**Digital subscriber line**

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| * [ARP](https://en.wikipedia.org/wiki/Address_Resolution_Protocol) * [NDP](https://en.wikipedia.org/wiki/Neighbor_Discovery_Protocol) * [OSPF](https://en.wikipedia.org/wiki/Open_Shortest_Path_First) * [Tunnels](https://en.wikipedia.org/wiki/Tunneling_protocol)   + [L2TP](https://en.wikipedia.org/wiki/Layer_2_Tunneling_Protocol) * [PPP](https://en.wikipedia.org/wiki/Point-to-Point_Protocol) * [MAC](https://en.wikipedia.org/wiki/Medium_access_control)   + [Ethernet](https://en.wikipedia.org/wiki/Ethernet)   + [Wi-Fi](https://en.wikipedia.org/wiki/Wi-Fi)   + DSL   + [ISDN](https://en.wikipedia.org/wiki/Integrated_Services_Digital_Network)   + [FDDI](https://en.wikipedia.org/wiki/Fiber_Distributed_Data_Interface) * [*more...*](https://en.wikipedia.org/wiki/Category:Link_protocols) |
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**Digital subscriber line** (**DSL**; originally **digital subscriber loop**) is a family of technologies that are used to transmit [digital data](https://en.wikipedia.org/wiki/Digital_data) over [telephone lines](https://en.wikipedia.org/wiki/Telephone_line). In telecommunications marketing, the term DSL is widely understood to mean [asymmetric digital subscriber line](https://en.wikipedia.org/wiki/Asymmetric_digital_subscriber_line) (ADSL), the most commonly installed DSL technology, for [Internet access](https://en.wikipedia.org/wiki/Internet_access).

DSL service can be delivered simultaneously with [wired telephone service](https://en.wikipedia.org/wiki/Plain_old_telephone_service) on the same telephone line since DSL uses higher [frequency bands](https://en.wikipedia.org/wiki/Frequency_band) for data. On the customer premises, a [DSL filter](https://en.wikipedia.org/wiki/DSL_filter) on each non-DSL outlet blocks any high-frequency interference to enable simultaneous use of the voice and DSL services.

The [bit rate](https://en.wikipedia.org/wiki/Bit_rate) of consumer DSL services typically ranges from 256 kbit/s to over 100 Mbit/s in the direction to the customer ([downstream](https://en.wikipedia.org/wiki/Downstream_(networking))), depending on DSL technology, line conditions, and service-level implementation. Bit rates of 1 [Gbit/s](https://en.wikipedia.org/wiki/Gbit/s) have been reached.[[1]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-1)

In ADSL, the data throughput in the [upstream](https://en.wikipedia.org/wiki/Upstream_(networking)) direction (the direction to the service provider) is lower, hence the designation of *asymmetric* service. In [symmetric digital subscriber line](https://en.wikipedia.org/wiki/Symmetric_digital_subscriber_line) (SDSL) services, the downstream and upstream data rates are equal. Researchers at [Bell Labs](https://en.wikipedia.org/wiki/Bell_Labs) have reached speeds over 1 Gbit/s for symmetrical broadband access services using traditional copper telephone lines, though such speeds have not yet been deployed elsewhere.[[2]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-2)[[3]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-3)



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**History**

It was originally thought that it was not possible to operate a conventional phone line beyond low-speed limits (typically under 9600 bit/s). In the 1950s, ordinary twisted-pair telephone cable often carried four megahertz (MHz) television signals between studios, suggesting that such lines would allow transmitting many megabits per second. One such circuit in the United Kingdom ran some 10 miles (16 km) between the [BBC](https://en.wikipedia.org/wiki/BBC) studios in [Newcastle-upon-Tyne](https://en.wikipedia.org/wiki/Newcastle-upon-Tyne) and the [Pontop Pike transmitting station](https://en.wikipedia.org/wiki/Pontop_Pike_transmitting_station). However, these cables had other impairments besides [Gaussian noise](https://en.wikipedia.org/wiki/Gaussian_noise), preventing such rates from becoming practical in the field. The 1980s saw the development of techniques for [broadband](https://en.wikipedia.org/wiki/Broadband) communications that allowed the limit to be greatly extended. A patent was filed in 1979 for the use of existing telephone wires for both telephones and data terminals that were connected to a remote computer via a digital data carrier system.[[4]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-4)

The motivation for digital subscriber line technology was the [Integrated Services Digital Network](https://en.wikipedia.org/wiki/Integrated_Services_Digital_Network) (ISDN) specification proposed in 1984 by the CCITT (now [ITU-T](https://en.wikipedia.org/wiki/ITU-T)) as part of Recommendation [I.120](https://en.wikipedia.org/w/index.php?title=I.120&action=edit&redlink=1), later reused as [ISDN digital subscriber line](https://en.wikipedia.org/wiki/ISDN_digital_subscriber_line) (IDSL). Employees at Bellcore (now [Telcordia Technologies](https://en.wikipedia.org/wiki/Telcordia_Technologies)) developed [asymmetric digital subscriber line](https://en.wikipedia.org/wiki/Asymmetric_digital_subscriber_line) (ADSL) by placing wide-band digital signals at frequencies above the existing [baseband](https://en.wikipedia.org/wiki/Baseband) analog voice signal carried on conventional [twisted pair](https://en.wikipedia.org/wiki/Twisted_pair) cabling between [telephone exchanges](https://en.wikipedia.org/wiki/Telephone_exchange) and customers.[[5]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-5) A patent was filed in 1988.[[6]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-6)

[Joseph W. Lechleider](https://en.wikipedia.org/wiki/Joseph_W._Lechleider)'s contribution to DSL was his insight that an asymmetric arrangement offered more than double the bandwidth capacity of symmetric DSL.[[7]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-7) This allowed Internet service providers to offer efficient service to consumers, who benefited greatly from the ability to download large amounts of data but rarely needed to upload comparable amounts. ADSL supports two modes of transport: fast channel and [interleaved channel](https://en.wikipedia.org/wiki/Bit-interleaving). Fast channel is preferred for [streaming multimedia](https://en.wikipedia.org/wiki/Streaming_multimedia), where an occasional *dropped* [*bit*](https://en.wikipedia.org/wiki/Bit) is acceptable, but lags are less so. Interleaved channel works better for file transfers, where the delivered data must be error-free but latency (time delay) incurred by the retransmission of error-containing packets is acceptable.

Consumer-oriented ADSL was designed to operate on existing lines already conditioned for [Basic Rate Interface](https://en.wikipedia.org/wiki/Basic_Rate_Interface) ISDN services. Engineers developed high speed DSL facilities such as [high bit rate digital subscriber line](https://en.wikipedia.org/wiki/High_bit_rate_digital_subscriber_line) (HDSL) and [symmetric digital subscriber line](https://en.wikipedia.org/wiki/Symmetric_digital_subscriber_line) (SDSL) to provision traditional [Digital Signal 1](https://en.wikipedia.org/wiki/Digital_Signal_1) (DS1) services over standard copper pair facilities.

Older ADSL standards delivered 8 [Mbit/s](https://en.wikipedia.org/wiki/Mbit/s) to the customer over about 2 km (1.2 mi) of [unshielded twisted-pair](https://en.wikipedia.org/wiki/Unshielded_twisted_pair) copper wire. Newer variants improved these rates. Distances greater than 2 km (1.2 mi) significantly reduce the [bandwidth](https://en.wikipedia.org/wiki/Bandwidth_(computing)) usable on the wires, thus reducing the data rate. But [ADSL loop extenders](https://en.wikipedia.org/wiki/ADSL_loop_extender) increase these distances by repeating the signal, allowing the LEC to deliver DSL speeds to any distance.[[8]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-8)

[](https://en.wikipedia.org/wiki/File:Lantiq_XWAY_VRX288_V1.1.png)

DSL [SoC](https://en.wikipedia.org/wiki/System_on_a_chip)

Until the late 1990s, the cost of [digital signal processors](https://en.wikipedia.org/wiki/Digital_signal_processor) for DSL was prohibitive. All types of DSL employ highly complex [digital signal processing](https://en.wikipedia.org/wiki/Digital_signal_processing) algorithms to overcome the inherent limitations of the existing [twisted pair](https://en.wikipedia.org/wiki/Twisted_pair) wires. Due to the advancements of [very-large-scale integration](https://en.wikipedia.org/wiki/Very-large-scale_integration) (VLSI) technology, the cost of the equipment associated with a DSL deployment lowered significantly. The two main pieces of equipment are a [digital subscriber line access multiplexer](https://en.wikipedia.org/wiki/Digital_subscriber_line_access_multiplexer) (DSLAM) at one end and a [DSL modem](https://en.wikipedia.org/wiki/DSL_modem) at the other end.

A DSL connection can be deployed over existing cable. Such deployment, even including equipment, is much cheaper than installing a new, high-bandwidth [fiber-optic](https://en.wikipedia.org/wiki/Fiber-optic) cable over the same route and distance. This is true both for ADSL and SDSL variations. The commercial success of DSL and similar technologies largely reflects the advances made in electronics over the decades that have increased performance and reduced costs even while digging trenches in the ground for new cables (copper or fiber optic) remains expensive.

These advantages made ADSL a better proposition for customers requiring [Internet access](https://en.wikipedia.org/wiki/Internet_access) than metered dial up, while also allowing voice calls to be received at the same time as a data connection. Telephone companies were also under pressure to move to ADSL owing to competition from cable companies, which use [DOCSIS cable modem](https://en.wikipedia.org/wiki/DOCSIS_cable_modem) technology to achieve similar speeds. Demand for high bandwidth applications, such as video and file sharing, also contributed to the popularity of ADSL technology.

Early DSL service required a dedicated [dry loop](https://en.wikipedia.org/wiki/Dry_loop), but when the U.S. [Federal Communications Commission](https://en.wikipedia.org/wiki/Federal_Communications_Commission) (FCC) required [incumbent local exchange carriers](https://en.wikipedia.org/wiki/Incumbent_local_exchange_carrier) (ILECs) to lease their lines to competing DSL service providers, shared-line DSL became available. Also known as DSL over [unbundled network element](https://en.wikipedia.org/wiki/Unbundled_network_element), this unbundling of services allows a single subscriber to receive two separate services from two separate providers on one cable pair. The DSL service provider's equipment is co-located in the same [telephone exchange](https://en.wikipedia.org/wiki/Telephone_exchange) as that of the ILEC supplying the customer's pre-existing voice service. The subscriber's circuit is rewired to interface with hardware supplied by the ILEC which combines a DSL frequency and POTS signals on a single copper pair.

By 2012, some carriers in the United States reported that DSL remote terminals with fiber [backhaul](https://en.wikipedia.org/wiki/Backhaul_(telecommunications)) were replacing older ADSL systems.[[9]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-9)

**Operation**

Telephones are connected to the [telephone exchange](https://en.wikipedia.org/wiki/Telephone_exchange) via a [local loop](https://en.wikipedia.org/wiki/Local_loop), which is a physical pair of wires. The local loop was originally intended mostly for the transmission of speech, encompassing an audio frequency range of 300 to 3400 [hertz](https://en.wikipedia.org/wiki/Hertz) ([commercial bandwidth](https://en.wikipedia.org/wiki/Commercial_bandwidth)). However, as long-distance [trunks](https://en.wikipedia.org/wiki/Trunking) were gradually converted from analog to digital operation, the idea of being able to pass data through the local loop (by utilizing frequencies above the voiceband) took hold, ultimately leading to DSL.

The [local loop](https://en.wikipedia.org/wiki/Local_loop) connecting the telephone exchange to most subscribers has the capability of carrying frequencies well beyond the 3400 Hz upper limit of [POTS](https://en.wikipedia.org/wiki/Plain_old_telephone_service). Depending on the length and quality of the loop, the upper limit can be tens of megahertz. DSL takes advantage of this unused [bandwidth](https://en.wikipedia.org/wiki/Bandwidth_(signal_processing)) of the local loop by creating 4312.5 Hz wide channels starting between 10 and 100 kHz, depending on how the system is configured. Allocation of channels continues to higher frequencies (up to 1.1 MHz for ADSL) until new channels are deemed unusable. Each channel is evaluated for usability in much the same way an [analog modem](https://en.wikipedia.org/wiki/Analog_modem) would on a POTS connection. More usable channels equate to more available bandwidth, which is why distance and line quality are a factor (the higher frequencies used by DSL travel only short distances).

The pool of usable channels is then split into two different frequency bands for [upstream](https://en.wikipedia.org/wiki/Upstream_(networking)) and [downstream](https://en.wikipedia.org/wiki/Downstream_(networking)) traffic, based on a preconfigured ratio. This segregation reduces interference. Once the channel groups have been established, the individual [channels](https://en.wikipedia.org/wiki/Communication_channel) are [bonded](https://en.wikipedia.org/wiki/Channel_bonding) into a pair of virtual circuits, one in each direction. Like analog modems, DSL [transceivers](https://en.wikipedia.org/wiki/Transceiver) constantly monitor the quality of each channel and will add or remove them from service depending on whether they are usable. Once upstream and downstream circuits are established, a [subscriber](https://en.wikipedia.org/wiki/Subscriber) can connect to a service such as an [Internet service provider](https://en.wikipedia.org/wiki/Internet_service_provider) or other network services, like a corporate [MPLS](https://en.wikipedia.org/wiki/MPLS) network.

The underlying technology of transport across DSL facilities uses [modulation](https://en.wikipedia.org/wiki/Modulation) of high-frequency [carrier waves](https://en.wikipedia.org/wiki/Carrier_wave), an analog signal transmission. A DSL circuit terminates at each end in a [modem](https://en.wikipedia.org/wiki/Modem) which modulates patterns of [bits](https://en.wikipedia.org/wiki/Binary_digit) into certain high-frequency impulses for transmission to the opposing modem. Signals received from the far-end modem are demodulated to yield a corresponding bit pattern that the modem passes on, in digital form, to its interfaced equipment, such as a computer, router, switch, etc.

Unlike traditional dial-up modems, which modulate bits into signals in the 300–3400 Hz audio baseband, DSL modems modulate frequencies from 4000 Hz to as high as 4 MHz. This frequency band separation enables DSL service and [plain old telephone service](https://en.wikipedia.org/wiki/Plain_old_telephone_service) (POTS) to coexist on the same cables. On the subscriber's end of the circuit, inline [DSL filters](https://en.wikipedia.org/wiki/DSL_filter) are installed on each telephone to pass voice frequencies but filter the high-frequency signals that would otherwise be heard as hiss. Also, nonlinear elements in the phone could otherwise generate audible [intermodulation](https://en.wikipedia.org/wiki/Intermodulation) and may impair the operation of the data modem in the absence of these [low-pass filters](https://en.wikipedia.org/wiki/Low-pass_filter). DSL and RADSL modulations do not use the voice-frequency band so [high-pass filters](https://en.wikipedia.org/wiki/High-pass_filter) are incorporated in the circuitry of DSL modems filter out voice frequencies.

[](https://en.wikipedia.org/wiki/File:T-DSL_Modem.jpg)

A DSL modem

Because DSL operates above the 3.4 kHz voice limit, it cannot pass through a [loading coil](https://en.wikipedia.org/wiki/Loading_coil), which is an inductive coil that is designed to counteract loss caused by shunt capacitance (capacitance between the two wires of the twisted pair). Loading coils are commonly set at regular intervals in POTS lines. Voice service cannot be maintained past a certain distance without such coils. Therefore, some areas that are within range for DSL service are disqualified from eligibility because of loading coil placement. Because of this, phone companies endeavor to remove loading coils on copper loops that can operate without them. Longer lines that require them can be replaced with fiber to the neighborhood or node ([FTTN](https://en.wikipedia.org/wiki/FTTN)).

Most residential and small-office DSL implementations reserve low frequencies for POTS, so that (with suitable filters and/or splitters) the existing voice service continues to operate independently of the DSL service. Thus POTS-based communications, including [fax machines](https://en.wikipedia.org/wiki/Fax) and analog modems, can share the wires with DSL. Only one DSL modem can use the [subscriber line](https://en.wikipedia.org/wiki/Subscriber_line) at a time. The standard way to let multiple computers share a DSL connection uses a [router](https://en.wikipedia.org/wiki/Router_(computing)) that establishes a connection between the DSL modem and a local [Ethernet](https://en.wikipedia.org/wiki/Ethernet), [Powerline](https://en.wikipedia.org/wiki/Power_line_communication), or [Wi-Fi](https://en.wikipedia.org/wiki/Wi-Fi) network on the customer's premises.

The theoretical foundations of DSL, like much of [communication](https://en.wikipedia.org/wiki/Communication) technology, can be traced back to [Claude Shannon](https://en.wikipedia.org/wiki/Claude_Shannon)'s seminal 1948 paper: [*A Mathematical Theory of Communication*](https://en.wikipedia.org/wiki/A_Mathematical_Theory_of_Communication). Generally, higher bit rate transmissions require a wider frequency band, though the ratio of [bit rate](https://en.wikipedia.org/wiki/Bit_rate) to [symbol rate](https://en.wikipedia.org/wiki/Symbol_rate) and thus to bandwidth are not linear due to significant innovations in [digital signal processing](https://en.wikipedia.org/wiki/Digital_signal_processing) and [digital modulation methods](https://en.wikipedia.org/wiki/Digital_modulation#Digital_modulation_methods).

**Naked DSL**

Main article: [Naked DSL](https://en.wikipedia.org/wiki/Naked_DSL)

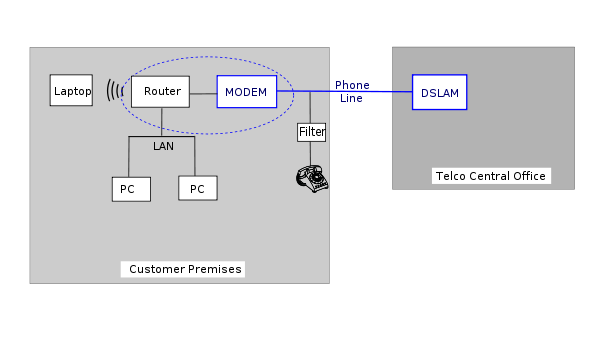
A [naked DSL](https://en.wikipedia.org/wiki/Naked_DSL) (also known as standalone or [dry loop](https://en.wikipedia.org/wiki/Dry_loop) DSL) is a way of providing DSL services without a [PSTN](https://en.wikipedia.org/wiki/PSTN) ([analogue](https://en.wikipedia.org/wiki/Analog_signal) [telephony](https://en.wikipedia.org/wiki/Telephony)) service. It is useful when the customer does not need the traditional [telephony](https://en.wikipedia.org/wiki/Telephony) voice service because voice service is received either on top of the DSL services (usually [VoIP](https://en.wikipedia.org/wiki/Voice_over_IP)) or through another network ([mobile telephony](https://en.wikipedia.org/wiki/Mobile_telephony)).

It is also commonly called a UNE (for [unbundled network element](https://en.wikipedia.org/wiki/Unbundled_network_element)) in the United States; in Australia it is known as a ULL (unconditioned local loop);[[10]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-10) in Belgium it is known as "raw copper" and in the UK it is known as Single Order GEA (SoGEA).[[11]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-11) It started making a comeback in the United States in 2004 when [Qwest](https://en.wikipedia.org/wiki/Qwest) started offering it, closely followed by [Speakeasy](https://en.wikipedia.org/wiki/Speakeasy_(ISP)). As a result of [AT&T](https://en.wikipedia.org/wiki/AT%26T_Corporation)'s merger with [SBC](https://en.wikipedia.org/wiki/SBC_Communications),[[12]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-12) and [Verizon](https://en.wikipedia.org/wiki/Verizon)'s merger with [MCI](https://en.wikipedia.org/wiki/MCI_Inc.),[[13]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-13) those telephone companies have an obligation to offer naked DSL to consumers.

**Typical setup**

On the customer side, the DSL transceiver, or ATU-R, or more commonly known as a DSL modem, is hooked up to a phone line. The telephone company connects the other end of the line to a [DSLAM](https://en.wikipedia.org/wiki/DSLAM), which concentrates a large number of individual DSL connections into a single box. The location of the DSLAM depends on the telco, but it cannot be located too far from the user because of [attenuation](https://en.wikipedia.org/wiki/Attenuation) between the DSLAM and the user's DSL modem. It is common for a few residential blocks to be connected to one DSLAM.

The accompanying figure is a schematic of a simple DSL connection (in blue). The right side shows a DSLAM residing in the telephone company's telephone exchange. The left side shows the customer premises equipment with an optional router. The router manages a local area network (LAN) which connects PCs and other local devices. With many service providers, the customer may opt for a modem which contains both a router and wireless access. This option (within the dashed bubble) often simplifies the connection.

[](https://en.wikipedia.org/wiki/File:Dsl_schematic.svg)

DSL Connection schematic

[](https://en.wikipedia.org/wiki/File:Outdoor_DSLAM.JPG)

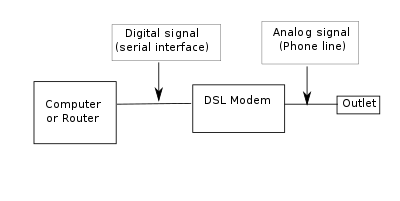
Example of a DSLAM from 2006

**Exchange equipment**

At the exchange, a [digital subscriber line access multiplexer](https://en.wikipedia.org/wiki/Digital_subscriber_line_access_multiplexer) (DSLAM) [terminates](https://en.wikipedia.org/wiki/Electrical_termination) the DSL circuits and aggregates them, where they are [handed off](https://en.wikipedia.org/wiki/Handoff) to other networking transports. In the case of ADSL, the voice component is also separated at this step, either by a filter integrated in the DSLAM or by a specialized filtering equipment installed before it. The DSLAM terminates all connections and recovers the original digital information.

**Customer equipment**

The customer end of the connection consists of a terminal adapter or "[DSL modem](https://en.wikipedia.org/wiki/DSL_modem)". This converts data between the digital signals used by computers and the analog [voltage](https://en.wikipedia.org/wiki/Voltage) signal of a suitable frequency range which is then applied to the phone line.

[](https://en.wikipedia.org/wiki/File:Dsl_modem_schematic.svg)

DSL Modem schematic

In some DSL variations (for example, [HDSL](https://en.wikipedia.org/wiki/HDSL)), the terminal adapter connects directly to the computer via a serial interface, using protocols such as [ethernet](https://en.wikipedia.org/wiki/Ethernet) or [V.35](https://en.wikipedia.org/wiki/V.35_(recommendation)). In other cases (particularly ADSL), it is common for the customer equipment to be integrated with higher level functionality, such as routing, firewalling, or other application-specific hardware and software. In this case, the equipment is referred to as a gateway.

Most DSL technologies require installation of appropriate filters to separate, or split, the DSL signal from the low-frequency voice signal. The separation can take place either at the [demarcation point](https://en.wikipedia.org/wiki/Demarcation_point), or with filters installed at the telephone outlets inside the customer premises. Each way has its practical and economic limitations.

**DSL modem initialization**

When the DSL modem powers up it goes through a series of steps to establish connections. The actual process varies from modem to modem but generally involves the following steps:

1. The DSL transceiver performs a self-test, including image load and activation.
2. The DSL transceiver then attempts to [synchronize](https://en.wikipedia.org/wiki/Synchronize) with the DSLAM. Data can only come into the computer when the DSLAM and the modem are synchronized. The synchronization process is relatively quick (in the range of seconds) but is very complex, involving extensive tests that allow both sides of the connection to optimize the performance for line characteristics including noise and error handling. External, or standalone modem units have an indicator labeled "CD", "DSL", or "LINK", which can be used to tell if the modem is synchronized. During synchronization the light flashes; when synchronized, the light stays lit, usually green.
3. If supported, the DSL transceiver establishes a [gateway](https://en.wikipedia.org/wiki/Gateway_(telecommunications)) internet connection.
4. The DSL transceiver establishes a connection with the router or computer. For residential variations of DSL, this is usually the [Ethernet](https://en.wikipedia.org/wiki/Ethernet) (RJ-45) port or a [USB](https://en.wikipedia.org/wiki/USB) port; in rare models, a [FireWire](https://en.wikipedia.org/wiki/FireWire) port is used. Older DSL modems sported a native ATM interface (usually, a 25 Mbit/s [serial interface](https://en.wikipedia.org/wiki/Serial_interface)). Also, some variations of DSL (such as SDSL) use synchronous serial connections.

Modern DSL [gateways](https://en.wikipedia.org/wiki/Gateway_(telecommunications)) often integrate routing and other functionality. Their initialization is very similar to a PC [boot up](https://en.wikipedia.org/wiki/Boot_up). The system image is loaded from the [flash storage](https://en.wikipedia.org/wiki/Flash_memory); the system boots, synchronizes the DSL connection and finally establishes the internet IP services and connection between the local network and the service provider, using protocols such as [DHCP](https://en.wikipedia.org/wiki/DHCP) or [PPPoE](https://en.wikipedia.org/wiki/PPPoE). According to *Implementation and Applications of DSL Technology* (2007), the PPPoE method far outweighed DHCP in terms of deployment on DSLs, and [PAP](https://en.wikipedia.org/wiki/Password_authentication_protocol) was the predominant form of subscriber authentication used in such circumstances.[[14]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-GoldenDedieu2007b-14) The system image can usually be updated to correct bugs, or to add new functionality.

**Protocols and configurations**

Many DSL technologies implement an [asynchronous transfer mode](https://en.wikipedia.org/wiki/Asynchronous_transfer_mode) (ATM) [layer](https://en.wikipedia.org/wiki/Abstraction_layer) over the low-level [bitstream](https://en.wikipedia.org/wiki/Bitstream) layer to enable the adaptation of a number of different technologies over the same link.

DSL implementations may create [bridged](https://en.wikipedia.org/wiki/Bridging_(networking)) or [routed](https://en.wikipedia.org/wiki/Routing) networks. In a bridged configuration, the group of subscriber computers effectively connect into a single subnet. The earliest implementations used [DHCP](https://en.wikipedia.org/wiki/Dynamic_Host_Configuration_Protocol) to provide network details such as the [IP address](https://en.wikipedia.org/wiki/IP_address) to the subscriber equipment, with [authentication](https://en.wikipedia.org/wiki/Authentication) via [MAC address](https://en.wikipedia.org/wiki/MAC_address) or an assigned host name. Later implementations often use [Point-to-Point Protocol](https://en.wikipedia.org/wiki/Point-to-Point_Protocol) (PPP) to authenticate with a user ID and password, and to provide network details ([Point-to-Point Protocol over Ethernet](https://en.wikipedia.org/wiki/Point-to-Point_Protocol_over_Ethernet) (PPPoE) or [Point-to-Point Protocol over ATM](https://en.wikipedia.org/wiki/Point-to-Point_Protocol_over_ATM) (PPPoA)).

**Transmission modulation methods**

Transmission methods vary by market, region, carrier, and equipment.

* DMT: [Discrete multitone modulation](https://en.wikipedia.org/wiki/Discrete_multitone_modulation), the most common kind, also known as OFDM ([Orthogonal frequency-division multiplexing](https://en.wikipedia.org/wiki/Orthogonal_frequency-division_multiplexing))
* [TC-PAM](https://en.wikipedia.org/wiki/TC-PAM): Trellis Coded Pulse Amplitude Modulation, used for [HDSL2](https://en.wikipedia.org/wiki/HDSL2) and [SHDSL](https://en.wikipedia.org/wiki/SHDSL)
* CAP: [Carrierless Amplitude Phase Modulation](https://en.wikipedia.org/wiki/Carrierless_Amplitude_Phase_Modulation) - deprecated in 1996 for ADSL, used for HDSL
* 2B1Q: [Two-binary, one-quaternary](https://en.wikipedia.org/wiki/Two-binary,_one-quaternary), used for IDSL and HDSL

**DSL technologies**

DSL technologies (sometimes collectively summarized as **xDSL**) include:

* [Symmetric digital subscriber line](https://en.wikipedia.org/wiki/Symmetric_digital_subscriber_line) (SDSL), umbrella term for xDSL where the bitrate is equal in both directions.
  + [ISDN digital subscriber line](https://en.wikipedia.org/wiki/ISDN_digital_subscriber_line) (IDSL), ISDN-based technology that provides a bitrate equivalent to two ISDN bearer and one data channel, 144 kbit/s symmetric over one pair
  + [High bit rate digital subscriber line](https://en.wikipedia.org/wiki/High_bit_rate_digital_subscriber_line) (HDSL), ITU-T G.991.1, the first DSL technology that used a higher frequency spectrum than ISDN, 1,544 kbit/s and 2,048 kbit/s symmetric services, either on 2 or 3 pairs at 784 kbit/s each, 2 pairs at 1,168 kbit/s each, or one pair at 2,320 kbit/s
  + [High bit rate digital subscriber line 2/4](https://en.wikipedia.org/wiki/High_bit_rate_digital_subscriber_line_2) (HDSL2, HDSL4), ANSI, 1,544 kbit/s symmetric over one pair (HDSL2) or two pairs (HDSL4)
  + [Symmetric digital subscriber line](https://en.wikipedia.org/wiki/Symmetric_digital_subscriber_line) (SDSL), specific proprietary technology, up to 1,544 kbit/s symmetric over one pair
  + [Single-pair high-speed digital subscriber line](https://en.wikipedia.org/wiki/Single-pair_high-speed_digital_subscriber_line) (G.SHDSL), ITU-T G.991.2, standardized successor of HDSL and proprietary SDSL, up to 5,696 kbit/s per pair, up to four pairs
* [Asymmetric digital subscriber line](https://en.wikipedia.org/wiki/Asymmetric_digital_subscriber_line) (ADSL), umbrella term for xDSL where the bitrate is greater in one direction than the other.
  + [ANSI T1.413 Issue 2](https://en.wikipedia.org/wiki/ANSI_T1.413_Issue_2), up to 8 Mbit/s and 1 Mbit/s
  + [G.dmt](https://en.wikipedia.org/wiki/G.992.1), ITU-T G.992.1, up to 10 Mbit/s and 1 Mbit/s
  + [G.lite](https://en.wikipedia.org/wiki/G.992.2), ITU-T G.992.2, more noise and attenuation resistant than G.dmt, up to 1,536 kbit/s and 512 kbit/s
  + [Asymmetric digital subscriber line 2](https://en.wikipedia.org/wiki/Asymmetric_digital_subscriber_line_2) (ADSL2), ITU-T G.992.3, up to 12 Mbit/s and 3.5 Mbit/s
  + [Asymmetric digital subscriber line 2 plus](https://en.wikipedia.org/wiki/Asymmetric_digital_subscriber_line_2_plus) (ADSL2+), ITU-T G.992.5, up to 24 Mbit/s and 3.5 Mbit/s
  + [Very-high-bit-rate digital subscriber line](https://en.wikipedia.org/wiki/Very-high-bit-rate_digital_subscriber_line) (VDSL), ITU-T G.993.1, up to 52 Mbit/s and 16 Mbit/s
  + [Very-high-bit-rate digital subscriber line 2](https://en.wikipedia.org/wiki/Very-high-bit-rate_digital_subscriber_line_2) (VDSL2), ITU-T G.993.2, an improved version of VDSL, compatible with ADSL2+, sum of both directions up to 200 Mbit/s. [G.vector](https://en.wikipedia.org/wiki/G.vector) crosstalk cancelling feature (ITU-T G.993.5) can be used to increase range at a given bitrate, e.g. 100 Mbit/s at up to 500 meters.[[15]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-15)
  + [G.fast](https://en.wikipedia.org/wiki/G.fast), ITU-T G.9700 and G.9701,[[16]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-ITUT-PR-2013-12-11-16) up to approximately 1 Gbit/s aggregate uplink and downlink at 100m.[[17]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-alu-17) Approved in December 2014, deployments planned for 2016.[[18]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-g9701-18)[[19]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-Alu-ONT-19)
* [Bonded DSL Rings](https://en.wikipedia.org/wiki/Bonded_DSL_Rings) (DSL Rings), a shared ring topology at 400 Mbit/s
* [Etherloop](https://en.wikipedia.org/wiki/Etherloop) Ethernet local loop
* [High Speed Voice and Data Link](https://en.wikipedia.org/wiki/High_Speed_Voice_and_Data_Link)
* Internet Protocol subscriber line (IPSL), developed by Rim Semiconductor in 2007, allowed for 40 Mbit/s using 26 [AWG](https://en.wikipedia.org/wiki/American_wire_gauge) copper telephone wire at a 5,500 ft (1,700 m) radius, 26 Mbit/s at a 6,000 ft (1,800 m) radius. The company operated until 2008.[[20]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-20)[[21]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-21)
* [Rate-adaptive digital subscriber line](https://en.wikipedia.org/wiki/Rate-adaptive_digital_subscriber_line) (RADSL), designed to increase range and noise tolerance by sacrificing upstream speed
* [Uni-DSL](https://en.wikipedia.org/wiki/Uni-DSL) (Uni digital subscriber line or UDSL), technology developed by Texas Instruments, backwards compatible with all DMT standards
* [Frequency Division Vectoring](https://en.wikipedia.org/w/index.php?title=Frequency_Division_Vectoring&action=edit&redlink=1), copper networks working with fiber[[22]](https://en.wikipedia.org/wiki/Digital_subscriber_line" \l "cite_note-22)
* [Hybrid Access Networks](https://en.wikipedia.org/wiki/Hybrid_Access_Networks) combine existing xDSL deployments with a wireless network such as [LTE](https://en.wikipedia.org/wiki/LTE_(telecommunication)) to increase bandwidth and quality of experience by balancing the traffic over the two access networks.[[23]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-BBF-TR348-23)

The line-length limitations from telephone exchange to subscriber impose severe limits on data transmission rates. Technologies such as [VDSL](https://en.wikipedia.org/wiki/VDSL) provide very high-speed but short-range links. VDSL is used as a method of delivering "[triple play](https://en.wikipedia.org/wiki/Triple_play_(telecommunications))" services (typically implemented in [fiber to the curb](https://en.wikipedia.org/wiki/Fiber_to_the_curb) network architectures).

**See also**

* [ADSL loop extender](https://en.wikipedia.org/wiki/ADSL_loop_extender)
* [Broadband Internet access](https://en.wikipedia.org/wiki/Broadband_Internet_access)
* [Dynamic spectrum management](https://en.wikipedia.org/wiki/Dynamic_spectrum_management) (DSM)
* [Electronic filter](https://en.wikipedia.org/wiki/Electronic_filter)
* [John Cioffi](https://en.wikipedia.org/wiki/John_Cioffi) – Known as "the father of DSL"[[24]](https://en.wikipedia.org/wiki/Digital_subscriber_line#cite_note-24)
* [List of countries by number of Internet subscriptions](https://en.wikipedia.org/wiki/List_of_countries_by_number_of_Internet_subscriptions)
* [List of device bandwidths](https://en.wikipedia.org/wiki/List_of_device_bandwidths)

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**External links**

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| --- | --- |
|  | Wikimedia Commons has media related to [***Digital Subscriber Line***](https://commons.wikimedia.org/wiki/Category:Digital_Subscriber_Line). |

* [ADSL Theory](https://whirlpool.net.au/wiki/?tag=ADSL_Theory)—Information about the background & workings of ADSL, and the factors involved in achieving a good sync between your modem and the [DSLAM](https://en.wikipedia.org/wiki/DSLAM).