one|comfort LABS

white paper

From Connectivity to Intelligence…

REAL-TIME ENVIRONMENTAL LEARNING BASED IoT FRAMEWORK FOR ENERGY EFFICIENT INTELLIGENT HOME SOLUTION

Introduction

Nearly 40% of the total energy consumption in US is currently attributed to the residential and commercial building usage, which stands much higher than the Industrial (33%) and Transportation (27%) sectors. Heating, ventilation and air conditioning (HVAC) system is one of the major energy consumers in buildings. However, even with the existing cost of HVAC systems the occupant dissatisfaction associated with indoor environment is pretty high leading to loss of productivity and health hazards.

There are existing solutions in the form of thermostats that learn user habits and research based Model Predictive Control (MPC) algorithms that strive to achieve energy efficiency. However, these existing approaches are either home (building) model agnostic or rely heavily on the home (building) layout and architectural information. But neither of these approaches involves real-time environmental learning to present an adaptable solution for changing environmental conditions and cannot be deployed to multi-occupant spaces. Most of the home (building) cater to multiple occupants concurrently and are subject to changing environmental conditions (opening/ closing of doors, windows, etc.), and hence need an adaptable collaborative framework based on real-time learning of environmental conditions and occupancy pattern. There can be thermal gradients within a home, as shown in Figure 1, that an intelligent HVAC system needs to learn and adapt to in real-time.

One comfort Labs has an end-to-end IoT framework (called blüem: Bluetooth environment monitoring and energy management) for intelligent home (building) solution based on real-time environment learning that leads to energy efficiency with enhanced occupant comfort and convenience.

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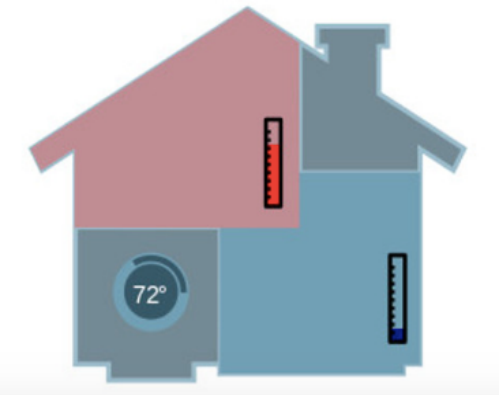
FIGURE 1: Typical Thermal Gradient in a Residential Home Resulting in Zones With Varying Temperatures



Novel components of the solution framework include:

- Adaptive learning of environment and user habits through a distributed sensor network
- Joint optimization of energy cost and occupant comfort
- Individual energy usage tracking and personalized feedback (energy ranking)
- Indoor localization enabled personalized comfort and identity management
- Thermal management and monitoring system (equivalent of Network Management System)
- IoT hub for sensor data aggregation and connectivity to third party smart home products
- Data analytics and learning for intelligent decision making
- Open platform APIs to automatically manage other smart home products

One comfort Labs have developed multi-purpose sensors for environmental data collection, an IoT hub for data aggregation, learning based software architecture and open APIs to enable connection (control) of other third party smart home products.

Features & Components

Conceptual deployment of a blüem framework in a home is displayed in Figure 2. Key components of the framework comprise a set of distributed sensors, a central IoT hub and a collection of third party smart home products.

FIGURE 2: Conceptual Visualization of the Blüem Framework Deployed in a Home

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Sensors: Blüem multi-purpose sensors are custom built in-house using off the shelf components. The sensors are built on an expandable platform and currently feature capability to measure following parameters: real-time indoor humidity and temperature, motion detection, indoor luminosity, audio signal inputs. Sensors also act as Bluetooth low energy (BLE) based beacons to enable indoor localization and can be plugged into an outlet or battery powered.

Hub: Blüem hub is currently built on top of a Raspberry Pi platform. Although a necessary evil for now (owing to different underlying RF protocols – WiFi, Bluetooth/ Bluetooth Smart, ZigBee, Z-Wave, LoRa in smart home products) the hub aggregates all sensor data for learning algorithms and facilitates connection with different third party smart home products. The hub also establishes secure channel for data exchange with the central server that hosts the optimization and learning algorithms.

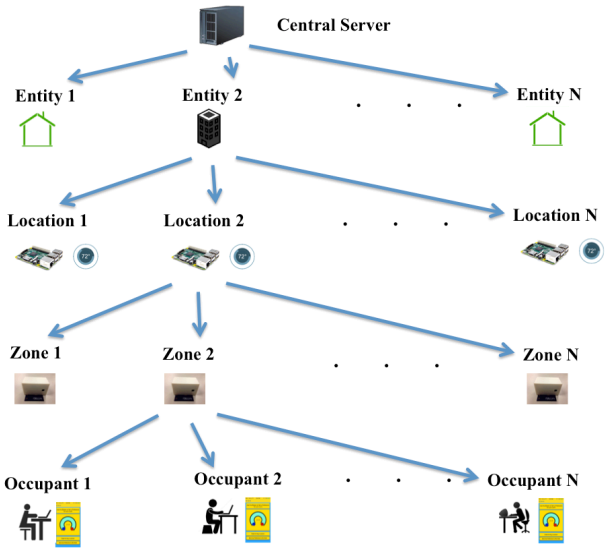
Mobile Application: A mobile application with an intuitive user interface enables users to provide their comfort related feedback and also enables identity management and indoor localization. One comfort Labs is also exploring other avenues for identity management using sensors for users not equipped with mobile devices.

Optimization & Learning Algorithm: At the core of the blüem framework is the learning algorithm that learns user preferences and environmental changes in real-time using sensor data. Based on this learning the optimization algorithm then makes optimal decisions with regard to thermostat settings and other smart home products as applicable.

Architecture

A hierarchical architecture of the blüem framework is displayed in Figure 3. This architecture allows for easy scalability irrespective of whether the solution is deployed in a residential or a commercial setting.

FIGURE 3: Hierarchical Architecture of the Blüem Framework



The central server is responsible for the authorization and authentication of users and stores the mapping of zones, locations and entities. Each entity (residential or commercial building) hosts an independent blüem framework system. An entity can have multiple locations identified by an independent thermal controller. Each location can be segregated into multiple zones as desired by the entity administrator. A homeowner or a building manager can be the administrator for their respective entity. Note that each zone is identified by the presence of a multipurpose blüem sensor that constantly collects the zonal environmental data. Zones can have independently controllable vents or other personal heating and cooling devices. Occupants within each zone are currently identified using the blüem smartphone application.

The number of occupants supported in each zone by the blüem framework is limited only by the physical constraint of the space. The framework is collaborative in the sense that it considers preference of each occupant to arrive at a logical consensus balancing it with the underlying energy expense of the zone.

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An entity administrator can further enable default settings for the locations with regard to energy pricing and other features like geo-fencing and can also control occupant authorizations for specific locations or zones.

Blüem framework uses time series database for logging all sensor data with timestamps that is then used by the optimization and learning algorithms in real-time. The optimization and learning algorithms are engaged at regular intervals for each entity independently. The algorithms are also triggered by any environmental changes, occupant preferences and/or changes in occupancy pattern.

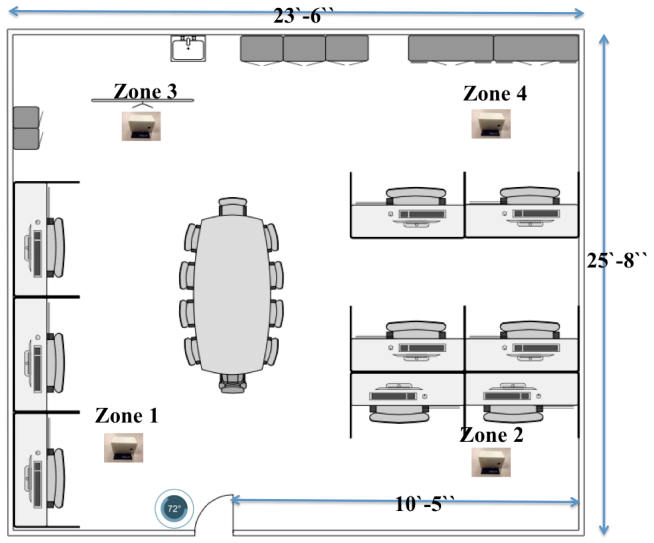
Field Testing and Deployment

The prototype blüem framework has been deployed in both a residential setting and a University based laboratory setting with multiple occupants. Based on the limited field-testing conducted so far, the framework has been observed as providing relative energy savings of up to 21% with enhanced comfort and convenience. In the University based multi-occupant setting deployment, as shown in Figure 4, occupants of both genders belonging to different age groups occupied the space. Despite the presence of occupants with varying preferences and metabolism rate, the framework created a relatively more comfortable and productive environment for the collective occupancy in general. This was achieved without any additional heating or cooling device installation and/or increment in energy usage. The overall energy usage was reduced in the space during the period of deployment. Further testing is in progress with real occupants and the feedback is used to add features that can enhance user experience of the system.

Customer Segments & Collaborations

Blüem framework can be successfully employed for all types of multi-occupant spaces (such as homes, student dorms, public libraries and corporate office buildings). One comfort Labs can further collaborate with companies in multiple sectors to custom built the blüem framework around their requirements and business model.

FIGURE 4: Deployment in a University Based Laboratory Setting with Multiple Occupants



Utility Companies: Utility companies have been looking to Demand-Response programs for reducing their peak loads. Energy efficient systems can help utility providers achieve their goals of system optimization, carbon reduction, resiliency and overall customer convenience. To this purpose, secure APIs from the blüem framework can be integrated with real-time energy pricing. Based on agreement between the consumer and the utility provider, energy consumption by the customer entity can be regulated in real-time using the optimization and learning algorithms of blüem framework.

Service Providers: Service providers in different segments can benefit from the intelligence of blüem framework. Energy Efficiency providers can obtain improved customer comfort and energy consumption data and can use the framework to meet their customer's cost saving goals.

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Solar installers can offer blüem package as an added incentive to their customers. This approach may further enhance the value of their offering. The framework can also incorporate home security and healthcare solutions. Finally, IP service providers can customize the framework to present a convenience package to their customers.

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