Very Small Aperture Terminal Broadband: What Is It?

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This paper discusses new directions in Very Small Aperture Terminal (VSAT)-based services that are receiving increasing attention as an alternative way to deliver broadband, including Internet access to homes and businesses across the world. VSAT broadband uses new technology to deliver data via the Ethernet. Where Transmission Control Protocol/Internet Protocol (TCP/IP) is the standard Internet technology, VSAT broadband vendors modify TCP/IP in proprietary fashions to optimize it for satellite links. This paper begins with a background description of standard VSAT. The advantages and challenges of the new VSAT broadband technology are addressed, as well as situations where it excels and where it does not.

Both the commercial and government markets for VSAT, including VSAT broadband, over the past few years are traced with illustrative examples and charts. FTS2001 prices of existing VSAT broadband services are presented in some detail. FTS2001 and FTS2001 Bridge are General Services Administration (GSA) Government-Wide Acquisition Contract (GWAC) vehicles with a fairly wide range of VSAT services that are substantially discounted from commercial rates. This paper also explores some of the potential issues with VSAT broadband services under Networx, the new GSA GWAC. Finally, this paper draws conclusions on the future of VSAT broadband.

Introduction

Very Small Aperture Terminal (VSAT) is a satellite-based telecommunications technology. Satellites have been used to transfer data back and forth from the earth since the 1960s. A satellite receives a signal from one ground location and rebroadcasts it so another ground-based station can receive the signal. VSATs access satellites in geosynchronous orbit to relay data from small remote earth stations (VSAT terminals) to either other VSAT terminals (in mesh configurations) or to master earth station “hubs” (in star configurations). As shown in Figure 1, a single hub handles many terminals to form a VSAT network.

Fixed Service Satellite (FSS) is the official classification for geostationary communications satellites used for broadcast feeds for television and radio stations and networks, as well as for telephony and data communications. FSS is a broad category of services that can provide bandwidths from Digital Signal 0 (DS0) to DS3 data rates for both C-band and Ku-band transmission. VSATs are a particular type of FSS; FSS terminals include dedicated earth stations and VSATs.

Background

VSAT refers to the satellite dish (antenna) as shown in Figure 2. A satellite terminal comprises a ground station and a satellite dish with a transceiver. As the definition itself indicates, *very small aperture* refers to the size of the VSAT dish which is smaller than 3 meters (m). In fact, most VSAT dishes range from 75 centimeters (cm) to 1.2 m. In contrast, a typical INTELSAT system has a 30 m antenna.

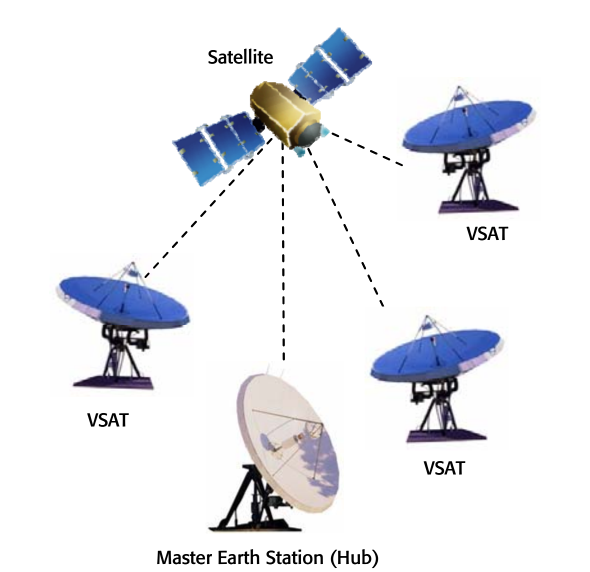

Figure 1. Basic VSAT network diagram

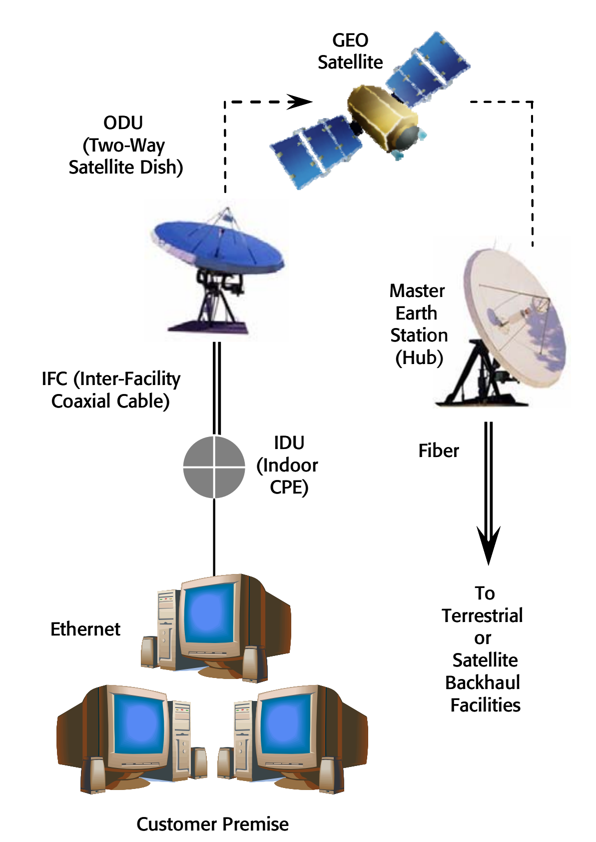

Figure 2. VSAT network architecture

The transceiver attached to the dish receives or sends a signal to a satellite in geosynchronous orbit in the sky. Reception and retransmission by the satellite are accomplished through a transponder. In general, for any kind of satellite system, including VSAT, the throughput is dependent, among other factors, on the size of the dish antenna. A large dish makes it possible to receive a higher data rate. The overall cost of a satellite system increases with increasing antenna size, making higher bandwidth more expensive. This is the reason standard narrowband VSATs are used when the data rate requirement is rather low. [1]

On the other hand, when the data rate requirement is high, VSAT will not be able to deliver the required bandwidth. For such situations, larger antennas are needed. For example, to set up a 115 Mbps carrier requires large (13 m +) dish antennas in both ends, as a VSAT antenna would not be able to deliver such high throughput.

That clearly establishes the context of contemporary VSAT technology development. The challenge is to pack in increasingly higher bandwidth capability within the relatively smaller VSAT antenna, than was possible before, in order to improve price/performance ratio—VSAT broadband does precisely that.

VSAT architecture

There are three components in a VSAT network. [2] The first is called the master earth station. The master earth station is the network control center for the entire VSAT network. Configuration, monitoring, and management of the VSAT network are done at this location. The master earth station has a large dish (6 m or bigger), fully redundant electronics, a self-contained backup power system, and a regulated air conditioning system. In addition, the master earth station is manned 24x7 throughout the year. Further details on the role of the master earth station in broadband VSAT Internet access are discussed later in this paper.

The second component in a VSAT network is the remote earth station. As shown in some detail in Figure 2, the remote earth station is comprised of the hardware installed at the customer's premises, including the outdoor unit (ODU), the indoor unit (IDU), and the inter-facility link (IFL). The ODU consists of a standard VSAT dish antenna, a solid state power amplifier (SSPA), a low noise amplifier (LNA), and a Feedhorn. A VSAT end user needs a box that interfaces between the user's computer on an Ethernet and an outside antenna with a transceiver. The IDU provides this interface; it is a VCR-sized unit that houses the communications electronics, including interface with the customer's equipment such as computers or telephones. The IFL consists of coaxial cables that connect the ODU to the IDU.

The third component of a VSAT network is the satellite itself. All signals sent between the VSAT earth stations are beamed through the satellite. The VSAT uses a geostationary (GEO) satellite which is orbiting at 36,000 km above the ground.

Figure 2 shows just one VSAT ground station on the left half of the diagram for simplicity. It should be noted that many such ground stations are linked to one Hub through the satellite as shown in Figure 1.

VSAT historical perspective

Transponders each work on a specific radio frequency wavelength, or "band." Satellite communications work on three primary bands—C, Ku, and Ka. [3] The first commercial VSATs were C-band (6 GHz) receive-only systems. More than 30,000 60 cm antenna systems were sold in the early 1980s. As a longer wavelength, C-band requires a larger antenna.

There are two distinct types of satellite connections—one-way and two-way. As mentioned above, one-way connections were the earliest available. One-way connections are generally receive-only. The bandwidth capacity of early VSAT systems was 64 Kbps or less. Later, a C-band (4 to 6 GHz) two-way system, using larger 1 m antennas, was developed and about 10,000 units were sold in 1984 to 1985.

With C-band, only a few DS0s of two-way bandwidth could be supported. The cost over throughput ratio (i.e., price per Kbs) of C-band VSAT was very high. Second generation VSATs (circa 1987) were Ku-band (12 to 14 GHz) VSATs that were developed to provide portable network connectivity for oil field drilling and exploration units. These systems were built with a two-way capability and higher frequencies which allowed Ku-band to support higher speeds. They also featured higher data rates and support for the popular network topologies of the day, such as X.25.

Since it has a shorter wavelength, the antenna size required for Ku-band is comparatively shorter to deliver the same bandwidth. Conversely, greater bandwidth can be delivered using antenna having the same size as a C-band antenna, thereby making Ku-band less expensive. Although introduction of Ku-band VSAT meant an improved price performance ratio, the cost of each earth station ($5 to $15,000 per unit) was still considered high and kept them from gaining wide acceptance.

Third generation systems (circa 1996) were Ku-band, multi-service platforms with improved data rates and support for older network topologies as well as the emerging Internet Protocol (IP). Up to T1 speed using standard third generation Ku-band VSAT technology is quite possible. With the advent of third generation systems, the bandwidth over price performance ratio of Ku-band got even better. Decreased earth station costs ($2 to $6,000 per unit) helped speed acceptance of VSAT and made them a viable alternative to frame relay/T1 or dedicated dial for enterprise and government users. A two-way connection using Ku-band VSATs is widely available throughout the U.S. Consequently, Ku-band is used by most current VSAT systems and makes up the vast majority of sites in use today for data applications.

VSAT is used both by home users who sign up with a large service such as DirecPC and by private companies that operate or lease their own VSAT systems. Traditionally, VSAT technology was used by businesses to connect remote sites in order to share narrowband data. These included point of sale transactions such as credit card, polling, or Radio Frequency Identification (RFID) data; or Supervisory Control and Data Acquisition (SCADA). Credit card companies were among the first to use this type of technology. It has now become commonplace and can be seen in gas stations and toll booths across North America. VSATs are also used for transportable, on-the-move, or mobile maritime communications.

VSAT advantages

VSAT offers a number of advantages over terrestrial alternatives. [4] For private applications, companies can have total control of their own communications system without depending on other companies. Business and home users also get higher speed reception than if using ordinary telephone service or Integrated Services Digital Network (ISDN). Businesses and organizations give many reasons for using VSAT networks over terrestrial alternatives, as listed below.

- VSAT services can be deployed almost anywhere. Additionally, one single network can deliver services to all sites. All sites being on the same network ensures full availability.
- Flexible network topology makes it easy to deploy, and add, relocate, or delete sites.
- Transmission costs are not distance dependent as with terrestrial networks. This not only makes costs predictable, but makes it more cost-effective than leased or dedicated phone lines to remote locations.
- More robust data networks compared to standard telephone lines are possible.
- Corporate-grade VSAT networks are private layer-2 networks over the air, providing a high level of security.
- Performance is insensitive to terrain or distance.
- Cost-effective emergency back-up and disaster recovery for critical data flow is easily supported.
- VSAT requires only one point of contact for all network issues. This facilitates proactive around-the-clock network support from the network control center at the hub.

VSAT broadband

Fourth generation VSAT systems (circa 2000) were the first generation of IP-native terminals designed to address the consumer broadband market. [5] These were the first true VSAT broadband systems. These terminals, featuring prices between $500 and $2,000 per unit, provided broadband connectivity of up to 512 Kbps upstream and over 1 Mbps downstream using Ku-band. Although satellite Internet using fourth generation VSAT did not ultimately challenge cable modem and DSL in the scale of deployments in the U.S., this generation of VSATs did much to legitimize VSAT as a competitive offering for many network needs.

The fifth generation of VSAT platforms (introduced in 2004) provides support for Ku-band frequencies. These systems offer higher speeds (up to 2 Mbps upstream) at lower prices ($500 to $1,500 per unit) than ever before. Thanks to some major technological advances, VSAT data rates can range up to 4 Mbps or even higher (i.e., broadband data) without having to use large (> 3 m) antennas. This allows VSAT technology to be used to deliver broadband Internet service to many locations that would not normally have access. This includes rural areas, as well as offshore businesses and residences, which will never have access to cable or DSL connectivity.

VSAT broadband definition

VSAT broadband offers two-way broadband access via satellite. It is typically installed in addition to a T1/E1, frame relay, ISDN connection, or to provide IP access to areas not reachable by traditional landlines. The purpose is to connect a customer's remote and/or temporary business location(s) directly to the Internet, Intranet, or wide area network/local area network (WAN/LAN) with terrestrial-like speed and performance at speeds of up to 4 Mbps or higher. The applicable VSAT network architecture is shown in Figure 3.

Whether a customer is using the Internet, building an enterprise network, or seeking a complete and redundant solution, VSAT broadband provides last-mile interconnectivity at the service levels a customer requires to ensure complete communications continuity. These VSAT broadband systems are based on IP, with a very broad spectrum of applications. In addition to being used for the provision of satellite Internet access to remote locations, Broadband VSAT technology is increasingly being used to carry Voice over IP (VoIP) or video. [6]

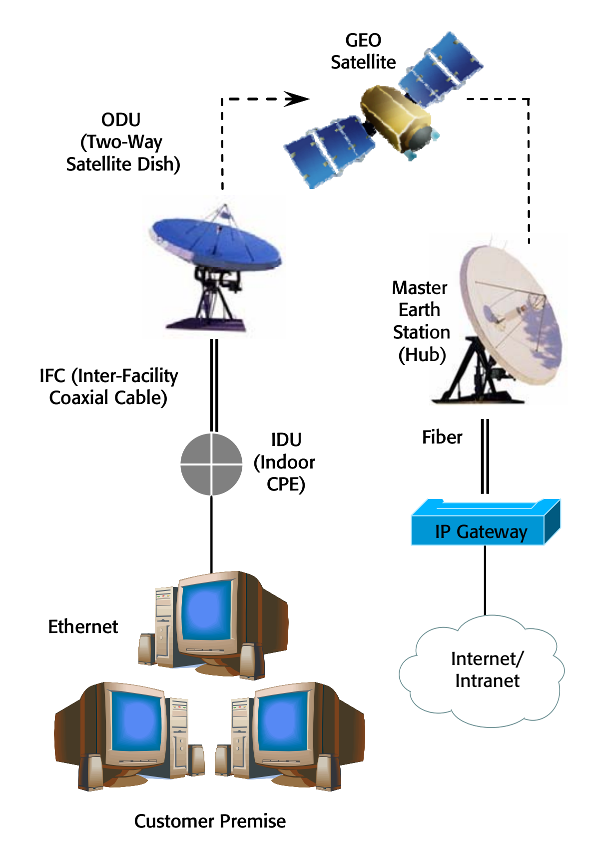

Figure 3. VSAT Internet architecture

By design, VSAT broadband optimizes satellite transmission specifically to deliver terrestrial-like TCP/IP connectivity for enterprise networks. The system is focused on both the reliable delivery of high-speed data rates over satellite transport and maintaining TCP/IP standards compliance, which enables data transfer with plug-and-play compatibility to terrestrial networks.

VSAT broadband is not a wholly different system in comparison to narrowband VSAT. Upgrade and enhancement of indoor equipment renders an existing VSAT system broadband capable. A VSAT broadband system can be configured to continue to be used for narrowband applications such as point of sales transactions in addition to the new high-speed data services.

How VSAT broadband works

A request for data from the Internet or customer's LAN by an end user on the remote/temporary Ethernet LAN is sent via the remote/temporary LAN to the site's network functionality equipment, i.e., the ground station. The equipment's IDU (after necessary modulation and translation) sends the information via coaxial cable to the ODU. The ODU converts the signal to Ku-band, amplifies the signal, and transmits it to the satellite where the signal is transmitted to the gateway for processing and forwarding to the Internet or the customer's LAN via a service provider's IP infrastructure.

When the requested data is transmitted from the terrestrial IP backbone network to a remote/temporary LAN, data is sent via the public Internet or a provider's IP network to the IP gateway shown in Figure 3. At the gateway, the transmission is modulated, converted to a Ku-band signal, amplified, and sent over a high-speed fiber link to the hub. From the hub, data is sent via the satellite link to the network functionality equipment in the ground station of the designated end user.

A hub may handle hundreds of remote users. Narrowband VSAT master stations routinely handle transmissions in hundreds of Mbps. VSAT broadband master stations, as can be imagined, are often required to handle data rates in excess of 1 Gbps. For the link between the master station and the Internet, fiber links capable of carrying bandwidth up to and in excess of 1 Gbps are used. Many vendors use one or more 1 Gbps Ethernet links.

At the end users network functionality equipment, the outdoor unit receives the Ku-band signal and, after necessary conversion, the signal is sent via the inter-facility coaxial cable to the IDU where the signal is demodulated, converted to IP packets, and forwarded to the customer's remote/temporary LAN.

The IDU of the network functionality equipment is designed to transmit standard IP data. Proprietary and legacy networks that are not IP-based, such as Novell, Appletalk, SNA, and X.25, can also be handled. An appropriate additional multi-protocol router would then be required to convert to and from IP to interact with the network functionality equipment connection. [7]

Technology challenges and solutions to VSAT broadband implementation

There are two major challenges to going beyond standard narrowband VSAT to true IP-based broadband (4 Mbps or higher) communications over the same Ku-band VSAT links. [8] One is obtaining higher speed without increasing the dish size beyond what has been accepted as the realm of VSAT terminal size (i.e., less than 3 m). As has been indicated, it is possible to achieve a two-way throughput capacity of up to 1.5 Mbps or 2.048 Mbps over a Ku-band VSAT. Supporting larger than 2 Mbps bandwidth over Ku-band VSAT is a major VSAT broadband challenge.

The other challenge is delivering TCP/IP over a satellite connection. Since TCP was designed for terrestrial networks that have less latency than a satellite network, the longer satellite latency (600 ms range) will cause TCP to expect an acknowledgment before the round trip to the remote site can be completed. TCP does not understand that a satellite is involved, and operates as if the satellite latency was caused by congestion.

The delay issue is addressed first. Latency can cause a severe performance problem over satellite links if not handled properly. If uncorrected, this effect causes all packets over a satellite network to be sent by TCP at the initial slow-start rate so as to prevent dropped packets. Applying standard TCP/IP to satellite Internet access circuits leads to underutilization of the link and degraded performance. In order to perform properly in conjunction with terrestrial IP networks (Internet, Intranet), satellite data networks must employ special techniques to deal with the increased latency caused by the 96,000-mile round-trip over the space segment of the connection due to the fact that geostationary satellites are 30,000 km above the earth's surface.

The latency issue is solved by using what is known as TCP acceleration. TCP acceleration is the name of a series of techniques for achieving better throughput on an Internet connection than standard TCP achieves without modifying the end applications. VSAT broadband systems deal with latency through the use of the most advanced TCP/IP acceleration technology available. This allows for terrestrial-like TCP performance over the satellite network.

TCP accelerators are special equipment placed within the network that optimizes TCP performance. In all current-generation VSAT broadband networks, TCP/IP acceleration is accomplished by special equipment at the carrier's main satellite hub site. In fact, it is often integrated with the IP router that is integrated into the hub gateway. A similar arrangement is often made at the remote station IDU. The VSAT systems' IDU is a single-box broadband satellite Internet modem with an onboard TCP optimization server.

The other problem of achieving higher bandwidth is tackled by using a compression server for on the fly traffic compression, which packs in much larger amounts of data than otherwise possible within the same packet size. To the satellite link, this still appears to be narrowband load; however, once decompressed at the receiving end, this increases the raw data rate over the standard Ku-band link speed. Frequently the compression server is integrated with the acceleration server.

Most of the solutions use User Datagram Protocol (UDP) as the primitive IP packet transport protocol. Speed and window size negotiations are still done inside the TCP accelerator protocol set, however, the data packets are sent over UDP. This is a modification of TCP and is highly proprietary. The large data packets and UDP-like transport, along with much larger buffers than normally stipulated by TCP, eliminate the need for frequent TCP control packets across the satellite link.

Since the effective size (after decompression) of data packets is large, packet errors necessitating packet retransmission can hamper throughput adversely. Advanced Forward Error Correction (FEC) algorithms are used in the hub and possibly at the IDU before sending packets over the space link. FEC ensures that packet errors are kept to a minimum thereby reducing the need for retransmission.

All these factors contribute towards delivering a very high data throughput (4 Kbps or higher) across the space link, while still being able to use VSAT terminals.

Equipment enhancement required

Vendors use proprietary equipment components to achieve broadband functionality. One common characteristic is to integrate an IP router into the IDU. This way, from the perspective of the remote/temporary network, the modified IDU functions as a standards-compliant static router, integrating easily with existing customer network infrastructure. This embellished IDU usually contains an Ethernet card and a satellite modem along with other standard pieces. It is usually the IDU that is endowed with the requisite intelligence to serve as the network functionality equipment to enable two-way broadband data communication over a Ku-band satellite connection.

For a symmetric operation requiring high-speed uplink, the IDU may also contain integrated servers/processors for acceleration, compression, large buffer, etc. The IDU is ideally designed to support all tiers of Internet service, thus the customer should not be required to purchase new equipment as network traffic increases. Even at the higher bandwidth service levels, a single networking equipment unit can support hundreds of end users. When all such complexities are incorporated into the IDU, for all practical purposes it serves as a gateway where processing functionalities are concerned.

The master station hub functions as an Internet gateway. The IDU routes IP traffic via the satellite link through the hub gateway to the Internet or the customer's LAN. The gateway connects to the Internet backbone and provides a high-speed bridge between a customer's remote/temporary site(s) and the customer's LAN. Data received by the gateway over the terrestrial connection is seamlessly transferred out to the network functionality equipment at a customer's remote/temporary location(s).

This necessitates major equipment enhancement at the hub to support high-speed data communications. The hub functions as the Internet gateway. Aside from a satellite dish, transmit/receive electronics, modem and processing electronics, and data networking equipment, the gateway also includes a router, server, and computers for acceleration, compression, buffering, etc., to enable broadband capability. [9]

Often a layer-2 IP switch to interface with the Internet backbone is also used wherein the IP switch at the hub is bridged to the router in the IDU. The Ku-band satellite connection provides the physical bridging medium.

Thus, as far as external appearance is concerned, the broadband VSAT network equipment rarely looks much different. In most solutions, all the additional software and hardware required to enable broadband capability are integrated within the equipment console in the IDU and in the master station hub.

VSAT broadband features

The VSAT broadband system provides TCP and Web acceleration in both directions and also supports line-rate TCP throughputs. Almost any VSAT broadband service includes a 3-DES link encryption device, ensuring encryption from originating to terminating end-point. These 3-DES modems are integrated with the routers at the IDU and the hub.

One advantage of using IP is that the bandwidth of the Broadband VSAT service is highly scalable from 128 Kbps to 4 Mbps and higher in small 128 Kbps increments. In addition, the Broadband VSAT system has features and controls that allow customers to deliver application quality of service (QoS) and other traffic engineered solutions to end users. [10]

Enforced quality of service. VSAT broadband satellite Internet access has the capability to perform network-based QoS prioritization. QoS can be based on protocol type, source port number, destination port number, source IP address, or destination IP address. This feature can also provide class-based queuing, assigning a percentage of bandwidth to each class. Rate limiting, which allocates only the bandwidth that is needed, is used in the network to maximize resources for all customers.

Perhaps most importantly, the VSAT broadband satellite Internet service can provide a Committed Information Rate (CIR)—with the ability to dedicate bandwidth as required in order to support voice or other bandwidth critical services.

Other features. Broadband VSAT can also be applied to deliver virtual private networks (VPNs) and VoIP, among other services. In conjunction with 3-DES encryption, IPSec capabilities are supported by almost all Broadband VSAT vendors. Although TCP acceleration avoids the delay problem for high-speed data applications, special issues arise in connection with acceleration, vis-à-vis VoIP or VPN protocols. Each such application requires careful attention to the delay problem. Corresponding solution techniques vary widely from vendor to vendor. For example, some vendors use a variation on Frequency Division Multiple Access (FDMA), the oldest of the technology, in order to provide collective access to the satellite space segment. On the other hand, an almost opposite method has been used by some other vendors to achieve the same objective. A number of vendors have successfully addressed such issues albeit in a highly proprietary way.

Utility of VSAT broadband

With the VSAT broadband solution, satellite data can compete quite well in terms of cost versus other sources of Ethernet. Satellite data can deliver in excess of a T1 of bandwidth almost anywhere at significantly reduced prices. More importantly, the size of the data pipe (and the cost) can be scaled upward and downward as needed. Listed below are some detailed situations where VSAT broadband excels and where it does not excel.

Situations where VSAT broadband excels

In general, broadband VSAT is applicable where high-speed infrastructure is either not available or does not exist. [11] Following are some of the ways that satellite data can be used profitably and with convenience.

Redundancy. VSAT broadband links can be used as a backup to terrestrial data sources. For many rural providers it can be nearly impossible to find a redundant Ethernet path to the outer world. Satellite data can provide the redundant path at affordable prices. It is the ultimate back-up since it does not rely on terrestrial access loops.

Scalable data pipes. With VSAT broadband, equipment data services can be provided to any location in increments as small as 128 Kbps and up to extremely large data pipes. It is often difficult in the terrestrial world to get a scalable Ethernet connection. Historical pricing has bunched products into multiples of T1s. However, if a remote location only needs 512 Kbps, then it is very inefficient to buy a full T1. Satellite data allows the delivery of just what is needed at each location, while also allowing for easy (almost instant) growth. In this way a provider can supply high-speed data services to customers who are not on their network.

Wire replacement. Equipment prices for satellite delivery have fallen to the point where VSAT broadband can provide a clear alternative to building new drops to remote locations. The savings in hardware costs can help avoid the huge fixed costs of building expensive fiber spurs. In fact, VSAT broadband service can be used as a gap service in the interim to serve customers before constructing permanent landline facilities, thereby allowing immediate service initiation. VSAT broadband will also allow customers to purchase from existing vendor services in new locations that may be remote from the vendor's current footprint, thereby realizing potential cost saving over having to negotiate with a new provider.

Situations where VSAT broadband does not excel

VSAT broadband is not only a good way to provide both primary and back-up high speed data services to remote locations without adequate infrastructure, it may be cost effective as a backup in urban areas as well. However, VSAT broadband does not excel in locations with very extensive, redundant, already existent Ethernet facilities.

VSAT broadband market

For enterprise and broadband systems, the latest publicly available numbers for VSAT broadband are from 2006. In North America, VSAT revenues were approximately $3.88B in 2006 for all services. The hardware revenues were approximately $746.9M. There are currently over 30 different vendors supplying VSAT equipment. The total number of VSAT terminals that have been ordered between 1995 and 2006 is 1,675,318. The total number of VSATs shipped during the same period is 1,574,546. The total number of sites in service is 1,026,378. [12]

As in North America, VSAT systems sold in other regions of the world are also usually broadband capable. Figure 4 illustrates the huge size of the North American VSAT market, but it also shows that the three other regions—Asia/Pacific, Latin America, and Europe—have significant size. This figure underscores the enormity of the global size of the VSAT market.

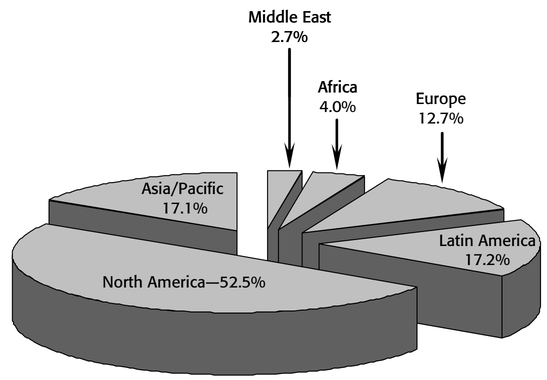

Figure 4. Star data regional market share—ordered terminals

Source: COMSYS Communications Systems, Ltd., "VSAT Statistics," *The COMSYS VSAT Report,* 10th Edition; http://www.comsys.co.uk/vsatstat.htm.

Figure 5 presents the historical distribution of the world VSAT equipment market share for the key players. The historical chart details annual sales from 1995; it illustrates the historical VSAT market share for vendors based on the number of terminals they have shipped. There are currently over 30 different vendors supplying VSAT equipment.

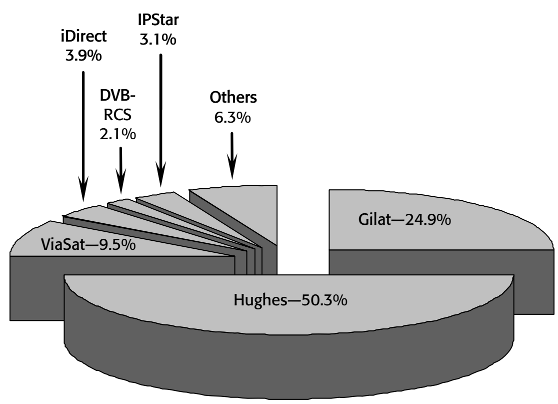

Figure 5. Star data historical world market share—ordered terminals

Source: COMSYS Communications Systems, Ltd., "VSAT Statistics," *The COMSYS VSAT Report,* 10th Edition; http://www.comsys.co.uk/vsatstat.htm.

The number of major VSAT operators is over 350 worldwide. Large enterprise customers, such as Ford, Exxon, Wal-Mart, McDonalds, and others, have pushed the total number of sites to over one million. These numbers show both the size and the broad range of popularity among large corporate enterprises for the coverage and versatility that VSAT provides.

As popular as VSAT broadband may be among large enterprises with national and global reach, the tremendous popularity that VSAT broadband currently enjoys has, to a large extent, been fueled by the penetration of VSAT broadband into small and medium enterprises as well as into the consumer market.

Commercial sales in the past few years

As shown in Figure 6, VSAT service was almost purely the domain of large enterprises until 1999 where it was used almost exclusively for standard narrowband point of sale (PoS) type of transactions. Since 2000, broadband-capable VSAT services started being offered routinely. This helped VSAT services penetrate the small and medium enterprise (SME) broadband, as well as the consumer Internet market segments. SMEs and individual consumers use VSAT for typical broadband use such as Internet access. Large enterprises use VSAT broadband for LAN-to-LAN connectivity and Internet access, along with traditional transaction-oriented applications.

In 2000, VSAT terminal sales to large enterprises were approximately \$80M, rising to approximately \$250M in 2006, roughly a three-fold increase. During the same time, terminal sales to SME broadband and consumer Internet customers jumped from less than \$50M to almost \$500M, a ten-fold rise. That clearly highlights the degree of popularity of VSAT broadband.

Broadband VSAT in FTS2001

VSAT services are considered application-level services which provide additional capability and functionality beyond other FTS2001 telecommunications services and that use other FTS2001 telecommunications services for underlying transmission support. For FTS2001, the end-to-end digital connection capability is provided for point-to-point and point-to-multipoint connections. Satellite terminals included dedicated earth stations and VSAT terminals. Data transmissions that are offered are simplex, half duplex, full duplex, asymmetrical, or broadcast. Support of Ethernet interconnect is required; it includes the following data rates:

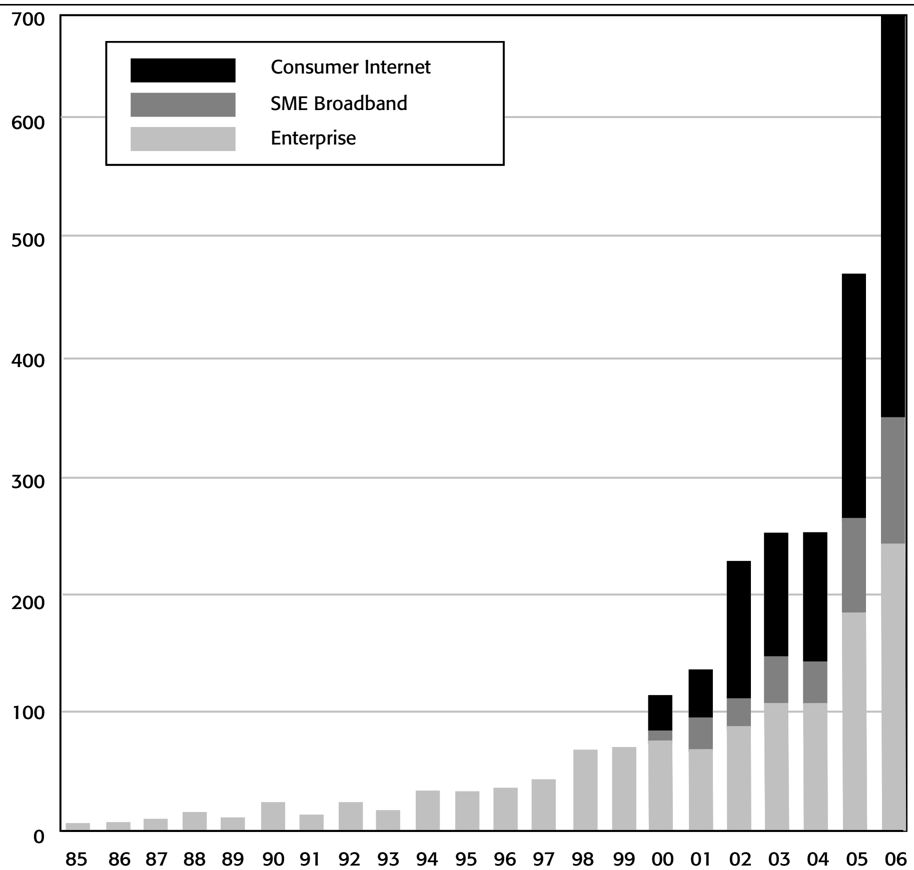

Figure 6. Star data annual sales by customer type—booked terminals

Source: COMSYS Communications Systems, Ltd., "VSAT Statistics," The COMSYS VSAT Report, 10th Edition; http://www.comsys.co.uk/vsatstat.htm.

- Data rates up to DS0 (4.8, 9.6, 19.2, and 56/64 kb/s)
- Data rates up to DS1 (128, 256, 384, 512, and 768 kb/s; and 1.544 Mb/s)
- Data rates at 3.3, 4.5, and 6.6 Mb/s

Department of Defense FTS2001 VSAT service. As a specific example of the use of VSAT in FTS2001, the Department of Defense (DOD) currently consumes roughly 15 percent of total FTS2001 VSAT capacity. The U.S. Air Force and the U.S. Navy's Space and Naval Warfare (SPAWAR) use FTS2001 for Ku-band satellite services. For DOD customers, the FTS2001 vendors offer the same solution provided by their commercial satellite services. This includes reserved transponder capacity and/or VSAT, for providing transmission augmentation and restoration using new and emerging satellite resources. The satellite links for FTS2001 are encrypted. [13]

FTS2001 Internet VSAT service. As stated above, VSAT services are considered application-level services which provide additional capability and functionality beyond other FTS2001 telecommunications services and that use other FTS2001 telecommunications services for underlying transmission support. Two specific FTS2001-based VSAT services are Internet broadband satellite services and iDirect broadband VSAT services.

Internet broadband satellite services. Internet VSAT services were first introduced to the FTS2001 long distance contract in January 2003 as a *value-added service*. This was an Ethernet-based two-way satellite service that used an IP infrastructure to deliver broadband access to locations within the contiguous lower 48 states. To provide this service, FTS2001 vendors rely on fourth generation VSAT technology allowing for broadband remote access to end users.

After an initial service trial period, the services were awarded and added to the FTS2001 contract through contract modification proposals. In January 2005, a more comprehensive solution termed Internet Broadband Satellite Corporate (IBSC) was added to the FTS2001 contract. IBSC is an extension of terrestrial networks by coupling the third party Tachyon satellite network with existing FTS2001 IP networks. [14] The service provides agencies with IP access to areas unreachable by traditional landlines, and service is available within the contiguous U.S. (CONUS), Alaska, Hawaii, Canada, Puerto Rico, Guatemala, and the U.S. Virgin Islands. Service is also available in Europe, parts of the Middle East, North Africa, and Latin America.

The FTS2001 IBSC solution provides two-way broadband Internet access solutions via satellite with terrestrial-like speed and performance. IBSC uses a fourth generation VSAT platform. Broadband access via satellite connects an agency's remote business location directly to the Internet, Intranet, or WAN/LAN network at speeds of up to 1.544 Mbps. IBSC is available with fast and easy installation and is targeted to be functional within 20 business days for fixed connectivity, or 10 business days for delivery and deployment of transportable units.

IBSC network architecture supports IPSec capability, has reliability of 99.9 percent, is available 24x7, and supports most (TCP/IP) applications that operate on the Internet. The customer premise equipment (CPE) located at the customer's remote location routes IP traffic via the satellite link through the Tachyon gateway to the public Internet or the customer's LAN. From the perspective of the remote network, the CPE functions as a standards-compliant static router, integrating with existing customer infrastructure. The CPE includes a small satellite dish with radio and Tachyon's indoor unit. This offering also included various antenna sizes, backup services, and quick-deploy options. Pricing for primary service with a 1.2 m antenna without de-icer is presented in Table 1.

Later in the same year, a newer version of IBSC was introduced for small and medium business (SMB) customers. Table 2 shows a limited number of bandwidth options are available.

Table 1. FTS2001 IBSC prices

Service Description	Non-Recurring Charge ($)	Monthly Recurring Charge ($)
Primary 128 x 128 Kbps	3,171	350
Primary 256 x 128 Kbps	3,171	375
Primary 384 x 128 Kbps	3,171	450
Primary 512 x 128 Kbps	3,385	1,000
Primary 768 x 128 Kbps	3,385	1,200
Primary 1.544 x 256 Kbps	3,385	2,275

Table 2. FTS2001 Internet satellite SMB prices

Service Description	Non-Recurring Charge ($)	Monthly Recurring Charge ($)
Primary 384 x 128 Kbps—for SMB	2,675	294.25
Primary 768 x 256 Kbps—for SMB	2,675	385.20
Primary 1.544 x 256 Kbps—for SMB	2,675	470.80

Comparison of IBSC and SMB prices shows that for the same bandwidth, the SMB pricing is significantly lower. SMBs have a smaller number of users per unit and, as such, the number of simultaneous users of a satellite channel is expected to be lower for SMBs. This would imply that the traffic load for SMBs for the same bandwidth will be less leading to less frequent use of the satellite channel and, hence, the reduced price.

iDirect broadband VSAT services. The latest and most advanced broadband satellite service available to the FTS2001 contract is the iDirect (a third party) satellite added in November 2006. iDirect is available in the CONUS and works in conjunction with existing transport networks such as VBNS+ or Private IP. iDirect also meets existing security and encryption standards, making it a secure alternative to existing satellite-based service. FTS2001 iDirect pricing is shown in Table 3.

This service is even less expensive than the IBSC and SMB services. It is available over a wide range of bandwidth (from 32 Kbps to 4,096 Kbps). It is highly scalable as the bandwidth supported increases incrementally in relatively small steps of 128 Kbps. Even for very high speeds, two-way symmetric bandwidths is the norm. That makes it suitable for customers with all types of needs. It also makes for easy service upgrade.

Table 3. FTS2001 iDirect prices

Service Description	Non-Recurring Charge ($)	Monthly Recurring Charge ($)
iDirect Primary 32 x 32 Data	2,906.54	55.00
iDirect Primary 64 x 64 Data	2,906.54	73.83
iDirect Primary 128 x 128 Data	2,906.54	118.69
iDirect Primary 256 x 256 Data	2,906.54	209.35
iDirect Primary 384 x 384 Data	2,906.54	299.07
iDirect Primary 512 x 512 Data	2,906.54	388.79
iDirect Primary 768 x 768 Data	4,504.67	569.16
iDirect Primary 1024 x 1024 Data	4,504.67	749.53
iDirect Primary 1024 x 1544 Data	5,401.87	931.78
iDirect Primary 1024 x 2048 Data	5,401.87	1,109.35
iDirect Primary 1544 x 1544 Data	5,401.87	1,114.95
iDirect Primary 1544 x 2048 Data	5,401.87	1,301.87
iDirect Primary 2048 x 2048 Data	5,401.87	1,470.09
iDirect Primary 4096 x 4096 Data	12,049.91	3,282.64

The iDirect system has features and controls that allow agencies to deliver application QoS and other traffic engineered solutions to end users. The iDirect system also provides TCP and Web acceleration in both directions, and supports line-rate TCP throughputs in the network. In addition, iDirect includes optional 3-DES link encryption, ensuring encryption from originating to terminating end-point. iDirect services include primary and backup access service, QoS, management, various antenna and converter configurations, mounts, spares, and installation services. Pricing for QoS is shown in Table 4.

iDirect is a truly fifth generation VSAT technology, offering a satellite-based broadband network that supports VoIP, streaming media, Internet access, and data backup. [15]

Table 4. FTS2001 iDirect with QoS prices

Service Description	Monthly Charge ($)
iDirect with QoS Primary 32 x 32 Data	928.97
iDirect with QoS Primary 64 x 64 Data	1,829.91
iDirect with QoS Primary 96 x 96 Data	2,730.84
iDirect with QoS Primary 128 x 128 Data	3,419.68
iDirect with QoS Primary 256 x 256 Data	7,233.64
iDirect with QoS Primary 384 x 384 Data	10,836.45
iDirect with QoS Primary 512 x 512 Data	14,439.25
iDirect with QoS Primary 544 x 544 Data	14,444.32
iDirect with QoS Primary 768 x 768 Data	21,644.86
Private IP Primary 1024 x 1024 Data, MRC	28,849.53
iDirect with QoS Primary 1536 x 1536 Data	40,734.32
iDirect with QoS Primary 1792 x 1792 Data	47,518.24
iDirect with QoS Primary 2048 x 2048 Data	57,671.03
iDirect with QoS Backup 32 x 32 Data	148.60
iDirect with QoS Backup 64 x 64 Data	259.81
iDirect with QoS Backup 96 x 96 Data	371.03
iDirect with QoS Backup 128 x 128 Data	454.08
iDirect with QoS Backup 256 x 256 Data	926.17
iDirect with QoS Backup 384 x 384 Data	1,371.03
iDirect with QoS Backup 512 x 512 Data	1,814.95
iDirect with QoS Backup 544 x 544 Data	1,813.68
iDirect with QoS Backup 768 x 768 Data	2,703.74
iDirect with QoS Backup 1024 x 1024 Data	3,592.52
iDirect with QoS Backup 1536 x 1536 Data	5,055.60
iDirect with QoS Backup 1792 x 1792 Data	5,892.48
iDirect with QoS Backup 2048 x 2048 Data	7,146.73

Scope of offerings in Networx

The GSA Networx contract, the follow-on for FTS2001, has extensive provision for satellite services. As in FTS2001,VSAT is included in Networx as an option within the FSS category. It provides for the use of voice, data, and video services over full and half duplex transmissions. It specifies all three frequency bands—C, Ku, and Ka. Multiple VSAT terminal sizes are included. Networx allows for the support of high bandwidth and support for QoS is specified explicitly. Networx provides for either permanent or temporary locations for systems and point-to-point connections.

Fifth generation VSAT platforms provide support for Ka-band frequencies (20 to 30 GHz). Of the three bands, Ka has the smallest wavelength and can use the smallest antenna to deliver the same throughput. Using Ka-band transmission and relatively large 3 m antennas, it is possible to deliver data rates above 8 Mbps.

Popularity of VSAT is expected to continue the FTS2001 positive growth trends and exhibit further growth under Networx. As agencies begin procuring Networx-based VSAT services and features, it is likely that more detailed specifications for Networx VSAT pricing formats will be required and contract modifications containing specific prices for various services and features will be proposed by vendors.

Conclusions

This paper has detailed the new directions in satellite broadband technology. A broad overview has been presented showing why this new avenue in satellite technology is meaningful and important. VSAT broadband has emerged as a leading technology for providing an alternative path into homes and businesses around the world.

The emergence of VSAT and its advantages have been presented. The historical perspective shows how the VSAT industry and technology have grown with the steady demands worldwide for increasing bandwidth. To briefly summarize, some of the advantages previously mentioned include:

- Availability—VSAT services can be deployed almost anywhere
- Flexibility—Easy to deploy and can be readily moved
- Redundancy—Can provide backup capability at an affordable price
- Scalable date structures—Can provide delivery of what is needed
- Performance—Insensitive to terrain or distance
- Footprint expansion—Allows service opportunities remote from current vendor footprint
- Cost advantages—Alternatives for instant backup and disaster recovery

The growth in the VSAT broadband market demonstrates the increasing viability of the technology. Annual sales by customer type from 1985 to 2006 display a logarithmic growth curve which clearly denotes the exponential demand for services. Annual sales in 1985 were approximately $2M, while in 2006 it approached almost $700M.

There are some remaining challenges to be addressed by VSAT broadband in regards to cost and performance, but the ubiquity and all-encompassing backup and availability capability which is independent of potential disaster scenarios in terrestrial networks will provide a clear and increasing path to further growth. ■

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