Multicast
(Using MBONE technology)

Computer Networks                    Case Study

The MBONE and Multicasting

We take a closer look at the MBONE and multicasting: what they are, how they work and what people are doing with them. Since we want this book to be interesting to people other than network engineers (although we have nothing against network engineers), we don't want to frighten you off. So although we endeavor to explain the concepts and background involved, we don't delve into the nitty-gritty details of multicast encapsulation, the pros and cons of reliable and unreliable datagram multicasting or the specifics of how tunneling works. If you want to know about these scary details, you can find information about them on the Internet.

Today, the MBONE is a critical piece of the technology that's needed to make multiple-person data, voice, and video conferencing on the Internet -- in fact, sharing any digital information -- cheap and convenient. Internet researcher John December says, "MBONE is truly the start of mass-communication that may supplant television. Used well, it could become an important component of mass communication."

How so? December thinks that a number of scenarios are possible: The culture of the MBONE may develop like the e-zine (electronic magazine) culture, eventually giving rise to hundreds of "channels" of programming. Some channels would be professionally produced; others would be quirky homebrew channels.

Another possibility is that organizations will adopt MBONE as a low-cost way to conduct meetings without all the expenses of telecom-equipped conference rooms. Smaller, informal organizations could use MBONE as well as large companies, because MBONE would be controlled personally, not commercially. Certainly, both of these MBONE scenarios, and others, could co-exist.

Multicasting

Multicasting is a technical term that means that you can send a piece of data (a packet) to multiple sites at the same time. (How big a packet is depends on the protocols involved - it may range from a few bytes to a few thousand.) The usual way of moving information around the Internet is by using unicast protocols -- tools that send packets to one site at a time.

You can think of multicasting as the Internet's version of broadcasting. A site that multicasts information is similar in many ways to a television station that broadcasts its signal. The signal originates from one source, but it can reach everyone in the station's signal area. The signal takes up some of the finite available bandwidth, and anyone who has the right equipment can tune in. The information passes on by those who don't want to catch the signal or don't have the right equipment.

On a multicast network, you can send a single packet of information from one computer for distribution to several other computers, instead of having to send that packet once for every destination. Because 5, 10, or 100 machines can receive the same packet, bandwidth is conserved. Also, when you use multicasting to send a packet, you don't need to know the address of everyone who wants to receive the multicast; instead, you simply "broadcast" it for anyone who is interested. (In addition, you can find out who is receiving the multicast -- something television executives undoubtedly wish they had the capability to do.)
MBONE Vs Multicasting

Unfortunately, the majority of the routers on the Internet today don't know how to handle multicasting. Most routers are set up to move traditional Internet Protocol (IP) unicast packets -- information that has a single, specific destination. Although the number of routers that know how to deal with multicast are growing, those products are still in the minority. Router manufacturers have been reluctant to create equipment that can do multicasting until there is a proven need for such equipment. But, as you might expect, it’s difficult for users to try out a technology until they have a way to use it. Without the right routers, there’s no multicasting. Without multicasting, there won’t be the right routers. Catch-22.

**Router** A router is a device that connects a local area network -- such as an inter-office LAN -- to a wide area network -- such as the Internet. The router's job is to move information between the two networks. Most routers today are unicast routers: They are designed to move information from a specific place to another specific place. However, routers that include multicasting capabilities are becoming more common.

In 1992, some bright fellows on the Internet Engineering Task Force (IETF) decided that what no one would do in hardware, they could do in software. So they created a “virtual network” -- a network that runs on top of the Internet -- and wrote software that allows multicast packets to traverse the Net. Armed with the custom software, these folks could send data to not just one Internet node, but to 2, 10, or 100 nodes. Thus, the MBONE was born.

The MBONE is called a virtual network because it shares the same physical media -- wires, routers and other equipment -- as the Internet. The MBONE allows multicast packets to travel through routers that are set up to handle only unicast traffic. Software that utilizes the MBONE hides the multicast packets in traditional unicast packets so that unicast routers can handle the information. The scheme of moving multicast packets by putting them in regular unicast packets is called tunneling. In the future, most commercial routers will support multicasting, eliminating the headaches of tunneling information through unicast routers.

When the multicast packets that are hidden in unicast packets reach a router that understands multicast packets, or a workstation that's running the right software, the packets are recognized and processed as the multicast packets they really are. Machines (workstations or routers) that are equipped to support multicast IP are called mrouters (multicast routers). Mrouters are either commercial routers that can handle multicasting or (more commonly) dedicated workstations running special software that works in conjunction with standard routers.

So, what's the difference between multicasting and the MBONE? Multicasting is a network routing facility -- a method of sending packets to more than one site at a time. The MBONE is a loose confederation of sites that currently implement IP multicasting. The MBONE -- or multicast backbone -- is a fancy kludge, a hack. It is at best a temporary utility that will eventually become obsolete when multicasting is a standard feature in Internet routers. By then there will be an established base of MBONE users (which should make the router manufacturers happy). The utilities and programs that work on today's MBONE will undoubtedly work on the multicast backbone of tomorrow.

Pavel Curtis, a researcher at Xerox PARC (Palo Alto Research Center) says, “I believe that IP multicast is very likely to remain an important part of the Internet for quite a long time, and that it will be the primary audio/video transmission medium on the Net.”

"On the other hand," he continues, "I think that the MBONE as an identifiable subset of machines on the Net is already beginning to fade away, as more and more router and computer vendors supply IP multicast support in their products; when multicast support is ubiquitous, the MBONE ceases to be identifiable as something other than the Net as a whole."
MBONE Features and Characteristics

Today, multicasting is used for videoconferencing, audioconferencing, shared collaborative workspaces, and more. Conference multicasts generally involve three types of media: audio, video, and a whiteboard -- a virtual note board that participants can share.

Perhaps the most sought-after function that the MBONE provides is videoconferencing. The MBONE originated from the Internet Engineering Task Force's attempts to multicast its meetings as Internet videoconferences. MBONE video is nowhere close to television quality, but at a few frames a second, video quality is good enough for many purposes. In the spirit of the IETF's early technically-oriented offerings, many of the MBONE events that take place are technical conferences, ranging from the SIGGraph '94 conference in Orlando, Florida, to the International Conference on High Energy Physics in Glasgow, Scotland, to the Second International Conference on Intelligent Systems for Molecular Biology from Stanford University. Users also were able to tune into the MBONE to see astronauts on the space shuttle Endeavor repairing the Hubble space telescope and panel discussions at the 1995 annual meeting of the Congress of Neurological Surgeons.

The IETF

The Internet Engineering Task Force is the branch of the Internet Architecture Board that addresses the immediate technical problems and challenges of the Internet. The IETF is a voluntary committee of technical people such as network operators, engineers, and telecommunications equipment vendors.

The IETF's parent organization, the Internet Architecture Board, concerns itself with the technical challenges facing the Internet, now and in the long term. Such challenges include how to effectively handle the continued burgeoning growth of the Internet, how to keep the Net operational even when each of us can pump 2 megabits per second through the fiber-optic cable that will one day be plugged into our computers, and how to help the network better handle the demands of real-time audio and video.

The MBONE's capability to carry remote audio and video makes it a wonderful tool for seminars, lectures, and other forms of "distance education." Imagine sitting in on a lecture that's being given live thousands of miles away and even asking questions or contributing to a panel discussion. According to Navy Lt. Tracey Emswiler, whose experiments with the MBONE are the basis for her master's thesis in information technology management, "Some people believe that teaching over the MBONE can't be done. We've proven that you can send regular live-broadcast lectures over the MBONE." An average of 10 to 12 universities and labs tune into each distance education lecture that is sent over the MBONE, including institutions in the United States, France, Great Britain, Japan and Germany.

Indeed, much of what happens today on the MBONE is of a technical nature, information that most of us would find dull. However, the nerds don't get to keep the MBONE to themselves. Besides esoteric engineering events, the MBONE is home to more exciting fare, such as multicasts of concerts, a do-it-yourself radio station, and even poetry readings.

The Seattle-based techno-ambient band Sky Cries Mary performed the first live rock concert on the MBONE, and the Rolling Stones multicasted 20 minutes of their November 18, 1994, Dallas Cotton Bowl concert as a promotion for a subsequent pay-per-view TV special.

Radio broadcasts, in part because of their lesser bandwidth requirements, have become common on the MBONE. Some examples include episodes of "The Cyberspace Report" (a public-affairs show from KUCI 88.9 FM in Irvine, California), Internet Talk Radio, and Radio Free vat.

Some MBONE users are experimenting with distributing Usenet news via the MBONE instead of with NNTP (Net News Transport Protocol). NNTP has been used to pass netnews traffic around since the early days of Usenet, but sending Usenet traffic via multicasting could significantly reduce the total amount of bandwidth.
used to transmit netnews. Rather than having thousands of copies of a message travel from site to site, each message could be broadcast on the MBONE only once and grabbed by each site as it passes through.

**Extent and coverage of MBONE**

Today, about 1,700 networks (in about 20 countries) are on the MBONE, making the MBONE approximately the size that the entire Internet was in 1990. Unfortunately, there is no way to know how many people within each of the 1,700 networks can access the MBONE.

The size of the MBONE, compared to the Internet as a whole, is relatively small. As of February 1995, the Internet was home to 48,500 subnetworks, so the MBONE was available on roughly 3.5 percent of the Internet.

Pavel Curtis estimates that by 1996 or 1997, multicasting will be broadly supported in routers. When that happens, and upgraded routers are installed in place of unicast routers, the MBONE and the Internet will effectively be one entity.

Figure 3-2: Growth of the MBONE.

**System Requirements for MBONE**

Although anyone who has the right equipment can use the MBONE, the hardware and connectivity requirements for using the MBONE are much greater than what's available on the equipment that most Internet users have in their homes. A PC or Macintosh system coupled with a standard modem doesn't have enough computing power or bandwidth to send or receive MBONE transmissions.

You need a good deal of power to handle multicast IP. Today, *multicasting software* -- the behind-the-scenes tools for moving, encoding, decompressing, and manipulating multicast packets -- is available only for high-end UNIX workstations, such as those from Sun, DEC, HP, IBM, and Silicon Graphics.

UNIX is a powerful, multitasking, multiuser operating system. UNIX was developed in 1969 by AT&T's Bell Laboratories, and today UNIX-based computers comprise a large portion of Internet-connected computers. This situation is changing, however. Multicasting tools are becoming available for Linux -- a free UNIX-like operating system that runs on relatively cheap IBM PC-compatible computers. Since MBONE tools can work on a Linux-based PC, it's not too much to imagine that MBONE tools will soon be available for home computers -- PCs that are running Microsoft Windows and Macintosh computers. It will probably take the most powerful home computers (with Pentium and PowerPC chips), but it seems to be a likely eventuality.

The software tools are being built: PC/TCP Version 2.3 from FTP Software Inc. supports multicasting for PCs, as does Windows 95, and it is rumored that the next version of MacTCP will support multicasting.

The ability to process multicast IP packets is one thing, but multicasting software is not much use without some multicast packets. Since the MBONE and Internet are not (yet) one and the same, before you can receive multicast packets, your network provider needs to get you hooked to the nearest MBONE node and to configure a "tunnel." This project should keep even expert network administrators busy for at least a week or two.

**Bandwidth Requirement for MBONE**

Even if users had the hardware to do multicasting today, another huge hurdle would prevent the MBONE from taking over the Internet: Most users don't have enough bandwidth. A multicast video stream of 1 to 4 frames per second eats about 128Kbps of bandwidth and gives you slow, grainy, bandwidth-hogging video. (By comparison, television-quality video scans at about 24 frames per second.)
Remember though, that a video stream uses the same bandwidth whether it is received by 1 workstation or 100. Incidentally, 128Kbps is about nine times the speed of a 14.4Kbps modem. A dual-channel ISDN line can move data at 128Kbps, so if you are one of the lucky few who have ISDN, you have barely enough bandwidth to receive multicast video. (Sending video requires another 128Kbps, which makes using ISDN for two-way videoconferencing barely tolerable, if not impossible.) Most experts agree that in order to do multicasting effectively and get other work done, you need a T-1 or faster link to the Internet (although some users have managed to make the tools work with as little as 56Kbps). That 128K video stream uses nearly 10 percent of a T-1 line; several simultaneous high-bandwidth sessions can easily saturate network links. High-speed connections to the Internet can cost thousands of dollars a month. Lower-speed connections cost much less. The faster you go, the more you pay.

In their paper, "MBONE Provides Audio and Video across the Internet," authors Michael Macedonia and Donald Brutzman write, "Only a few years ago, transmitting video across the Internet was considered impossible. Development of effective multicast protocols disproved that widespread opinion. In this respect, MBONE is like the proverbial talking dog: It's not so much what the dog has to say that is amazing, it's more that the dog can talk at all!" Macedonia and Brutzman's paper is reprinted in Chapter 8.

**ISDN**

*ISDN* -- Integrated Services Digital Network -- is a type of telephone service that enables you to get high-speed data connections through your phone line. ISDN is basically the telephone network turned completely digital, using existing wiring.

ISDN is much cheaper than many other methods of moving data at high speeds, but it is still expensive relative to a normal phone line. (Normal phone lines -- the kind that work reliably with your 14.4Kbps modem, fax, answering machine, and the *Sports Illustrated* football phone, are known in some circles at *POTS* -- plain old telephone service.)

ISDN is new, but it is catching on. A major drawback to ISDN is that because it moves digital data instead of analog data, it doesn't work with your regular modem, answering machine, or football phone. You need special, expensive equipment to perform those functions at ISDN speeds.

On the bright side, ISDN is faster than a standard modem. ISDN is available in various parts of the world, including Australia, Western Europe, Japan, Singapore, France, and portions of the U.S. Audio multicasts, partly because of their lesser bandwidth requirements, are more common on the MBONE than are video multicasts. Multicast audio typically uses 56 to 64Kbps of bandwidth. (Thanks to heavy hacking and experimental compression tools, MBONE audio and interactive whiteboard traffic have been demonstrated by using as little as 9600 bps lines. These demonstrations are one indication that eventually those of us who access the Internet from home at 14.4Kbps will be able to have some access to the MBONE.)

"For the multicast broadcasting model that the MBONE establishes to succeed as a mainstream medium, current technologies simply have to advance," writes Internet guru Aaron Weiss. MBONE services simply eat more bandwidth than most of us can afford. Before multicasting becomes commonplace, either bandwidth needs to be available more cheaply, or our ability to compress bandwidth-hogging information into a limited bandwidth space needs to improve. "Network bandwidth has to fatten or audio-video compression schemes have to flatten," Weiss writes. "Presumably, both will occur, which also will require increased CPU power at the home computer level. Although it's probable that all three of these developments will take place, the time frame is not clear," he says.

Even if you could push 128 kilobits (or more) each second around the Internet affordably, it's a good bet that when enough of us could push that much data around that fast, the sheer load of all that data pulsing though the Internet would bring it to a standstill. One of the IETF's jobs is to plan for this eventuality.

"Until recently, experts believed that the MBONE could not be used for transmission of simultaneous video, audio, and data because of limited bandwidth," notes Professor Don Brutzman. "This effort to push the
envelope of computing technology has provided valuable data to computer scientists and has shown that methods can be employed to work around the bandwidth problem."

There's a ceiling to the amount of information that can move around on the MBONE as a whole: 500Mbps (million bits per second). At full tilt, the MBONE itself can handle no more than four simultaneous videoconferencing sessions or eight audio sessions.

"Although there is much to experience on the MBONE, there isn't much space for everyone. There is only about 500Kbps of bandwidth available to the entire MBONE community at any one time. With video streams typically running at about 128Kbps and audio streams at 64Kbps, there is a small and finite limit on the number of simultaneous transmissions the MBONE can handle," writes Weiss.

This limited resource environment presents MBONE users with what Weiss calls "the classic sandbox scenario": sharing and playing nice. Sharing means planning multicast events in advance and scheduling them with the rest of the MBONE community to eliminate conflicts. Internet e-mail lists have been set up for announcing scheduled events.

Sometimes two planned events conflict (for example, a High Energy Physics conference conflicted with a planned IETF meeting, so the physics conference was broadcast at a later time). At times, oversight or naivete can wreak havoc. "In mid-1994, a host in Japan was found to have been sending 650Kbps video-streams over the entire MBONE, effectively trashing it," according to Weiss. The problem, as it turned out, was caused not by malice, but by a program bug that enabled the multicast packets to escape a local network. Such unintentional flooding happens periodically and is a testament to the experimental nature of the MBONE.

**TTL**

An infinitely loud megaphone, one that could be heard anywhere in the world, would be a bad thing: once a few dozen of us had them, we wouldn't be able to get useful information from the din. The MBONE is no exception. Broadcast packets need to have a finite life lest they bounce around the network forever. The MBONE includes procedures for limiting how far multicast packets may travel, to prevent them from saturating the entire Internet. Each packet has a time to live (TTL) value, a counter that is decremented every time the packet passes through an mrouter. Because of TTLs, each multicast packet is a ticking time bomb. If an MBONE broadcast were a TV station (as in the analogy at the beginning of this chapter), TTLs would be the station's signal area -- the limitation of how far the information can travel before petering out.

Those multicasting something that's of little interest to the outside world (for example, a company board meeting) might produce a packet that had a small time to live (perhaps 10). As the packet moved around the company's internal network, its TTL would be notched down every time it passed through an mrouter. When the packet's TTL reached 0, the packet would die and not be passed further. With careful planning, those multicasting can keep their multicast packets on their internal networks or within their state or country. Events of interest to the world at large are generally multicast with long TTLs -- perhaps 200 -- to guarantee that the information will reach around the world.

**Available Alternatives to the MBONE**

The MBONE shows promise for the future, but other tools are now available for using multimedia on the Internet. For example, CU-SeeMe is a videoconferencing tool for the Mac and PCs that works without the MBONE. CU-SeeMe uses reflectors -- computers that provide the multipoint distribution functionality that multicasting would normally handle. Reflectors allow multi-person videoconferences without multicasting. Multimedia on the Internet can also be handled by streaming technology software, which sends and receives an ongoing flow of information that can be interpreted and displayed (or heard) in real time. In this way, streaming technology software works like the MBONE; but this software does not use multicasting, and it does not require as much bandwidth as multicasting does. One example of streaming technology software is RealAudio.