

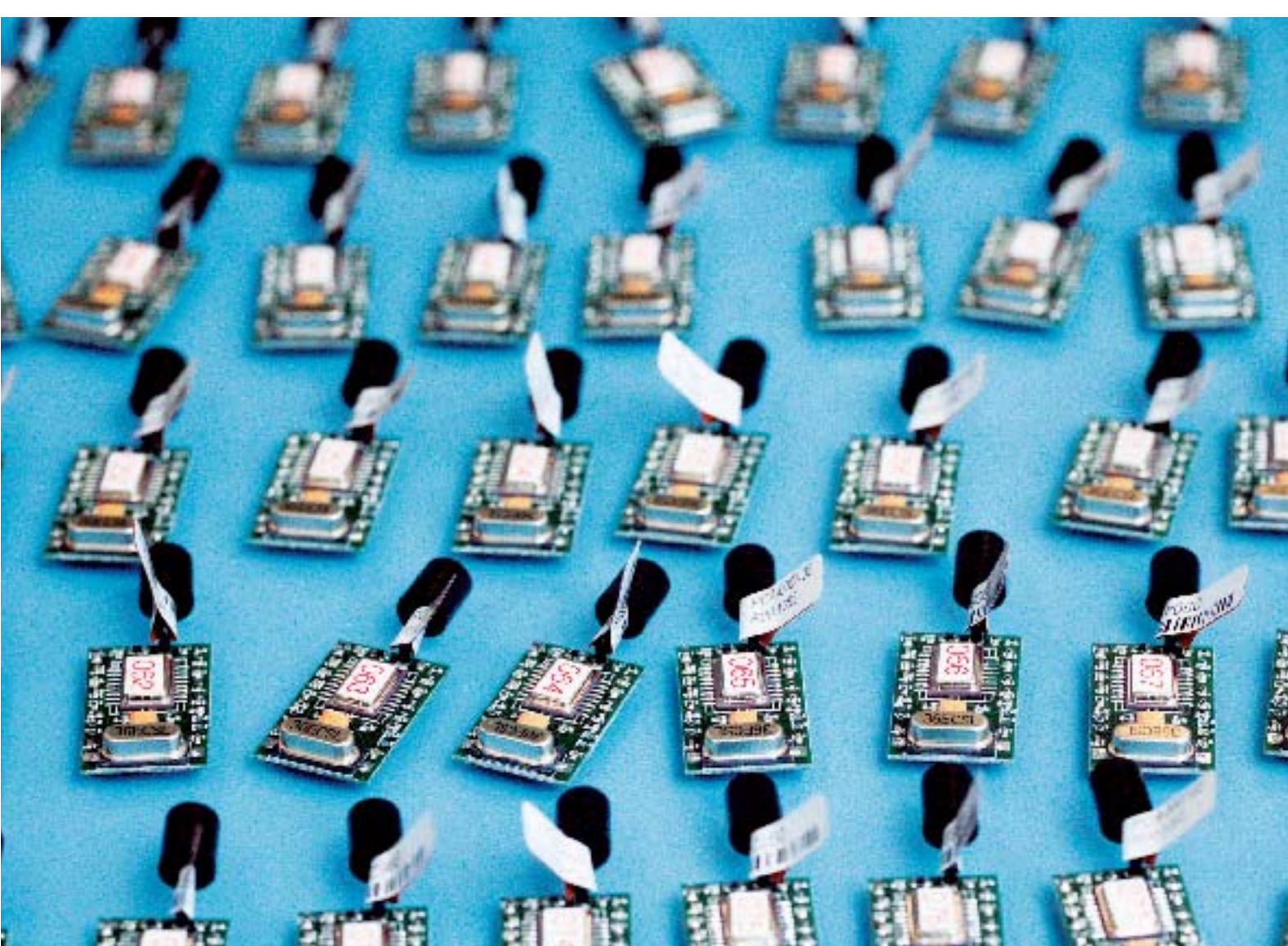
A man with glasses and a light blue button-down shirt is holding a small, green and black electronic device in his hands. The device has several wires attached to it. The background is a plain, light-colored wall.

DEMO

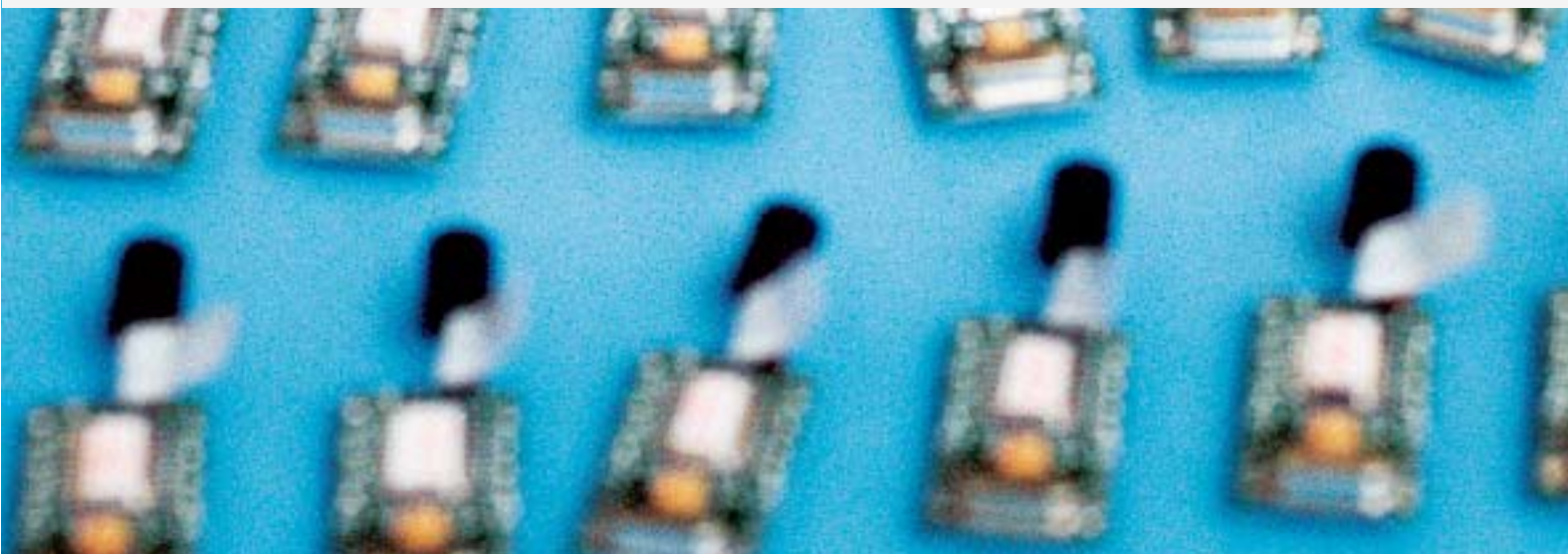
SENSOR WORLD

IMAGINE A WORLD IN WHICH TINY WIRELESS SENSORS REPORT BACK TO YOU ON EVERYTHING FROM AIR QUALITY TO TEMPERATURE CHANGES TO TRAFFIC CONDITIONS. **SOKWOO RHEE** AT **MILLENNIAL NET** IS BRINGING IT CLOSER.

PHOTOGRAPHS BY KATHLEEN DOOHER



EMBEDDED IN HOMES, OFFICES, CARS, AND FACTORIES, thousands of tiny computerized sentries could track inventories, monitor electricity use, and even detect ground vibrations and toxic gases to provide early warning of earthquakes and chemical spills. But how are researchers turning this vision into reality? “What we bring to the table is, we make real products,” says Sokwoo Rhee, chief technology officer of Millennial Net, an MIT spinoff. By designing ultralow-power, postage-stamp-size hardware and smart networking software for sensors, he says, his team is building the “Swiss Army knife of wireless applications” that can go anywhere, anytime. Millennial Net’s products are already being used to automate and report meter readings, detect carbon monoxide and turn on ventilation fans in parking garages, and track temperature-sensitive items like food and drink in transport. The goal is to be integrated into “millions of devices by 2007,” says Rhee, so that a sensor in a streetlight, say, could alert you to weather or traffic problems via your cell phone. At Millennial Net’s headquarters in Cambridge, MA, Rhee showed *TR* associate editor Gregory T. Huang how to assemble a wireless mesh of networked sensors—and deploy them to do work in the real world.

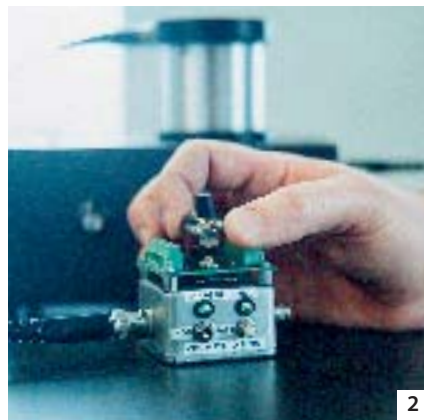




1. NODE NEWS IS GOOD NEWS. Say you want to set up a wireless sensor network to closely monitor temperatures and energy use at many spots in a large office building. The first step is to gather network “nodes,” which are connected to different kinds of sensors and communicate wirelessly with one another.

In his office, Rhee tests out some newly minted nodes. Each node has a processor, memory, a radio, and a battery and is programmed to store data and talk to other nodes. Rhee probes each piece of hardware, checking the strength and timing of various electrical signals. “We look at the network behavior to see how the nodes interact with each other,” he says. The nodes must be able to organize themselves into a usable network and adapt to other nodes’ getting turned on or off or moved around.

2. POWER PLAY. Key to a practical sensor network is power consumption: nodes may need to work for years without access



to fresh batteries. Rhee’s nodes need so little power that they could run on vibrations from the environment—say, a rattling heating duct or a bumpy truck ride. To test this approach, Rhee places a cylindrical “energy harvester” on top of a vibrating platform. The harvester converts the vibrations into electricity to power a sensor node (*in hand*). This project is early-stage, says Rhee, but eventually his nodes could be completely battery free.



3. NETWORK GOES LIVE. Next, Rhee gets his state-of-the-art sensor network up and running. To make sure things are working, he spreads nodes around the lab. One by one, they come online, taking temperature readings and routing data to each other. One node connects to a laptop, which shows the status of all nodes—who’s talking to whom and when—and lets the user click around to get more info. This could also be done via a handheld computer.



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4-5. SENSORS THAT DO WINDOWS. With the user interface set up, it's time to deploy the sensor network to do real work. Under a window in the lab, Rhee installs a node equipped with temperature and humidity sensors (4). The node keeps tabs on the window's performance: how much heat is lost, how much moisture leaks through. In an early application, says Rhee, window and door manufacturers are installing networked sensors in condominiums for warranty protection and checking them remotely using cell-phone modems and a local computer.

As a step toward automated building maintenance, Millennial Net is making sensor nodes communicate with a specially modified thermostat (5). The thermostat is equipped with a tiny computer and acts as central command. "Eventually," says Rhee, "thermostats will be integrated with wall sensors" to regulate room temperatures, detect insulation problems, and save energy.



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6-7. HITTING THE ROAD. An advantage of small, low-power nodes is that they're mobile. To monitor shipping conditions en route to a supplier—important for perishables like meat, dairy goods, and medicines—a sensor node in a protective white case can be mounted in the back of a truck, measuring temperature and humidity every few minutes (6). Upon arrival at the loading dock, the node sends its tracking history to a fixed node on the wall (7). This node is connected to the receiving company's computer, which stores a detailed record.

Wireless sensor networks are still a fledgling business. Applications continue to be refined, says Rhee, but "putting more products on the market" will create the framework for new uses. If it's successful, his company stands to lead the way to a more efficient and better-networked world. ■