largest volcanic eruptions. Stainforth emphasizes that his method does not yet allow him to attach probabilities to the different outcomes. But the upshot, he says, is that "we can't say what level of atmospheric carbon dioxide is safe." The finding runs against recent efforts to do so by politicians.

And according to Stainforth, this illustrates something that makes public-resource computing a special asset to science. Rather than a hurdle to be overcome, "public participation is half of the goal." This is particularly true for a field like climate prediction, in which the public can influence the very system being studied, but it may also be true for less political topics. "We in the SETI community have always felt that we were doing the search not just for ourselves but on behalf of all people," says Sullivan. What better way to "democratize" science than to have a research group of several million people?

—John Bohannon

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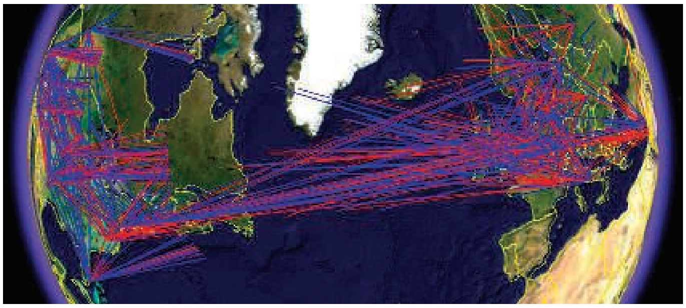
NEWS

Data-Bots Chart the Internet

It's hard to map the global Internet from a small number of viewpoints. The solution may be to enlist computer users worldwide as local cartographers of cyberspace

Anyone who has tried to study the twists and turns in the data superhighway knows the problem: It is difficult even to get a decent map of the Internet. Because it grew up in a haphazard fashion with no structure imposed, no one knows how the myriad telephone lines and satellite links weave together its more than 300,000,000 computers. Today's best maps offer a badly distorted picture, incomplete and biased by a U.S. viewpoint, hampering computer scientists' efforts to design software that would make the Internet more stable and less prone to attack. But a new mapping effort may succeed where others have failed. "We want to let the Internet measure itself," says computer scientist Yuval Shavitt of Tel Aviv University in Israel, who, along with colleagues, hopes to enlist many thousands of volunteers worldwide to take part in the effort.



Gridlock. Accurate Internet maps could provide users with data traffic reports.

At the lowest level, the computers that comprise the Internet are known as "routers." They carry out the basic information housekeeping of the Net, shuttling e-mails and information packets to and fro. At a somewhat higher linked-facility level, however, the Internet can also be viewed as a network of subnetworks, or "autonomous systems," each of which corresponds to an Internet service provider or other collection of routers gathered together under a single administration. But how is this network of networks wired up?

Two years ago, computer scientist Kimberly Claffy and colleagues from the Cooperative Association for Internet Data Analysis at the University of California, San Diego, used a form of Internet "tomography" to find out. They sent out information-gathering packets from 25 computers to probe over 1 million different destinations in the Internet. Along the way, each packet recorded the links along which it moved, thereby tracing out a single path through the Internet—a chain of linked autonomous systems. Putting millions of such paths together, the researchers eventually built up a rough picture of more than 12,000 autonomous systems with more than 35,000 links between them (see www.caida.org/analysis/topology/as_core_network).

Through such efforts, researchers now understand that the Internet has a highly skewed structure, with some autonomous systems playing the role of organizing "hubs" that have far more links than most others. But researchers also know that their very best maps are still seriously incomplete.

The trouble is that all mapping efforts to date have started out from a fairly small number of sites, 50 at the most. So the maps produced tend to be biased by the locations of those sites. From some computer A, for example, researchers can send probing packets out toward computers B and C and thereby learn paths connecting A to B and A to C. But the probes would be unlikely to explore links between B and C, for the same reason that driving from New York to Boston and from New York to Montreal tells one little about the roads between Boston and Montreal. "If you send probes from only a few points, you naturally get a very partial point of view," says physicist Alessandro Vespignani, an expert on Internet topology at Indiana University, Bloomington.

To overcome this problem, Shavitt and colleagues are pioneering a new approach inspired by the idea of distributed computing. Anyone can now download a program from the Web site www.netdimes.org that will help in a global effort to map the Internet. Using no more than a few percent of the host computer's processing power, the program acts as a software agent, sending out probing packets to map local connections in and around the autonomous system in which the computer sits. "What we ask for is not so much processing power but location," says Shavitt. "We hope that the more places we have presence in, the more accurate our maps will be."

Since the project's inception late last year, individuals have downloaded nearly 800 agents that are now working together to map the Internet from 50 nations spread across all the continents. "We've already mapped out about 40,000 links between about 15,000 distinct autonomous systems, and we can already see that the Internet is about 25% denser than it was previously thought to be," says Shavitt. "This is a great project with a very new perspective," says Vespignani, who points out that better maps will help Internet administrators in predicting information bottlenecks and other hot spots.

Shavitt and his colleagues estimate that once they have about 2000 agents operating, it should be possible to get a complete map of the Internet at the autonomous-system level in less than 2 hours. Once they can do that, they hope to provide individual users with local Internet "weather reports." Ultimately, they would like to map the Internet at the level of individual routers—getting a more detailed map of the physical Internet. "We'll need about 20,000 agents distributed uniformly over the globe to get a good map at that level," says Shavitt. Then there'll be no excuse for getting lost in cyberspace.

—Mark Buchanan

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