Microwave LANs

HARVARD AND BU ARE COOKING WITH MICROWAVE LAN EXTENSIONS.

by Patricia Schnaidt

Microwave can do more than cook your dinner quickly. A low frequency microwave will also speedily transmit data from one LAN to another. When underground rock or water, as well as distance, separate your LANs, microwave is a reliable and inexpensive alternative to fiber. Here's a look at how Harvard and Boston University use microwave to link their networks, which are separated by the Charles River.

In April, 1987, Boston University decided it wanted to connect the network on its Charles River campus to Harvard University's LAN. "The project started spontaneously," says Howie McCausland, network manager at Harvard. "The initial desire was connectivity. It was 'Wouldn't this be neat if Harvard and BU. . .'" However, the challenge of connectivity wasn't the sole motivation.

With one huge LAN, Harvard and BU professors can work together easily. Harvard and BU Classics professors are trying to bring technology to Classics. They are setting up a database of classical Greek and Latin literature, as well as digitizing maps. They are currently working on a remote file system with a dictionary server at BU. The two universities' Geography departments meanwhile are working on a remote graphics package using XWindows. Without a link between the two LANs, these projects could be not done efficiently — or at all.

Besides cooperation between Harvard and BU professors, BU can get faster access to Massachusetts Institute of Technology's computers. BU had only a 1200-baud line to MIT while Harvard has a T-1 link to MIT. MIT is then connected to the von Neumann Supercomputer Center at Princeton University. By connecting the networks, BU and MIT professors can work together.

Both universities have extensive LANs and connecting them is no easy feat. The BU LAN is several Ethernet subnetworks connected to a Proteon (Westboro, MA) ProNet-80 fiber Token Ring backbone. The Harvard LAN, too, is an extended Ethernet. Individual subnets are connected with bridges and repeaters. Then the subnets are joined to a fiber backbone composed of three Codenoll (Yonkers, NY) passive stars. The Harvard LAN covers a third of the campus, including all the research buildings, labs and science buildings.

The link between the two universities' networks was largely the work of Mike Orlov, BU's network systems engineer. Orlov evaluated the various ways to connect these remote networks. The problem was both "physical and bureaucratic separation," he says. BU is in Boston and Harvard is two miles away in Cambridge. The distance posed less of a problem than some other barriers. The universities are separated by the Charles River, an interstate and several local highways.

With the river and highways, fiber was out of the question. The universities would need the state's permission to cross the highway — and that takes a long time. The river also made fiber impractical. A 56K-bits-per-second line leased from a public data network was too slow. A T-1 line, at 1.544M bits per second, lacked the speed and the bandwidth. With leased lines, the universities would have to pay line charges each month. BU and Harvard wanted to unite the LANs transparently, yet maintain Ethernet's 10M-bits-per-second data rate. Orlov decided to connect the two networks via microwave.

A Viable Solution

Harvard and BU are not in a unique situation. Fiber is not always feasible. If a network must cross a river or cut through underground rock, running fiber is prohibitively expensive. And when fiber is possible, its price is not just the cost of digging up the street. To cross a state highway, you need the state's permission and you often must pay a right-of-way fee. Plus, it can take an excessive amount of time. In such situations, microwave can be the cheapest and fastest solution. One microwave convert was quoted $850,000 and nine months to run one mile of fiber. Microwave Bypass Systems (Cambridge, MA) can install a similar microwave link in 30 to 60 days for about $45,000.

Microwave has other advantages over fiber. Once fiber is installed, it's permanent. If you move, you can't take it with you and you lose your investment. With microwave, you simply pick up the pieces and move to the new location.

One of fiber's strong points is its bandwidth. But microwave's 23GHz frequency is plenty wide to run voice, video and data channels. Two baseband transmitters and receivers for Ethernet can be rack-mounted, then two units for video and another two for voice can be added. These systems are multiplexed to a single antenna on the roof. Since roof rental is based on the number of dishes, combining several transmissions with RF multiplexing isn't just aesthetic — it's economic.

Microwave is a reliable transmission medium. Neither flying birds nor bad weather puts it out. "Reliability is a function of the frequency, distance, rain rate and antenna size," says David Theodore, Microwave Bypass president. "Going 4.5 miles with a 23GHz microwave is feasible in Boston, but not in Florida because of the hard hits of rain. A severe downpour — 4 inches of rain an hour — will put out a signal. But in a downpour like that, the telephone and electricity will probably go down too. A rainy area calls for a larger antenna and a lower frequency microwave, or a shorter path length." Microwave installers consult a rainfall chart for the area where the link is to be installed.

Microwave does have some problems with security. Microwave, infrared and laser are considered *unguided* media, as opposed to *guided* media like coax or fiber. Of the unguided media,

microwave is the most impervious to the weather. However, it is the least secure because its beam width is the widest. An FCC license is required because microwave is fairly easy to jam and eavesdrop. To siphon signals, the antenna must be in the middle of the beam path, which is a few feet wide. Then you need a microwave transceiver to bring the data down and decipher it. But all this is conspicuous if someone is looking. And if security is a priority, the network software can encrypt the data.

Using microwave does not introduce any transmission delays. This means Harvard and BU users can exchange data at the same 10M-bits-per-second speed the local users have. "The users say it works instantly," says Barry Shein, BU special projects manager.

A microwave link cannot be longer than 4.5 miles, the limitation imposed by Ethernet's propagation delay. While 4.5 miles may seem restrictive, most installations have their data centers within that distance. The further away the vital data traffic is, the more it costs to bring it in and the less reliable it is. With another microwave radio as a repeater to regenerate the signals, the network may span an additional 4.5 miles. However, Theodore recommends T-1 for distances greater than five miles.

The Microwave Pieces

Perhaps the hardest part about installing a microwave LAN extension is finding an installer. Microwave LAN extensions combine telecommunications and networking expertise. Last year, DEC and MA/COM provided the components and let local MA/COM installers put in the links. The partnership was dissolved. One company should be knowledgeable in both areas and not shuttle users from vendor to vendor. Orlov knew about microwave and Microwave Bypass from previous research.

Microwave is simple to use. First and foremost, you need *direct line-of-sight*. This means no object can obstruct the path between the two antennae. If you don't have line-of-sight, sometimes it is possible to use repeaters to "bend" the signal, or make a turn. Microwave Bypass engineers verify line-of-sight during the site survey. The engineers also need the building's coordinates to get the microwave frequency from the FCC.

After the site survey, Microwave Bypass does the frequency coordination. This means it calls the FCC to determine what frequencies are available in the user's area. Then it chooses a completely different frequency to reduce the chance of interference. After the FCC form is filled out, it takes 30 to 60 days to get the license. If the user can't wait that long, Microwave Bypass has a common carrier's license which can be used to turn the user's system on.

Once you've got the line-of-sight and the license is in the works, you need equipment. Each side of the link requires a MAC-layer bridge, a microwave Ethernet transceiver, a microwave transmitter, a microwave receiver and an antenna.

A *MAC-layer bridge* routes remote packets to the other side of the network. Microwave Bypass makes a MAC-layer bridge, the LanLink 1000. Because a bridge operates on the Media Access Control sublayer of the OSI model, it does not care about the upper-layer protocols, and the same bridge can route DECnet, OSI, XNS or TCP/IP packets. A bridge forwards packets that are not local to the remote network. To determine which packets are not local, a bridge compares packets' source and destination addresses to a table of local addresses. The network manager does not have to build this table, because the LANLink 1000 does. To the user, the link is transparent.

The bridge connects to the *microwave Ethernet transceiver* via a transceiver cable. The Microwave Bypass Etherwave Transceiver simulates the Ethernet bus. It also matches the impedance between the Ethernet bus and microwave — which means it converts Ethernet signals to microwave signals.

The *microwave transmitter* and *receiver* are attached to the Etherwave Transceiver via a BNC connector and 75-ohm cable. The transmitter sends the microwave signals to the antenna and across the link. The receiver receives the incoming signals from the antenna and shunts them to the transceiver. A two-foot or four-foot *parabolic antenna* is placed on a building roof. 23GHz microwave is used for data transmission. This frequency is low enough that no one gets fried if they get in the way of the signal. The microwave transmitter, receiver and antenna are from International Microwave in Stamford, CT.

HOSPITALIZING MICROWAVE

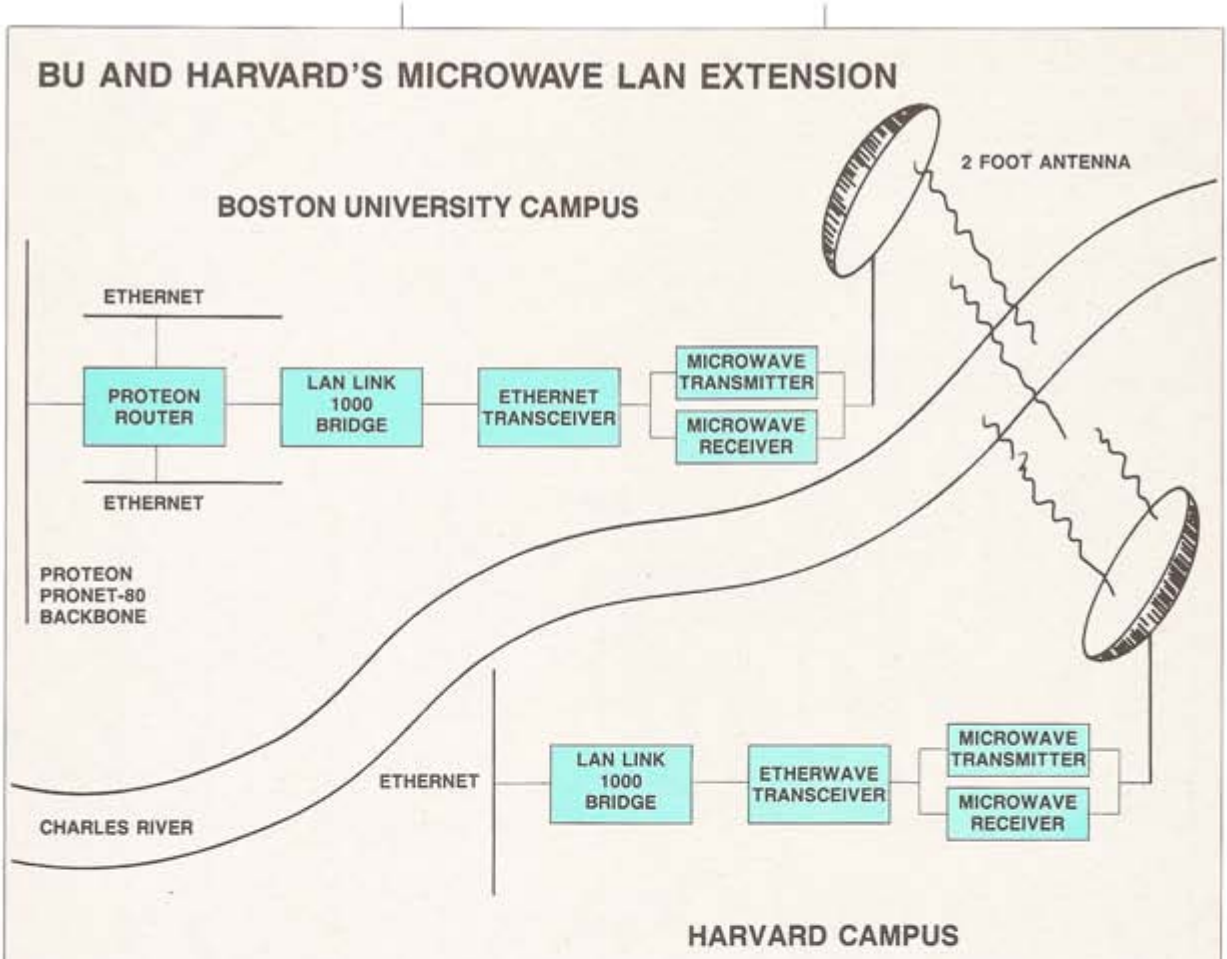
Harvard and BU don't have the only Microwave Bypass microwave link in Boston. Massachusetts General Hospital's (MGH) computer center is in Charleston, MA, 1.3 miles away from its main campus in Boston. The problem? The Charles River and several highways separate the campuses.

"We wanted fiber as either a primary or a backup link, but we had trouble getting it. So we used microwave. We will put in fiber in the future, even though it will be expensive," says Dave Murphy, MGH network manager. Right now, fiber and microwave have equivalent bandwidth, but fiber will have greater bandwidth when Fiber Distributed Data Interface (FDDI) becomes a reality.

"X.25 and T-1 lines weren't options for us," says Murphy. "We must ensure the network response time is equivalent to copper. Most of the traffic across the link is from our 1,600 terminals. These terminals are connected to either LAT terminal servers to a VAX/VMS host or from one LAT terminal server to another for a non-DEC machine. Our traffic is already 4 to 6% of the Ethernet bandwidth, which is about the bandwidth of T-1 lines. As for X.25 lines, the public data networks are just beginning to support the LAT protocol over 56K-bits-per-second lines."

The microwave link carries data from nearly every hospital department to the computer center. Because the data is so critical, MGH installed two microwave links. If the primary link fails, the MAC-layer bridge switches to the backup link. MGH uses DEC's LAN Bridge 100. "We have other DEC bridges in our network and I wanted software compatibility. Plus, part of the DEC LAN Bridge 100 internal software is a reconfiguration topology adjustment. At that time, the Microwave Bypass bridges had to be connected electrically to do automatic failover, while the DEC bridge can do it in software," says Murphy.

But MGH has not needed the back-up link yet. "The link is reliable. We've had zero problems. It went up in the middle of September, 1987 and has been up ever since," says Murphy.Managing a microwave link is no different from managing a repeater, says Murphy. "There is no active management. Since we have automatic failover, I don't have to worry that the link is up. Our link only goes 8,000 feet, so I don't have to worry about the signal/noise ratio or rain. My only concern is the antenna could be hit by lightning. But there are taller buildings in the area." There's no maintenance except occasionally checking the frequencies, which Microwave Bypass does.



Linked LANs — *Microwave connects Harvard and Boston Universities' networks. Microwave is the best way to span the two miles, the Charles River and the highways that separate the universities. Each side requires a MAC-layer bridge, a microwave Ethernet transceiver, a microwave transmitter and receiver and an antenna. The antennae are on top of the tallest building on each campus to ensure line-of-sight.*

Microwave Bypass and International Microwave have a joint marketing agreement.

The Harvard-BU Link

The Harvard-BU link was installed in a few days in November, 1987. "Installation was nothing special," says Shein. "The most difficult part of the installation was getting the money. The vendor takes care of the FCC license. We didn't have to deal with the bureaucracy," says Shein.

To get line-of-sight, the antennae were put on top of the tallest buildings on each campus — Warren Tower at BU and William James Tower at Harvard. "The obnoxious part of the installation was running the transceiver cable down through the building and into a wiring closet where it attaches to the MAC-layer bridge. It is an old building and is filled with asbestos. I had to put on an asbestos-proof suit and a mask," recalls McCausland.

Managing the link is the same as managing one big Ethernet, says Orlov. No special tools are needed. The bridge supplies LAN administrators with management statistics, such as collisions and resource errors.

The BU and Harvard link has been operating since December, 1987. Reliability is crucial because each university's network could bring down the other's. However, the link has never been interrupted, even though it crosses the perpetually foggy Charles River. "The first heavy snowstorm of the year happened right after it was installed. I got on and sent huge amounts of data across to test the reliability. No packets were dropped. It was only unreliable for one period of time. Snow accumulations on the antenna caused about 5% retransmissions," says McCausland.

Harvard and BU are both pleased with the link. "I like this technology," says McCausland. "I like the Ethernet-microwave solution because it is protocol-transparent. We are considering our options to connect Harvard's remote campuses. Currently, we connect Harvard Medical School to the main campus with a fiber link leased from the phone company. However, it is an experimental project which ends this year. It will probably be offered to us again with expensive tariffs. I am considering a microwave link to replace it." BU, too, is considering a second microwave link, to connect to MIT directly, instead of going through Harvard's network. ❑