**Satellite Internet access**

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| **Satellite Internet** |
| Example of satellite dedicated to internet access |
| **Satellite Internet Characteristics** |
| **Medium** | Air or Vacuum |
| **License** | ITU |
| **Maximum download rate** | 1 Gbps |
| **Maximum upload rate** | 10 Mbps |
| **Average download rate** | 1 Mbps |
| **Average upload rate** | 256 Kbps |
| **Latency (one-way)** | Up to 900 ms |
| **Frequency bands** | L, C, Ku, Ka |
| **Coverage** | 100 - 6,000km |
| **Additional services** | VoIP, SDTV, HDTV, VOD, Datacast |
| **Average CPE price** | €300 (modem + satellite dish) |

**Satellite Internet access** is Internet access provided through satellites. The service can be provided to users world-wide through Low Earth Orbit (LEO) satellites. Geostationary satellites can offer higher data speeds, but their signals cannot reach some polar regions of the world. Different types of satellite systems have a wide range of different features and technical limitations, which can greatly affect their usefulness and performance in specific applications.

**Mechanics and limitations of satellite communication**

**Signal latency**



Satellite Internet access via VSAT in Ghana

Latency is the delay between requesting data and the receipt of a response, or in the case of one-way communication, between the actual moment of a signal's broadcast and the time received at its destination. Compared to ground-based communication, all geostationary satellite communications experience high latency due to the signal having to travel 35,786 km (22,236 mi) to a satellite in geostationary orbit and back to Earth again. Even at the speed of light (about 300,000 km/s or 186,000 miles per second), this delay can be significant. If all other signaling delays could be eliminated it still takes a radio signal about 250 milliseconds, or about a quarter of a second, to travel to the satellite and back to the ground. For an internet packet, that delay is doubled before a reply is received. That is the theoretical minimum. Factoring in other normal delays from network sources gives a typical one-way connection latency of 500–700 ms from the user to the ISP, or about 1,000–1,400 milliseconds latency for the total Round Trip Time (RTT) back to the user. This is far worse than most dial-up modem users' experience, at typically only 150–200 ms total latency.

**Geostationary useless for low-latency applications**

This inherent latency makes Satellite Internet service essentially unusable for applications requiring real-time user input, such as online games or remote surgery. This delay can also be irritating and debilitating with interactive applications, such as VoIP, videoconferencing, or other person to person communication. It will cause most general market applications (such as Skype) to behave unpredictably and fail, as these are not designed for the difficult compensation for the high latency connections. As research has repeatedly demonstrated that perceived delays in answering questions subconsciously suggests doubt to the listener and can generate mistrust even when both sides are aware of the lag, geostationary connections are best avoided for important voice calls. Other research into interactive systems has repeatedly demonstrated that latency lag is the most debilitating and irritating of all interactive system flaws and often gives an extremely negative impression of the system or its usefulness. Some researchers have gone so far as to recommend simply refusing connections to those with latency likely to result in poor interactive user experience.

The functionality of live interactive access to a distant computer can also be subject to the problems caused by high latency. However these problems are more than tolerable for basic email access and web browsing, and in most cases are barely noticeable. This is not true, however, for character-by-character command shell or virtual private networks (which typically involve several round trips using layered protocols) which are almost universally unusable through geostationary connections. Typical VPN connections made over satellite will be at least double (and often, with poor protocols and misguided security measures) quadruple or worse the underlying basic latency. Unless the VPN is literally re-engineered to accommodate high-latency users, it will be useless for anything but email, download and a static web.

**Acceptable latencies, but lower speeds, of lower orbits**

For geostationary satellites there is no way to eliminate latency, but the problem can be somewhat mitigated in Internet communications with TCP acceleration features that shorten the round trip time (RTT) per packet by splitting the feedback loop between the sender and the receiver. Such acceleration features are usually present in recent technology developments embedded in new satellite Internet services.

Medium Earth Orbit (MEO) and Low Earth Orbit (LEO) satellites do not have such great delays. The current LEO constellations of Globalstar and Iridium satellites have delays of less than 40 ms round trip, but their throughput is less than broadband at 64 kbit/s per channel. The Globalstar constellation orbits 1,420 km above the earth and Iridium orbits at 670 km altitude. The proposed O3b Networks MEO constellation scheduled for deployment in 2010 would orbit at 8,062 km, with RTT latency of approximately 125 ms. The proposed new network is also designed for much higher throughput with links well in excess of 1 Gbps (Gigabits per second).

**Ultralight atmospheric aircraft as satellites**

A proposed alternative to geostationary relay satellites is a special-purpose solar-powered ultralight aircraft, which would fly along a circular path above a fixed ground location, operating under autonomous computer control at a height of approximately 20,000 meters. Onboard batteries would be charged during daylight hours by solar panels covering the wings, and would provide power to the plane during night. Ground-based satellite dishes would relay signals to and from the aircraft, resulting in a greatly reduced round-trip signal latency of only 0.25 milliseconds. The planes could then run forever without refueling. Several such schemes involving various types of aircraft have been proposed in the past.

**Rain fade**



A foldable Bigpond Satellite Internet dish

Satellite communications are affected by moisture and various forms of precipitation (such as rain or snow) in the signal path between end users or ground stations and the satellite being utilized. The effects are less pronounced on the lower frequency 'L' and 'C' bands, but can become quite severe on the higher frequency 'Ku' and 'Ka' band. For satellite Internet services in tropical areas with heavy rain, use of the C band (4/6 GHz) with a circular polarization satellite is popular. Satellite communications on the Ka band (19/29 GHz) can use special techniques such as large *rain margins*, *adaptive uplink power control* and *reduced bit rates* during precipitation.

"Rain margins" are the extra communication link requirements needed to account for signal degradations due to moisture and precipitation, and are of acute importance on all systems operating at frequencies over 10 GHz.

The amount of time during which service is lost can be reduced by increasing the size of the satellite communication dish so as to gather more of the satellite signal on the downlink and also to produce a more intense transmission on the uplink.

Modern consumer-grade dish antennas tend to be fairly small, which reduces the rain margin or increases the required satellite downlink power and cost.

Large commercial dishes of 3.7m to 13m diameter are used to achieve large rain margins and also to reduce the cost per bit by requiring far less power from the satellite.

Modern download DVB-S2 carriers, with RCS feedback, are intended to allow the modulation method to be dynamically altered, in response to rain problems at a receive site. This allows the bit rates to be increased substantially during normal clear sky conditions, thus reducing overall costs per bit.

**Line of sight**



Fresnel zone. d is the distance between the transmitter and the receiver, b is the radius of the Fresnel zone.

Typically a completely clear line of sight between the dish and the satellite is required for the system to work. In addition to the signal being susceptible to absorption and scattering by moisture, the signal is similarly impacted by the presence of trees and other vegetation in the path of the signal. As the radio frequency decreases, to below 900 MHz, penetration through vegetation increases, but most satellite communications operate above 2 GHz making them sensitive to even minor obstructions such as tree foliage. A dish installation in the winter must factor in plant foliage growth that will appear in the spring and summer.

**Fresnel zone**

The radio signal width between two ground satellite dish receivers is not perfectly straight and uniform, as if it were a beam of light. Instead as the signal propagates away from the transmitting dish, it widens towards the center point between the two dishes and then narrows again as it approaches the receiving dish. This is known as the Fresnel zone, and limits the usefulness of satellite dishes in locations where there is extremely limited open sky for signal reception. The signal path through space must be clear not only for direct line of sight, but must also be clear for the expanding Fresnel zone, which may be several meters larger in diameter than the ground-based satellite dish.

**Two-way satellite-only communication**



The back panel of a satellite modem, with coaxial connections for both incoming and outgoing signals, and an Ethernet port for connection to the internal network.

Two-way satellite Internet service involves both sending and receiving data from the remote VSAT site via satellite to a hub teleport, which then relays data via the terrestrial Internet. The satellite dish at each location must be precisely pointed to avoid interference with other satellites. Some providers oblige the customer to pay for a member of the provider's staff to install the system and correctly align the dish—although the European ASTRA2Connect system encourages user-installation and provides detailed instructions for this. Many customers in the Middle East and Africa are also encouraged to do self-installs. At each VSAT site the uplink frequency, bit rate and power must be accurately set, under control of the service provider hub.

There are several types of two way satellite Internet services, including time division multiple access (TDMA) and single channel per carrier (SCPC). Two-way systems can be simple VSAT terminals with a 60–100 cm dish and output power of only a few watts intended for consumers and small business or larger systems which provide more bandwidth. Such systems are frequently marketed as "satellite broadband" and can cost two to three times as much per month as land-based systems such as ADSL. The modems required for this service are often proprietary, but some are compatible with several different providers. They are also expensive, costing in the range of US$600 to $2000.



The two-way "iLNB" used on the ASTRA2Connect.

The two-way "iLNB" used on the ASTRA2Connect terminal dish has a 500 mW transmitter and single-polarity receive LNB, both operating in the Ku band. Pricing for Astra2Connect modems range from 299 to 350€. These types of system are generally unsuitable for use on moving vehicles, although some dishes may be fitted to an automatic pan and tilt mechanism to continuously re-align the dish—but these are cumbersome and very expensive. The technology for ASTRA2Connect was delivered by a Belgian company called Newtec.



The Too way satellite modem

**Bandwidth**

Satellite internet customers range from individual home users with one PC to large remote business sites with several hundred PCs.

Home users tend to make use of shared satellite capacity, to reduce the cost, while still allowing high peak bit rates when congestion is absent. There are usually restrictive time based bandwidth allowances so that each user gets their fair share, according to their payment. When a user exceeds their Mbytes allowances, the company may slow down their access, deprioritize their traffic or charge for the excess bandwidth used. For consumer satellite internet, the allowance can range from 200 MB per day to 17,000 MB per month. A shared download carrier may have a bit rate of 1 to 40 Mbit/s and be shared by up to 100 to 4000 end users. Note that the average bit rate per end user PC is only about 10 - 20kbit/s.

The uplink direction for shared user customers is normally TDMA, which involves transmitting occasional short packet bursts in between other users (similar to how a cellphone shares a cell tower)

Business users tend to opt for dedicated bandwidth services where any congestion is under their local control.

Each remote location may also be equipped with a telephone modem; the connections for this are as with a conventional dial-up ISP. Two-way satellite systems may sometimes use the modem channel in both directions for data where latency is more important than bandwidth, reserving the satellite channel for download data where bandwidth is more important than latency, such as for file transfers.

In 2006 the European Commission sponsored the UNIC project which aims at developing an end-to-end scientific test bed for the distribution of new broadband interactive TV-centric services delivered over low-cost two-way satellite to actual end-users in the home. The UNIC architecture employs DVB-S2 standard for downlink and DVB-RCS standard for uplink.

Normal VSAT dishes (1.2 - 2.4m dia) are widely used for VoIP phone services. A voice call is sent by means of packets via the satellite and internet. Using coding and compression techniques the bit rate needed per call is only 10.8 kbit/s each way.

**Portable satellite Internet**

**Portable satellite modem**

These usually come in the shape of a self-contained flat rectangular box that needs to be pointed in the general direction of the satellite—unlike VSAT the alignment need not be very precise and the modems have built in signal strength meters to help the user align the device properly. The modems have commonly used connectors such as Ethernet or Universal serial bus. Some also have an integrated Bluetooth transceiver and double as a satellite phone. The modems also tend to have their own batteries so they can be connected to a laptop without draining its battery. The most common such system is INMARSAT's BGAN—these terminals are about the size of a briefcase and have near-symmetric connection speeds of around 350–500 kbit/s. Smaller modems exist like those offered by Thuraya but only connect at 144 kbit/s in a limited coverage area.

Using such a modem is extremely expensive—bandwidth costs between $5 and $7 per megabyte. The modems themselves are also expensive, usually costing between $1000 and $5000.

**Internet via satellite phone**

For many years now satellite phones have been able to connect to the internet. Bandwidth varies from about 2400 bit/s for Iridium network satellites and ACeS based phones to 15 kbit/s upstream and 60 kbit/s downstream for Thuraya handsets. Globalstar also provides internet access at 9600 bit/s—like Iridium and ACeS a dial-up connection is required and is billed per minute, however both Globalstar and Iridium are planning to launch new satellites offering always-on data services at higher speeds. With Thuraya phones the 9600 bit/s dial-up connection is also possible, the 60 kbit/s service is always-on and the user is billed for data transferred (about $5 per megabyte). The phones can be connected to a laptop or other computer using a USB or RS-232 interface. Due to the low bandwidths involved it is extremely slow to browse the web with such a connection, but useful for sending email, Secure Shell data and using other low-bandwidth protocols. Since satellite phones tend to have omnidirectional antennas no alignment is required as long as there is a line of sight between the phone and the satellite.

**One-way receive, with terrestrial transmit**

One-way terrestrial return satellite Internet systems are used with traditional dial-up access to the Internet, with outbound data traveling through a telephone modem, but downloads sent via satellite at a speed near that of broadband Internet access. In the U.S., an FCC license is required for the uplink station only; no license is required for the users.

Another type of 1-way satellite internet system involves the use of General Packet Radio Service (GPRS) for the back-channel. By utilizing a connection that is offered in standard GPRS or EDGE, the upload volume is very low and since this service is not per-time charged, but charged by volume uploaded, users are able to surf and download in broadband speeds. Another view of using GPRS as return would be the mobility when the service is provided by a satellite that transmits in the field of 50 to 53 dBW. Using a 33 cm wide satellite dish, a notebook and a normal GPRS equipped GSM phone, users can get mobile satellite broadband.

**System hardware components**

The transmitting station (also called "teleport", "head end", "uplink facility", or "hub") has two components:

* Internet connection: The ISP's routers connect to proxy servers which can enforce quality of service (QoS) bandwidth limits and guarantees for user traffic. These are then connected to a DVB encapsulator which is then connected to a DVB-S modulator. The radio frequency (RF) signal from the DVB-S modulator is connected to an up converter which is connected via feed line to the outdoor unit.
* Satellite uplink: The block upconverter (BUC) and optional low-noise block converter (LNB), which may use a waveguide to connect to the optional orthomode transducer (OMT) which is bolted to the feed horn which is connected by metal supports to the satellite dish and mount.

At the remote location (Earth station) the setup consists of:

* Outdoor unit
	+ Satellite dish with mount
	+ Feedhorn
	+ Universal LNB, for Ku-band.
	+ Feed line
* Indoor unit
	+ DVB-S Peripheral Component Interconnect (PCI) card internal to a computer
	+ or, DVB external modem where an 8P8C (RJ-45) Ethernet port or a Universal Serial Bus (USB) port connects the modem to the computer

**System software components**

Remote sites require a minimum of programming to provide authentication and set proxy server settings. Filtering is usually provided by the DVB card driver.

Often, non-standard IP stacks are used to address the latency and asymmetry problems of the satellite connection. Data sent over the satellite link is generally also encrypted, as otherwise it would be accessible to anyone with a satellite receiver.

Many IP-over-satellite implementations use paired proxy servers at both endpoints so that certain communications between clients and servers do not need to accept the latency inherent in a satellite connection. For similar reasons, there exist special Virtual private network (VPN) implementations designed for use over satellite links because standard VPN software cannot handle the long packet travel times.

Upload speeds are limited by the user's dial-up modem, and latency is high, as it is for any satellite based Internet (minimum of 240 ms one-way, resulting in a minimum round-trip time of almost 500ms). Download speeds can be very fast compared to dial-up.

**Theory of operation**

Remote sites use proxy server or(and) Virtual private network servers at the earth station (teleport), which is configured to route all outbound traffic to the QoS server, which makes sure no user exceeds their allotted bandwidth or monthly traffic limits. Traffic is then sent to the encapsulator, which puts the IP packets inside of DVB packets. The DVB packets are then sent to the DVB modem and then to the transmitter (BUC).

**One-way multicast, receive only**

One-way multicast satellite Internet systems are used for Internet Protocol (IP) multicast-based data, audio and video distribution. In the U.S., a Federal Communications Commission (FCC) license is required only for the uplink station and no license is required for users. Note that most Internet protocols will not work correctly over one-way access, since they require a return channel. However, Internet content such as web pages can still be distributed over a one-way system by "pushing" them out to local storage at end user sites, though full interactivity is not possible. This is much like TV or radio content which offers little user interface.

**System hardware components**

Similar to one-way terrestrial return, satellite Internet access may include interfaces to the public switched telephone network for squawk box applications. An Internet connection is not required, but many applications include a File Transfer Protocol (FTP) server to queue data for broadcast.

**System software components**

Most one-way multicast applications require custom programming at the remote sites. The software at the remote site must filter, store, present a selection interface to and display the data. The software at the transmitting station must provide access control, priority queuing, sending, and encapsulating of the data.

**Efficiency increases**

**Reducing satellite latency**

Much of the slowdown associated with satellite Internet is that for each request, many roundtrips must be completed before any useful data can be received by the requester. Special IP stacks and proxies can also reduce latency through lessening the number of roundtrips, or simplifying and reducing the length of protocol headers. These types of technologies are generally referred to as TCP acceleration, HTTP pre-fetching and DNS caching.

**Elimination of advertising materials**

While also effective for terrestrial communications, the use of ad-blocking software such as Adblock for Firefox is exceptionally beneficial for satellite Internet, as most Internet advertising websites use cache busting in order to render the browser and ISP's cache useless, by displaying advertisements (for the purpose of maximizing the number of ad views seen by the affiliate marketing company's server).