2009 BFRL Project Description

Project Title: Development of Testbed for Wireless Sensor Network Use in Buildings

September 5, 2008

Principal Investigator: William Healy

Co-Investigator(s): Won-Suk Jang

BFRL Program: Cybernetic Building Systems

Objective: To provide potential users of wireless sensor networks in buildings a gauge of their performance by developing a set of measurement techniques to assess the performance of a sensor system in building applications.

Problem:

What is the problem? Advanced sensor technology promises to enable deployment of a large number of sensors in and around buildings to better measure the in-situ performance of building systems, to diagnose construction or operational defects that waste energy, and to provide feedback to occupants on net energy consumption. A key component to such sensor systems is the use of wireless methods to transmit data. While wireless technology facilitates easy deployment of sensors throughout a building, engineers and operators who consider using those sensor systems do not have the measurement science to describe how wireless systems will work in particular applications. For example, an authenticated Measurement Need on Wireless Sensor Networks from the recent USMS assessment states that "Potential end-users of wireless sensor networks have shown reluctance towards using them in a wider range of applications because of uncertainty in the reliability of the wireless links." Furthermore, a recent DOE roadmap entitled "Advanced Sensors and Controls for Building Applications" recommended the development of an Operational Test & Evaluation Program for sensor systems that would "provide systematic and comparable testing, employ and develop testing protocols that are standards based, and help to identify environmental vulnerabilities and operational limitations."

Why is it hard to solve? The development of measurement science that can be used to assess the performance and reliability of wireless sensor networks in buildings is extremely challenging due to the variability in both building types and application requirements. The proposed measurement methods or testbeds should be broad enough to apply to a wide variety of use-cases, yet they must be simple enough to provide useful metrics with minimal effort.

How is it solved today, and by whom? The measurement science to evaluate the performance of wireless sensor systems in buildings is not available. While some studies in the U.S.[1] and the

[1] http://www.boulder.nist.gov/div818/81802/MetrologyForWirelessSys/

National Physical Lab in the U.K.[2] have been undertaken to evaluate how wireless signals propagate in particular buildings, no efforts have been undertaken to develop a comprehensive suite of measurements to assess the performance of wireless sensor networks for building applications. As mentioned in the DOE roadmap on "Advanced Sensors and Controls for Building Applications" in reference to a sensor evaluation method, "no testing and qualification program like the one described in this [document] currently exists."

Why NIST? This project will promote U.S. innovation and competitiveness in the use of wireless sensing technologies in buildings where appropriate by providing the measurement science that will (a) help users of wireless sensor technology gauge the reliability and effectiveness of systems in particular buildings and (b) provide developers of wireless sensor hardware and software a target to which systems should be designed for building applications. This project aligns with BFRL's strategic priority area in Measurement Science for Net-Zero Energy, High Performance Buildings by developing the measurement tools that will enable widespread sensing in buildings to identify opportunities through which energy consumption can be reduced. BFRL is the appropriate organization to lead these efforts because of the measurement challenge in developing an objective testbed to assess performance in buildings.

Approach:

What is the new technical idea? NIST proposes to develop a testbed comprised of several modules that will be used to measure the performance of a wireless sensor network in building-related applications. Each module of the testbed will focus on a different performance metric that is of importance to engineers who make use of the technology. During FY2008, NIST staff interviewed over 30 people from the building controls sector, the research community, building operations sector, and wireless hardware industry to understand the obstacles in adopting wireless technology in buildings. These discussions indicated that users are concerned about a variety of issues, notably interference, battery life, ease of use, robustness, reliability, and security. The technical approach that will be pursued to overcome these concerns is demonstrated by the current development of a test method to assess the quality of a wireless link in various building scenarios. After carrying out exploratory research to scope the particular challenges in buildings, we will develop a short series of tests that can be used to predict the communication link quality for a particular building's construction. The data that result from these measurements can, for example, be used to predict allowable spacing between adjacent wireless communication points to ensure high transmission success rate and optimal network topology. It is envisioned that other components of the testbed will be developed over the next two years in a similar manner, and a method will be devised to combine results from each component to yield a single metric of utility depending upon the user's requirements.

Why can we succeed now? Engineers have begun to use wireless sensors in an assortment of applications in buildings because of the emergence of wireless hardware and the software that operates the sensors in an efficient manner. The hardware and software needed to assess the suitability of wireless sensors to buildings has become available, and emerging reports of user experiences are beginning to indicate the major concerns of users. NIST also has the services of

[2] http://www.npl.co.uk/server.php?show=ConWebDoc.2535

Dr. Won-Suk Jang, a guest researcher in the Building Environment Division, who is an expert in the programming, setup, and use of wireless sensor networks in building applications. Dr. Jang's participation in this project will increase the probability of success.

What is the research plan? NIST has identified the key areas that will be explored as part of the testbed. Key areas of concern where measurements could provide a greater degree of confidence in the performance of wireless sensor networks include signal quality in different building construction, robustness to changes in the building environment (e.g. interference from other wireless devices) and network topology, lifetime of sensor nodes, and ease of use. The overarching goal is to develop the measurement science that will provide a metric for sensor network performance in each of the areas of concern. We are developing a test method to evaluate the wireless link quality in different construction types. We will continue the work begun in FY2008 by focusing on the development of test methods to (a) measure the robustness in the building environment and (b) measure the expected lifetime of sensors within the sensor network.

Task 1: Perform tests to sufficiently scope the major sources of interference and reliability loss in the built environment. These tests, supported by literature searches, will help identify the key parts of building operations that will affect the performance of a wireless sensor network and will form the basis for any test method to assess reliability. Hardware will be procured to assess the performance of a variety of wireless systems, such as those that operate on popular protocols such as the IEEE 802 family of standards.

Task 2: Develop test methods to simulate the effect of building operations on reliability. This test method will capture the effect of the key sources of interference and will result in a metric to evaluate the sensor network's reliability under various building environments.

Task 3: Perform tests to sufficiently scope the major issues in assessing the lifetime of wireless sensors. These tests will examine the major ways in which wireless sensors use electricity from batteries and the varying demands that different applications place on them.

Task 4: Develop test methods to objectively assess the lifetime of sensors in a wireless network to provide an estimate of the frequency of battery maintenance.

A testbed to address ease of use will be developed. The final part of the project will involve devising ways for users to give different weightings to each of the components of the testbed to produce an overall rating of their proposed wireless sensor system.

Recent Results:

Output: Healy, W.M. and Jang, W.S., (2008) "Practical challenges in wireless sensor network use in building applications," NIST Technical Note, in WERB Review.

Outcome: Developed needs assessment that will serve as the basis for an R&D plan that will provide measurement techniques that gauge wireless sensor network performance

Standards and Codes: It is expected that the results of this research could be utilized as part of standard test methods for evaluating the performance of wireless sensor systems in buildings that are developed by SDO's such as IEEE or ASHRAE.