Fiber Optics to the Home

Fiber optics has helped push the telecommunications system into hyperdrive. But only when fiber connections reach all the way into the home will the technology's promise be fully realized. BY JEFF HECHT

It's 2020, and the Gernsbacks have settled into their new home. Dad is watching football on the flat-panel screen in his home theater, but he isn't satisfied with standard broadcasts. The Custom SuperView channel lets him select four current or instant-replay views from any of a dozen high-definition cameras stationed around the stadium. Mom is upstairs working, using telepresence to control a robot cleaning up a toxic waste site in New Jersey. Their teenage son is playing three-dimensional chess with a friend in Paris; a supercomputer in New York calculates the data used to show the pieces on their digital holographic displays. His sister, meanwhile, is practicing with a choir made up of people who live in a dozen cities in North and South America; a computer in Mexico City merges their voices and transmits the music back to their computers in real time, while creating an array of their faces on a single screen.

Some of this technology can be found in well-equipped laboratories today, but not in homes. Today's information superhighway lacks the bandwidth to deliver the required signals, deteriorating into a muddy footpath as it reaches your front yard. Most homes connect to the Net through modems that deliver at most 56,000 bits per second. High-end users are switching to cable modems and digital subscriber lines (DSL) that can carry a few megabits per second. That's a big leap ahead, but hardly enough to satisfy the Gernsback household: The scenario described above would demand 100 to 200 megabits per second.

I named our futuristic family after Hugo Gernsback, a technophile and writer who published America's first science-fiction magazine in 1926. But in just a couple of months, some residents of Palo Alto, Calif.,

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will get a taste of these powers when their homes are wired directly to optical fibers. Palo Alto is not alone on the fiber forefront. Last fall, BellSouth began stringing fiber to up to 400 homes in Dunwoody, Ga., an affluent suburb just north of Atlanta. Unlike other fiber-to-the-home systems that have been rolled out in the past as field trials, Dunwoody is a permanent installation. North of the border, Futureway Communications, a new Canadian phone company seeking a niche offering high-end services, is stringing fiber to homes in five Toronto suburbs. Optical Solutions, a young Minneapolis company, is supplying Futureway with fiber connections for 20,000 homes, and has sold hundreds of home links to other small phone companies.

Competing With Copper

These leading-edge systems are still rare. Most telephone and cable television companies rely on fiber only as a "backbone" technology for piping signals between their own facilities. In fact, fibers are the standard links to and from the switching offices serving each community, and often stretch from there to large business customers or neighborhood distribution nodes. A single pair of fibers now can carry up to hundreds of gigabits per second, with each fiber transmitting separate signals at dozens of wavelengths in one direction. Yet the rest of the distribution network is virtually all copper—that's an investment worth well over $100 billion and phone and cable companies are not eager to abandon it. Late last year, regional telephone company SBC Communications announced a three-year, $6 billion fiber construction program in its service area in the western United States.

But conventional wisdom holds that running fiber all the way to a home is too costly, so SBC's fibers will stop at distribution nodes that typically serve hundreds of customers. Data will still slog into the home itself on old-fashioned copper. It's as if a relay team of Olympic-class sprinters had to rely on a geriatric patient for the final leg of the race—known in telecommunications lingo as "the last mile."

Phone and cable companies each promise a different cure for the World Wide Wait suffered by home users of dialup modems *(see "Battle of the Last Mile," p. 52)*. Cable systems deliver up to 36 megabits per second through the same coaxial cable that pipes CNN and HBO to the television set. The phone companies have devised DSL as a ploy to trick ordinary copper wire into behaving as if it were a fatter info-pipe, carrying up to several megabits per second.

People who switch from ordinary Net connections to cable modems typically traverse an arc of experience that begins with delight: The link is always on, just like electricity in a socket, and information flows at speeds that leave dialup modems in the dust. Then the drawbacks become apparent: cable bandwidth is shared among a group of users, so the lightning-fast connections experienced at first start to drag as more of your neighbors sign on. Security is another issue; if file sharing is enabled—a common default setting—everyone on a cable modem line can access your files. DSL has a different problem. The higher signal frequencies that carry DSL's digital data fade as they travel through copper wire, restricting these connections to homes within about five kilometers of cable from a phone switching station. Wireless systems—an emerging high-bandwidth alternative—can suffer blockages from bad weather, trees and buildings.

If the past is any guideline, moreover, demand for bandwidth will soon outstrip the capacity of these jury-rigged alternatives. Already, today's image-intense Web sites crawl when viewed at 56 kilobits/second. Full-motion video, for example, appears as a jerky, low-resolution picture in a corner of the screen. The need for higher capacity into the home is likely to intensify as companies roar ahead with e-commerce. Why show just a static picture and product specifications for a refrigerator if you can have a top salesman deliver a video pitch while demonstrating it on the screen? A reasonable target may be 100 megabits/second, which should enable full-screen, full-motion video and would probably satisfy the Gernsbacks. Then again, satisfaction is a moving target. Bandwidth is a drug; once you're hooked, you only want more. A single optical fiber can easily carry more than 600 megabits/second to individual users—far beyond the capability of either DSL or cable lines. Indeed, DSL and cable modems would whet consumers' appetites by giving them a taste of bandwidth plenty that only fiber can satisfy.

Now is the time to make that investment, at least for new installations, argues Asim Saber, president of Optical Solutions. Saber says that installing fiber will cost an extra 15 percent to 25 percent, but claims that the payoff will come in a few years as bandwidth demand soars. Better, he says, to spend more now than be forced to rip up the sidewalks in 8 or 10 years to add capacity.

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Different This Time?

It's not as if no one has tried fibering homes before. Skeptics point to earlier field trials that have failed to find much of a home market for fiber's tremendous bandwidth. Japan's Ministry for International Trade and Industry sponsored the first, which began service to about 150 homes in 1978. The experiment consumed a staggering $80 million over several years, but—along with similar trials in Canada and France—failed to identify compelling new services that would justify the high cost of installing fiber.

A decade ago, BellSouth and several other U.S. phone companies thought they had found a high-bandwidth activity that consumers would pay for: video on demand. Dozens of homes were fibered in trial systems around the country, but the spark never caught: The level of consumer interest was deemed insufficient to justify the purchase of costly video servers and fiber equipment. Cable companies quickly countered by adding more channels and pay-per-view services to their existing coaxial cables. But a funny thing has happened since the last time fiber was reeled out to domiciles: the Internet. The explosive growth of the World Wide Web has suddenly made millions of people crave bandwidth—a commodity that they scarcely knew existed a few years before.

For the coming decade, fiber-watchers in the United States will want to focus their attention on the southeast. BellSouth—the

phone company that serves the region—"is leading the charge in North America" for fibering the home, says Richard Mack, vice president of KMI, a Newport, R.I.-based market research firm. The interest in new technology reflects the rapid growth of its service area. Most new communities want buried utilities, and it is far cheaper to lay extra fibers for future expansion now than to return years later to dig up streets and yards to replace obsolete cables.

Dunwoody residents will continue to receive voice telephone service over existing copper lines, and customers will be offered two new services over fiber. One is DSL-grade data transmission for $50 to $60 a month. The second is a video service offering 120 digital and 70 analog channels. Next year, the company expects such fiber systems to become standard for large new subdivisions. By then, customers with fiber connections in their homes could install the equipment themselves. "We don't have to roll a truck at all," says Dan Spears, research director at BellSouth Science & Technology.

BellSouth admits that the Dunwoody fiber system is costing more to install than copper, but says the goal is to gain experience with the technology. As the cost of fiber to the home comes down, BellSouth "will deploy it in new build situations as we're now deploying fiber to the curb," says Dave Kettler, vice president of BellSouth Science & Technology.

Scattered groundswells of interest in home fiber connections are appearing in affluent U.S. towns. In Concord, Mass., the Concord Communications Infrastructure Committee, a town advisory panel, has suggested the town build its own digital fiber network to homes. Cable modems have yet to reach the town, many homes are outside the reach of DSL, and both have limited room for expansion, complains Marc Daigle, an engineer and member of the committee.

Palo Alto's city council has already approved spending $380,000 to build a fiber network serving nearly 700 homes in an older area near the city center. Residents will get connections at 10 or 100 megabits per second. They will pay about 70 percent of the cost, including monthly charges plus installation fees of $1,200 or $2,400, depending on data rate. More than 70 people signed up before the city had set a firm price, says Manuel Topete, who is managing the fiber system for the city's utility department.

The system will offer data transmission at otherwise unobtainable speed. "The trial is all based on Internet delivery," says Michael Eager, a Palo Alto consultant active in the project. "I don't think people would have been significantly interested if we were just talking about 500 channels of television."

Optical Solutions also has found strong interest. The company has sold fiber-to-the-home equipment to a dozen carriers in seven states, says president Asim Saber—plus the order from Futureway in Concorde, Ontario, for hardware to serve 20,000 homes in five Toronto suburbs. Founded in 1994, Optical Solutions accelerated its growth from 13 employees in late 1998 to 65 a year later; Saber expects a head count of 120 by later this spring. Last year Optical Solutions, which is betting its future on fiber to the home, also landed a $16 million investment in a private placement.

Futureway represents a new but promising market for Optical Solutions—new phone companies competing for business by offering high-end services unavailable from the big established companies. Similar ventures are starting to pop up elsewhere. In December, WideOpenWest of Littleton, Colo., announced plans to build fiber-to-the-curb systems in the Denver and Portland, Ore., areas. Optical Solutions' other customers are independent phone companies seeking to offer broadband services in rural areas. Rye Telephone of Colorado City, Colo., is installing fiber to 500 homes in a

Battle of the Last Mile

TECHNOLOGY	HOW IT WORKS	CAPACITY (Mbit/s)	ADVANTAGE	LIMITATIONS
Fiber to the home	Fiber carries data to homes. Could also carry broadcast video, either in same signal or at other wavelengths.	Several hundred, up to 1,000	Highest speed	■ Cost of construction
Digital subscriber line (DSL)	Transmits digital data on phone lines at frequencies higher than those used for voice. Frequencies are separated at the home. Individual homes get dedicated lines.	Downstream: 6-8 Upstream: up to 1.5	Can use existing phone lines	■ No service for homes more than 5.5 km from phone switching node ■ Top speeds possible only on short lines ■ Not available for all phone customers
Cable modem	Data travels to home on TV (coaxial) cable in a frequency band used for one video channel. Upstream transmission is at a lower frequency or on phone wires.	Downstream: typically ~1 Upstream: typically 0.1-0.5	Uses existing coaxial cable	■ Individual data rate drops with number of users ■ Poor security ■ Not available on all cable systems
Wireless (terrestrial)	Local antenna broadcasts microwaves, picked up by home antenna. Broadcasts video signals, and can transmit data.	Comparable to DSL	No cable installation	■ Multipath interference from buildings ■ Trees, terrain and rain can block signals ■ Interference possible from other cells ■ Signals travel limited distance (like cell phone)
Wireless (satellite)	Satellite broadcasts data signals; individual receivers pick off their signal. Might be added to direct broadcast satellite service, or to mobile low-earth-orbit service such as Teledesic.	To be defined	No cable, no local broadcast antennas	■ Better suited to broadcasting because of large satellite coverage area ■ Limited data rates likely

sprawling 80-square-kilometer community called Hatchet Ranch. DSL can't handle those distances, and cable companies typically avoid such sprawling areas.

Standardizing Flexibility

For fiber optics to infiltrate a significant number of homes, telephone companies need to settle on technical standards. Just such an effort is under way. Representatives of 20 companies—including British Telecom, BellSouth, France Telecom, Nippon Telegraph and Telephone, GTE and SBC—have teamed to devise a Full Service Access Network (FSAN) running from telephone-company facilities to homes and businesses. FSAN has already been accepted by the International Telecommunications Union and could accelerate the deployment of fiber to the home by providing a set of standards for mass-produced transmission equipment. The FSAN architecture covers a range of fiber uses, from carrying signals to neighborhood nodes and business customers to serving individual homes. FSAN could therefore allow fiber to infiltrate the network piece by piece.

That's important, because fiber is inching its way toward the home. SBC Communications' $6 billion Project Pronto will bring more than 20,000 kilometers of new fiber cable, extending the optical network to within 2.7 kilometers of most of the homes the company serves. SBC isn't alone; US West is laying fiber to within 1.2 kilometers and Bell Canada to within 900 meters, says Claude Roman, an analyst at market research firm RHK in South San Francisco.

And even before Dunwoody, BellSouth was routinely running fiber down every street in new developments. By the end of last year, the company had installed a hybrid fiber/copper service for half a million homes. Buried fiber cables run to service boxes that sit like fat, square fire hydrants along the curb, and copper wires fan out from each box to several homes. In Dunwoody, the company is "overlaying" fiber—stringing it in parallel with existing copper wires to homes.

FSAN makes this expansion easier with a design called a "passive optical network." The idea is to keep costly and sensitive active components, such as transmitters and receivers, on the ends of the system. Instead of directing signals through intermediate switches, the system simply divides the light among as many as 32 output fibers. No components between the central switch and the end of the fiber require electrical power, helping reduce construction and maintenance costs.

Upgrades to an FSAN system should be easy, generally entailing changes only of the equipment at the ends of the fiber. Data speeds can be boosted by dividing fiber capacity among fewer customers. In the longer term, each fiber might carry one wavelength channel per customer—a technique known as wavelength multiplexing *(see "Wavelength Division Multiplexing," TR March/April 1999)*.

As companies **roar** ahead with e-commerce, the capacity required will outstrip that of **jury-rigged** copper alternatives.

The companies that developed the FSAN standard—among them Lucent Technologies, NEC and Hewlett-Packard—stress its adaptability. Some already are designing products. "We're developing a system that will provide low-cost fiber access for small to medium business because we think that's where the most obvious prove-in is for fiber all the way to customers," says Ed Harstead, who manages fiber-to-the-home research at Lucent. Indeed, fiber-to-the-business sales will help drive down prices of hardware for more cost-sensitive applications—a key to launching home fiber systems. British Telecom and France Telecom, two of the companies behind the standard, are eager to apply FSAN to business subscribers; BT plans to run fibers to commercial districts, with fibers branching among businesses as they would among homes. Nippon Telegraph and Telephone, which has tested fiber to the home and is cooperating with BellSouth, is now concentrating on business customers as well. From a technical standpoint, "it's difficult to distinguish fiber to the business from fiber to the home," says Kenji Okada, supervisor of NTT Access Network Service Systems Labs.

Technical standards such as FSAN can't overcome all the hurdles that may impede the fiberization of homes. BellSouth has the advantage of serving a region that is undergoing rapid economic and population growth. That means lots of new housing developments, each one a relatively easy opportunity for fiberization because the ground is already dug up for laying all sorts of power and telecommunications infrastructure. That's not the situation in most of the United States, where installing fiber means new construction. Not to mention the headaches in Europe. BellSouth's Spears says a Telecom Italia colleague was amazed by a photo of a landscape stripped bare by a developer. Spears recalls the Italian told him, "When we go into Rome and start digging in the street, we may run into some artifact, and they put a fence around it and halt construction until archaeologists do their work."

The market for fiber to the home is young, and analysts shy away from forecasting its growth. "It's hard to make projections based on services that don't exist yet," says Jeff Kagan, an industry analyst in Marietta, Ga. In the short term, the biggest question mark is how U.S. consumers and cable operators will respond to digital high-definition television, which will gobble up bandwidth like nothing we have seen so far. In the long term, continued growth of the Internet will push digital demand upward. The static images common on many Web pages load slowly at 56,000 bits/second, driving demand for DSL and cable modems in the megabits/second range. As increasing numbers of Web-site designers yield to the temptation to display moving images, even these lightning-like hookups may begin to feel sluggish.

Extrapolating the 20-fold growth in bandwidth of the 1990s—modems jumped from 2,400 to 56,000 bits/second—leads to a projection that by 2020, 100 megabits/second will be routine. And that may be conservative. Adel Saleh, chief network architect at Corvus in Columbia, Md., says that 100 megabits/second could come to homes as soon as 2005. Saleh predicts that by 2010, wavelength multiplexed systems will provide bandwidth on the order of 1,000 megabits/second. With that kind of capacity, the biggest problem will be figuring out how to tap into our inner Gernsback. TR