SCIENCE@BERKELEY LAB

Lighting it Right with Smart Dust

Allan Chen, a_chen@lbl.gov

The next time you walk into an empty meeting room or office on a sunny day, notice whether the lights are on. If yes, and the room has windows, you might wonder why someone—or some automatic system—hasn't turned them off to save energy.

It's a sunny day and the room is empty. Why are the lights on?

Decades after scientists recognized the potential for saving energy by letting daylight give the electric lights a rest, automated systems that can do the job are only now close to appearing on the market. Researchers from Berkeley Lab's Environmental Energy Technologies Division (EETD), the high-tech start-up company Dust Networks, and SVA Lighting are working together on just this kind of technology—a technology that could save hundreds of millions of dollars annually on lighting-energy costs.

The Department of Energy has funded a research project to develop wireless networking solutions for lighting control systems that can use daylight more effectively. The project brings Francis Rubinstein and David Watson of EETD and Steve Purdy of SVA Lighting Design together with Dana Teasdale of Dust Networks, a company that provides wireless-mesh networking technology based on "smart motes."

The expression "smart dust" was coined by Kristofer Pister, one of Dust Networks' founders in 2002 and a professor of electrical engineering and computer sciences at the University of California at Berkeley. He used the term to describe tiny, expendable sensors, which are the key to low-power, connected networks that include control devices and computers. Smart-mote technology is now finding its way into commercial and industrial applications for making buildings more comfortable, reducing energy costs, and optimizing the use of materials and energy in industrial processes.

Although wireless motes already have many applications, researchers expect their use for energy efficiency and environmental comfort in buildings to become widespread once products appear on the marketplace—a prospect that could be just a few years away.

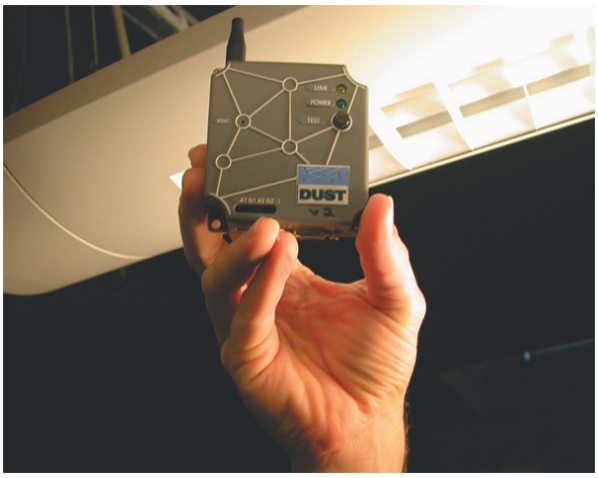
Saving lighting energy through daylight and user controls

If buildings could automatically dim electric lights in daylit spaces, and building occupants could manually dim local lighting according to preference, the U.S. could save more than half a quadrillion Btus (British thermal units) a year, about 14 percent of the 3.7 quadrillion Btus used annually for lighting in commercial buildings—a total equivalent to the output of over 175 modern power plants.

These strategies require smart-building infrastructures—sensors that measure how much daylight is available in a room and lighting fixtures that respond quickly and reliably to user input, plus automated systems, software-based control algorithms, and a network that ties all of these devices and systems together.

Berkeley Lab's Rubinstein has been applying networking systems to daylighting and lighting control for years. Starting in 2000, his team began developing an integrated building equipment control system (IBECS) that allows facilities managers to automatically control lighting in commercial buildings from a computer workstation. The wired systems they developed proved cost effective in new construction and major renovation projects, where the cost of adding wiring is not prohibitive. But to penetrate the much larger existing-building market, additional control wiring would have to be eliminated.

"Existing commercial buildings use over 95 percent of all electricity for lighting, but it is not cost effective to add control wiring to the ceiling to control lighting loads," says Rubinstein. The need is for "technology that is reliable and inexpensive enough to be retrofitted to commercial buildings."



A Dust Networks mote, part of a prototype system being tested to demonstrate wireless control of office fluorescent lighting.

Dust settles on the problem

Rubinstein teamed with Dust Networks in 2003 to test wireless-mesh networking in existing buildings with components based on Dust Networks' SmartMesh™ technology, including an analog control module and "mote-integrated dimmable ballasts" (MDBs), which work in existing lighting systems.

The ballast is the unit in a fluorescent lighting system that provides power at the proper frequency. Dimmable ballasts allow lights to be tuned continuously from full brightness to a low level (usually about five percent of total brightness) to save electricity and reduce glare. Berkeley Lab researchers worked with the lighting industry in the 1970s to develop the first electronic ballasts, replacing less efficient magnetic versions. Today, energy-efficient, nondimming electronic ballasts account for the major share of the market.

The building-controls research team built prototype MDBs incorporating mote technology, with an antenna on the mote allowing wireless communication. The motes receive instructions from Dust Networks' SmartMesh Manager, a single-board computer connecting the entire network.

No wiring makes it cheaper—and it can sense the environment too

Since mote-embedded MDBs need no low-power wiring, the control system is less expensive and easier to install. Old ballasts can be replaced with new MDBs during routine building maintenance. Wireless sensors have also been developed that can tell whether a room is occupied or empty and can monitor its heating and cooling needs.

"The use of wireless technology substantially reduces the installed cost of these systems," says Berkeley Lab's David Watson.

Preliminary analysis indicates that installing this wireless control system in an existing 16,000 square-foot building costs about 30 percent less than a comparable wired system. The wireless system will pay for itself in three years.

Energy management and control in buildings may soon join the wireless revolution, and the marketplace will have a new wireless solution for saving energy in commercial buildings.

This is an edited version of an article appearing in the January, 2006 edition of Science@Berkeley Lab, the online science magazine of Lawrence Berkeley National Laboratory. The full-length version, including links to further information, may be accessed at http://www.lbl.gov/Science-Articles/Archive/sabl/2006/Jan/06-smart-dust.html.