

THERMOSTAT
Research Opportunity Notice

Overall Objective

The overall objective of any proposed R&D prepared in response to this “thermostat” research opportunity notice (RON) is to develop enabling technology for an integrated communicating temperature sensing node that can support dynamic tariffs and demand response (DR). Two different but related platforms are the focus of this RON. The first is a thermostat (NewStat). The second is a temperature sensing node (TempNode). Proposed R&D may address part or all of the technologies and/or any related technologies which further the goals described in this RON. The outcome of any R&D tasks funded is not to produce a product but to advance enabling technologies for such a product.

Specific Goals

The specific goals for a NewStat enabled by any proposed R&D tasks include:

- Installed cost comparable to current low-end products, i.e., <\$30
- Communications range of 10-300 meters with a very efficient wireless network
- Easy installation with compatibility to legacy control wiring
- Scavenge energy for operation to extend battery life or eliminate batteries
- Support for dynamic tariffs and DR strategies with a user interface (UI)
- Measure environmental parameters in addition to temperature

The specific goals for a TempNode enabled by any proposed R&D tasks include:

- Installed cost for each node < \$10
- Communications range 10-50 meters with a very efficient wireless network
- Easy installation in self-organizing networks including other devices, e.g., NewStat
- Scavenge energy for operation to extend battery life or eliminate batteries
- Support for dynamic tariffs and DR strategies
- Measure environmental parameters in addition to temperature

Some Background

Electromechanical (EM) and electronic thermostats are available.

EM thermostats generally provide one or two manually adjustable setpoints and either require no external power to operate or “steal power” from the 24-volt ac circuit they are controlling. They use bimetal elements as temperature sensors and mercury or mechanical contacts as actuators.

Electronic thermostats generally have more sophistication. They usually contain a user display, provide a programmable series of setpoints, use solid-state elements as temperature sensors, and either solid-state elements or mechanical relays as actuators. These units typically contain a battery and may also “steal power”.

What all these thermostats do not do is provide a communications means to other devices and allow their setpoints to be modified intelligently based on information sent or received over that communications link.

Purpose of this RON

The purpose of this RON is to solicit proposals for R&D tasks to develop enabling technologies that will support the creation of an inexpensive, integrated solution for intelligent temperature

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measuring and reporting platforms. Such platforms could act as a space thermostat (NewStat) or as one of a group of sensing nodes (TempNodes) acting together to enable intelligent control for some other device. A main goal of funded R&D under this RON is to create enabling technology that will lead to an order-of-magnitude (10 times) increase in functionality while reducing total installed costs to one tenth (1/10th) of an equivalent thermostat and temperature node using today's technology.

R&D Task Goals

The goals and features of NewStat and TempNode are somewhat different as noted above. The enabling technology, however, substantially overlaps and will be described below.

NewStat installed cost <\$30, TempNode installed cost <\$10: A NewStat should be cost competitive with the lowest cost thermostats presently in use. It is important that a NewStat be able to use legacy controls wiring to HVAC (heating, ventilating, and air conditioning) equipment.

The TempNode has an even lower cost target, as it is a simpler device because it has neither a user display nor a need for actuators. Its cost should be low enough to allow economic installation of multiple cooperating nodes within the same environmental space.

These cost targets will require a totally integrated solution, with sensors, computation and communications all on a single chip. There are substantial challenges to be solved in this integration such as properly measuring environmental temperatures while dissipating the energy required for wireless communications.

Communications range 10-300 meters (NewStat) & 10-50 meters (TempNode), with a very efficient wireless network: The amount of information communicated to/from the NewStat and TempNode each day is relatively small. The technologies developed for these devices should enable the definition of a wireless network and protocols that communicate this information very efficiently, with very little energy. These may be "bursty" communications or some other solution.

A NewStat's communications are primarily "outward looking", i.e., towards a wide-area network (WAN). Most likely NewStat will be communicating with some device external to the space that it controls. This is the route it will take to get dynamic pricing information and send acknowledgements in exchange for the information it receives. For these outward communications the NewStat may require ranges of up to 300 meters.

A NewStat may also have an "inward looking" communications link to a local-area network (LAN) so that it can pass information to/from other local nodes such as a group of TempNodes or the building electric meter (e.g., NewMeter).

A TempNode's communications will likely be LAN connected as it communicates with other TempNodes, with the space NewStat, and other non-temperature nodes. Local communications will allow for shorter ranges and less energy consumption.

Easy installation: The installation of the NewStat should be no more difficult than that of a current technology thermostat, even though it will provide substantial additional capability. Wireless communications should be enabled with no user intervention. Local setpoint programming and DR strategies should be implemented in a clear and intuitive manner via a UI.

The NewStat should provide an intuitive and simple UI to allow a user to input his/her desires for actions to be taken in response to dynamic pricing and DR requirements. It also must be able to inform a user about the actions NewStat has taken. The task of designing a UI through which users can indicate their wishes in a clear and intuitive manner may be one of the greatest

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challenges for the NewStat. Unless the UI can meet the needs of all users, it will be as useless as the flashing clock on many VCRs.

The installation of a TempNode should be even easier. Ideally, it should attach to an appropriate surface or structure and begin to operate with no user intervention. It should be able to scavenge power from its environment, set itself up in the communications network, etc. all without assistance.

Scavenge ambient energy for operation to extend battery life or eliminate batteries: This goal is to develop technologies that can scavenge the energy that a NewStat or TempNode requires from ambient sources such as vibration, illumination, and heat, or parasitically from the power wiring being monitored, or from some other source. This goal also implies that NewStat and TempNode energy budgets be kept as small as possible.

Support for dynamic tariff and DR: The NewStat must be capable of acting on a dynamic tariff or DR information automatically based on user preferences. It must be able to inform users and energy providers as to what actions have been taken in response to a DR signal. This implies that information may have to be communicated internally and externally.

Measure environmental parameters in addition to temperature: One expected byproduct of the increased integration implemented in the NewStat and TempNode is increased functionality at little or no cost. One possible area of increased functionality is the inclusion of a humidity sensor so that the computation of comfort level vs. energy usage can be performed.

There are other useful measurements that might need to be added to NewStats and TempNodes later. These include indoor air quality (IAQ), carbon monoxide (CO), smoke, etc.

Candidate or Example Implementation of the NewStat

What follows is a description of one possible implementation of the NewStat. This is not intended to be a how-to guide to implement NewStat. It is simply an example of one possible approach that would meet many of the goals outlined above. The purpose of this exercise is to help clarify how a successful NewStat might look and to help create ideas for research topics.

The NewStat is implemented as a single chip, including all computational capability, all radio functionality, and temperature and humidity sensors. The firmware for this chip, and possibly the hardware itself, can be reconfigured remotely, allowing its functionality to be changed over time, as new features are required and new capabilities are implemented. Even the actuator for controlling HVAC equipment, to which the NewStat is connected, is implemented on-chip.

The NewStat includes the ability to communicate both externally with a node outside the space (WAN) and internally with TempNodes and other nodes within the space (LAN).

The NewStat implements algorithms that use data from TempNodes and its own memory to optimally adjust the setpoints based on user comfort and dynamic DR tariffs. It also contains algorithms that monitor the health of the HVAC equipment to which it is connected and provides the user with early warnings of failure or maintenance requirements.

The NewStat contains a UI through which it can interact with the user in a clear and intuitive manner.

The NewStat can be installed by any user within a few minutes without any new wiring. It will scavenge the power it needs to operate from the environment and never require battery changes.

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The NewStat will be packaged for easy installation, and so that it correctly measures environmental temperature.

Finally, the NewStat will have an installed cost under \$30.

Candidate or example implementation of the TempNode

The TempNode will have most of the features of the NewStat listed above. In addition, it will be capable of becoming a member of a self-organizing wireless network, so that a group of TempNodes can cooperate in the measurement of environmental parameters within a controlled space.

The TempNode will be capable of being implemented to measure other environmental parameters than temperature. Humidity, IAQ, light levels, smoke detection, and other parameters are likely candidates.

The TempNode will be able to implement algorithms in cooperation with others in its group to monitor environmental parameters and send important non-comfort, non-energy information such as the detection of extreme temperature rise as a possible safety concern.

Finally, the TempNode will have an installed cost under \$10.

Summary

The purpose of this RON is to solicit proposals for R&D tasks related to enabling technologies for a NewStat and a TempNode. The outcome of these R&D tasks is not to produce a product but to advance enabling technology for such products.

Proposals may address part or all of the technologies, and/or any related technology, which furthers the goals described herein.

Areas of likely interest are temperature and humidity sensors; their integration on-chip with computation and wireless functions; algorithms for comfort and for response to dynamic tariffs; energy scavenging; self-organizing wireless networks; operating systems; user interfaces; packaging; and others not mentioned here.

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Acronyms

CO	Carbon Monoxide
DR	Demand Response
EM	Electromechanical
HVAC	Heating, Ventilation, and Air Conditioning
IAQ	Indoor Air Quality
LAN	Local-Area Network
R&D	Research and Development
RON	Research Opportunity Notice
UI	User Interface
WAN	Wide-Area Network

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Definitions

ANSI C12	Series of ANSI standards that pertain to electricity metering.
Apparent Power	Apparent Power (Kva , kilovolts-amps) is the vector sum of the Real Power and Reactive Power. (See Real Power, Reactive Power, and Power Factor)
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)
Firmware	Software that is embedded in the electronic device.
Indoor Air Quality	The nature of air that affects the health and well-being of occupants. The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) defines acceptable indoor air quality as: "Air in which there are no known contaminants at harmful concentrations and with which a substantial majority (usually 80%) of the people exposed do not express dissatisfaction."
Local-Area Network	A network consisting of nodes that are confined within a localized area. For example, a floor of a building, or the building itself. (See Wide-Area Network)
Modulation	Method of superimposing a signal on a carrier wave form. For example, in radio broadcasts, AM (amplitude modulation) and FM (frequency modulation) are used.
Multi-phase	Alternating current (AC) electricity that consists of more than one phase of current. For example, common residential 240V AC power used for electric ovens and clothes dryers is multi-phase. (See Single-phase)
Non-contact	No physical connection to the current-carrying wire.
Platform	Hardware and software with the ability to perform multiple functions
Power Factor	Ratio of Real Power to Apparent Power. Also the cosine of the angle between the Real Power vector and the Apparent Power vector. (See Apparent Power, Real Power, and Reactive Power)
Reactive Power	Electrical power (Kvar, kilovolts-amps reactive) consumed by a capacitive or inductive load. The Reactive Power vector is orthogonal to the Real Power vector. (See Apparent power, Real Power, and Power Factor)
Real Power	Electrical power (KW, kilowatts) consumed by a resistive load and is the power that is used for real work. The Real Power vector is orthogonal to the Reactive Power vector. (See Apparent power, Reactive Power, and Power Factor)
Revenue Meter	Meter that can be used for billing purposes.
Revenue-grade	Measuring accuracy that meets the requirements needed for billing purposes.
Self-organizing Network	A network consisting of nodes with no fixed hierarchy. Network processes such as configuration, message routing, and node discovery are ad hoc.
Single-phase	Alternating current (AC) electricity that consists of one phase of current. For example, common residential 120V AC power is single-phase. (See Multi-phase)
Soft	Can be re-programmed with new software.
Stranded	Made obsolete because the technology is no longer supported.

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Definitions

Tariffs	The effective rates for electricity that includes rules, rate schedules, and service area maps.
User Interface	An interface for interaction between a user and an intelligent device.
Wide-Area Network	A network consisting of nodes that are dispersed over a wide area. For example, nodes that are located in different buildings, or in different cities. (See Local-Area Network)
Wireless	No wires between source of information and receiver of the information

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