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Internet With the Speed of Light

Technology

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The word *broadband* is used a great deal today without much thought given to its meaning. Although digital subscriber lines (DSL) offered over telephone lines and cable modem service from cable television operators are called high-speed broadband, these services can't compare to fiber optic links, which deliver data at least 50 times faster using light rather than electrical waves. While DSL and cable merely offer a faster way to connect to a text-and-graphics Internet, fiber would revolutionize communications by allowing the Internet to be used as personal television. Users could send and receive television-quality, live or recorded video as easily as they could call on the phone or send e-mail.

Thus, while government and the communications industry suggest that DSL and cable modems are the way to bridge the "last mile" between home and office and the Internet, a few are asking if it makes sense to promote these out-of-date technologies and if instead we should be investing in a new communications infrastructure with fiber optics.

The Photophone

Alexander Graham Bell is credited with inventing not only the conventional telephone but also optical telephony. He came up with his telephone in 1876. Four years later, he introduced the "photophone." At a lecture in Boston, Bell pithily described his invention as an "apparatus for the production and reproduction of sound by means of light."

The photophone worked by bouncing light off a mirror that was caused to vibrate by the sound of a human voice. A selenium receiver caught the flickering light, converted it to an electrical current, and fed that to a conventional telephone. In early tests, the photophone could transmit over distances of more than 200 meters. Bell hoped that someday the invention would serve as a wireless telephone. He concluded his Boston lecture by asking that "the scientific favor which was so readily extended to the telephone may be extended by you to this new claimant."

Bell's plea was ignored in the 19th century. The photophone was innovative and the precursor of today's fiber optic technology, but it was handicapped. Its beam of light couldn't pass through objects, around corners, or over the horizon. Better-suited to wireless communications was the radio that Guglielmo Marconi perfected in 1896.

The Copper Wire Infrastructure

Bell concentrated his efforts on commercializing the conventional telephone. The "twisted pair" of copper wires that he began draping from telephone poles still forms the last mile of the "modern," 21st century telephone network.

Another idea for connecting the last mile came from John Walson, an appliance store owner in Mahanoy City, Pa. Walson put an antenna on a mountaintop in June of 1946 and plucked television signals off the air. He then retransmitted those signals via coaxial copper cable to customers who purchased televisions from him. At the time, this was known as community antenna television or CATV. Today, it's called cable television.

Thus, the nation is stitched together with two different, wire communications networks: one for telephones, the other for cable television. Their wires sag from utility poles and snake through underground conduits to offices, apartments, and houses.

Then, with the advent of the personal computer and the Internet, the public discovered communications could mean something more than just chatting on the phone or watching television. The last mile became the on-ramp to the information super highway.

Broadband and Last Mile Speed

One definition of broadband is "operating at, responsive to, or comprising a wide band of frequencies." But the term is also applied to high-speed digital transmissions. Speed is measured by the "bit rate" or the number of bits transmitted per second (bps), where a bit is "1" or "0."

Because the telephone network was originally designed to carry only the narrow band of signals needed to transmit analog voice conversations, it didn't readily lend itself to high-speed digital transmissions. The early modems, which computers need to "talk" over telephone lines, transmitted at 300 bps. Modem speeds then increased until reaching the current maximum of 56,000 bps or 56 kilobits per second (Kbps).

More speed can be tweaked from telephone wires by using DSL technology. DSL can reach speeds of 6 megabits per second (Mbps) for short distances. When delivered over longer distances, such as to the typical home, DSL peaks at 1.5 Mbps. (A megabit equals 1 million bits or 1,000 kilobits. Thus, 1.5 Mbps service is 27 times faster than 56 Kbps service.) There are different varieties of DSL on the market, some of which are even slower. A commonly marketed version for the home operates at only 384 Kbps.

Cable television companies, on the other hand, have true broadband transmission pipelines to work with. The twisted-pair and the telephone network were designed only for the frequencies needed to carry voice communications, but the thick coaxial cables of cable television can carry multiple channels of frequency-hogging video signals. Advanced cable systems can transmit 110 channels of standard, analog video signals over a single coaxial cable. By converting to digital transmission technology, they can use "compression" techniques to squeeze additional programs into each channel, thus providing the consumer with hundreds of channels of programming.

Many cable companies have decided that the provision of Internet access is lucrative enough to merit devoting at least one channel to such use. A single analog cable channel, when devoted to digital transmission, has a 27 Mbps capacity. But, this must be partitioned between upstream and downstream use and shared by multiple cable subscribers. As a result, users typically experience a download speed of 2.0 Mbps or less.

The Speed of Fiber

Meanwhile, scientists and engineers were figuring out how to make practical use of Alexander Graham Bell's idea of a photophone through the use of lasers and optical fiber technology. With ultra pure glass fibers as conduits and signal boosters at regular intervals, laser light can bypass obstructions and travel for thousands of miles.

Light excels at high-speed digital transmission. Indeed, its speed depends not on the thickness of the strand but, rather, on the speed at which the lasers and the signal boosters can flicker. A single fiber can transmit at 1, 10, 100, or 800 gigabits per second (Gbps), depending on the lasers and boosters used. (One gigabit equals a billion bits or 1,000 megabits.) Of course, the higher the speed of the lasers and boosters, the more expensive they are. As a result, the speed of a fiber optic line is determined as much by economics as by engineering.

Proposals to string fiber optics to homes and offices—to cover the last mile of the communications network—plan on a speed of at least 1 Gbps. The proposals assume a single strand will be shared by multiple users, just as with cable, and so the speed available to an individual user is usually stated as 100 Mbps. Still, this is between 50 and 260 times faster than cable modem service and home-DSL and almost 1,800 times faster than a 56 Kbps modem. Moreover, the speed of a fiber link can be changed merely by replacing the lasers and boosters, obviating the need to lay down more cable to increase capacity in the future.

Personal Television

What makes fiber to homes and offices radically different from competing technologies is that it can transmit live, high-quality, full-motion video in both directions. As users of DSL and cable modem service well know, these services currently are not capable of bringing DVD-quality television pictures to the home in real time—much less send it out. A DVD-quality signal, when digitized and compressed using current standards, requires roughly 5 Mbps capacity for real-time transmission. This is beyond the capability of DSL and cable modems. A high-definition television signal requires more bandwidth. Even with compression, it needs 20 Mbps. In other words, neither DSL nor cable modems can transmit quality video in real time, but a single strand of fiber could deliver 20 standard-definition or five high-definition channels of video.

Fiber's capacity could bring about fundamental changes in the way people communicate. For example, for entertainment purposes, such as video on demand, fiber could transform the video rental and cable television business by delivering programming to the consumer through a single strand with telephone service thrown in to boot.

More important, the high capacity of fiber could turn the Internet into personal television. You could be at work and watch your child at day care or school. You could show an injury to your doctor before deciding if an office visit is needed. You could call your aging relative on a video phone and see for yourself how she was doing. You could have weekly video get-togethers with a family scattered around the world. You could have business teleconferences from your office, home, or anywhere else that had fiber optic access. Dispatchers and supervisors for emergency services could see the situation even before the response team arrived. Educators would have a significant new tool for teaching and interacting with students.

Fiber's capacity is so much greater than existing wire technologies that if Alexander Graham Bell were to start over again today, his photophone would prevail. All the "wires" in the network would be fiber optic cables.

The Obstacles to Fiber

But if fiber is such a superior technology, why isn't it being deployed to homes and offices?

First, nearly every home and office in the country already has a telephone line, and many of these are suitable for at least the slow version of DSL. According to Federal Communications Commission statistics, there are 174 million switched, business, and residential access lines in the United States. Virtually all these lines are copper. Fiber lines are used to connect telephone switching centers, but, except for a handful of newly constructed projects, none of these runs to the home.

Replacing the existing copper wire access lines with fiber optic cable would be a huge financial undertaking. One estimate puts the average cost of laying fiber optic cable to homes and businesses at $1,200 per line. Although the cost might drop if widespread fiber installations began, the price tag for rewiring every single one of the 174 million telephone access lines in the country might be on the order of $200 billion. For new installations though—for new homes and buildings that do not have an existing telephone access line—laying fiber should cost the same as laying copper wire.

The economics get better if fiber optic cable is also used to provide cable television service. In this case, there would be only one line running to the home and added revenue for the cable service. For example, if customers are willing to pay $30 per month for telephone service and $40 per month for cable television service, then they should be willing to pay more than $70 per month for a fiber optic connection that can provide both services plus Internet video access.

Second, the value of a network increases only as the number of subscribers increase. A single telephone is worthless unless there is someone to call. By the same token, a distinguishing feature of fiber to the home—the ability to transmit video—is of no practical benefit unless other users have that feature as well. Thus, fiber must be widely deployed, and yet the cost of wide deployment is substantial. Of course, the $200 billion estimated cost of rewiring the country with fiber could be compared with the federal highway budget of $32 billion for FY 2002. If an equal amount were invested annually to deploy last-mile fiber along the information superhighway, the whole country might be rewired in seven years.

Third, broadband is only as broad as its narrowest link. That is, it does little good to have a 100 Mbps fiber cable to the home unless the upstream connections are at least as fast. Users who connect to the Internet from their offices via 10 Mbps local area networks may have noticed that they still aren't surfing at blinding speed. This is because office LANs often connect to the Internet through a so-called T-1 line, which operates at only 1.5 Mbps. Thus, the entire communications network must be brought up to speed—although much of it already is.

Fourth, questions arise as to what business model to follow for fiber. The federal government had no role in the creation of the telephone network. Alexander Graham Bell and his companies obtained easements from local governments, strung wires down the streets, and acquired other companies that had strung wire. Twenty-seven years later, they had a national monopoly that only then drew the concern of the federal government. Cable television's history is not too different.

Other infrastructures followed different business models. Government built the roads and the real superhighways. Government owns and operates water and sewer facilities. Some electric utilities are owned by government; others are owned privately, but subject to government regulation. Railroads were built by private corporations with massive incentives from the federal government, and passenger service is now run by the federal government.

A policy of deregulation has swept the communications industry in recent years. Local, monopoly telephone services remain subject to regulation. Cable television service is franchised by local governments, but not regulated. Still, it is not clear that telephone and cable companies will deploy fiber, at least not in the short run. They have no financial incentive to scrap their massive investment in copper and replace it with glass. And it is not clear how attractive broadband would be to private investment if it is subject to government regulation. Thus, some advocate municipal government ownership of the last mile if fiber is deployed.

THE FUTURE OF BROADBAND

Despite all the interest in broadband, few are asking the tough questions. Why does the consumer need more speed? Is there a present or foreseeable need for the capacity fiber offers? Would personal television move the Internet to a significantly higher level of utility? Would the benefits justify the costs? Who should provide the infrastructure and on what terms?

Congress legislated on broadband in 1996 without asking these questions. The Telecommunications Act of 1996 directed the Federal Communications Commission to encourage the deployment of a "high-speed, switched broadband telecommunications capability that enables users to originate and receive high-quality voice, data, graphics, and video." It also told the FCC to conduct periodic inquiry into whether broadband was being deployed fast enough. If the FCC concluded that broadband was not being deployed "on a reasonable and timely basis," then it was to take steps to accelerate deployment by "removing barriers to infrastructure investment and by promoting competition."

The FCC's initial inquiry concluded in 1999 with the finding that "deployment of broadband appears reasonable and timely today." Surprisingly, fiber optics was not one of the broadband technologies considered. More surprising was the FCC's definition of broadband to be the relatively slow speed of 200 Kbps or faster, which it explained as a speed that allowed a user "to change Web pages as fast as one can flip through the pages of a book and to transmit full-motion video."

But in fact, full-motion video can't be transmitted at 200 Kbps in real time, at least not with any quality. Someone has quipped that it is better to talk over a conventional phone while gazing at a photograph of the other person than to use a video phone connected at that speed. Transmission of DVD-quality video requires 25 times greater capacity.

Since passage of the 1996 act, the FCC has begun keeping statistics on broadband deployment. According to these figures, there were 5.8 million "residential and small business" broadband service lines as of December 2001. Of these, 4.4 million were cable; 1.2 million were DSL; 140,000 were "other wireline"; 58,000 were satellite or fixed wireless (where signals to the home are sent from a satellite or ground radio transmitter, but signals to the network typically go via telephone); and 3,523 were fiber. In other words, five years after Congress said it wanted rapid deployment of broadband services that would permit users to originate and receive high-quality video, only 3,523 such lines were in service.

Fortunately, some are beginning to ask the fundamental questions. A committee of the Institute of Electrical and Electronics Engineers-USA, a professional society involved in standards-setting and national technical policies, has taken up the subject of a "U.S. National Policy for Accelerating Broadband Deployment." It is looking at how DSL, cable, and fiber stack up for meeting the country's need for broadband infrastructure and will soon issue a report. Sen. Joseph Lieberman (D-Conn.) too has called for development of a national broadband strategy.

The future of the nation's communications infrastructure, though a complex topic, demands attention. The policy of the 1990s—leave it to the marketplace—has brought uneven results where infrastructure investments were concerned. Indeed, Congress took that approach toward broadband in the 1996 act, and yet six years later, only a handful of access lines can transmit quality live video. It is time for an in-depth look at how to communicate in the 21st century.

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