Wireless Measurement System for Building Monitoring and Commissioning

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Introduction

- **Purpose and significance of this work**
  - Large cuts in building energy use are needed to support global warming goals - time is of the essence (e.g., CA AB32)
  - Major new funding is becoming available for this effort
  - New regulations (standards, labeling, certification, etc.) will require unprecedented levels of performance checking and verification
  - Comfort needs to be maintained with energy reductions
  - Many new system types with asymmetrical environments will be used
  - We need better, faster, more efficient means to measure and analyze building performance
Commissioning at the New York Times

**Purpose**

- To develop a multi-function mobile cart and associated tools to support underfloor air distribution (UFAD) commissioning
- Provide data to support UFAD commissioning research
UFAD System overview

Variable plenum pressure

Swirl diffusers

Variable-speed fan coil serving linear bar grilles
UFAD commissioning toolkit

- **Artificial loads**
  - Thermal plume generators to simulate occupied conditions for internal load

- **Cart**
  - Mobile sensor platform supporting wireless temperature sensor network
  - Laptop computer for logging, analysis, and human interface

- **Procedures**
  - Functional testing procedures for UFAD systems
  - Cart operating instructions
UFAD commissioning cart

Self-adjusting ceiling bumper with thermocouple and infrared sensor for measuring ceiling temperatures

Telescoping mast extends to 15 feet

Thermocouples (temperature sensors) at fixed intervals

Custom software collects data from wired and wireless sensors, processes and stores data and provides data visualization

Lanyard and cleat for raising and lowering mast

12-volt gel battery provides approximately eight hours of mobile operation

Wireless temperature sensor motes

Mouse caddy

Plenum temperature and pressure probe

USB hub

Aluminum hand truck frame

Thermocouple analogue to digital (A-D) converter

Plenum pressure sensor unit

Pneumatic tires

Infrared sensor (below frame) measures floor temperature
New York Times cart system architecture

NYT Cart system diagram
Commissioning at NYT
Pre-occupancy workflow

- **Pre-test**
  - Prepare mote maps & test setup
  - Deploy motes
  - Deploy artificial loads
  - Steady state tests
  - “Live walk thru”

- **Commissioning tests**
  - Multiple single zone tests for entire floor, 6-10 locations per zone
  - Save data after each zone test

- **Analysis**
  - Review results offline, compare tests
  - Retest modifications plan

200 artificial loads
70 motes
Detailed view
Analysis screens

- Metrics calculations
Analysis screens

- Acceptance checking
Some things we learned

- **Cx process**
  - Few “knobs” to turn:
    - *Supply temperature is not a tuning parameter for individual zones*
  - Artificial loads work well, but not practical

- **UFAD**
  - Plenum and zones “decoupled” - Plenum temperatures vary widely by location, yet zone profiles consistent
  - Return and ceiling temperatures cool
  - Leakage prevention requires constant surveillance

- **Cart and software**
  - Not practical to analyze while testing
  - Better filtering for analysis needed
  - Smaller, more reliable base station needed
New Project Objectives:
Advanced wireless monitoring system

- Design and demonstrate next generation, all wireless, monitoring and measurement system that can be portable, highly flexible, and easily deployed for all types of new and existing buildings

- Develop functional specifications for prototype system
  - Hardware - Motes & sensors
  - Software – Data acquisition, display, analysis
  - Build two prototype systems
NEW: Proposed System Architecture
Potential uses

- **Commissioning (Cx)**
  - Retro/Re/continuous commissioning
  - Functional testing
  - Controls and operations analysis support

- **Post occupancy evaluation (POE)**
  - Energy performance
  - Comfort performance
    - “Real-time” comfort modeling
    - Desktop monitoring

- **Measurement and verification**

- **Research and case studies**
Possible applications

- New and existing traditional buildings/systems
- Advanced high performance buildings/systems
  - Radiant cooling and heating
  - UFAD/DV/chilled beams – stratified environments
  - Mixed Mode/Natural Ventilation
  - Personal Environmental Control (PEC)
- Data Centers
  - At least 10% energy savings possible (IBM)
- Cool Communities
  - Outside sensors
  - Camera actuation, image capture
Distinguishing features

- Un-tethered measurement system with known calibration and flexible deployment
- Easy deployment
  - Pre-configured mote setup
  - Mote location mapping
- Large sub-system point capacity
  - Multiple sub-systems per project
- BMS interface – seamless integration with mote data
- Remote server
  - Data archiving – automatic transfers
  - Application specific analysis support
Prototype system components

- Motes
  - Mesh technology - Dust Networks @ 2.4 GHz (low power, international standards)
  - 250 motes possible per gateway (or manager), multiple managers possible for a single test series
  - Multi-sensor motes – 8 sensors per mote (direct connect)
  - Maxim “1-wire” temperature sensors
    - **Accuracy**: ± 0.1°C in 10-40°C range (9-12 bit resolution)
  - Configurable sampling rates (burst rate option or image transfers)
  - Automatic I/O configuration
  - Location identification
    - **Near term** - Tablet PC geo tagging and mote naming conventions
    - **Far term** – Indoor GPS solutions
Sensors

- Voltage input
- **Temperature**
  - Air temperature
  - Water temperature
  - Surface temperature
  - Globe temperature
- **Air velocity**
- **Relative humidity**
- **Pressure**
- **Light/solar**
- **Power**
Prototype system components

- **Base station**
  - Small profile PC (FIT PC 2) running DB software
    - 1.1, 1.6 Ghz clock
    - 1GB memory, 2.5” SATA HDD
    - 6W
    - $250-350
  - Interface to Dust mesh network
  - Interface to cell network for access – building independent cell data modems
  - Linux OS, Firebird DB
  - BACnet interface
    - Two way access between systems
    - Command BMS points
Prototype system components

- Application server
  - Data archive and applications server
  - 5 sub-systems each running 5 tests
  - Accessible by 5 users concurrently
  - LabView based interface that supports multiple APIs
  - User annotation during and post test
    - Standard real time displays
    - User created data analysis algorithms and metrics calculations
    - Comparisons to previous data/information, standards, acceptance criteria
Applications examples

UFAD stratification performance

Room temperature analysis

Sept. 2007: Temperature Difference from 74 °F

Perimeter H/C Deadband
Perimeter/Interior
Interior

Perimeter

Percent of Readings

0 10 20 30 40 50
-6 -5 -4 -3 -2 -1 0 1 2 3 4
Summary

- Wireless is here and coming on strong!

- **Wireless system benefits:**
  - independence from but potential integration with/augmentation of existing BMS
  - independence from existing LAN
  - reduced labor (for data gathering and analysis)
  - operations-centric instead of design-centric (many sites could be commissioned all the time from anywhere)

- For the large transformations coming, better tools are needed...wireless can help

- Business models may be changing; now is the time to plan on how best to use it to your best advantage
Questions, comments, contributions

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