Measurement and Communication – Group 2 (Culler)

ARPA-E Advanced Buildings Workshop

Breakout Group #2:

Measurement and Communication
(Chair: David Culler, UC Berkeley)

Overview by Culler

- Back of his mind the issues are:
  - Critical technologies
  - State of the art
  - Barriers to adoption/ROI
- Views of building monitoring
  - Load tree (people tree?)
  - Environment and activity
  - Climate plant

General discussion

- Goals: we are trying to achieve
  - Only delivering when and where they are needed
  - Purpose of measurement? Raise awareness by occupants with the goal of changing their behavior
  - Provide the feedback to the people involved in a way that is meaningful to them (actionable and meaningful)
  - Adding to delivery of what is needed- specifically quantity and quality (i.e. spectrum of light requested)
  - Provide information to the end user about what is possible, provide information to the control system about what are the energy and heat flows at a specific point in the system (inputs) and the current state of the building
  - Provide information to the service providers (i.e. grid providers) – supply chain optimization
  - Note what motivates people- $$, service quality, degree of green, comfort
  - Evaluation of both real time and life cycle measurements- through seasons, retrofit cycles, etc.
  - Provide measurements that either self-diagnose or tell you when they are broken (uncertainty minimization) – actionable and reliable information

    - Culler's view of the critical issues
        - Direct control loop
        - Supervisory loop
        - Leaks and losses
        - Tuning modeling validation and optimization
        - Fault, failure, contradiction detection
        - Safety and health (plant, building, etc.)
        - Waste elimination (par time, part space)
        - Recommissioning guidance
        - Design improvement (learning from older buildings)
        - Characterizing load
        - Inferring user directives
        - Long term learning
- Standards which can be applied industry-wide

- Characterizing load – peer groups are important (people like to know how their performance compares to others)
    - Different people want to know different information
    - Motivating with measurement
- Standards – focus on interoperability of systems (different vendors, manufacturers, etc.) -> need for systems to talk to each other
    - Communication between systems
    - Communication between systems and the user (red light means the same thing on every piece of equipment)
- Discussion of the automotive analogy – why is there no "little red light" in building systems, why has the market not demanded buildings provide feedback the way cars do
    - Customer demand for more information
    - Mass production
    - Commodization of automobiles versus customization of building
    - Service industry with cars (100's of diagnostics) as compared to homes (which has no service industry and very few diagnostics)
- Even though buildings are custom, if the systems could talk to each other it would go a long way to improving the efficiency of the building
- Interoperability of communications is just as important and as big of a challenge as measurement requirements
- Important to assume that buildings will always have legacy systems and they will always have something broken (at least in the communication system)
    - Is a role of future systems to provide oversite of legacy equipment
    - Communication part is key- people need to know that equipment is broken, ideally before there is a major failure of something
    - Make performance more clear – analogy of a prius shows you how your MPG drops when you accelerate too hard – let people know how their energy use is doing with real time information to promote active feedback

Slide 2

What are the critical parameters that should be measured in a building?

Physical Measurements
- Mass flow
  - Hard to measure, critical to plant
  - Wet and dry
- Electrical Power
  - Disambiguation of use, usage per equipment
- Temperature
  - Increased spatial fidelity, occupant relevance
  - IR can be used widely
- Humidity/Moisture
- Others?
- Occupancy
- Light & radiation
- Mode of operation (status, broad config)
- Weather (OTA, Solar load, humidity)
- Pressure
- Indoor environment qual (voc, co2, ..)
- Acoustics
- Physical config of building

Derived measurements

Distillates
- Efficiency - +> utility & delivery cost
- Satisfaction
- Heat flux
- Energy flows (total and breakdown)
- Breakdown is as important as the measurement

- Critical parameters (slide 2)
  - Suggestion to change into physical measurements and parameters (distillate – derived measurement)
  - Occupancy
  - Occupant satisfaction
  - Efficiency – both the utility measurements and the delivery cost
  - Two lists- physical measurements and parameters (measures of performance based upon the physical measurements)
  - Light and radiation
  - Electric power – need to include point of use, information about if something is on or not at a given point in time
  - Heat flux – esp for a building walls (i.e. infrared pictures)
  - Modes of operation (cooling, start-up, high occupancy, etc.) – both a measurement and a parameter
  - Weather – outside temp, etc.
  - Temperature –
    - increase fidelity (i.e. personal thermostat which follows the person)
    - need to know both temperature and air quality (not just the temp of the wall)
  - Mass flow
    - Very hard to measure (unlike temperature)
    - Depends on what type of mass you want to measure

        - Area of need which needs to be addressed
        - With natural systems – mass flow becomes even more important to measure (needed for IAQ measurements)
        - Water flows
    - Discussion of the difference between things which need to be audited (i.e. an IR picture of a building to see energy flux through the walls) versus what needs to be measured in much tighter frequencies
    - Need to measure inputs into the building (electricity, steam, gas, solar energy, etc.)
    - Acoustics
    - Configuration of the building (doors open, closed, etc.) – related to modes of the building

Slide 3

Where should these measurements be taken?
What is the appropriate frequency for each type of measurement?

- Where should measurements be taken – decided to skip
  - Spatial needs
  - Temporal needs

Slide 4

In order to precisely and accurately take measurements, what are the present sensor capabilities?

- Wide use of low first cost
- Dominated by installation and comm of the points
- Priced per point
- Temp is fairly easy,
- but humidity is harder
  - 3-5% rh but really issue is accuracy over time, stability
- Co2
- Every socket measures, every breaker
- Airflow
  - 5% in complex geometry, remote, wireless, non-intrusive
  - Crude 50% would also be huge
- heat flux
- Occupancy – false positives

- How much do they cost?
- What is the fidelity of the collected data?
- Are they feasible to use in the marketplace?
  - Ease more important that cost of purchase

Throughout discussion points keep coming up – flows of information and domains of concern about the process of the building

- Info to user
- Info to the maintainer
- Info to the control system – far finer than info to the user
- Info to the designer/facility manager (validation)
- Info to the grid and other parts of the supply chain

Slide 4 – are we limited by sensors?

- Can measure temperature better than humidity
  - Even that can get very uncalibrated and return garbage information
  - Higher quality sensors exist, but the cost is too high for buildings
- Cost of sensors is not the hardware but the installation (connectivity is a key cost driver) – drives the need for an integrated approach
  - Note for some measurements even the cost of the sensor is large (i.e. humidity, air flow,)
- Need both the plugs to be communicating (and the circuit breaker) as well as think about the frequency of the of the measurements needs to be determined
- There are sensors where a lot of work is needed
  - Heat flux
  - Air flow
  - Humidity

- What are the fidelity needs of the sensors? Is there a large market for low fidelity sensors? How would precision with spatial density a trade-off?
    - Where is the threshold for god enough? (3-5 % relative)
    - Still have the issue of accuracy over time
    - Ability for remote sensing to ease installation an d understand sensors that the measurer is not adjacent to – remote from the actuation point
        - Non-intrusive measurement advances
        - Ease of measurement is very important (value of wireless)
    - Occupancy is important to measure – critical to know how many people are being serviced and where they are in the building (zoning, lighting, controls)
        - If truly low cost IR measurement existed, you'd know how well mixed the room truly is, exactly how much heat is being lost through the wall
- Communications and protocols
    - Wireless communication is critical enabling technology
    - Trust in wireless information – can use existing standards and improve robustness – existing standards are more than enough for building monitoring – important to note how often the information will be reviewed
    - Can buildings be built with horizontal systems organization or is vertical necessary (links to the need for protocols)
    - Are exiting protocols adequate- do they address the needs of the equipment that they are trying to control?
    - Is there a protocol between the grid people and the designers of the appliances (no smart appliance standards yet) – smart systems (appliance, grid etc.) if they do not talk to each other are still dumb
    - How is the data taken and put into a useful package for both current and future managers
        - Esp if there is a legacy building where the data might not be available for previous points in time
        - Data understanding – key to know what data we already have interoperability requirements are key (and understanding time scales – including dealing with older communication protocols)
    - Unlike other systems, building communication systems are very heterogeneous and it is very possible that the protocols, etc. will not be the same in all the systems in a building due to the age of the building
        - Possible that buildings could learn from the weather community for how they deal with large amounts of spread apart data
        - Different types of models will drive the management of a sytem differently
    - Models need to be continually updated and validated to keep systems calibrated

Note that buildings are built and then systems are designed, versus the design of other products where the modeling and simulation is done before the systems are chosen – capture the deviations due in construction

Slide 5

What modeling capability is required?
Is distributed or centralized processing of data preferable?

- Has to guide sensor design, placement and selection
- Simulation

- Model and model use drives communication
- Buildings need and should learn from weather forecasting
- Drives ability to exhange useful information

- Models of a diversity of type
  - Physics vs data driven
  - Engineering models

- Tools to validate models easily
  - Sketch up + e+ + data => iterate
- Too many knobs to adjust
- Capture deviations introduced in construction

See previous discussion notes – no additional discussion here – slide skipped.

Slide 6

Domains of communiction

- To/from occupant
- To/from Maintenance
- Control system
- Validation/modeling/optimize design
- Supply chain

See previous discussion notes – no additional discussion here – slide skipped.

Slides 7 and 8

What level of security is needed for these wireless systems to safely and accurately transmit measured data? What is required to make these networks tamper proof?

Security

- Clearly risks
- Potential safety
- What is the failure mode
- Many of the issues pertain to electronically controlled, not just wireless per se
- Wireless link issues
- Diagnosability

Security- not seen as a real issue at this time (with the current infrastructure) - would become more of an issue with wireless and smart grid development/deployment

- There are real safety issues with smarter systems – i.e. if all the lights are suddenly turned off
- Diagnosabilty is important and will become harder as systems become more integrated (figuring out what the problem is and how to fix it)
- Question – if a whole building is controlled wirelessly, what is the default management scheme, how is the system overridden in the even of a sub-system failure (shift from mechanical to electronic controls of systems)
- Difference between physical security- not contained within the property walls with wireless
- What would be the point of entry for security- through the internet, maintenance staff's PC, wireless system, etc.?

Slide 9

What wireless systems will be required to transmit the collected data?
Are the protocols we presently use sufficient (e.g. NIST- Bacnet)? If not, do we need better protocols? What would those protocols include?

- Wireless essential
- Many Don't trust wireless
- Need interfaces – not just protocols
- Is there any relationship between grids and smart applicances
- Separate data representation and model from transport and link
- How is data assimilated and mashup
- Integration with design data

- Interoperability requirements vary

See previous discussion notes – no additional discussion here – slide skipped.

Additional Slides

Highest Impact Applications

- Applications with highest potential impact on ARPA-E mission areas:
  - Greenhouse gas emissions reductions; and/or
  - Improved efficiency of power generation and delivery
- Application A:
  - Why?
- Application B:
  - Why?
- Etc

Required Performance/Cost for Significant Economic Adoption in Highest Mission Impact Applications

Application A:

- Performance Metrics?
- Cost Metrics?

Application B:

- Performance Metrics?
- Cost Metrics?

Etc

Key Technical Barriers

Technology #A:

- Barrier(s)
- Origin of technical barrier(s)
- Promising emerging approaches to overcome barriers

Technology #B:

- Barrier(s)
- Origin of technical barrier(s)
- Promising emerging approaches to overcome barriers

Etc

Funding Gaps and Path to Transition

- Most significant funding gaps in government/private sector?
- Optimal roles for ARPA-E vs DOE EERE in supporting Measurement and Communications?
- Level of technology validation/demonstration required for successful hand-off of ARPA-E project to private sector (VC/corp R&D)/other funding entities?
- Necessary levels of funding for an ARPA-E advanced building technology project (~3 years)
  - Proof of concept: $??
  - Meaningful “bench” scale system prototype: $??
  - Meaningful small-scale demonstration project: $??