

Photo by Daniel Dubois

Stephen Williams, Kenneth Frampton and Isaac Amundson, left to right, holding synchronous calling nodes

## Sensor network mimics synchronized calling by frogs, cicadas

By David F. Salisbury

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**T**he modern world is filled with the uncoordinated beeping and buzzing of countless electronic devices. So it was only a matter of time before someone designed an electronic network with the ability to synchronize dozens of tiny buzzers, in much the same way that frogs and cicadas coordinate their night-time choruses.

“Several years ago I was on a camping trip and we pitched our tent in an area that was filled with hundreds of tree frogs,” says Kenneth D. Frampton, an assistant professor of mechanical engineering at Vanderbilt University, who dreamed up the project. “The frogs were so loud that I couldn’t get to sleep. So I began listening to the chorus and was fascinated by how the pattern of synchronized calling moved around: Frogs in one area would croak all together for a while, then gradually one group would develop a different rhythm and drift off on its own.”

## Synchronized calling networks

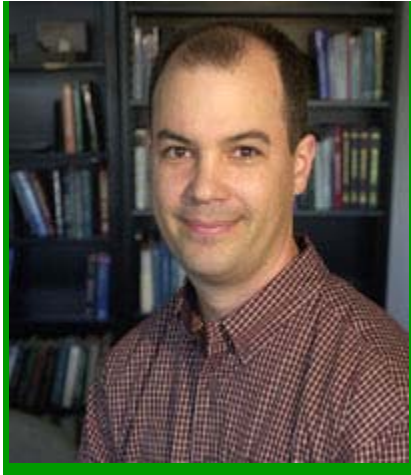


Photo by Daniel Dubois

Ken Frampton

Last summer's emergence of cicada brood X brought back that memory and prompted Frampton to assign undergraduates Efosa Ojomo and Praveen Mudindi—working under the supervision of graduate students Stephen Williams and Isaac Amundson—with the task of simulating this complex natural behavior using a wireless distributed sensor network. They presented the results of their project on Nov. 16 at the annual meeting of the Acoustical Society of America in San Diego.

Consulting the literature about animal vocalizations, the engineers discovered that a number of different theories have been advanced to explain such naturally occurring synchronized behaviors. They may have evolved cooperatively in order to maximize signal loudness, to confuse predators or to improve call features that attract potential mates. Or they may have evolved competitively in order to mask or jam the calls of nearby animals.

“Whichever theory is true, it is clear that these behavior patterns are complex and offer an interesting inspiration for group behaviors,” says Frampton.

One thing that these behaviors have in common is that they are produced by groups of animals who are in communication with each other but who are acting on their own. Networks consisting of nodes that communicate with each other but act independently according to simple rules are becoming increasingly popular and were the obvious system to use.

“There is a great deal that we do not yet know about the group behavior of such systems,” says Frampton. “So, in addition to being a lot of fun, the synchronized calling experiment is adding to our understanding of the behavior of this kind of network.”

The engineers began with a wireless network of 15 to 20 “Motes,” a wireless network designed by computer scientists at the University of California, Berkeley and manufactured commercially by [Crossbow Inc.](#) These are small microprocessors equipped with wireless communications. The researchers added a microphone and a buzzer to each node.

To mimic synchronized calling behaviors, the researchers first programmed a single leader, dubbed the alpha node, to begin calling (buzzing) with an arbitrary duration and frequency. The alpha node was set so it called at this rate regardless of any other calling in its vicinity. The remainder of the devices, referred to as beta nodes, were programmed differently. They were instructed to listen with their microphones and when they hear a call that is sufficiently loud, to estimate its duration and frequency and then begin calling in synch with the detected call.

“Although this behavioral algorithm is quite simple, it produces some interesting group behaviors,” Frampton reports.

When all is quiet and an alpha node begins calling, at first only those beta nodes nearby hear the call and respond. Then, as more betas swell the chorus, nodes farther away hear the call and join in. In this fashion, synchronized calling gradually spreads concentrically out from the alpha node until all the nodes are synchronized.



Photo by Steve Green

Efosa Ojomo

## Synchronized calling networks



Photo by Daniel Dubois

Steven Williams, left, and Isaac Amundson inspecting nodes

A second interesting behavior occurs when a beta node “hiccups” and starts buzzing out of synch with its neighbors. Such hiccups can be caused by measurement noise, operating system jitter and other factors. Occasionally, when such a hiccup occurs, neighboring nodes resynchronize to the errant node. Normally, these transients quickly disappear as the wayward group resynchronizes with the larger group.

The most interesting behavior pattern appeared when the researchers introduced a third kind of node that they labeled omega. This node was programmed identically to an alpha node but set to a different duration and frequency. When introduced into the array, an omega node begins to attract neighboring nodes to its call cycle. Unlike the hiccup case, however, the omega group does not resynchronize with the original group. Rather, the omega node eventually recruits a growing number of nodes to its calling cycle until a “balance

of power” is reached with the alpha node. The eventual balance between the two groups depends strongly on the initial arrangement of the sensors.

“While this is a rather whimsical application of a sensor network, it demonstrates the unique system behaviors that can arise in truly distributed processing,” says Frampton. Even when nodes follow very simple rules, the behavior of the group can be quite complex. Although this project is not likely to improve knowledge on synchronized calling in nature, it does demonstrate the types of complex behavior patterns that will be important for future developments in sensor networks, Frampton says.



# Synchronized calling networks

## Undergraduate played key role in developing the synchronized calling network

By Ximena Lavender

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Photo by Steve Green

Efosa Ojomo

Standing up in front of a room full of the nation's top experts and presenting the results of your recent research—and then defending by responding to probing questions from the audience—is a prospect that can make even veteran presenters nervous. But not Efosa Ojomo, a Vanderbilt senior who has yet to receive his bachelor's degree in computer engineering.

In November the supremely self-confident young engineer presented a summary of the research that he conducted this past summer at the annual meeting of the Acoustical Society of America in San Diego, California. He reported on the successful creation of an electronic network that can mimic the synchronous calling behavior of a number of different animals, including cicadas and frogs, with amazing fidelity. His presentation was one that the conference press officer highlighted for the media covering the meeting.

“I was intimidated at first,” Ojomo acknowledges, “and I was the first one after lunch, but it felt good being able to stand your ground in front of an older, more experienced audience.”

“I was impressed with his self-confidence,” says Kenneth D. Frampton, the assistant professor of mechanical engineering who supervised the project. “He even had some fun and cracked a few

jokes.”

The research project was part of a summer internship program for under-represented minority students from the southeastern United States. Called the [Vanderbilt Summer Internship Program in Hybrid and Embedded Software Research or SIPHER](#), the program focuses on hybrid systems—frequently called smart devices—that combine computers with electrical and mechanical components. These systems are becoming increasingly commonplace in everything from toys to telephones, from automobiles to airplanes. The program is funded by the National Science Foundation. (See [Engineering undergrads encounter “real life” problem solving](#)).

To create the synchronous calling network, Frampton had Ojomo start with an off-the-shelf, distributed networking system. Each node consisted of a radio transceiver that allows the nodes to communicate with each other and an onboard microprocessor that can be programmed to control the node's behavior. The nodes are designed so that additional sensors and devices can be added.



Photo by Daniel Dubois

Kenneth Frampton holds up network node

## Synchronized calling networks

For the summer, Ojomo was paired up with another undergraduate, Praveen Mudindi from Alabama A&M University, and they worked under the supervision of graduate students Stephen Williams and Isaac Amundson. The students added sensitive microphones and buzzers to the nodes and wrote the programs that controlled each node's behavior. At the end of the summer, Mudindi returned to Alabama while Ojomo continued to work on getting the bugs out of the system.

Ojomo worked specifically on programming the devices and on developing a louder buzzer, when they found that the buzzers they were using weren't loud enough for their application. He acknowledges that he "got a lot of help from Stephen and Isaac."



Photo by Daniel Dubois

Close up on one of the synchronous calling nodes

Through his participation in [Vanderbilt's summer internship program](#), Ojomo says he has learned that an important part of a successful research career "is to get your name, your lab's name and Vanderbilt's name out there." The way to do that is to prepare papers on the research that are good enough for publication and to present your work at major conferences, such as the ASA meeting in San Diego, he adds.

According to Ojomo, his talk went "really well" overall. His presentation included a demonstration. He distributed a number of nodes to members of the audience. Then the Vanderbilt researchers turned on the network and the audience were able to hear first-hand how the devices went in and out of synchronization.

"The audience loved the simulation," says Ojomo. "But it didn't work as well as it did in the lab, because the presentation room was acoustically dead." The walls in the laboratory reflect sound more efficiently, allowing the sensors to detect the calls from other nodes more readily.

Ojomo credits Senior Associate Dean Arthur Overholser at the School of Engineering with convincing him to transfer to Vanderbilt from Fisk University, which he attended for three years. At Fisk Ojomo was a computer science major, but changed to computer engineering when he entered Vanderbilt.

The next step in Ojomo's scientific career will be moving to Austin, Texas to accept a job at National Instruments. Eventually, he would like to go back to graduate school to obtain an advanced degree.

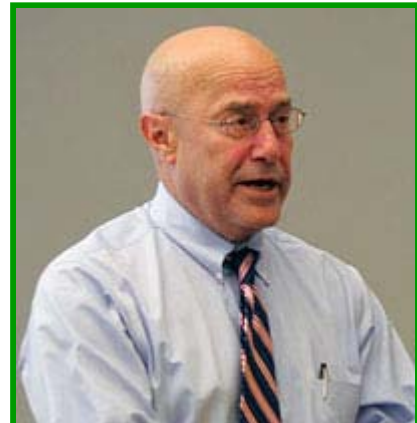


Photo by Neil Brake

Arthur Overholser



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