Emerging Technology: Broadband from Outer Space

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Jan 7, 2002 (9:37 AM)
URL: http://www.networkmagazine.com/article/NMG20020104S0001

The broadband market came down to Earth last year. Cable, wireless, and DSL once promised to provide high data rates at low cost, but all three have suffered major setbacks. With fiber far from most areas, it seems we're stuck with either high-priced T1 or slow dial up.

Cable targets the residential market. Incumbent carriers that would rather pay fines than allow competitors to challenge their monopoly have driven DSL providers out of business. AT&T and Sprint are both winding down their fixed-wireless divisions, citing lack of demand and technical issues.

But one type of broadband is still flying high. Satellite networks are finding a new way to compete in the local loop, providing high speeds and global coverage. These networks are about to get faster and cheaper, thanks to a new generation of satellites launching this year. In this article you'll learn about broadband satellite services, how they work, and what to expect from these services in the future.

Three companies plan to build and operate these new broadband networks: Spaceway (www.spaceway.com), developed by General Motors' spin-off Hughes; Astrolink (www.astrolink.com), from aerospace giant Lockheed Martin; and Euro Skyway (www.euroskyway.it), from Italian company Alenia Spazio.

These networks use satellites containing their own switches, along with highly focused antennas that target particular neighborhoods or individual customers. The companies say these networks will enable them to serve anyone, from an individual consumer to the largest enterprise. Only Spaceway and Hughes promise global service; Alenia Spazio will only cover Europe and Asia. (See table).

RING TOPOLOGY

Don't confuse these new networks with the ill-fated Low Earth Orbit (LEO) constellations such as Iridium (www.iridium.com) and Globalstar (www.globalstar.com), which need dozens of satellites and are aimed at mobile telephony. Though some companies have broadband LEOs on the drawing board, they won't launch until some financial and technical problems are resolved. LEOs have been four years away for most of the last decade.

The services rolling out in 2002 and 2003 are based on a variant of tried-and-tested fixed satellite technology, used by thousands of businesses and millions of TV viewers worldwide. The satellites fly in a Geostationary Earth Orbit (GEO), which is tied to the earth's rotation, so the satellites seem to hang in a fixed position in the sky. Customers

access them through a Very Small Aperture Terminal (VSAT), not necessarily dish-shaped anymore. And some VSATs don't have to be pointed at the satellite, though all require a direct line of sight.

The next generation of fixed satellite technology will add new technology to overcome two of the GEO's longstanding problems: It's a long way from Earth-22,300 miles-and the orbit forces satellites over the equator. The great distance means that, even at the speed of light, radio waves take a noticeable time to travel to the satellites and back. This distance caused the time delay that once plagued international phone calls, but this delay has now all but disappeared because the signals are routed over fiber instead.

The delay is exacerbated by the "bent pipe" architecture of existing networks. The satellite amplifies a signal and sends it back to a switch on the ground for processing (see Figure 1). If both ends of a communications link rely on this satellite, the data has to make two roundtrips into space, pushing latency to more than half a second.

Engineers can't change the speed of light, but they can reduce the distance signals have to travel. Spaceway, Astrolink, and Euro Skyway will all put switching intelligence onboard the satellite, so two users can communicate directly. Spaceway also has Intersatellite Links (ISL), which can bypass the Earth even when different satellites serve the two users. When the network becomes truly global in 2004, data might travel through several satellites going from one side of the Earth to the other.

Equatorial orbits make satellites difficult for people to use at latitudes in the far north or south for two reasons. First, radio waves have to pass through a large cross section of the atmosphere to reach high latitudes, reducing signal strength and requiring users to have a larger dish (see Figure 2). Second, if the satellite lies low on the horizon, buildings or trees can block the line of sight.

GEO satellites can't surmount this blocking barrier, which led the LEO constellations to tout the benefits of satellites scattered all over the sky. (If you're outside, you can almost always reach an Iridium or Globalstar LEO satellite.) However, the blocking problem actually affects few users. High buildings tend to be in major business districts, where fiber is a better alternative to satellite. It's true that low-lying snowdrifts can block the field of view in the polar regions, but most people who pass through the Arctic aren't on the ground, they're in planes, where a line of sight is guaranteed.

The new fixed satellite technologies overcome atmospheric fading by increasing signal strength. They use targeted beams, which point a transmission directly to whoever needs it. This approach also gives the networks increased capacity by reusing the same spectrum in different areas, meaning users don't need to filter out data intended for others. Existing satellites are inherently point-to-multipoint, broadcasting data throughout their coverage area, so it's wasteful to use them for point-to-point applications, such as corporate network access and interactive Web surfing.

"Satellite capacity is still very expensive, and its big advantage is that you can broadcast it to a lot of users at once," says Jonathan Barter, data broadcast manager at Kingston Consulting (www.kingstonconsulting.com), a system integrator specializing in satellites. Without localized beams, that advantage is lost.

BLOATED WINDOWS

Spaceway is set to launch in 2002, but will initially serve only the continental United States ("Conus," in satellite parlance.) Global coverage, and the Spaceway network's competitors, won't arrive until 2003 or 2004. If you can't wait, you can still find some innovative new services that use existing satellites. These services employ new technology in the ground segment, including the user's VSAT, the service provider's switch, or both.

The point-to-multipoint bias of most satellites is usually a problem, but there are two ways that it can be turned into an advantage. The most obvious is to connect an entire network to the satellite, treating it rather like a large Ethernet hub. Whenever a user sends data to the satellite, it gets automatically rebroadcasted to everyone. Again, as in Ethernet, the transmissions are not coordinated, so collisions occur if the network becomes overloaded. Whenever this occurs, the data is simply re-sent.

The latency makes collisions more damaging than under Ethernet, but they're also less likely because of the intrinsic asymmetry of most satellite terminals. A typical broadband dish transmits at 512Kbits/sec, but receives at 2Mbits/sec. Up to four dishes can transmit at the same time, but five would cause a collision, compared to two users in Ethernet.

Many companies find this kind of point-to-multipoint network ideal for connecting branch offices, especially those in rural areas. "The terrestrial services were too expensive and were not available to all our stores," says Larry Beckwith, vice president of information services at Bob Evans Farms (www.bobevans.com), a restaurant company. Beckwith needed to link together 400 outlets and chose a private IP network from Spacenet (www.spacenet.com).

Larger networks also favor satellites. The U.S. Postal Service, Spacenet's biggest customer (measured by number of nodes), uses the Spacenet system to connect 17,000 post offices in remote areas. Most of Spacenet's customers are in North America, but the company covers most of the world. Spacenet uses satellites run by Gilat Satellite Networks (www.gilat.com), its parent company, and adds some proprietary techniques to overcome problems high latency has traditionally caused with Internet protocols. IP itself is okay, but TCP and HTTP both need modification to function correctly with GEO satellites.

TCP usually waits for an acknowledgement that one batch of IP packets has been received before it sends the next. Combined with high latency, this reduces throughput to a small fraction of the real link speed. This can even break the network entirely if the delay is so long that the sending node times out and resends the packets.

TCPSat, the standard solution, increases the size of the "window," the amount of data TCP can send before pausing for an acknowledgement. TCPSat is described in RFCs 2488 and 2414, and built in to some TCP/IP stacks. Spacenet augmented this by spoofing the acknowledgements and sending data through the connectionless UDP protocol. This protocol has less tolerance for errors, but errors are less likely. Satellite links are more reliable than most other kinds of network because they don't separate the local access lines from the intercontinental backbone.

LATENT IMAGE

The problems with HTTP aren't as serious, but they can still slow Web page display by several seconds. Browsers must load a page's main HTML file before requesting each of its linked style sheets and embedded images or applets. Each request entails a separate roundtrip to the server.

This approach makes sense over a narrowband link because most people want to read the text in a page without having to wait for images to load, but it isn't necessary with broadband. To speed up the process, Spacenet runs a proxy that scans HTML code for embedded objects, requesting them before the page is sent.

Start-up Tachyon (www.tachyon.com) uses TCP and HTTP acceleration techniques similar to Spacenet's, but adds a twist. Tachyon tries to boost Web surfing speed by using the satellite's point-to-multipoint capability as a content-distribution network. Tachyon's technology is based on caching for the same reason that many ISPs and organizations install Web caches-many Web surfers visit the same sites and don't interact with them, so the Web caches can save bandwidth by keeping a local copy of popular sites.

However, Tachyon uses a separate cache for every user, not a central one shared by a network. The cache sits on a separate appliance (a Pentium-class PC with a large disk drive) installed next to the user's dish, and the cache is updated continuously by content broadcast from the satellite. When a user requests a Web page, it can often be retrieved instantly from the cache, saving bandwidth and time.

The drawback to separate caches is the same as with all caching: They don't help with interactive applications or encrypted links, both of which corporate VPNs and well-hyped Web services use extensively. Even Web sites that appear static are often implemented using uncacheable Java Server Page (JSP) or Active Server Page (ASP) code, which can personalize a site for each user or help it mesh with a back-end database.

Tachyon doesn't operate its own network. Instead, it leases transponders (blocks of frequencies on specific satellites, typically sufficient for T3 or 45Mbits/sec) from other operators, so it reaches new markets quickly. So far, Tachyon is available in Europe and the United States.

Because launching satellites is risky and expensive, leasing transponders is a popular way for small operators such as Tachyon to get into the market. Large corporate users who

want to build their own network can also choose this option. Because capacity can go almost anywhere, GEO transponders have become even more commodifed than other kinds of bandwidth. They even have their own special marketplace, the London Satellite Exchange (www.e-sax.com), which publishes a price index showing a steady downward trend.

DON'T TRY THIS AT HOME

Satellites are also becoming a popular option in the consumer market, offering services that seem superficially similar to Spacenet and Tachyon. Although they're cheaper, business users should be careful before choosing them, even for employees working at home.

Starband (www.starband.com), a joint venture between Gilat and satellite TV operator Echostar (www.echostar.com), offers the first two-way consumer satellite service. Customers can use the same dish for both TV and Internet, because the satellites serving both are close together. Starband's price and performance is supposedly comparable to DSL, but without the limited availability.

Starband sounds good, but it's strictly for consumers. Its IP acceleration scheme is implemented so it doesn't function with many VPN clients, meaning many remote workers will experience problems. Worse, the Starband service agreement contains a clause granting Starband a royalty-free license to copy and distribute work transmitted through the service.

Many consumers use one-way satellite Internet connections pioneered by DirecPC from Hughes. These connections transmit Web pages to a user via satellite, but rely on a dial-up modem and phone to send the user's mouse clicks back to an ISP. They're inexpensive, but only suitable for Web surfing. DirecPC's other weakness is that it ties up the user's phone line, unlike true broadband technologies.

Still, DirecPC and its clones can be useful for asymmetric applications. And if you don't want to buy from a consumer-focused company, you can even roll your own similar system, thanks to Unidirectional Link Routing (UDLR), a new protocol. Originally developed by Hitachi (www.hitachi.co.jp), Cisco Systems, and France's government-run National Institute for Computer Science Research (www.inria.fr), UDLR was standardized in March 2001 as RFC 3077.

UDLR provides a way to emulate a full-duplex TCP/IP link over any two one-way channels, through tunneling and encapsulation. Though initially used for satellite communications, UDLR is also intended for future Internet delivery schemes. For example, the digital TV standard used outside of the United States has plenty of spare bandwidth for data broadcasting. A cell phone equipped with a TV tuner, already proposed for some location-tracking technologies, could use UDLR to receive wireless Web content at higher speeds than the ordinary cellular link.

Many analysts expect the one-way satellite market to shrink, thanks to cheaper two-way services aimed at consumers. Starband is spawning many imitators, and DirecPC even has a two-way version. BCR Research (www.bcrresearch.com) says that satellite is now the fastest-growing access technology, expected to account for 20.5 percent of all broadband deployments in 2002.

The satellite industry's growth should continue when Spaceway goes online, as this targets both the office and residential markets. (Hughes thinks that it will have enough bandwidth available to serve both adequately. Corporate customers will get a business-class link for a business-class price, while lower-paying consumers get a less reliable best-effort service.) However, Forrester Research (www.forrester.com) predicts that its upward trajectory will be interrupted, thanks to regulatory wrangling over Hughes' future.

General Motors has been trying to sell Hughes for about two years. Most analysts had expected that it would go to Rupert Murdoch's News Corporation, which already runs satellite TV networks in Europe and has been trying to enter the U.S. market. Instead, Echostar emerged as the buyer in November 2001. As Echostar already has a large share of the U.S. market, this plan has provoked anti-trust concerns. Forrester predicts that, until regulators either approve the takeover or force it to be abandoned, both Echostar and Hughes will focus on satisfying the FCC, not on acquiring new customers or launching advanced new services.

If the takeover does eventually happen, things might not get any better. A lack of competition is likely to result in increased cost and reduced choice for users. Despite its heavenly aspirations, these regulatory wrangles and a possible monopoly make satellite sound a lot like DSL.

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Broadband Reaches Afghanistan

Though most broadband satellites are intended for fixed access, some service providers have shrunk their terminals enough to make them portable. These aren't yet small enough to be carried by regular business travelers-the smallest weighs a few kilograms and just about fits into a briefcase-but they're useful for some specialized applications in regions where you can't find other networks. These terminals have recently found a new application as "videophones," used by war reporters in Afghanistan.

The CNN and BBC correspondents both use the Inmarsat network (www.inmarsat.com), which has always targeted both moving and stationary customers. The system was originally developed for maritime use. Ocean liners were fitted with a large dish that had to remain pointed at a specific point in the sky as the ship moved. Modern terminals can be fitted to smaller and more maneuverable vehicles, thanks to nondirectional antennas with no moving parts.

When most of us hear the word "videophone," we think of a tiny gadget with a small screen in the front. The systems in Afghanistan are different. "Videophone is a slight misnomer," says Stephen Rogers, Inmarsat's communications director. "It's not really a phone; it's a video camera connected to our ground unit."

The setup also includes powerful compression, as the briefcase-sized units only have a throughput of 64Kbits/sec, one-sixth the capacity of a traditional ISDN videoconferencing system. The setup saves on bandwidth by transmitting only the parts of an image that change between frames, so presenters sending live video have learned to stand still. The less they move, the more detail the viewer sees.

Some pay phones in the back of airplane seats also use Inmarsat, though others use the narrowband voice networks. Globalstar, which covers the world with 48 Low Earth Orbit (LEO) satellites, has developed a system that multiplexes several voice channels together to carry video. Globalstar is pushing this system as an aircraft security measure, so ground controllers can see what's happening in the cabin or the cockpit.

Like the other service providers, Inmarsat has plans for even more powerful satellites, again aimed at the portable market. Set to launch in 2004, these will further reduce the terminal size and boost throughput to 432Kbits/sec. That's still less than some existing fixed systems, but the ground units should be small enough for travelers to slip inside a laptop bag.

Resources

The Global VSAT Forum, www.gvf.org, is the industry's trade association. Its site details the benefits of satellite services and campaigns to simplify and unify the complex regulations surrounding international networking.

Consulting firm Analysis has a searchable database of satellite constellations at www.analysis.com/scripts/satellite.exe?pto=info.

One of the best sources of information about satellite networking is at www.ee.surrey.ac.uk/Personal/L.Wood/constellations/. Even though this is an amateur site run by a Ph.D. student, it's more useful than most of the professional sites.

You can find more about Unidirectional Link Routing (UDLR) at Udicast, www.udcast.fr, a company started by the protocol's developers.