Wi-Fi Nodes to Talk Amongst Themselves

By: **Steven Cherry**

ILLUSTRATION: DAN PAGE

Wi-Fi is one of the great success stories of the past decade, and the industry that's grown up around it hasn't been standing still. In the past few years, amendments to the IEEE 802.11 family of standards have improved security and greatly increased the speed with which data can be moved around. Soon Wi-Fi access points will be able to cluster together in what are called mesh networks, making large wireless networks cheaper to operate by allowing a cluster of access points to exchange traffic and share a single high-speed connection to the Internet. Last March, an IEEE task group approved the new mesh capability, known formally as 802.11s.

Meshing is already used in some wireless applications—for example, in the sensor networks used to monitor manufacturing processes and in heating, ventilation, and air-conditioning systems. In 2003, the IEEE approved a standard for those networks, 802.15.4, popularly known as ZigBee. Unlike the new Wi-Fi standard, ZigBee was designed to support relatively low-power, low-data-rate networks.

There is also a need for high-speed mesh networks, and indeed several Wi-Fi and other wireless equipment makers already offer access points that use proprietary mesh-networking techniques. They include Motorola Inc., of Schaumburg, Ill.; Nortel Networks Corp., in Brampton, Ont., Canada; and Tropos Networks Inc., of Sunnyvale, Calif. Last year, Tropos's mesh equipment gave critically needed Internet access to residents and emergency workers in New Orleans and other U.S. cities in the Gulf region immediately after Hurricane Katrina. The city government of Las Vegas uses a mesh network to support many municipal activities; its network's technology is based on military research commercialized by Mesh Network Inc., which is now part of Motorola [see "Viva Mesh Vegas," *IEEE Spectrum*, January 2005]. And Nortel recently built a network in Taipei with almost 10 000 nodes.

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In addition to these companies, at least 12 others contributed to the effort to draft the new standard, including such industry powerhouses as Cisco and Intel. Once their products conform to 802.11s, mesh networks can be built up using equipment from any of them, lowering costs and improving reliability.

Wi-Fi networks have always been about making Internet access cheaper and better. An entire office can be served without thick masses of cables snaking out from an equipment closet, as dozens of PDAs, laptops, and desktop computers can connect to each Wi-Fi access point. Millions of households around the world also use Wi-Fi equipment. Although homes usually need only a single access point, several may be needed to cover a single floor of an office building, because each access point has a range of only about 30 meters.

But Wi-Fi networks haven't done away with wires entirely; once a user connects to an access point, the access point itself needs to be connected to the Internet. If you have, say, 10 access points, you would need 10 wired connections to the Internet—backhaul points, as they are

known—at a cost of hundreds or even thousands of dollars each. And you have the inconvenience of locating the access points only in places that lend themselves to wired access. Backhaul is the largest expense in a wireless network.

Meshing Wi-Fi access points is an obvious solution. Why shouldn't they share a single backhaul connection in much the same way that users share an individual access point? Easier said than done. Several software protocols needed to be hammered out. One is a routing protocol that tells a group of access points how data packets should hop around the network so that the packets eventually end up at the backhaul connection. Another is a congestion protocol, which ensures that any given access point doesn't become overloaded with data at any given moment.

The congestion problem turns out to be even harder than it seems. For one thing, users connecting to access points close to the backhaul connection will naturally enjoy higher data rates than users two or three access points away, a phenomenon called "spatial bias" by researchers at Rice University, in Houston. Tropos Networks and other mesh manufacturers currently correct for that by simply limiting the maximum data rate for users at access points close to the backhaul connection. "But you want to do it dynamically," says associate professor of electrical and computer engineering Edward W. Knightly. "If usage on the network happens to be light, you want people to have the highest data rates they can get." Software written at Rice does just that in a trial 10-access-point public mesh network. The network is run by graduate student Joseph Camp as part of his doctoral dissertation, and by Knightly, Camp's thesis adviser.

The congestion problem was first attacked by another student of Knightly's, Bahar Sadeghi, in her Ph.D. thesis. After graduating in 2003, she went to work for Intel, where her research continued and formed part of Intel's contribution to the 802.11s standard.

Before you start looking for words such as "802.11s-compatible" on boxes of Wi-Fi equipment, be aware that the IEEE's March approval is provisional. It represents a standards document agreed to by the task group's members. The larger 802.11 committee and then the IEEE Board of Directors need to approve the standard. Each of these could take a year or so, resulting in a final standard in mid-2008. Still, the task group's approval was hard-won, and, by the sometimes achingly slow terms of high-tech standards, speedy. Back in January 2005, 35 companies expressed intentions to submit proposals; 15 had done so by the June 2005 deadline. With the task group meeting every two months, by 2006 most members backed one or another of two proposals. One grouping, calling itself the Wi-Mesh Alliance, was led by Nortel. The second, known as SEEMesh, included Cisco, Intel, and Motorola. Motorola's contribution includes some of the military-derived technology it gained through its 2004 acquisition of Mesh Networks.

It was at this point that some other standards efforts inside and outside the IEEE have fractured, such as in the arena of next-generation DVDs, where two technologies, Blu-ray and HD DVD, are now making their way toward what will surely be a confusing marketplace for consumers. So last January, prior to a scheduled meeting, during which the two proposals would have been put to a vote, the two sides approached Donald E. Eastlake, of Motorola Laboratories, chair of the 802.11s task group, saying that with more time they thought they could merge their proposals. A joint proposal was indeed forged by the next meeting, and it won the unanimous support of task group members.

Besides needing to secure final approval of the standard, manufacturers will have to find ways to test their equipment for compatibility and interoperability. It's expected, though, that some companies will gamble on their ability to produce early products that come so close to meeting the final standard that any differences can be fixed with software updates. That would mean that mesh-capable access points may be available in stores less than a year from now.