Software-Defined Solutions for Managing Energy Use in Small to Medium Sized Commercial Buildings

2014 Building Technologies Office Peer Review

Building Operating System Services (BOSS)

Application Stack

User interfaces: smart phone/web-based
Control algorithms: schedule, optimization, demand response

Security/Authorization Service: BOSS WAVE (Wide Area Verified Exchange)

Building System Services

Database (Time series service)

Security/Authorization Service: BOSS WAVE (Wide Area Verified Exchange)

Physical Data/Device

Occupancy light sensors

Temperature actuators

Thermostat

HVAC

Light control

Appliance control

Transaction Manager

Hardware abstraction layer service

Hardware Presentation layer: sMAP (Simple Monitoring and Actuation Profile)

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California Institute for Energy & Environment, UC Berkeley
Project Summary

Timeline:
Start date: December 09, 2013 (New Project)
Planned end date: October 31, 2014

Key Milestones:
2. Successful integration of hardware with BOSS software platform, Oct 31, 2014
3. Software apps display sufficient maturity to allow full evaluation of BOSS system, Oct 31, 2014

Budget:
Total DOE $ to date: $60,710
Total future DOE $: $440,561

Target Market/Audience:
Small and medium commercial building owners/tenants, manufacturers of equipment and suppliers of services.

Key Partners:
- California Institute for Energy & Environment
- Software Defined Buildings/EECS/UC Berkeley
- Western Cooling Efficiency Center/UC Davis
- Lawrence Berkeley National Laboratory
- Building Robotics

Project Goal:
Develop a working prototype of an open software-architecture, open source Building Automation System (BAS) for small commercial buildings, based on Building Operating System Services (BOSS). The prototype includes a plug-and-play thermostat, lighting and general controllers, user interface with display, system set-up and auto-mapping.
Purpose and Objectives

Problem Statement: Light commercial buildings (5k-50k sf) account for 42% of the floor area of US commercial buildings, yet do not benefit from Building Automation Systems. These buildings have extremely varied usage and different ownership, operation, and bill payment; BAS operators’ skills are likely limited.

Target Market and Audience:
• 43 billion sf, ~700 billion kWh/year, ~2 billion MMBtu/year fuels
• Stage 1—Energy Efficiency Application (App) Developers, Thermostat Vendors, Lighting Controls Vendors, Commercial Equipment Vendors (e.g., copiers)
• Stage 2—RTU Vendors, Lighting System Vendors
• Primary Vendors to Small Commercial Buildings (e.g., security/alarm companies)

Impact of Project:
• 1\textsuperscript{st} R&D Year—Open architecture shows potential for vendor access to market
• 2\textsuperscript{nd} & 3\textsuperscript{rd} R&D Years through 1 year after project—enables app development, stage 1 energy efficiency apps offered by vendors, service offered by initial primary vendors - 15% energy savings in 1% of market.
• Years 2-3 Post—Stage 2 apps offered by vendors - 25% savings in 5% of market.
• Years 3+ Post—Other primary vendors - 25% savings in 25+% of market - $5B/yr.
**Approach**

**Approach:** Because the BOSS platform is built on a RESTful web services integration of heterogeneous data, the architecture is inherently **scalable** to adapt the size of the network (e.g., of sensors or other nodes) to suit smaller or larger buildings or provide greater or fewer data points.

**Key Issues:** All communication (e.g. commands sent, sensor data published, subscription requests) are secure (BOSS Wide Area Verified Exchange (BOSSwave)). Simple Monitoring and Actuation Profile (sMAP) drivers provide agnostic physical access to sensors, actuators, or data streams—can be WiFi, ZigBEE, Ethernet, BACnet/IP etc.

**Distinctive Characteristics:** The key innovations are a **layered open software architecture**, and the data aggregator and archiver **sMAP**. The modular architecture is the disruptive technology to the market as a means for third parties to easily create new applications (control algorithms, diagnostics, visualization) or add new devices (occupancy sensors, actuator/monitor for specific load), while radically reducing cost of implementation.
sMAP – simple Monitoring and Actuation Profile

Uniform Access to Diverse Physical Information

Applications
- Modeling
- Control
- Visualization
- Location
- Debugging
- Actuation
- Authentication
- Continuous Commissioning
- Personal Feedback

Physical Information
- Water
- Structural
- Weather
- Environmental
- Occupancy
- Geographical

Electrical
- Electrical
  - Dent Instruments PowerScout 18, ION 6200, Obvius Aquisuite; PSL pQube, Veris Industries, Schneider Electric ION power meters accessed with Modbus/Ethernet, HTTP, OPC-DA

Actuator
- Siemens Apogee BMS, Legrand WattStopper, Johnson Control BMS Accessed by BACnet/IP

www.openbms.org
Building Operating System Services (BOSS)

Portability
Reliability
Fault-Tolerance
Security
Data Archiving
Hardware
Independence

Hardware Presentation Layer
- JSON data stream + attribute metadata as resource-oriented web services

Physical Systems
Security: BOSS Wide Area Verified Exchange (BOSSwave)

- Web of trust model
- Decentralized
- Push to (multiple) subscribers – not poll
- Revocation
- Verify
  - Origin, Authorization of Operation, Target
- Limit
  - Processing of unauthorized ops, bandwidth of fanout
- Tolerate
  - Intermittent connection
BOSSwave

App must prove to Broker that it is authorized to publish to light34

WAVE URI: \(<nvk>/\langle\text{path}\rangle/\langle\text{op}\rangle\)

\(A \xrightarrow{t,p} B_x\)  D.o.T: A grants B permission p to t, unforgeably

Topics namespace

<UCB>/UCB/Soda/rm389/light34

resolved

<UCB>/UCB/Soda/rm389/light34

/switch16

/Cory/rm...

/mvk2/...

Lighting app

App must prove to Broker that it is authorized to publish to light34
Proposed openBAS

Internet
Periodic updates to Repository

DSL/CABLE Modem

WAN Port
LAN Port

WAP

WAP

WAP

Building LAN

Overhead lighting

Roof Top HVAC Units

Ethernet to device (e.g., thermostat), BACnet if applicable

BOSS server
FITPC with openBAS platform including:
• sMAP sources (instances of drivers for particular devices)
• Discovery
• Repository:
  • TimeSeries Archiver/database
  • sMAP drivers
  • Config
  • Discovery registry

TimeSeries Database
Progress and Accomplishments

Lessons Learned: Some commercially available controllers more easily integrated into platform than others (e.g., reliability, open Application Programming Interface (APIs))

Accomplishments: Wrote several device interfaces (sMAP drivers). Implemented Auto-discovery (PlugNPlay) of device (e.g., find device on network, discover type of device, autoload appropriate driver). Developed communication and data security (BOSSwave). Demonstrated the implementation of two different thermostats, two different lighting control devices, and a general controller.

Market Impact:
• Efforts—Including robust authentication and authorization capability, see Project Integration (p.11) for collaboration and coordination regarding APIs and accepted standards.
• Actual impact—On track for end of year 1 architecture to be compelling for potential equipment vendors to open APIs to monitoring and actuation requests, and energy efficiency vendors to develop applications.

Awards/Recognition:
Project Integration and Collaboration

Project Integration:
• Initiated conversations with key equipment vendors (e.g., lighting controls) regarding opening API to monitoring and actuation access.
• Software architecture builds upon accepted standards (E.g., WiFi, MQTT-3)

Partners, Subcontractors, and Collaborators:
California Institute for Energy & Environment, UC Berkeley: Project management and administration, market delivery strategy plan
Software Defined Buildings, Electrical Engineering Computer Science, UC Berkeley: System integration, software platform, user interface, apps
Western Cooling Efficiency Center, UC Davis: HVAC controller and apps, demos
Lawrence Berkeley National Laboratory: Lighting controller and apps, FLEXLAB
Building Robotics: Software platform and applications

Communications: EPRI’s Power Delivery & Utilization Program, Software Defined Buildings Summer and Winter retreats (UC Berkeley/industry), Green Tech Center/ITU/SDU (Denmark), Centre for Sustainable Communications in KTH (Sweden), Saga University (Japan), Daikin Konwakai (St. Michael’s, MD)
Next Steps and Future Plans:

Year 1:
- Implement user interfaces for different types of users (occupant, building manager, installer/app vendor)
- Develop market delivery strategy plan
- Integrate the software with hardware and user interface
- Test increasingly sophisticated control algorithms
- Demonstrate BOSS capabilities

Year 2:
- Test-bed implementation in LBNL’s FLEXLAB
- Refine-expand controller capabilities, sensors, and user interface

Year 3:
- Deployment in three buildings
- Refine-expand controller capabilities (e.g., DR) and user interface
- Evaluate, measure, and verify
REFERENCE SLIDES
BOSS Software platform = backbone of OpenBAS

Applications

Building System Services

Hardware presentation layer

Hardware devices

User Interface
- Status display
- System set-up

Control applications
- (model building, optimization, fault detection/diagnostics, demand response)
- Transaction Manager
- Execution Environment
- Hardware Abstraction Layer

TimeSeries Service

Auto-mapping Discovery

sMAP driver

sMAP driver

sMAP driver

Security: BOSSWAVE (Wide Area Verified Exchange)

Hardware devices
- HVAC RoofTop Unit
- Thermostat
- 6lowpan WiFi
- ZigBEE

Applications
- Thermostat
- Lighting gateway
- General control
- (bathroom fans, refrigerators, signage, security)

Hardware Abstraction Layer

Execution Environment

Transaction Manager

sMAP driver

6lowpan WiFi
ZigBEE

General control
(bathroom fans, refrigerators, signage, security)

User Interface

Control applications
- (model building, optimization, fault detection/diagnostics, demand response)

TimeSeries Service

Auto-mapping Discovery

sMAP driver

sMAP driver

sMAP driver

6lowpan WiFi
ZigBEE

General control
(bathroom fans, refrigerators, signage, security)
Project Budget

Project Budget: $501,271 project budget
Variances: More travel than anticipated (participation at BTO review and CMU workshop)
Cost to Date: $60,710 spent (12% budget), $0 cost share recorded of $12,500 project budget (0% budget).
Additional Funding: None

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<th>Budget History</th>
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<tr>
<td>December 9, 2013—FY2013 (past)</td>
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<tr>
<td>DOE</td>
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# Project Plan and Schedule

## Project Schedule

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<th>Task</th>
<th>FY2013</th>
<th>FY2014</th>
<th>FY2015</th>
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<tbody>
<tr>
<td>Project Start: Dec 9, 2014</td>
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<td>Projected End: Oct 31, 2014</td>
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<td>Go-No go decision point Oct 31, 2014</td>
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<td>Completed Work</td>
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<td>Active Task (in progress work)</td>
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<td><strong>Milestone/Deliverable (Originally Planned)</strong></td>
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<td><strong>Milestone/Deliverable (Actual)</strong></td>
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<td>Q1 Task: Functioning OpenBAS Software Platform</td>
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<td>Q2 Task: Integrated three hardware devices</td>
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<td>Q4 Task: Developed software tools (display, setup, automapping)</td>
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<td>Q4 Task: Developed user interface</td>
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<td>Q1 Task: Market delivery strategy plan</td>
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<td>Q1 Milestone: Demonstration of operation of hardware devices</td>
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<td>Q1 Milestone: Demonstration of integration of hardware with software platform</td>
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<tr>
<td>Q1 Milestone: Demonstration of software applications</td>
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