Team strives to optimize vital wireless networks

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When lives are on the line amid the terrifying fog of war or the desperate chaos of a disaster, fundamental questions of information theory don't seem all that urgent. But a better understanding of how wireless networks operate could help lift the fog and bring order to the chaos, thereby saving lives.

With a new $6.5 million grant from the Defense Advanced Research Projects Agency (DARPA), researchers from Stanford and three other universities have begun a large-scale research effort to understand and improve field communications for soldiers and first responders. The work could affect people in other ways through improved data security, automated homes and highways, novel biomedical applications and ubiquitous access to multimedia data and entertainment.

"Mobile ad hoc networks have been the basis of military communication for decades but most of the work hasn't been based on anything fundamental," says Stanford electrical engineering Associate Professor Andrea Goldsmith, the lead principal investigator on the project. "We don't really know the performance limits or the optimal methods to communicate over wireless networks."

Wireless ad hoc networks are essentially decentralized federations of mobile transmitters that can route data among each other whenever they are in range. They are flexible and easy to establish. But they're not well optimized and their capacity is unknown. The reason is that unlike in a point-to-point connection on a fixed network, wireless ad hoc networks are characterized by energy and delay constraints, interference between transmitted signals, and rapidly changing conditions such as nodes entering and leaving the network and moving around. The result has been networks that, while quickly deployable, aren't nearly as reliable, fast or secure as they could be. Imagine a tank commander under fire but unable to call for air support, or a firefighter whose message about low water pressure ends up lost in a queue of less urgent messages.

To ultimately enable better network performance, Goldsmith and 11 colleagues from Stanford, the Massachusetts Institute of Technology, the University of Illinois at Urbana-Champaign and the California Institute of Technology will work together to discover the theoretical underpinnings of ad hoc wireless networking. The other Stanford researchers are electrical engineer Stephen Boyd, the Samsung Professor in the School of Engineering, and Ramesh Johari, assistant professor of management science and engineering. This team will work in parallel with another DARPA-funded team led by the University of Texas-Austin.

New ideas for wireless networks

The grants represent a rare and unusually large investment in basic theoretical research, Goldsmith says. The grant process was therefore unusually competitive. "Answering the proposal generated a lot of new ideas in the fundamentals of wireless network design and performance," says Goldsmith. "It really energized the research community."

The most basic issue the team must answer is the capacity limit of wireless networks. "Obviously, if we don't know what it is, we don't know how close we are to hitting it," Goldsmith says. "We also don't have the design insights and guidance that come with knowing fundamental limits and the techniques that achieve those limits."

For example, a needed innovation is giving the network the "intelligence" to detect when it is near full capacity and to give different kinds of messages (distress calls, for example) priority over others (routine surveillance video feeds). Another critical area of investigation is how to prolong the lifetime of networks with battery-powered nodes that cannot be recharged—for example, nodes deployed in remote locations.

Beyond that, a key question will be how to design a network to be as secure from hackers as possible within performance constraints (for example, encryption takes resources from communications). Other potential innovations could include developing new ways to route information around the network and methods for transmitters to cooperatively allocate resources such as power and bandwidth, either to bolster the network's stability or to optimize its performance.

In addition to supporting military and first-responder communications, Goldsmith envisions commercial uses for improved networks, such as linking sensors along "smart" highways to enable automated driving. Cars could drive faster and with less congestion if they were intelligently controlled by a network that was aware of traffic and road conditions. Similar ideas can be used to design energy-efficient smart homes and buildings, intelligent security, and systems to assist the elderly and disabled.

Source: Stanford University, by David Orenstein