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# Design and Development of an Integrated Workstation Automation Hub

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Environmental Technologies Area

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## Abstract

Miscellaneous Electronic Loads (MELs) account for one third of all electricity consumption in U.S. commercial buildings, and are drivers for a significant energy use in India. Many of the MEL-specific plug-load devices are concentrated at workstations in offices. The use of intelligence, and integrated controls and communications at the workstation for an *Office Automation Hub* – offers the opportunity to improve both energy efficiency and occupant comfort, along with services for Smart Grid operations. Software and hardware solutions are available from a wide array of vendors for the different components, but an integrated system with interoperable communications is yet to be developed and deployed. In this study, we propose system- and component-level specifications for the Office Automation Hub, their functions, and a prioritized list for the design of a proof-of-concept system. Leveraging the strength of both the U.S. and India technology sectors, this specification serves as a guide for researchers and industry in both countries to support the development, testing, and evaluation of a prototype product. Further evaluation of such integrated technologies for performance and cost is necessary to identify the potential to reduce energy consumptions in MELs and to improve occupant comfort.

## Background: Defining the Office Automation

A *workstation automation hub* is the foundation of an integrated occupant-driven environmental comfort and energy management system within an office. Software and hardware solutions are available from a wide array of vendors, and in this study we sought to understand the differences and commonalities among those vendor solutions. In this document, we proposed a set of specifications for a workstation automation hub that enables automated energy-efficient behaviors and enhances occupant comfort. This document describes the draft specifications for discussion with key partners (e.g., Infosys and technology integrators). In addition, it specifies the system's components, the functions of those components, and a prioritized list for a design of a proof-of-concept system.

*Office automation* is a term in flux. It has previously been used to describe the integration of business processes, with the computer as the epicenter. Its goal is to streamline previously disparate processes, decrease unnecessary devices in the workspace, and increase occupant productivity. Thus, the term "office automation" can be interpreted to mean the addition of a device or the consolidation of several devices for the purpose of enhancing productivity.

With the advent of the Internet of Things (IoT),[1] office automation has begun to take on a new, more specific meaning. The IoT devices enable higher levels of automation and device coordination through the use of sensors (e.g., occupancy, temperature, light), direct user feedback, and device-to-device communication. Office automation has expanded beyond the workspace and into the user's work environment. The benefits of this expansion include increased occupant comfort, more efficient use of energy, and a reduction of the number of direct user inputs necessary to achieve those benefits.

Lawrence Berkeley National Laboratory (LBNL) has developed and led the workstation automation hub activity in close collaboration with U.S. vendors and Infosys, one of India's largest software services companies. Under this collaborative and interactive effort, LBNL identified the different components of the workstation hub, developed technical specifications, and rated each component from 1 to 3, according to its importance to the performance of the workstation hub (with 1 being very important). Infosys and the U.S. companies are using this specification to support the development, testing, and evaluation of a prototype as an iteration of this activity.

## U.S. India Partnership: A Collaborative Effort to Create an Integrated Automated Office Solution

This collaborative effort between the United States and India started with the common vision to improve energy efficiency of Miscellaneous Electronic Loads (MELs) and to bring greater information and control to the end user. The collaboration envisions the development of a hardware and software platform and the identification of new opportunities for automation services such as demand response (DR). Currently, such activities are hindered by the lack of data and cost-effective technologies. Working with start-up technology integrators such as Autani[2] and Ubiquiti[3] in the United States and Infosys in India, LBNL

[1] The Internet of Things (IoT) is a general term that describes internet-connected devices such as appliances, thermostats, lighting, etc.
[2] Autani website: http://www.autani.com/.

provides unique capabilities to leverage collaboration, evaluate product effectiveness, and advance emerging technologies. This work addresses current gaps that have hindered the realization of energy savings in office settings and seeks to leverage emerging technologies that enable those savings.

Electricity use attributable to MELs accounts for approximately 30 percent of the total energy used in U.S. buildings (Lanzisera, et al. 2013). The automated office solution has the potential to help users reduce energy consumption attributable to MELS significantly, due to the high concentration of plug-load devices in office settings.

In addition to strengthening the U.S.-India partnership in this area, the automated workstation specification development supports research and development for integrated workstation-based automation, including plug-load control capabilities to enable ease of use and energy efficiency of both plug-loads and any associated building system components. This activity evolved from an earlier LBNL activity with Infosys to develop a new generation of smart power outlets and strips with occupancy and light sensors, and embedded sensors that could be integrated into furniture and equipment systems to leverage workstation- and building-level energy information gathering and dissemination (Ghatikar 2013). New capabilities that we considered include decentralized control, standardized data exchange with other systems, and the ability to automatically identify plugged-in devices that provide appropriate energy-saving controls.

## Workstation Automation Hub Specifications

LBNL created the workstation automation hub specification. It focuses on currently available components that can enable energy savings in stand-alone operations, or through coordinated behaviors with other connected devices. The specification also includes a priority order, with components of priority "1" being the most critical to an office automation solution. The prioritization was developed in partnership with Infosys, who will support prototype development in future iterations of this activity. Table 1, below, describes each component of the proposed workstation automation hub, and indications of each component's priority for inclusion in such a system.

**Table 1. Workstation Hub Specifications**

| Components | Description/Use | Priority |
|---|---|---|
| **Lighting:** | | |
| Dimmable high-efficiency and high-lighting-quality indirect (up) light for general illumination, controlled separately from task light | Light-emitting diode (LED) | 1 |
| New and retrofit kits for dimmable ballasts using wireless signals | Used for adjusting legacy ceiling-mounted fixtures for general lighting (in workstation area) | 3 |

[3] Ubiquiti website: http://www.ubnt.com.

| | | |
|---|---|---|
| Network: Light status reporting over the network | Light status reporting can be used to estimate lighting energy and determine control system effectiveness. | 2 |
| Photo sensors: Light-level sensing at desktop surface | For daylighting control and feedback to occupants | 1 |
| Occupancy sensors: For workstation, narrow field of view; for general area, wider field of view | For use in occupant-specific lighting control, as well as for input to building automation system (BAS) | 1 |
| **Tethered (e.g., USB) or Wireless Sensors:** | Sensors could be embedded in furniture and equipment | |
| Occupancy | Local and BAS control. These sensors can be for local control (attached directly to a controlled device) or networked for room and building controls. | 1 |
| Temperature dry bulb | User feedback and BAS input | 1 |
| Light level (photo sensors) | Feedback and lighting control | 1 |
| Window switch | For operable windows, alarm and BAS input | 2 |
| Humidity | Feedback and BAS input | 2 |
| Mean Radiant Temperature (MRT) | Feedback and BAS input | 3 |
| Local battery status | To monitor status of laptop, uninterruptable power supply (UPS), etc. (e.g., DR) | 3 |
| **Heating, Ventilating and Air Conditioning:** | | |
| Advanced personal fan (directional, variable speed drive [VSD]) | Fan to be monitored and controlled | 1 |
| Low-power heating system (foot panel or warm chair) | This is a higher priority for international markets. | 3 |
| Integrated local cooling such as radiant panels in workstation walls | Can be controlled at various levels (e.g., workstation or building zone) | 3 |
| Integrated local cooling such as the comfort chair being developed at University of California, Berkeley | Can be controlled at various levels (e.g., workstation or building zone | 3 |

**Table 2. Workstation Hub Specifications (cont'd)**

| Components | Description/Use | Priority |
|---|---|---|
| **Plug Loads:** | | |
| Outlet(s) individually controlled and monitored; hard switch control over each outlet's power state. Software to identify if load can be shut off when space is unoccupied. | Policies to be set at the organization level and controllable by individual occupants | 1 |

| | | |
|---|---|---|
| Low-voltage direct current (DC) for peripherals (via a powered USB hub in furniture, with control and metering capability) | Direct current (DC) peripherals will reduce conversion losses that result from converting alternating current (AC) to DC and will allow improved interface with the local DC battery storage system. | 3 |
| **Energy Storage:** | | |
| Integration and control of a battery, either in a laptop or in a desktop UPS that may serve as the automation hub | Intelligent battery and UPS power management and optimization for localized or grid-based demand response (DR) | 2 |
| **Metering and Monitoring:** | | |
| All loads associated with the workstation are metered and monitored. | Consider the accuracy of meters used to monitor workstation-related loads. In general, meters should be accurate to within 5% of the load or better. | 1 |
| **Controls/Communication and Protocols:** | Autonomous control of local resources with local or network input for high-level policies or user-driven control. | 1 |
| Sensors and actuators ideally using standard Internet protocols (wired or wireless) | Support industry standards such as BACnet, ZigBee, Wi-Fi, or Smart Energy Profile, Bluetooth, PLC, and others. | 1 |
| Data availability over the network using the Internet protocol (IP) | All metered and monitored components | 1 |
| Web-based access compatible (software) | Standardized access to information for different components for user interfaces | 2 |
| Self-forming network | Devices added to the network are automatically discovered. This capability would speed/simplify installation. | 3 |
| Network switch in workstation hub | Add metered power over Ethernet (PoE) | 3 |
| IP phone powered using PoE similar to network switch. | Workstation network will enable use of IP telephony. | 3 |

## LBNL Office Automation Survey

To supplement the workstation automation hub specification, LBNL surveyed currently available products aimed at automating office environments. The goal of this survey was to broadly determine the state of office automation technology, assess product compatibility, and better understand how to implement a whole-office solution. The list is intended to be representative rather than exhaustive. The survey and its findings are described below.

The following categories formed the basis for products of interest:

- Lighting (task lighting and general office lighting)
- Heating ventilating and air conditioning (HVAC)

- Environmental Sensors (occupancy, light, temperature)
- Plug Load Monitoring and Control

Table 2, below, describes the products surveyed. This list represents a small subset of the products available on the market that could be used in an office automation system and is meant primarily to provide an overview of the various offerings available in each of the product categories listed above.

**Table 3. Survey of Products for Use in Office Automation**

| Component Category | Vendor | Product | Description | Website | Connectivity |
|---|---|---|---|---|---|
| Lighting (task, under cabinet) | Pegasus Lighting | LED Thin Under Cabinet Task Light Bars | A variety of lengths (8"–16") and lumen outputs (127–654) are available. | http://www.pegasuslighting.com/led-thin-narrow-under-cabinet-task-light-bars.html | 110 V, could be used in conjunction with a smart power strip. |
| Lighting (freestanding desk, task light) | Workrite Ergonomics | Astra LED Task Light | Freestanding desk light. 5 points of brightness adjustment. Horizontal and vertical position adjustment. | http://workriteergo.com/task-lighting/ | 110 V, could be used in conjunction with a smart power strip. |
| Lighting (task, under cabinet) | Workrite Ergonomics | Fino LED Task Lite | Dimmable under-cabinet light. Thin profile. | http://workriteergo.com/task-lighting/ | 110 V, could be used in conjunction with a smart power strip. |
| Environment Sensor (Occupancy) | WattStopper | LMUC-100 Digital Ultrasonic Ceiling Mount Occupancy Sensor | Wireless configuration/remote control, ultrasonic. Can be used with lighting, plug loads, or both. | http://www.wattstopper.com/products/digital-lighting-management/occupancy-sensors/lmuc-100.aspx#.UwYyqnlf-XI | Can be accessed via WiFi and Infrared (IR) remote control. |

**Table 4. Survey of Products for Use in Office Automation (cont'd)**

| Component Category | Vendor | Product | Description | Website | Connectivity |
|---|---|---|---|---|---|
| Environment Sensor (Temperature) | Ubiquiti | mFi Temperature Sensor | Can be used with mPort (separate hardware) to trigger actions (fan, lights, etc.) based on the temperature reading. | http://www.itamtech.com/index.php/home-office-automation/mfi-temperature-sensor.html | Proprietary connection with separately supplied software. |
| HVAC (Personal) | Deli | USB-Powered Personal Desk Fan | Runs off of computer USB port. If plugged into laptop or desktop, USB port will turn off when computer sleeps. | http://www.staples.com/Deli-USB-Powered-Personal-Desk-Fan/product_219634 | USB |
| HVAC (Personal) | Vornado | Flippi V6 | Directional, 2 speeds, small desktop fan. | http://www.vornado.com/circulators/Flippi-V6 | 110 V, could be used in conjunction with a smart power strip. |
| HVAC (Personal) | Seville | UltraSlimline 12" Personal Fan | Oscillating, multi-directional, 3 speeds. | https://www.sevilleclassics.com/UltraSlimline_Personal_Fan_EHF10190 | 110 V, could be used in conjunction with a smart power strip. |
| Plug Load Monitoring and Control (multi-device) | Autani | Distro Managed Power Strip | 6 outlets, load control and metering, used with EMC PC Energy Management Client. Individually addressable and monitored outlets. Programmable behavior via software. | http://www.autani.com/1093/distro-wirelessly-managed-power-strip/ | WiFi connectivity. Use in conjunction with Autani monitoring and control software. |
| Plug Load Monitoring and Control (multi-device) | EnergyHub | Strip | 6 outlets, connects to home base (sold separately) | http://shop.energyhub.com/collections/all-products/products/strip | Connects to EnergyHub HomeBase display. HomeBase can control up to 9 strips. HomeBase is accessible through a web application. |

**Table 5. Survey of Products for Use in Office Automation (cont'd)**

| Component Category | Vendor | Product | Description | Website | Connectivity |
|---|---|---|---|---|---|
| Plug Load Monitoring and Control (single-device) | Autani | SmartLet Outlet Controller | Switches 120 V receptacles on/off based upon occupancy, schedules, and demand response events. Wirelessly configured; alerts to PC / tablet / smartphone. Can be integrated with Autani LightCenter+ dimming and switching systems. | http://www.autani.com/700/smartlet-outlet-controller/ | Can be configured individually over WiFi. Group behaviors can be configured with Autani software. |
| Plug Load Monitoring and Control (single-device) | Bert | Bert® 110<br>Bert® 110M<br>Bert® EMV | - Bert® 110: Controls plug loads by storing 7-day on/off schedules with multiple on/off commands each day.<br>- Bert® 110M has additional measurement function.<br>- Bert® EMV combines Bert® 110M and Bertbrain 1000 Reporting and Analysis Software plus 1 preconfigured router to control and benchmark plug loads. | http://www.bertbrain.com/ | WiFi. configurable with downloadable Bert® software. |
| Plug Load Monitoring and Control (single-device) | EnergyHub | Socket | Wirelessly connects individual appliance/device to EnergyHub Home Base. | http://shop.energyhub.com/collections/all-products/products/socket | Connects to EnergyHub HomeBase display. HomeBase can control up to 9 strips. HomeBase is accessible through a web application. |

**Table 6. Survey of Products for Use in Office Automation (cont'd)**

| Component Category | Vendor | Product | Description | Website | Connectivity |
|---|---|---|---|---|---|
| Plug Load Monitoring and Control (single-device) | Lutron | Maestro Wireless RF Plug-In Appliance Module | Works with lighting and appliance load up to 15 A. Part of Maestro line of lighting control products. | http://www.smarthome.com/66307WH/Lutron-MRF2-15APS-1-WH-Maestro-Wireless-RF-Plug-In-Appliance-Module-White/p.aspx | IR. Used in conjunction with Lutron Pico Wireless controls. |
| Plug Load Monitoring and Control (single-device) | Plugwise | Plugwise System | Monitors and controls with device-level plugs, gateway, and custom software via ZigBee wireless connection. | http://www.plugwise.com/ | ZigBee wireless and Plugwise software. |
| Plug Load Monitoring and Control (single-device) | Telkonet | EcoGuard | Energy management outlet and meter; controls and measures devices via ZigBee wireless module | http://www.telkonet.com/products/ecosmart/datasheets/EcoGuard.pdf | ZigBee wireless and Telkonet software. |
| Room Control (Lighting) | Autani | Arc-R Switched Room Controller | Wireless lighting circuit manager. Can control up to 2 independent circuits using Autani software or native controls (switches). Can also be configured to work with Autani wired or wireless occupancy sensors. | http://www.autani.com/690/arc-r-switched-room-controller/ | WiFi. Use in conjunction with Autani software. |
| Room Control (Lighting) | Autani | Afc-A Diming Fixture Control | Control of 1–10 LED lighting fixtures. Detects daylight levels and automatically dims fixtures. Thresholds and schedules are programmable over software interface. Native controls are retained. | http://www.autani.com/865/afc-a-dimming-fixture-controller/ | WiFi. Use in conjunction with Autani software. |

**Table 7. Survey of Products for Use in Office Automation (cont'd)**

| Component Category | Vendor | Product | Description | Website | Connectivity |
|---|---|---|---|---|---|
| Room Control (Lighting) | Autani | MINI Wireless Motion Sensor | Selectable detection patterns (standard, slight, spot, and 10m). To be used with other Autani products to enable automated functions based on occupancy. Wireless interface with other Autani sensors and controls. | http://www.autani.com/883/mini-wireless-motion-sensor/ | WiFi. Use in conjunction with Autani software. |

## Findings

While the categories related to office automation in LBNL's survey were not exhaustive, it did enable several broad conclusions to be drawn about the state of office automation offerings. These findings are listed and described in detail below:

1. A number of companies offer suites of products designed to work together and form a complete solution. Inter-vendor hardware and software compatibility and data interoperability is uncommon.
2. Communication protocols using Wi-Fi or Ethernet IP standards appear to be the most commonly used by companies offering complete hardware and software solutions. The ZigBee-based wireless protocol is also used in some instances, but it seems to be less common.
3. Without separation of hardware functionality and software monitoring/control, it is necessary to source hardware and software from a single company to ensure compatibility.

### Suite offerings from vendors: Lack of interoperability and compatibility with vendor offerings

While vendors can offer proprietary solutions on the communication protocol, the standardization of IP and data interoperability is key to enable different vendor components to be compatible and interoperable, to provide an integrated approach to workstation automation. These requirements are also key to enabling integration of workstation sensor and occupancy data with other building components (e.g., common lighting and HVAC systems).

One way to enable interoperability is to support open standards for data communications and allow access to application programming interfaces (APIs) that enable components from different vendors to communicate. Such integration can provide additional energy-efficiency strategies in addition to enabling participation in grid-related programs such as demand response. The benefits of such standardization are well studied in commercial and industrial building systems (Piette et al. 2009; Ghatikar and Bienert 2011).

A related finding is that vendors in this space typically provide both hardware and software. Using a vendor's hardware also entails using that vendors' proprietary software solution for monitoring and control. The lack of common and standardized data communications for monitoring and control software further highlights the advantages and disadvantages of using a single product suite.

### Vendors are typically using common communication protocols

Vendors seem to have coalesced around common wired and wireless communication standards, including Wi-Fi, Ethernet, and to a lesser extent, ZigBee. However, use of a common communications protocol does not guarantee interoperability among products if those products use different data standards for monitoring and control on the firmware or software levels.

### Use of a single vendor is the best option today for a complete and compatible solution

The survey results suggest that the best option for an automated office solution that includes both environmental monitoring and control capabilities is to use a single vendor's product suite.

Vendors such as Ubiquiti and Autani offer complete integrated office automation solutions, which include controls, sensors, and software components. There are benefits to using vendors with this approach, the most obvious of which is some level of assurance of compatibility among hardware components, and between hardware and software. The primary disadvantage is the upgrade and expansion limitations introduced by sourcing all components of office automation to a single vendor or their integration with other building components. Especially in the early stages of this class of product offering, standards for communication, monitoring, and control are subject to change.

In the future, a decoupling of hardware and software system components would likely enable increased interoperability among vendor offerings. Separating hardware from software offerings would likely offer benefits to vendors, as it would allow them to focus on their areas of expertise, whether that expertise is in hardware, or software. The use of similar and readily available standardized communication protocols and data standards by the vendors is an encouraging sign that the focus is trending towards increased compatibility and interoperability among products and building components.

## Future Work

The specifications developed through this work will (and in fact, have already started to) be used for the design of one or more proof-of-concept systems. Lawrence Berkeley National Laboratory will continue to work with U.S. companies and Infosys to further develop the integrated workstation automation hub concept. Follow-on work will include the design, procurement, and installation of a workstation automation hub within a test-bed setup in the Infosys' campus. This demonstration will be evaluated for energy savings potential and user satisfaction. Lawrence Berkeley National Laboratory will engage with the identified U.S companies to evaluate their technology locally and/or on the Infosys campus to evaluate the technologies' potential for integration into the office automation demonstration.

In conjunction with demonstration of the proof-of-concept prototype, the market potential for office automation systems should be evaluated. Depending on validation of the energy savings potential and non-energy user benefits such as increased comfort and productivity, this type of system could have significant potential for deployments in the U.S. and India.

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