Enabling Technology Development Project
October 19, 2007

ENABLING TECHNOLOGIES FOR LEGACY BUILDINGS

Research Opportunity Notice

Overall Objective

The objective of this Research Opportunity Notice (RON) is to solicit research and development (R&D) proposals to provide disruptive enabling technologies for energy reduction and demand response (DR) applications in legacy (already built) buildings. Proposed R&D may address one or more enabling technologies which further the goals described in this RON. R&D proposals should focus on enabling technologies development as opposed to commercial product development.

Primary Goals

The primary goals for developing enabling technologies that reduce energy consumption and promote DR for legacy building applications include:

- Use standards-based communications between sensors, actuators, embedded control computers, etc., to facilitate operational or supervisory control tasks (as opposed to unitary or equipment control tasks) that minimize 24/7/365 energy use, facilitate signal-driven DR and reduce carbon production while maintaining proper building functionality (e.g., comfort, indoor air quality, lighting, etc.).
- Achieve less than two-year payback of retrofit (and factory-installed) hardware and software products through lower energy-consumption, product, installation and maintenance costs.

Additional goals include:

- Sensors that are self-calibrating, report anomalies and faults automatically, and scavenge environmental sources for power supply.
- Communications that automatically form ad hoc, self-healing networks.
- Actuators that support variable-speed (frequency) operations.

Some Background

Legacy buildings are far more energy consumptive than they might be if modern digital control systems could be cost-effectively retrofitted and used to employ low-energy strategies. Direct digital control (DDC) systems in new buildings are typically composed of standalone machine or zone controllers connected to (1) machine-embedded sensors or nearby thermostats via analog (e.g., 4-20 ma) wires and (2) supervisory panels via twisted pair (e.g., RS-485) networks. Installing a wired controls infrastructure during building construction is usually cost-effective. However, retrofitting a wired control system after construction is often cost-prohibitive.

New technology paradigms are emerging that could make retrofitting controls systems more cost-effective. These paradigms include wireless communications networks,

MEMS (Micro Electro-Mechanical Systems) sensors integrated on the same silicon with communications, computation, self-generating power supplies, more modern control systems that allow for new downloaded logic (in addition to setpoints), etc. Although some of these technologies have been around for 5-20 years and are being used in other industry applications (e.g., MEMS sensors are used in automotive braking systems), they have not been adopted in many building controls applications. An example of a product that has benefited from recent enabling technologies development is the Federspiel Controls, Inc. DART™ system. DART™ is a retrofit HVAC (heating, ventilating & air-conditioning) application in which significant operational electrical fan energy can be saved by converting a CAV (constant-air-volume) AHU (air handling unit) to a VAV (variable-air-volume) AHU. DART™ uses recently available commercial WSN (wireless sensor network) technology that makes it possible to cost-effectively retrofit sensors and a variable-speed fan drive in order to implement an energy efficient digital control system strategy. Using an enabling technology such as WSN has allowed Federspiel Controls to sell DART™ primarily because the low installation cost yields a reasonable investment payback through energy saved.

Another example of a wireless technology application is the Field Diagnostic Services ACRx® Sentinel system. This system is designed for continuous monitoring of Package Rooftop Air Conditioning equipment. The system employs temperature and pressure sensors to compare measured unit performance with a model and can detect and diagnose faults in refrigeration and air handling components.

At present, the system uses a wiring harness for sensors local to the unit and wireless communication to relay information between rooftop units for off-site processing. A possible upgrade would be to use wireless communication between sensors in a local unit. A similar application would be wireless communication between sensors on built-up air handlers and other sorts of equipment, to facilitate monitoring and diagnostics. New enabling technologies could make these kinds of applications more cost effective.

Other applications could involve lighting sensors, both for permanent installation and for temporary or commissioning applications and occupancy sensors for lighting or HVAC controls. Proposals for basic technology improvements, with respect to reliability, communications, battery life or energy scavenging, or sensing capabilities that can lead to further applications would be welcome, as would proposals on system level technology improvements, where there is the potential to improve performance and energy efficiency in buildings.

The DART™ and ACRx® Sentinel examples demonstrate that energy savings opportunities exist for using enabling technologies retrofitted into legacy building applications. The purpose of this RON is to promote the further development of disruptive technologies (e.g., new MEMS wireless sensors that operate on scavenged environmental energy) that can facilitate the cost-effective deployment of buildings applications such as continuous commissioning, fault detection and diagnosis (FDD), etc., in order to save wasted energy.

Enabling Technologies Applications

Disruptive enabling technologies have the potential to eliminate cost and other barriers that allow new system- and machine-level paradigms that result in:

- Reasonable payback periods from lower energy usage and other savings.
- Improved reliability from condition-based maintenance (CBM) and continuous commissioning.
- Improved operations from information-rich environments with integrated energy management and comfort management systems.

Some Potential Enabling Technologies

1. ***Machine-integrated MEMS-based sensors***. These integrated sensors will provide system-level information in addition to monitoring equipment status and condition functions. For low manufacturing cost and low energy consumption, the sensors will utilize Micro-Electromechanical System (MEMS) technology. Proposed research in this area should leverage research currently underway at UC Berkeley, but other approaches will be considered.

   Sensing features:
   - Voltage, current, power factor, etc., for managing energy and peak power usage, reporting power quality problems, identifying & locating faults, etc.
   - Temperature, humidity, etc., for managing comfort.
   - Light levels, motion, etc., for managing occupancy.

   Communications features:
   - Wireless (radio-frequency, RF, or Power-line Carrier, PLC) mesh network communications with ad hoc self-healing characteristics to support ever evolving building configurations and usages.
   - Connectivity to emerging utility-owned Advanced Metering Infrastructure (AMI) networks for interval-metering, billing and grid-related information.

   Easy installation features:
   - Passive, proximity, and non-intrusive.
   - Self-calibrating.
   - Scavenge energy from the environment (no batteries or wiring for power).

2. ***Control and Communications Integration technology***. The research in this technology will look into new ways to operate buildings that are different from today's methods. If integrated MEMS-based sensors are deployed on a large scale, there will be a rich environment of real-time information. Using this information, new control strategies may be viable that were previously not possible. Novel new control strategies in a new paradigm of real-time information-rich environment.

Summary

The purpose of this RON is to solicit proposals for research and enabling technologies development for the building applications. The outcome of these R&D efforts is not to produce a product but to advance the enabling technology that will contribute to making buildings operate more efficiently and with an automatic demand responsive capability.

Candidate research topics are listed in the prior section. Proposals may address these research topics or other related topics not listed that further the goals described herein.

Acronyms

AHU	Air-Handling Unit
AMI	Advanced Metering Infrastructure
CAV	Constant Air Volume
CBM	Condition-Based Maintenance
DART™	Discharge Air Regulation Technique
DDC	Direct Digital Control
DR	Demand Response
HVAC	Heating, Ventilation, and Air Conditioning
MEMS	Micro-Electromechanical System
PLC	Power-line Carrier
R&D	Research and Development
RF	Radio Frequency
RON	Research Opportunity Notice
VAV	Variable Air Volume
WSN	Wireless Sensor Network

Definitions

Condition-based Maintenance	Equipment maintenance is based on the equipment's health, rather than based on a schedule or equipment failure.
Demand Response	Reducing demand in response to a curtailment notification or short term price signal
Dynamic Tariff	A tariff in which the retail electricity rate is characterized by one or more dispatchable prices intended to reduce and/or shift peak load. (See Tariffs)
MEMS	Micro-Electro-Mechanical Systems (MEMS) is the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through micro-fabrication technology
Tariffs	The effective rates for electricity that includes rules, rate schedules, and service area maps.
Wireless	No wires between source of information and receiver of the information