Wireless Unjammed

The threat of gridlock looms as more users crowd into a finite radio spectrum. UC Santa Barbara's Haitao Zheng has some ideas to keep the traffic flowing.

Southern California commuters know exactly what happens when too many people try to get somewhere on the same freeway at the same time. Everyone sits there and no one gets anywhere. Out of sight and (for most of us) out of mind, the electromagnetic freeway of wireless communication is facing the same fate not far in the future if it is not used more efficiently. The spectrum may be invisible, but it's not infinite.

What does look infinite, or close to it, is the potential marketplace of devices and services that use the spectrum and demand increasingly larger expanses of it to fit their expanding data. More people are going wireless and demanding richer content when they do. They're surfing the Internet at the local Starbucks, for instance, rather than just chatting on the cell phone. Meanwhile, new devices keep piling into the wireless networks. Radio sensors beam signals to track merchandise. Robots and other gadgets keep doctors posted on patients. And much of the spectrum is already allocated to designated uses – such as AM and FM radio, television, mobile phones, the military, pagers – leaving precious little for all the new technologies.

The spectrum isn't filled up yet. But it will take some ingenious management of the available space to keep all those signals moving smoothly. This is where researchers such as Haitao (Heather) Zheng are making their mark. Zheng, an assistant professor of computer science at UCSB, is working on new ways to allocate available frequencies through decision-making rules programmed into the devices – such as laptops – that use a wireless network. This technology is called "cognitive radio," and it draws on game theory as well as electronics.

Finding and Filling Spectrum Gaps

The traditional method of divvying up the spectrum is top-down: Assigning frequencies to users through licenses or designated bands (as in citizen's band radio). But this is not a practical way to organize wireless networks that serve a constantly changing population of users, as in airport terminals or coffee shops. It's also inefficient, because assigned frequencies often sit idle. At certain locations and times of day, Zheng says, up to 70% of the spoken-for spectrum may go unused while users without allocated frequencies jostle for room in the available free space.

Cognitive radio, in contrast, is a bottom-up solution. It consists of electronics that scan the spectrum for unused frequencies, enabling wireless devices to find any open slots available for a local network. When they exit the network – when the laptop user leaves the Starbucks, for instance – the slot is freed up for another device (as long as the licensed user of the frequency doesn't want it).

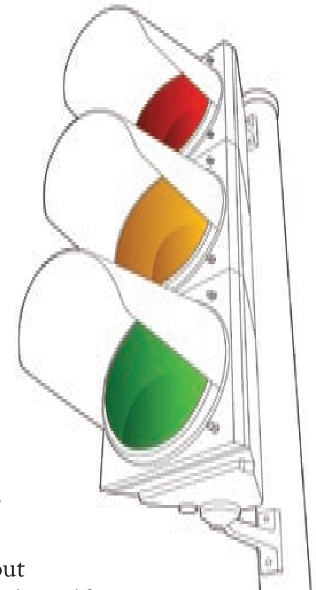
In cognitive radio parlance, licensed users are "primary" and everyone else is "secondary." The challenge is to make as much room as possible for secondary users and to distribute it fairly.

That's not a simple task when the demand for available spectrum nearly outstrips the supply. With no central authority assigning frequencies to the free-floating secondary users, it's up to the users themselves to work out spectrum-sharing arrangements on the fly. They could do so by

communicating with one another – like drivers using turn signals, horns and gestures (friendly or otherwise) to change lanes on a clogged freeway. But this communication uses some of the precious bandwidth. Far from being a solution, it adds to the problem.

Rules for the Wireless Road

The alternative approach – and the focus of Zheng's work – is to program each of the wireless devices with decision-making rules that enable them to share bandwidth without conflict and without having to send messages. "If you let them collaborate and have certain rules to regulate their behavior," she says, "then they can sort out all the optimizations on their own without centralized controls." Zheng has developed an algorithm which each device first detects and chooses idle channels, and then (if necessary) takes channels from other users who have more than they need. The rules boost the overall efficiency of the system by leading users to use channels with the fewest competing users.



Zheng has run simulations to test the validity of this "device-centric spectrum management" model, as she calls it. On that level, it works. But will it keep order in an actual coffee house or university campus? To find out, Zheng is setting up a "test bed" of 20 to 30 users to try out her theory under something like real-world conditions. She says she will have this experiment up and running "probably in a few months," and she hopes to expand it to include students all over the UCSB campus.

The 30-year-old Zheng is completing her first year at UCSB but has already gained an international reputation for her research. In October 2005, MIT's Technology Review honored Zheng as one of the top 35 innovators under the age of 35. In April 2006, the magazine listed cognitive radio as one of its "10 Emerging Technologies" and noted Zheng's work in this area. Entering China's Xian Jiaotong University at just 15, she started graduate work at the University of Maryland when she was 20 and earned her PhD at 24. After four years at Lucent Technology's Bell Labs, she returned to China at Microsoft Research Asia in Beijing. Interacting with students there piqued her interest in teaching, and last year she joined the UCSB computer science faculty. There she continues her research on cognitive radio and spectrum allocation as well as directing the LINK Laboratory for Intelligent Networking. "We have a great department moving upward," she says of UCSB Computer Science, and she is now doing her part to raise its profile further.