



## Blazing trails, dropping bread crumbs

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### Diminutive wireless relays create a path for building and extending ad hoc networks

Networking experts believe that miniature wireless relays will help extend the range of impromptu networks fielded in tactical and emergency response settings.

The Defense Department hopes to make mobile ad hoc networks (Manets) and other forms of rapidly deployable networks a viable means for establishing communications in situations where infrastructure is damaged or nonexistent.

Similarly, such networks are finding their way into first-responder communications and may eventually play a role in restoring voice and data transmission in natural or man-made disasters.

However, the wireless networks do have limitations. Manets and mesh networks rely on communications nodes that are both message transceivers and routers. A sender's message travels through intermediary nodes until it reaches the recipient. As those nodes move farther apart, communication degrades.

That's where the wireless modules — some as small as a matchbox — come in.

The technology, colloquially known as bread crumbs in a reference to "Hansel and Gretel," lets roaming users drop a trail of relays as they start to lose connectivity. The technology is featured in technology demonstrations, pilot projects and a few examples of production networks.

"This is a way of extending the range of radios in a very scalable fashion," said Nader Moayeri, manager of the Wireless Communication Technologies Group at the National Institute of Standards and Technology. Moayeri has been exploring bread crumbs in emergency response applications.

However, the bread crumbs aren't always scattered. In some situations, they are an intrinsic part of a portable network solution as opposed to a supplemental aid. In other situations, wireless relays travel on communications robots or support the operation of remotely controlled devices.

Also, researchers and product vendors are looking to broaden the scope of their wireless wares by exploring different communications protocols and radio frequencies.

#### Little helpers

The wireless relays typically include a processor, a radio and an antenna.

They generally run on batteries, although some products may use other power sources, such as an AC adapter.

Jason Redi, principal scientist at BBN Technologies, differentiated bread crumbs from repeaters, which regenerate weakening signals. Redi said the bread crumbs he works with "run a full ad hoc network stack" and can determine which path and links to use to optimize performance. Each node has a picture in its head of where the other nodes are, he said. The intelligent nodes can also assess signal strength and prompt users when to drop another bread crumb. Moayeri said a bread crumb could employ an LED indicator or an audio tone as a signal.

NIST has developed a bread crumb prototype that incorporates an antenna, radio and Gumstix1s Wi-Fi platform. The components fit in a 4-inch by 2-inch by 1-inch box. NIST uses the module in a test bed that focuses on first-responder communications. The idea is for emergency responders entering a building to leave behind a trail of wireless nodes to maintain contact with an incident command center outside.

The nodes transmit not only voice but also the first responder's vital signs and location, Moayeri said. The localization feature is based on passive radio frequency identification tags.

Moayeri said some observers have expressed concern that the wireless devices could be destroyed in a fire or if a wall collapsed inside a building. But bread crumb deployments are viable, and any system will break at some point, he said. Meanwhile, humans aren't alone in dropping bread crumbs. BBN is working on a technology demonstration with the

Space and Naval Warfare Systems Command. In the demonstration, a teleoperated explosive-ordnance disposal robot drops bread crumbs — nodes roughly the size of a deck of playing cards — as it moves farther away from the operator. Redi said that application could be useful when the radio frequency link between operator and robot is short, as would be the case in high-jamming areas.

In this example, a deployer node attached to the robot assesses link quality and triggers the placement of nodes as needed.

In some prototypes, the bread crumb and robot become one. SRI International's Artificial Intelligence Center envisions mobile robots able to create a multihop network. The relay robots — or commbots, as SRI calls them — would re-establish communications in an infrastructure-damaging disaster.

Meanwhile, the Defense Advanced Research Projects Agency wants a communications robot for warfighters. The agency's LANdroid program seeks "small, inexpensive, smart robotic radio network relay nodes" according to a DARPA bidders' day presentation in July. In DARPA's vision, warfighters would drop the robots while on the move, and the deployed nodes would move autonomously to optimize communications within the mesh network.

DARPA is looking for solutions in control software and robot technology. The LANdroid program will also involve technology evaluation tasks.

"We have not yet awarded contracts but hope to do so in the coming months," a DARPA spokeswoman said.

The concept of robots autonomously accomplishing a mission remains "very much in the research phase," Redi said. But he described the task of maintaining network connectivity as a simple behavior for robots and one within the reach of current technology.

BBN participated in an earlier Spawar demonstration, in which mobile relay nodes were used to link a robot to a base station.

"The relay robots convoy behind the main robot at the start of a mission and automatically stop where needed to form an ad hoc network guaranteeing a link between the lead robot and the base station," a Spawar white paper states.

Bread crumbs aren't only the stuff of prototypes. Xacta, a unit of integrator Telos, has incorporated Rajant's BreadCrumb products into its recently released Comms on the Move solution. The company had previously built a satellite-based offering that enables a military unit to maintain connectivity with the Internet or other units in the deployed environment.

However, the company came to realize that "additional technology was needed to be able to provide [customers] with a complete solution," said Tom Badders, business development director at Xacta Secure Networks.

The addition of Rajant's BreadCrumb communications nodes broadens the solution for mobile applications, such as vehicles in a convoy. The main vehicle in a convoy could use Xacta's satellite connection to link beyond the immediate group, and the Rajant technology would let all vehicles in the convoy communicate with one another. In addition, Badders said, personnel in vehicles trailing the lead vehicle could use the Rajant BreadCrumb to connect through the satellite in the lead vehicle.

"A BreadCrumb in each vehicle connects them as a single moving network for voice, data and video," Badders said.

For Rajant, its BreadCrumb devices are the solution rather than a supplemental technology. The company's wireless gear ranges from 6-inch by 3.75-inch by 1.5-inch devices to larger models that may be mounted in vehicles or used in fixed infrastructure.

Rajant's products have been supporting 802.11b, the 802.115 wireless standard, but the company has also introduced a product that also supports 802.11g. That product is compatible with 802.11b, said Glenn Booth, vice president of marketing at Rajant.

### **Room for improvement**

As mesh networks unfold, work on the underlying relays continues. For example, NIST migrated to a new platform for its mesh network test bed.

The initial wireless relay had a maximum raw data rate of 35 kilobits/sec throughput, which Moayeri said he considers inadequate for the application. That data rate "is not going to do a good job" of transmitting voice or surveillance video, he said, noting that packet header overhead must be taken into account along with the data being transmitted.

NIST's new relay, which uses the Gumstix Wi-Fi platform, provides good voice quality in a multihop network, Moayeri added. "Getting higher speeds and greater throughput is a need," Badders said.

In the Wi-Fi world, 802.11b radios, with a maximum data rate of 11 megabits/sec, generally produce sustained throughput of 6 megabits/sec to 7 megabits/sec.

The 802.11g radios are rated at 54 megabits/sec and generally get sustained throughput of 32 megabits/sec to 36 megabits/sec, Badders said. In a large, multihop, mesh network, throughput would degrade to about 1 megabit/sec for

802.11b radios and 10 megabits/sec for 802.11g radios, he added.

Rajant plans to offer a multiband product, which incorporates 802.11a, b and g, by year's end. The use of 802.11a, which uses the 5 GHz band, will help customers avoid the noise encountered by radios operating in the 2.4 GHz band, Booth said.

"The number of g radios and b radios is staggering," he said. In addition, other electronic devices, such as microwave ovens and baby monitors, use the 2.4 GHz frequency.

Meanwhile, Redi cited the need to develop medium access control protocols geared toward ad hoc networks. MAC protocols optimized for traditional networking infrastructure contribute to poor performance and delays when used in adhoc networks.

Redi also pointed to antenna deployment as an area of inquiry. Antennas don't work as well when they're low to the ground, he said, so developers have experimented with spring-loaded antennas that pop up when a relay hits the ground.

Interest from agencies such as DARPA bodes well for further exploration of bread crumbs. The results may lead to wider adoption of the technology — whether on the ground, mounted in vehicles or independently mobile.

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