

Broadband

Introduction to Broadband

Most computers today are able to process at more than 1 GHz. Conventional analog modems however can only run up to 56 Kbps, and this limits the amount of information that can be sent and received over the telephone line at any one time. Broadband telecommunication solves this limitation by providing a wide band of channels to transmit information on a wire concurrently.

There are a number of broadband access platforms. One of the most popular is Digital Subscriber Line (DSL). Other broadband platforms include Integrated Services Digital Network (ISDN), leased line, cable access, satellite, fiber optic, and fixed wireless access (FWA). In this document, we will only discuss DSL.

Introduction to Digital Subscriber Line

Digital Subscriber Line (DSL) is a cost effective option for broadband connections. This is because it uses existing telephone infrastructure for both voice and data traffic to enable high-speed data transmissions to and from customers' premises. By upgrading the modem and telecommunication equipment, the customer can upgrade to DSL connection using the existing cable infrastructure. DSL is a 'last-mile' or 'local loop' solution that carries signals from the telephone company central offices (COs) along a relatively short distance via wired connection to and from the home or business.

How DSL work?

The traditional phone service, which is also known as Plain Old Telephone Service (POTS), was created to exchange voice information using analog signal. Computers, however, communicate using digital signal, so in order for it to travel along the telephone network, a modem is necessary to convert digital data to analog signal and vice versa.

The analog telephone frequency uses less than 4 kHz of bandwidth on the line and the maximum amount of data that can be transmitted using POTS system is 56 Kbps.

This can be easily achieved by using conventional dial-up modems. A typical telephone cabling system, on the other hand, is able to support a greater range of frequencies. With the use of DSL modems, digital signal can transmit data together with analog voice signal on the same wire. It can separate the signals and prevent interference between each other.

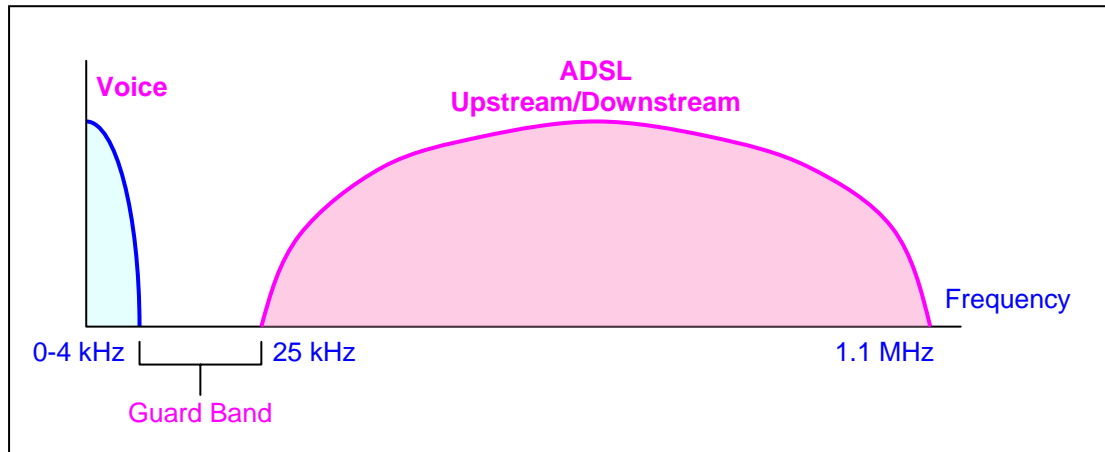


Figure 1. Splitting the Frequency

DSL modems establish connection from one end of a copper wire to another using point-to-point dedicated circuits to provide 'always on' connectivity.

Factors Affecting the Performance of DSL

There are several factors that can affect DSL performance. The most common factors are attenuation, bridge taps, load coils, and cross talk. Other factors include return loss, longitudinal balance, noise, split pairs, gauge changes and interruptions. Environmental factors can also affect transmission lines used for telecommunications.

a. Attenuation

As the distance between the customer's premises and the telephone company's central office (CO) increases, the data rate will drop. The downstream frequencies will suffer degradation of digital signal or the loss of amplitude of an electric signal during transmission, known as *attenuation*.

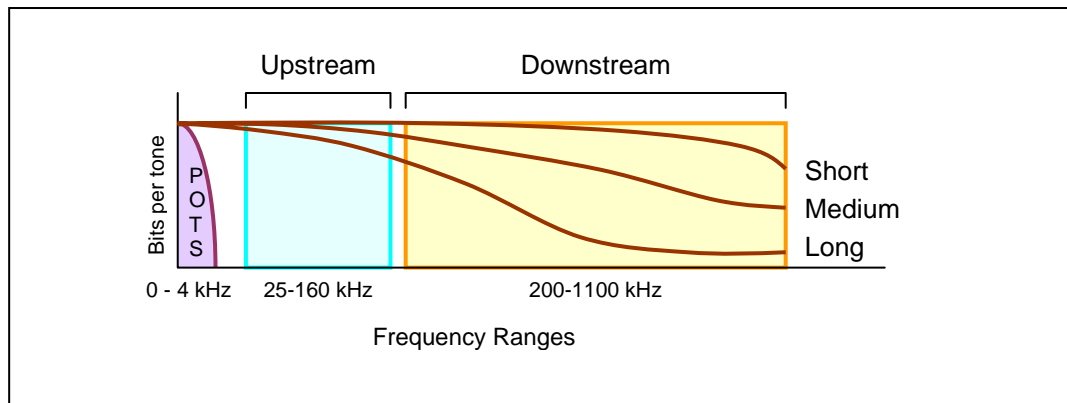


Figure 2. Attenuation for Different Distance

b. Bridge Taps

A *bridge tap* is an extra wire with an unterminated end in the local loop. When the DSL signal is sent across the wire, it will reflect through the cable pair, and at the open end bounced back on the wire. This 'bounced back' signal will then be mixed with the original signal, confusing the modem. Bridge taps should therefore be removed before installing DSL connection to ensure a clear signal.

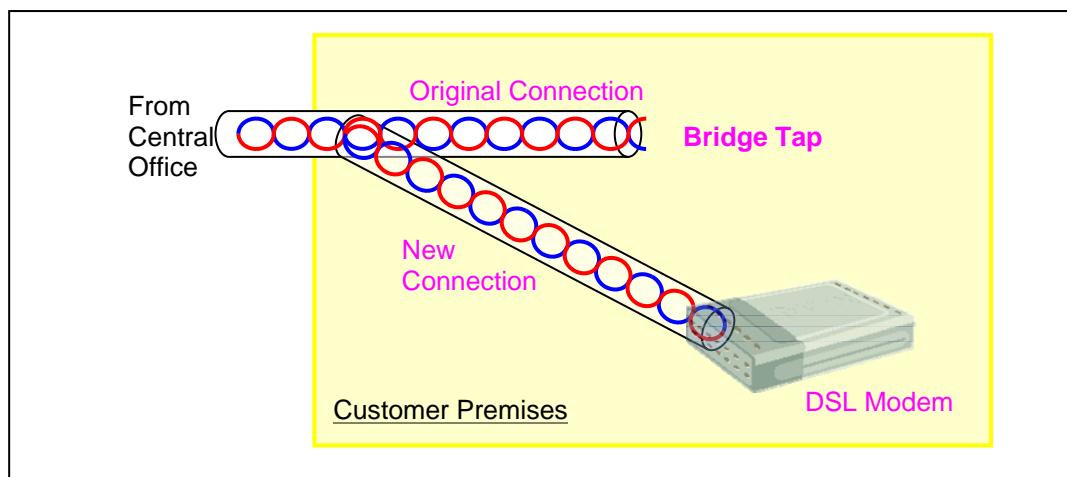


Figure 3. Bridge Tap

c. Load Coils

A *load coil* is a device for boosting the frequencies carrying analog voice signals on a local loop longer than 18,000 feet (5,486 meters). Load coils are installed to compensate for the signal loss caused by bridge taps. It can however cause distortion at high frequencies carrying digital information. All load coils should be removed before high frequencies transmission can be used on the local loop.

d. Crosstalk

Crosstalk is caused by electric or magnetic fields of another telecommunication signal to the circuit. It can cause severe degradation in transmission. The two main types of crosstalk are Near End Crosstalk (NEXT) and Far End Crosstalk (FEXT). NEXT occurs when a strong local transmitter interferes with another collocated receiver. FEXT occurs when there is interference at the receiving end.

e. Return Loss

Return loss is a summation of all reflected signal energy returning to where it originated. It is the ratio of signal transmitted into a system to the amount of signal that is reflected to the source. Causes of return loss may be due to discontinuities occurring at connections where the cable is terminated incorrectly, or by impedance mismatches occurring if a cable is bent or damaged.

f. Longitudinal Balance

Longitudinal balance is the balance between the resistance to the flow of a current in a circuit and the earth of each conductor. Longitudinal balance should be as equal as possible. When the line is balanced between the signals on the two conductors, there should be no difference.

g. Noise

Signal and *noise* make up the total power in a transmission line. Although noise is always present, it should always be kept as low as possible in relation to the signal. Radio and television transmitters, power distribution systems, electrical machines and mechanical vibration are some sources of noise.

h. Impulse Noise

Impulse noise refers to large spikes of electrical interference that are typically caused by power switching equipment.

i. Split Pairs

Split pairs occur when one conductor in a pair is separated from the other. This can result in noise, crosstalk, and radiation, leading to the serious degradation of xDSL services.

j. Gauge Changes

Many different cable types with conductors of different gauges or diameters are suitable for use with xDSL. However, if different gauges in cable runs are mixed, they can cause impairments which will affect the line's ability to carry xDSL services.

Asymmetric Digital Subscriber Line Technology

Asymmetric Digital Subscriber Line (ADSL) is a popular variant in the DSL family. Bandwidth used by ADSL is mostly for data downstream to the user and a small portion is used for data upstream to the service provider. This is suitable for Internet browsing applications which typically require more bandwidth for sending data downstream than upstream.

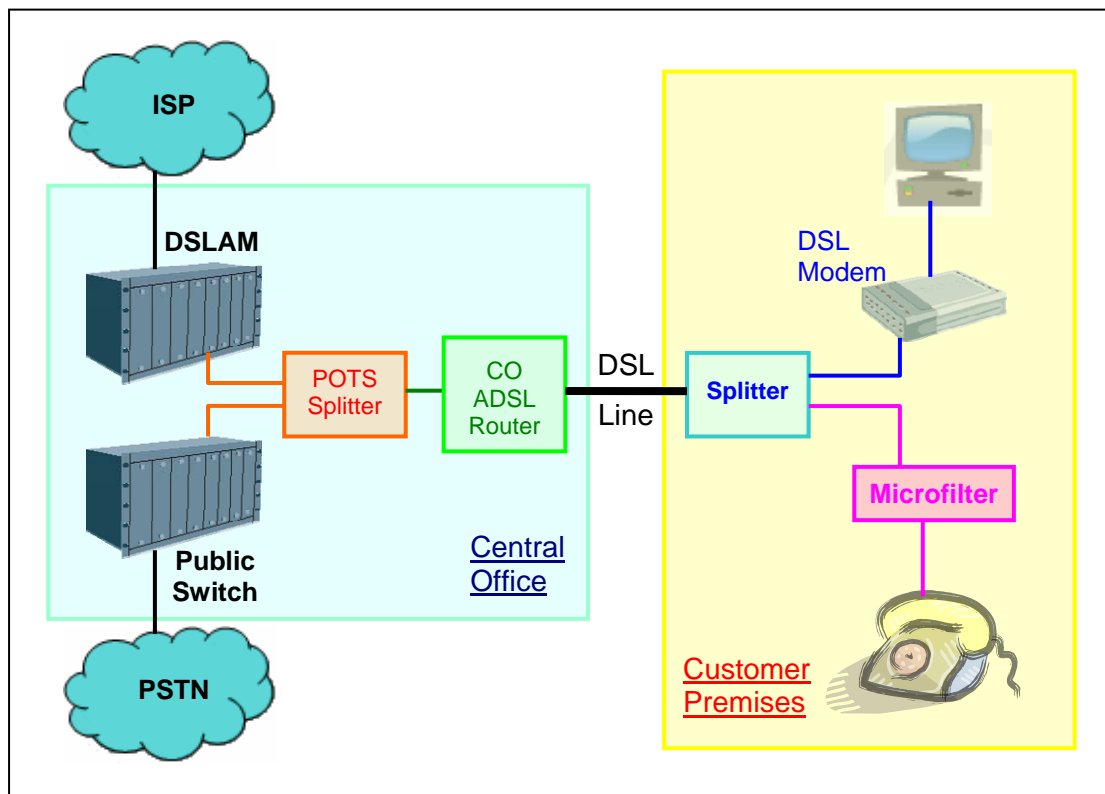


Figure 4. DSL Connection

The digital data is sent from a computer through a DSL modem and a splitter. A splitter is a device that divides a telephone signal into two or more signals, each carrying a selected frequency range, and has the ability to reassemble signals from multiple sources into a single signal. The voice signal is sent from the telephone

through the splitter where analog voice and digital data signals are combined and sent over the same line.

At the other end of the line, the local loop goes into a splitter at the local telephone company's central office (CO) where the analog voice frequencies and the digital data frequencies are split. The voice frequencies are sent to the local telephone exchange while the digital data is sent to a Digital Subscriber Line Access Multiplexer (DSLAM) before it is sent to the Internet Service Provider (ISP). A DSLAM is a network device located at the CO that receives signals from multiple customer DSL connections and redirects them to a single high speed connection to the Internet Service Provider (ISP) and vice versa.

There are two main types of DSLAM: *IP DSLAM* and *ATM DSLAM*. When ADSL was first introduced, the main high-speed data backbone transport used in networks was ATM. DSLAMs were developed with ATM uplink port (ATM DSLAM) to enable ADSL link to connect seamlessly into ATM networks. With the availability of the Gigabit Ethernet and 10 Gigabit Ethernet, DSLAMs now includes Ethernet uplink ports (IP DSLAMS).

Modulation Technologies

Modulation is the overlaying of information or signal to an electronic or optical signal carrier. When a connection is established with the Internet, the ADSL modem acts as the device that divides the 4 kHz frequency used by telephone signals and the remaining 1 MHz available bandwidth on the copper pair line to create multiple channels for 'send' and 'receive' signals using modulation.

There are two competing standards for modulating ADSL. The Discrete Multi-Tone (DMT) is the most widely used method today while the Carrierless Amplitude Phase (CAP) is the original technology used for DSL deployments.

Carrierless Amplitude Phase (CAP)

Carrierless Amplitude Phase (CAP) is an encoding method that divides the signal into two distinct bands. The upstream data channel to the service provider is carried in the band between 25 and 160 kHz, while the downstream data channel to the user is carried in the band beginning from 200 kHz to a variable end point. The variable end point depends on a number of factors, such as line length and noise, but the

maximum is about 1.1 MHz. The upstream and downstream data channels are widely separated from each other to minimize the possibility of interference.

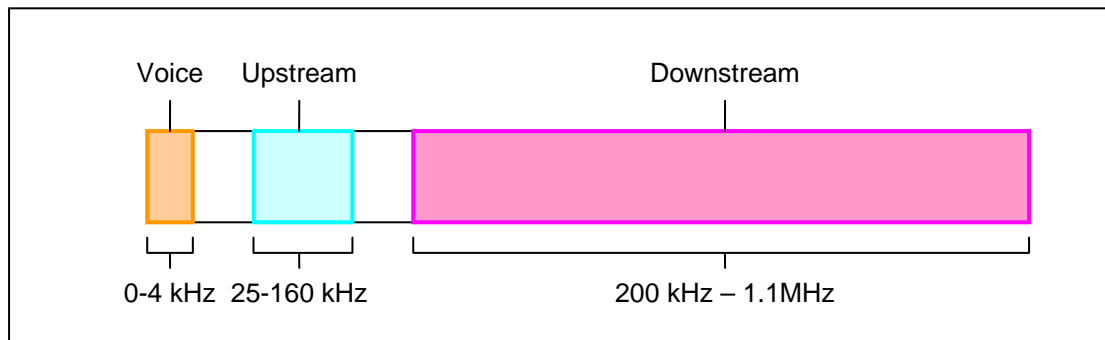


Figure 5. Carrierless Amplitude Phase Modulation (CAP)

Discrete Multi-tone (DMT)

The Discrete Multi-tone (DMT) is the most widely used modulation method. This method separates a DSL signal into 256 channels of 4.3125 kHz each. DMT has 32 upstream frequency carriers and 224 downstream frequency carriers. Up to 15 bits per signal can be encoded on each frequency carrier on a good quality line.

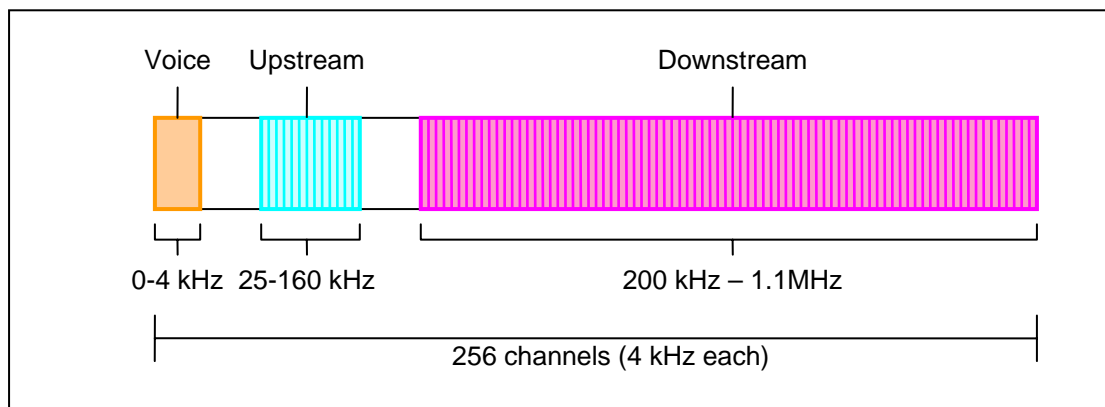


Figure 6. Discrete Multi-Tone Modulation (DMT)

Each of the 256 channels is monitored separately so as to ensure that the data traveling alone is not distorted. DMT constantly shifts signals between different channels to provide optimal transmission and reception. Where a channel has interference, DMT will shift the signal to other unused channels. In some applications, the lower channels may also be used as bi-directional channels for both upstream and downstream data.

The implementation of DMT is more complex than CAP. This is because DMT needs to monitor and sort out information on bi-directional channels and maintain good quality on all 256 channels.

To create multiple channels, ADSL modems must divide the available bandwidth of a telephone line in one of two ways: Frequency Division Multiplexing (FDM) or Echo Cancellation.

Frequency Division Multiplexing

Frequency Division Multiplexing (FDM) separates the low-speed upstream channel from the high-speed downstream channel using different bands. To prevent interference between the two frequency bands, a space called *guardband* is required between the upstream and downstream frequencies. Most of the ADSL modems today are using FDM.

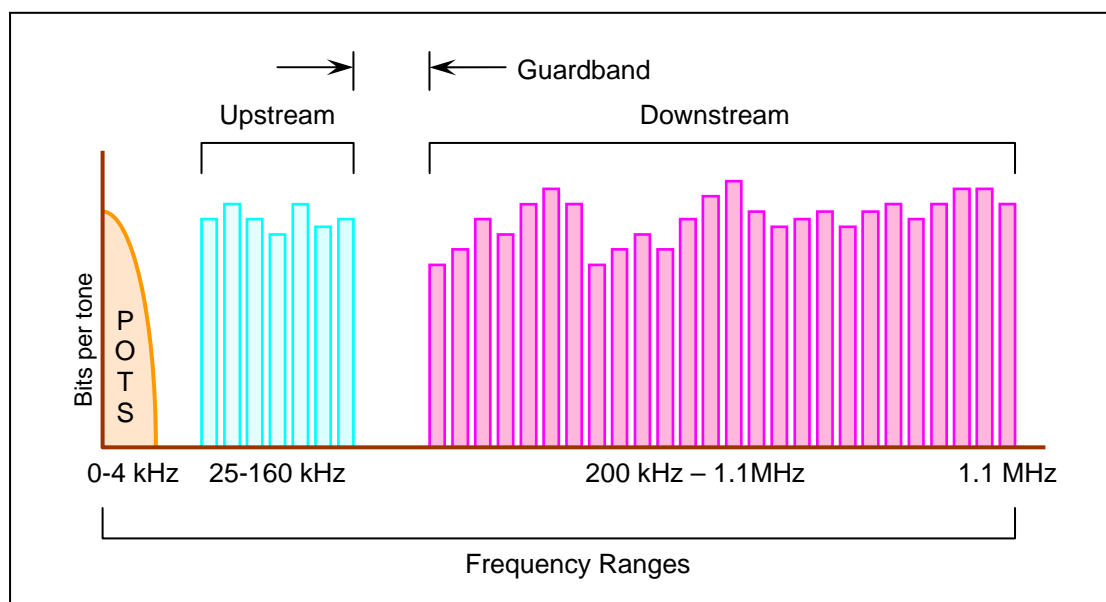


Figure 7. Frequency Division Multiplexing (FDM)

Echo Cancellation

Echo Cancellation assigns the upstream channel to overlap the downstream and separates the two by means of local echo cancellation to prevent signal corruption. The primary purpose is to obtain a clear signal in the event that both upstream and downstream send data simultaneously on the lower frequencies, which can cause signal corruption or echo.

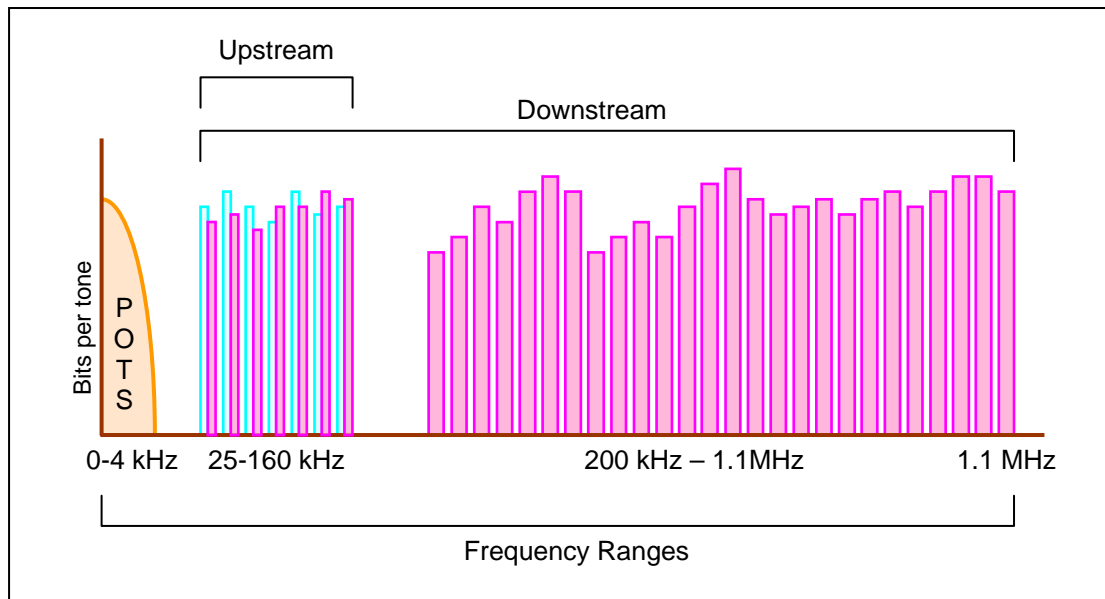


Figure 8. Echo Cancellation

Other DSL Technologies

There are many different DSL technologies. Depending on different applications, different data rate will be required. In general, the variations of DSL technology have been implemented to meet the need of different users. DSL variants can be broadly divided into three types: *Symmetric DSL*, *Asymmetric DSL*, and *Symmetric and Asymmetric DSL*.

Symmetric DSL transmits data at the same rate upstream and downstream. Asymmetric DSL transmits data at a faster rate downstream than upstream. Symmetric and Asymmetric DSL connections transmit data both symmetrically and asymmetrically.

1. Symmetric DSL

- High data rate Digital Subscriber Line (HDSL)

HDSL is the earliest version of symmetric DSL. It was created as an alternative to T1 and E1 services. T1 is an American standard digital line transmitting data at speeds up to 1.544 Mbps. E1 is the European digital line equivalent transmitting data at speeds up to 2.048 Mbps. HDSL uses more advanced modulation techniques than T1 and E1. HDSL splits a 1.544 Mbps signal into two twisted wire pairs that run at 784 Kbps. HDSL runs on longer loops without

repeaters, but does not allow the use of standard telephone service over the same line.

- **Single line Digital Subscriber Line (SDSL)**

SDSL is the single line version of HDSL. It supports both POTS and SDSL simultaneously with equal data rates up to 2.3 Mbps for both upstream and downstream channels. SDSL is suitable for individual subscriber premise that has only one telephone line. SDSL can reach a maximum of 10,000 feet (3 kilometers).

- **Symmetric High bit rate Digital Subscriber Line (SHDSL)**

SHDSL is the first standardized multi-rate DSL. It provides transmission speeds up to 2.3 Mbps across a single pair and up to 4.6 Mbps over two pairs. SHDSL has better loop reach and has lesser crosstalk interference compared to older versions of DSL. SHDSL is able to use existing copper base to achieve increased data rates, longer reach, and lesser noise. SHDSL is suitable for business applications that require higher-speed bandwidth in both directions.

2. Asymmetric DSL

- **Asymmetric Digital Subscriber Line (ADSL)**

ADSL, as explained in the earlier sections of this document, is essentially the transmission of integrated voice and data services using high data rates downstream and lower data rates upstream. ADSL enables the customers to use standard telephone service and high-speed digital transmissions on a regular telephone line. It is suitable for home and small offices that require fast downstream speed.

- **Asymmetric Digital Subscriber Line Lite (ADSL Lite)**

ADSL Lite is also known as G.lite or splitterless ADSL. It is developed for the plug and play market. G.Lite is slower and does not require signals to split at the user's end. It is split only at the telephone company. It delivers up to 1.5 Mbps downstream and 384 Kbps upstream.

- **Asymmetric Digital Subscriber Line 2 (ADSL2)**

ADSL2 has improved performance and interoperability over ADSL. It supports new applications, services, and deployment scenarios. It can achieve up to approximately 12 Mbps downstream.

ADSL2 increases the reach of ADSL by about 600 feet (200 meters). It provides greater noise immunity, better diagnostics, and lower crosstalk. It allows the ability to use multiple copper pairs to increase bandwidth or size of the pipes using bonding.

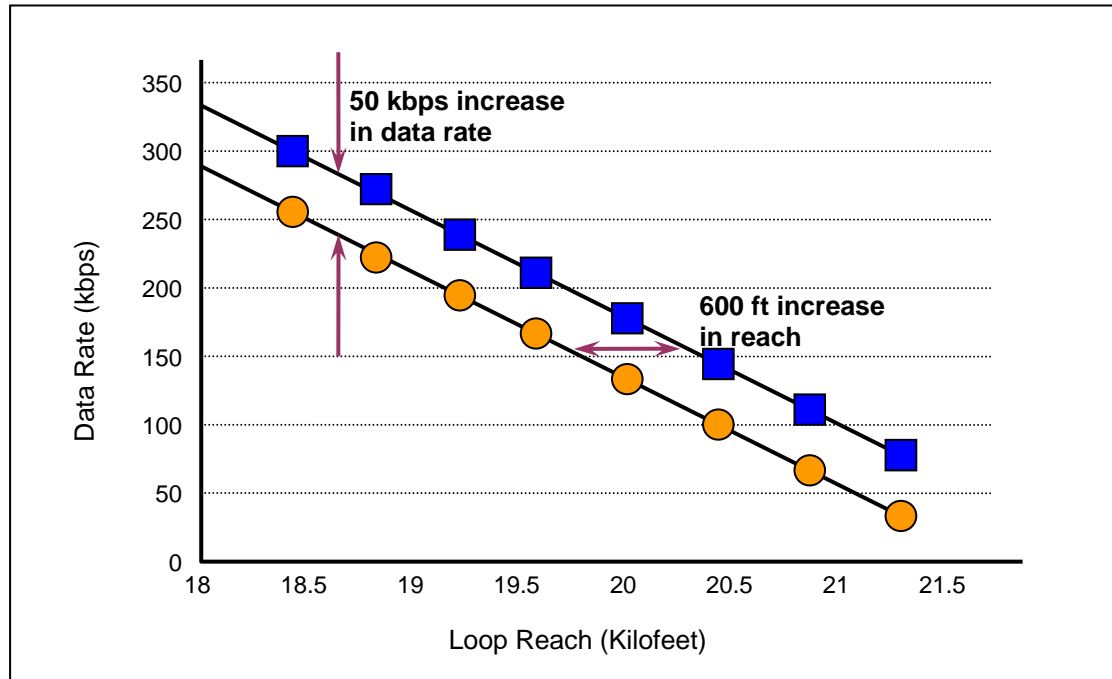


Figure 9. ADSL2 Improves Data Rate and Loop Reach

- **Asymmetric Digital Subscriber Line 2+ (ADSL2+)**

ADSL2+ provides further enhancement over ADSL2. It increases the downstream rate to 20 Mbps and phone lines to as long as 5,000 feet (1.5 kilometers). The maximum frequency used for downstream data transmission is doubled from 1.1 MHz to 2.2 MHz. ADSL2+ can interoperate with ADSL and ADSL2.

- **Asymmetric Digital Subscriber Line 2++ (ADSL2++ or ADSL4)**

ADSL2++ or ADSL4 is a proposed solution to increase the downstream data rate to 52 Mbps and extend maximum frequency to 3.75 MHz.

3. Both Symmetric and Asymmetric DSL

- **Very high bit rate Digital Subscriber Line (VDSL)**

VDSL provides the highest data rates using DSL technologies. It supports asymmetric transmission speeds of up to 52 Mbps over short distances. It also supports symmetric transmission speed of 10 Mbps full duplex over distances up to 4,260 feet (1.3 kilometers). VDSL is useful for supplying high bandwidth

services to buildings such as hotels, apartments, university campuses, and office towers. VDSL can handle high bandwidth applications such as VPNs, video on demand, teleconferencing, surveillance systems, high definition television, and file downloading and uploading.

Summary: Digital Subscriber Line

DSL is the solution to broadband connections using telephone infrastructure for voice and data transmission. ADSL is a DSL variant that uses asymmetric technology to provide uninterrupted permanent 'always-on' access that typically involves more downstream usage of bandwidth than upstream. ADSL modems are connected at both ends of the phone lines. There are essentially three channels in ADSL: a high-speed downstream channel, a medium speed upstream and downstream duplex channel, and a basic telephone POTS service channel.