The Orbiting Internet: Fiber in the Sky

Byte, November 1997 / Cover Story / The Orbiting Internet: Fiber in the Sky

The Orbiting Internet: Fiber in the Sky

Broadband satellite systems stand ready to bring multimegabit data rates worldwide. Sounds great. What's the catch?

By John Montgomery

Something special is in the air: your data. Or, at least, it's about to be. The technological and regulatory hurdles to create true high-speed satellite networks have fallen. We've seen low- and mid-bandwidth systems such as Motorola's Iridium and Hughes' DirecPC. But those were almost a parlor trick compared to the promise of 2 Mbps, 20 Mbps, and even 155 Mbps streaming down from the sky. And all you need is a small antenna, a satellite-to-computer gateway (a small black box), and the service itself. In all, you'll probably buy satellite service pretty much the way you buy Internet service from an Internet service provider (ISP) today.

So, it's time to ditch your T1 lines and asynchronous transfer mode (ATM) hardware, right? Not quite yet. Just as Iridium's universal telephone didn't kill the cellular phone, broadband satellite systems won't kill terrestrial lines. Every broadband satellite system creator I talked to was clear that broadband satellite systems will complement terrestrial networks. They will provide high-speed service where terrestrial infrastructure does not exist, and they will enable easy multipoint distribution of video. But high-speed, low-cost landlines are here to stay.

So where will these emerging data networks fit in? Better yet, how will they fit in? What makes them different from each other? Simple questions, it seems. The answers are also simple -- at least until you start to dig. By examining some of the main systems in development, I was able to determine that these systems, while touting much the same capabilities, are vastly different. Some of the most visible ones may prove the most difficult to implement. Some of the most staid-looking systems may beat every other system to the punch.

Playing with the Bands

Satellite communications is nothing new. For years, you could hook up a very small aperture terminal (VSAT) system and buy time on a satellite. Dennis Conti, vice president of VSAT at Hughes Network Systems, says that a VSAT system can deliver up to 24 Mbps in a point-to-multipoint link (e.g., a multicast) and up to 1.5 Mbps in a point-to-point link. Pretty impressive statistics.

But, according to Tony Trujillo, director of corporate communications at Intelsat, a leading global satellite operator, with VSAT, "customers buy very specific time on a specific satellite." This creates a system that's good for predictable communications (e.g., periodic uplinks by news agencies or satellite offices), but not so good for the ad hoc networking that most of us are used to.

For "anytime, anywhere" networking, you need new technologies. Primary among them are more tightly focused beams and digital signal technology, which together can increase frequency reuse (and thereby increase bandwidth) and reduce dish size from meters to centimeters. According to some, you also need a large and unused chunk of the electromagnetic spectrum.

All these technical requirements began to come together in 1993, when NASA launched its Advanced Communication Technology Satellite, or ACTS (see the sidebar "NASA Gets into the ACTS"). ACTS pioneered the testing of an all-digital, Ka-band (20-30 GHz), spot-beam, geosynchronous earth orbit (GEO) satellite system -- for definitions of these terms, see the sidebars "The Air Up There," "NASA Gets into the ACTS," and "I'm with the Band" -- capable of delivering hundreds of megabits per second of bandwidth. With NASA showing that such a system could work (and offering time on the system to interested institutions), it was not long before others were interested. Very interested.

Earlier this year, the FCC granted orbital locations and Ka-band licenses to 13 companies. Some are names you may recognize: EchoStar, Hughes, Loral, and Motorola. Others may be more obscure: Ka-Star, NetSat 28, PanAmSat, and Teledesic. Regardless of name recognition, they all aim to bring information into your home and office at incredible speeds -- up to 155 Mbps. These broadband systems are not going on-line before 2000 (although Loral's Cyberstar will start offering 400-Kbps rates next year), and most will not be fully operational until 2002.

What are they going to use it for? According to the FCC, just about everything you would use a terrestrial line for: desktop-to-desktop videoconferencing, Internet access, electronic messaging, faxing, telemedicine, direct-to-home video, electronic transaction processing, distance learning, and even news gathering.

Is This Trip Necessary?

Who needs this stuff, anyway? Most of the market that needs data services seems to be well served by landlines. "These systems will be important globally. In the U.S.? We're well served, although things are changing quickly," says Erwin Edelman of NASA's Lewis Research Center.

A first guess at an obvious market is in places that have underdeveloped communications infrastructures. In some countries, stringing copper or fiber is out of the question -- the empty distances to cover are too great and available money is too little. (There are places where people will rip down any copper wire to resell it.) Still, a wireless, solar-powered telephone has some appeal. Of course, you don't need a broadband satellite to make phone calls, though. Systems such as Iridium will likely serve that market. Marco Caceres, of the Teal Group, says, "For most of the people in the world, the services Ka-band supplies aren't interesting."

So who does need this new class of broadband satellite communications? The first answer I heard from virtually every broadband vendor is the same: multinational corporations. "For some applications, landlines will always be superior. But when your reach is diverse and you have last- and first-mile problems, then satellite will be the better choice," says Edward Fitzpatrick, Hughes Communications' vice president for Spaceway.

Of course, there are even places in the U.S. that won't get broadband data service for a long time. For example, until recently, BYTE's office in Peterborough, New Hampshire, would have had serious problems getting anything more than a T1. But imagine if one of these satellite services had been in place -- we could have tapped it no matter where we were. That is the second market that most of the broadband vendors cited -- low-population areas.

The main problem satellite systems solve is getting high-bandwidth access to places without a high-bandwidth infrastructure. It's unlikely that a satellite system could compete with Digital Subscriber Line (DSL) to the home or fiber to the office -- if you can get those services. Still, if you're in a rural area of the U.S. -- or in a low-population area in any country -- you may not be able to get such services. Satellites will deliver them, enabling not only high-speed Internet browsing (a technology that some industry pundits focus on relentlessly), but all forms of high-speed networking, including such things as videoconferencing, collaborative work sharing, and telemedicine.

Is the telephone dead? Says Teledesic president Russell Daggatt, "It's not going to replace the current phone network – the capacity isn't there." Put simply, terrestrial networks and satellite networks will complement each other. "Nobody's going to put up a satellite dish and take out their telephone," agrees Ron Maehl, president of Cyberstar. "We don't believe satellite should compete with fiber or Asymmetric Digital Subscriber Line (ADSL) -- it should complement them, especially for bursty service. Use the technologies for what they're best suited."

LEO vs. GEO

But bandwidth is only half the story. The other half is latency -- the amount of time for your data to get from point A to point B. Here is where the rubber starts to meet the road. It's all well and good to talk about high-bandwidth satellite systems -- that technology has existed in VSATs for years. But to deliver on the promise of highly interactive satellite networks is a different matter altogether. "There are some applications not suitable to satellite," says Karl Savatiel, president of Astrolink and vice president for broadband systems at Lockheed. "Bond transactions, for example, are too latency-sensitive."

That is true -- at least for a GEO system such as Astrolink. GEO satellites park some 22,300 miles above the equator: 0.24 second -- an eon to computers -- of round trip away. With that kind of latency built into the system (not counting whatever latency is added by the various gateways and translations the data must go through), a telephone conversation is an annoying, awkward mess. And any kind of interactive application has to be nonlatency-sensitive. So Bank of America can probably forget putting its on-line transaction processing (OLTP) system through a geostationary satellite. Such systems include not only Astrolink, but Loral's Cyberstar and Hughes' Spaceway projects.

So here's a simple solution: Move the satellites closer to earth. That's just what systems such as Teledesic, Alcatel's Skybridge, and Motorola's Celestri will do. With low earth orbits (LEOs) under 1000 miles, these systems offer latency that's barely apparent: hundredths of a second.

Of course, it's not that simple. While GEOs are a well-known technology (TV broadcasts, for example, have been using them for decades), LEOs are new and face new challenges. Perhaps the biggest one is that you need a lot of them to get total global coverage. At one point, Teledesic planned a constellation of more than 800 satellites, for example (that number recently dropped to 288 when it signed an agreement to work with Boeing). Until recently, the concept of launching dozens or hundreds of multimillion-dollar satellites was a pipe dream.

Each of Teledesic's 288 satellites will cost in the realm of $20 million, according to Daggatt. That's $5.76 billion just in satellites. That does not include launch fees or insurance -- which, in the case of some satellite systems, is the price of the satellite again.

Price is only one issue. Who is going to launch all these satellites? Teledesic has set an 18-month to two-year launch window to get its 288 satellites airborne. All told, the LEO system creators are talking about putting more satellites into orbit in the next five years than the world has put into orbit since the Soviets launched Sputnik 40 years ago. To make it happen, a huge jump in launch capacity is necessary.

Once the LEO satellites are in orbit, there's an entirely new set of problems. First, there's the matter of space junk: leftovers from past space missions of all sizes, speeds, and lethality. "With all these satellites in orbit, it's possible that debris will start running into them," says the Teal Group's Caceres. "They aren't that far from manned systems." Great -- just what Mir needs.

More Problems for LEO

If the satellites don't get aced by space junk, they still will fall into the atmosphere eventually. Unlike GEOs that, when their operational life is over, move into a parking orbit a few miles higher than normal, LEO systems will burn up in the atmosphere, like SkyLab. Although satellite life may be 10 or 12 years, "with LEOs, you must have a plan for satellite replacement," says Myron Wagner, vice president and director of engineering for Motorola's

Celestri system (a hybrid LEO/GEO system). It's possible, however, and Wagner cites Iridium as a pioneer in this field.

Let's say you solve these challenges. There are more. For example, there's the matter of acquiring and tracking these fast-moving satellites. A LEO satellite may be visible for only 20-30 minutes before it passes over the horizon. This poses no small feat for aiming the antenna and keeping the link active.

A technology called a phased-array antenna solves the antenna problem. Unlike a satellite dish, which mechanically tracks satellite locations, phased-array antennas are self-aiming boxes consisting of many smaller antennas. They can track several satellites using the slightly different signals received by the array of antennas -- without physically moving, reducing wear and tear among other advantages.

The problem of keeping a link active when your satellite disappears every half hour is solved by keeping at least two satellites in view at all times (many LEOs will keep three or more in view). The antenna array is aware of all the satellites' positions and starts a new link before it severs the one to the setting satellite. This is "make before break" in satellite parlance.

All LEOs have to solve these challenges. Some of them have others, too. For example, there is the matter of whether a LEO constellation uses intersatellite routing. The problem is, how do you get a signal from the footprint of one satellite into the footprint of another? In other words, if a LEO user in New York wants to communicate with one in Moscow, the LEO system needs to figure out how to route the signal.

If the system is a bent pipe, such as Alcatel's Skybridge, the satellites don't have to be very smart. The LEO satellite over New York will beam the signal down to a ground station, which will route the signal over landlines to a ground station near Moscow. That station will feed the signal up to the LEO satellite over Moscow, which will in turn bounce it down to the user there.

According to Motorola's Wagner, however, "Bent pipes are not good. There are too many hops from sky to earth." And that means dreaded latency -- defeating the whole reason LEOs are supposed to be better than GEOs. Instead, some systems, including Teledesic and Celestri, use satellite-to-satellite routing. The Teledesic constellation communicates in the 40-50-GHz band. Celestri uses lasers for its links.

The downside is, of course, that each satellite has to have more communications and tracking hardware -- more intelligence -- and therefore a higher price than a bent-pipe system. Also, the performance gain over a bent pipe is not tremendous -- a few hundredths of a second.

Alcatel's Skybridge faces yet another set of challenges, because it selected the Ku- band instead of the Ka-band. According to Mark MacGann, director of public affairs for Skybridge, this lower frequency lets Skybridge be "the cheapest system in low earth orbit." That's because Skybridge can use less powerful transmitters. The Ku- band is pretty crowded, though, with many GEOs working there, and that spells interference when Skybridge satellites are over the equator. "We took the GEO arc," says MacGann, "and defined a nonoperating zone of a minimum of plus or minus 10 degrees. Once a Skybridge satellite comes within that arc, it shuts off its offending beams, and the ground terminal switches to another satellite." A simple solution.

Niches in the GEO Sphere

In spite of the concerns of latency, GEOs and LEOs will likely coexist. Guy Christensen, of Leslie Taylor and Associates, sums up the markets based on whether the system is a GEO, with its inherent 0.24-second delay, or a low-latency LEO. LEOs will be good for high-speed networking, teleconferencing, and telemedicine -- interactive applications. GEOs will be better for information downloading and video distribution -- broadcasting and multicasting.

Some GEO vendors disagree. Hughes' Conti says, "Today, we're able to use GEO satellites to transport at least 24 Mbps of broadcast IP data and over 2 Mbps of point-to-point TCP/IP data. The latter uses technologies such as TCP spoofing. HNS has been using this technique for over three years to deliver Internet/intranet content at high speed to both consumers and enterprises." If necessary, ground terminals using the Spaceway system will use similar TCP spoofing technologies.

But there's still the 0.24-second delay that you just can't get around. Daggatt says that any lossless protocol is going to have problems with this latency. Even if TCP spoofing works (and he is skeptical about that, given TCP's 64-Kb buffer), there's the matter of other protocols. "It's reasonable to think that future network protocols will be designed for terrestrial networks," he says. "You need systems that offer low error rates and low delay. People talk about voice and data as though there were two types of data. They aren't. And if the network doesn't work for voice, it won't work for other applications."

LEO Meets GEO

One of the systems I looked at is considering offering the best of both worlds: a hybrid solution. Motorola's Celestri plans a LEO constellation of 63 satellites (initially) coupled with one GEO satellite over the U.S. Motorola has the rights to eight more GEO orbital slots if it needs them. The LEO constellation and the GEO satellites will be able to communicate directly through a satellite-to-satellite network.

"We want users to be unaware of the kind of system they're using. The only way we know to do that is with a LEO configuration," says Wagner. The hybrid configuration will enable Celestri to take advantage of LEO's shorter delays for interactive uses and GEO's power in the broadcast arena.

Alcatel and Lockheed have had similar thoughts. They are looking at a partnership that will enable Skybridge and Cyberstar to work together through land-based gateways. It's not going to be quite as transparent as Celestri's system, because it will need to route traffic through terrestrial gateways, but it does hint at the power of a hybrid configuration.

Space Security Unit

Once you get beyond the latency and bandwidth issues (which is what the satellite creators spend a lot of time arguing over), there is another challenge: security. If your data is being packaged up and broadcast into space, can't anybody with a scanner just tune in? In theory, the answer is yes. But the access technologies that these systems use -- combinations of code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), and a bunch of other xDMA protocols -- make that at least as difficult as it will be to intercept a digital cellular signal. On top of that, many of the networks will offer some kind of internal security systems. But exactly what kind? Well, that gets a bit murky.

All the vendors I spoke with told me that they were aware of the potential security concerns that customers would have. Few, however, had concrete solutions. Sig Dekany of Astrolink, for example, says, "I can say only that it does involve encryption. Additionally, second-tier security at the user level will come by way of public- key encryption." Representatives at Spaceway and Cyberstar were even less forthcoming, saying only that they were working on the problem and had not yet decided on a solution. Teledesic said that there is encryption within its network, and, if users want, they can add more. That seems to be the general consensus: If you want security, you're going to have to add it yourself.

But is that so different from running private business over any public network? Would you, for example, engage in trusted transactions over the Internet? Of course not. You would purchase some kind of encryption software, a virtual private network (VPN) system, for example. And because all the satellite systems claim that they will be completely transparent to your network, it's likely that the VPN system you purchase for the Internet will work just as well -- and just as transparently -- over a satellite system.

Down-to-Earth Price Tags

What will be the price for this magical universal service? Surprisingly, on a per-bit basis, every company I talked to said it will be probably not much more than what you're paying for your landline services. That may seem like a pretty amazing statement, considering the investment required to get some of these systems running -- Teledesic, for example, is forecasting a $9 billion start-up charge (which some critics say is low); Motorola's Celestri is at $13 billion. But Teledesic president Daggatt thinks it's reasonable. "It's a very high-capacity system. And unlike a wire-line network, where all the capacity of the infrastructure is rigidly dedicated to locations and users regardless of whether they are actually using it at any particular moment, Teledesic offers 'bandwidth on demand,' where the system capacity used is limited to that required by a particular user and a particular application at a particular moment. That allows the high system capacity of the Teledesic network to extend to a very large user base."

Other system operators agree. Savatiel says, "The price can compete with underutilized T1s, like 25 percent utilized T1s." Astrolink will be in the range of 20 to 25 cents per minute for 64 Kbps, but remember that you will pay only for time that you use. "If you provide a good value to end users, you'll be rewarded," says Savatiel. Astrolink will word reseller agreements to try to avoid price gouging -- a practice more common in countries where telecommunications is a monopoly. Cyberstar's Maehl puts it a different way: "We're trying to wait to see what the market wants." He sees Cyberstar's service coming in at about $20 per month for basic service on its Ku-band system (which has a lower bandwidth than the planned Ka-band system) and a similar price on its eventual Ka-band system.

The price you see as a customer, however, is likely to be set by your service provider. Satellite system creators are wholesale service providers. None of the satellite systems will be selling bandwidth to end users. They'll sell to gateway providers such as telephone companies, who will probably resell the satellite bandwidth to service providers (like ISPs), who will sell to customers.

The goal is to make the satellite systems transparent to end users -- you buy the service, and somebody else worries about the plumbing. This transparency is incredibly important. Cyberstar, for example, is working on deals with router vendors to facilitate intelligent routing of hybrid networks. "Satellite guys can't just do satellites -- we have to know about the network architecture as well," says Maehl.

Shooting for the Stars

According to analysts conducting research for Motorola, the total telecommunications market is about $650 billion, and that's going to double in 10 years, chiefly due to data communications. In other words, there are a whole lot of people out there needing a whole lot of bandwidth. And we'll need every hose we have to put out that fire: fiber, ATM, Synchronous Optical Network (SONET), xDSL, Gigabit Ethernet, cable modems, satellites, and probably a few that haven't even been thought of yet.

"I don't think the fact that it's a satellite system is going to make a difference," says Guy

Christensen. He sees all telecommunications systems competing on their availability, price, and speed. That means there are going to be two big winners: whoever gets its broadband service to consumers first, and whoever can offer the most bandwidth with at least not-unreasonable latency.

At this point, the race could fall to any of the companies putting together a broadband satellite system. Or even to someone we've never heard of. The profile of the broadband satellite race has changed a great deal since last spring. AT&T has dropped out. Teledesic changed its configuration. And Motorola is collapsing two of its systems (M-Star and Millennium) into Celestri.

Gentleman, to your launch pads.