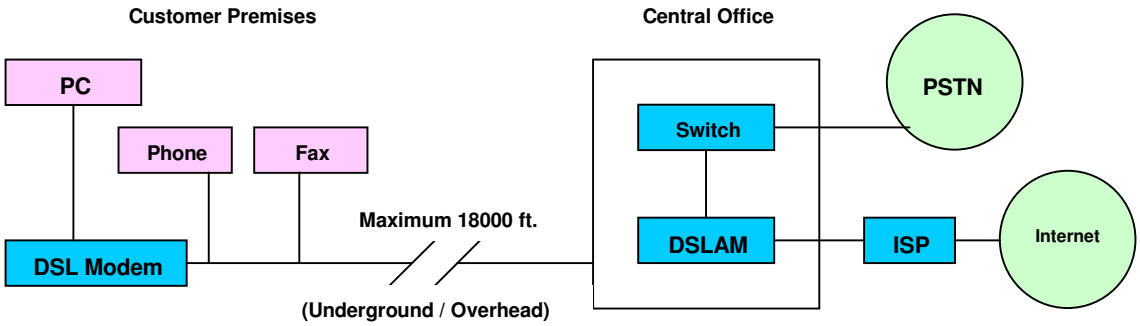
IDSL **ISDN DSL**. Symmetric data rates of up to 144 kbps using existing phone lines. Capable of using the same modem or terminal adaptor used for ISDN and is "always available".

SDSL **Symmetric DSL**. Vendor proprietary version of symmetric DSL offering speeds from 128 kbps to 2.3 Mbps. This is an umbrella term for a number of supplier-specific symmetric DSL services.

Of all these flavours, ADSL and HDSL have found the widest implementation, with the former being more popular for home and small office usage.

5 DSL DEVICES

DSL is actually not a physical line, but a modem pair. One DSL modem is located at the customer premises (Customer Premise Equipment or CPE) and another DSL Access Multiplexer (DSLAM) is at the Central Office (CO). These two modems create a Digital Subscriber Line or DSL. DSL modems transmit data at the rate of up to 160 Kbps over copper lines, up to 18000 feet.



DSL Modem or DSL Transceiver, as it is also referred to as, is connected to the customer's computer via USB or a 10-Base T connection.

DSLAM at the Central Office or the Access Provider is the one that actually makes the DSL happen. It accepts connections from various customers and aggregates them into a single high capacity connection to the Internet. In addition, the DSLAM also does IP routing and Dynamic IP address assignment.

6 MODULATION TECHNOLOGIES

A pair of copper wires used for standard phone line installation has plenty of bandwidth available for carrying data in addition to voice conversations. Voice and fax calls use only the frequencies below 4 KHz, thereby leaving all the higher frequencies for data transmission.

DSL uses the Quadrature Amplitude Modulation (QAM) technology to modify the carrier signal. DSL uses either CAP or DMT techniques, both of which are based on QAM, but vary in their implementation.

CAP **Carrier-less Amplitude Phase**

Incoming data modules a single carrier that is then transmitted down a telephone line. The carrier itself is suppressed before the transmission. It contains no information and can be reconstructed at the receiver. Hence it is called "carrier-less".

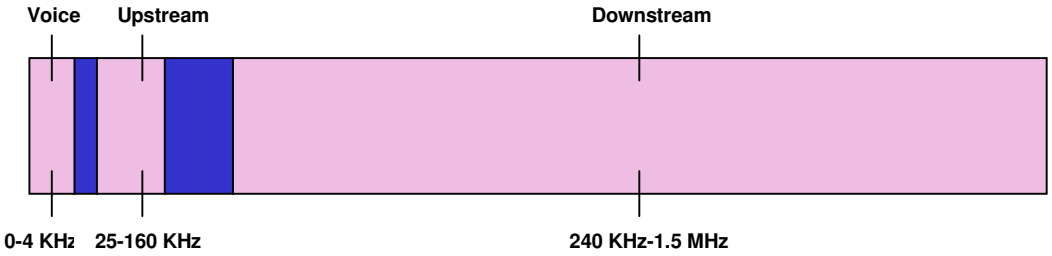
DMT **Discrete Multi Tone**

This is a version of multi-carrier modulation, in which incoming data is collected and then distributed over a large number of small individual carriers. DMT creates these channels using Discrete Fast Fourier Transform.

6.1 CARRIERLESS AMPLITUDE PHASE (CAP)

CAP divides the signals on the telephone lines into three distinct categories:

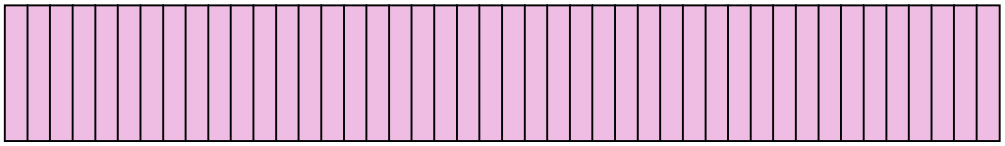
0 KHz to 4 KHz : Voice
25 KHz to 160 KHz : Upstream Internet Traffic
240 KHz to 1.5 MHz : Downstream Internet Traffic



CAP suppresses the carrier signal before transmission. The message signal is first modulated by a carrier signal and stored in memory. Pieces of this modulated signal are reassembled and passed through a band-shaping filter before transmission. The filter actually imposes a carrier on this assembled signal, converting it into a modulated wave.

6.2 DISCRETE MULTI TONE (DMT)

DMT divides the signals into 247 separate channels, each offering a range of 4 KHz.



247 Channels (4 KHz each)

A few channels, starting at about 8 KHz are used as bi-directional channels, while the other channels are used either for transmission or reception. The channels are monitored periodically for quality. If the quality of any specific channel is found to be poor, the signals are shifted to the next available best channel. This way, signals are shifted constantly from one channel to another, for better transmission and reception. Low pass filters are used to filter data from entering into telephonic conversations.

7 APPLICATIONS OF DSL

- Interactive Video – movies on demand, video on demand, video conferencing
- High-speed Data communication – Internet access, Telecommuting, Remote LAN access, specialized network access.

8 DSL VS. CABLE

Both DSL and Cable Modem technologies offer high-speed Internet access. Even though they are similar in many respects, the two technologies differ on some fundamental aspects such as speed, bandwidth, security, reliability and quality of service. While some of the differences are due to historical reasons, some others are due to the approach of service providers.

Speed: In terms of theoretical raw peak performance, cable modem outweighs DSL. Cable can achieve, theoretically, up to 30 Mbps, while most forms of DSL cannot reach beyond 10 Mbps. In practice, both forms rarely reach their peak performance.

Bandwidth: Cable modem technology delivers “shared” bandwidth within the neighbourhood, while DSL delivers “dedicated” bandwidth. DSL typically is provided in the range from 128 kbps to 1.544 Mbps, varying as the equipment.

Security: DSL can be considered to be more secure of the two, more due to a perceived weakness in the cable modem. All cable modem customers in a region belong to the same LAN, thus opening avenues for file sharing and other menaces of a typical network neighbourhood. This calls for security firewalls, strict authentication and packet filtering mechanisms to be built into cable modem standard specifications.

Reliability: Both DSL and Cable provide an “always on connection” capability, thereby giving a “Static IP address” to the session; and in turn, providing a fixed target to network attackers. As a result, many DSL and cable customers have to purchase a DSL Router or a Cable Router, that enhances the functionality of a basic modem with security features such as packet filtering and network address translation. Customers can choose from a variety of precautions offered by the broadband router, to suit their applications.

Despite tall claims by vendors about out-weighing the benefits of one another, both DSL and Cable modem providers are working towards winning customers and expanding their customer base. Drastically cutting costs, providing more value-added services, improvising on the security features and constantly withstanding competitive pressures from vendors of the other forms of technology, both forms of broadband technology are here to stay for some more time.

9 DSL CONSORTIUMS

Alliance Group	Companies like Alcatel and Texas Instruments. They support VDSL through DMT technology.
Coalition Group	Companies like Lucent and Broadcom. They support VDSL through CAP technology.

10 DSL STANDARDS

- International Telecommunication Union (ITU). G.992.1 (G.dmt), G.992.2 (G.lite) standards information. http://www.itu.int
- American National Standards Institute (ANSI). ANSI TI.413-1998, ADSL Metallic Interface. http://www.ansi.org
- Universal ADSL Working Group. G.lite standards information. http://uawg.org
- Standards Committee T1-Telecommunications. XDSL standards and relevant documents from T1E1.4 Working group. http://www.t1.org
- European Telecommunications Standards Institute (ETSI). ADSL, VDSL and SDSL standards. http://www.etsi.org
- Internet Engineering Task Force (IETF). ADSL MIB working group. http://www.ietf.org, http://www.ietf.org/html-charters/adslmib-charter.html