Sharing the airwaves: Michigan Tech professor researches cognitive radio

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A new technology called cognitive radio will someday allow wireless devices, like these cell phones, to share the radio spectrum and avoid annoying bottlenecks.

(PhysOrg.com) -- Imagine yourself driving along an interstate highway, with about a thousand lanes of traffic zipping by. You notice that there are only a few cars in the outside lane, and you'd like to move over there.

Unfortunately, that lane is set aside for specially licensed vehicles, and yours isn't one of them. In fact, you're only allowed to drive in one lane, the one you're in right now. Even if traffic in your lane gets so thick it grinds to a halt, you're stuck. Too bad for you.

Traffic in part of the radio spectrum is like that. By decree of the Federal Communications Commission (FCC), everything from cell phones and wireless LAN to TV shows and FM radio is only allowed to transmit on certain frequencies of the radio spectrum, period. (This is why WMTU only broadcasts at 91.9 megahertz.) No switching around. That policy worked pretty well until about 10 years ago, when cell phones, WiFi and PDAs began proliferating and clogging up frequencies in the radio spectrum's ultra high frequency band (300 to 3,000 megahertz), where they do most of their business.

Meanwhile, frequencies in other bands used by amateur radios and pagers are rarely bogged down by too much traffic. And even frequencies that carry cell phone calls or email messages aren't full most of the time. A 2004 test in New York City showed that only about 16 percent of the spectrum is occupied at any given moment.

That means that theoretically, there's really plenty of room in the radio spectrum for everyone, says Zhi (Gerry) Tian, an associate professor of electrical and computer engineering. "Even while you make a phone call, you are not talking all the time," she notes. "So the FCC is opening the door to changing its policy."

That door is cracking open on a new technology called cognitive radio. Instead of being stuck on one frequency, new, intelligent devices would be able to dynamically pick the best frequencies and use them to transmit their signals.

Primary users like AT&T and Verizon buy the rights to a portion of the radio frequency spectrum. If they could share unused portions amicably, everyone would benefit. But sharing frequencies only works if the borrower, or secondary user, can accurately identify and occupy idle "white spaces" in the primary user's spectrum.

Doing that is a many-layered problem, Tian says. First, your cognitive radio network would have to identify frequencies that have white space.

Then, it would have to get that information to the user that needs it. Alternatively, cognitive radios could form a peer-to-peer network and decide among themselves what frequencies to use, without help from a central controller.

Identifying unoccupied frequencies isn't as easy as glancing over your shoulder on the highway to find holes in traffic. It's a complicated problem, involving sampling many points on the radio spectrum.

If time and money were no object, you could take a huge number of samples from the very wide spectrum and pinpoint exactly where the white spaces are. But the telecommunications industry is all about time and money, so Tian is trying something different.

Her team is applying a new technique called compressive sampling, which takes advantage of the "sparsity" of the signals sent out over the spectrum. She and her team use compressive sampling to reduce the amount of data needed to find the white space—and still maintain a high degree of accuracy.

Once the white space is found, the next challenge is getting the information to the user. A cognitive radio network could collect all the information in a central spot and then send it to all its smart cell phones and laptops, but that takes a lot of power. Tian is exploring a different, energy-saving approach.

"What if we did this in a decentralized way?" she asks. "What if each device could talk to its neighbor, so they could collaborate without using a central spot?"

"Eventually, we want them to communicate good information to each other that percolates around the network."

In addition, your cognitive radio device would have to cooperate with other cognitive radios, once it receives the information. That's called dynamic spectrum sharing.

"You don't want to have multiple cognitive radios find the same hole and all jump in there at once," says Tian. "You need a receiver that senses the spectrum and talks to the cognitive radio's central processing unit—its brain. Then the CPU has to decide where to transmit while protecting the primary user."

Cognitive radios will have to be super smart, she says. Because the last thing you want is a million-iPhone pileup on the radio spectrum superhighway.

Her cognitive radio research is still in the prototype stage, but Tian is already applying some of these techniques in another application far removed from managing the flow of text messages among teenagers: battlefield sensing.

The US military is studying the use of small sensors that could be scattered in a war zone to detect anything from enemy combatants to explosives to biological weapons. "You need to make sure the field is covered, so we are looking at cheap sensors that could be left all over the place," said Tian. "The processing has to be efficient, because they are battery powered." By the same token, these techniques could also be used to improve the efficiency of civilian sensor networks that may one day monitor the health of infrastructure such as dams and bridges.

Sensors that use compressive sampling could gather more information faster. And, just as with cognitive radio, sensors that cooperate with each other could improve the network's overall performance and efficiency.

"In all these things, you try to reduce the power consumption," she said.

“If you can reduce the amount of power a sensor needs, then you can increase the lifetime of the network.”

That’s important, she says, because anytime you increase the longevity of a sensor network, the longer it can help save soldiers’ lives.

Provided by Michigan Technological University

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