Poster Abstract: Adaptive and Personalized Energy Saving Suggestions for Occupants in Smart Buildings

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ABSTRACT

The smart buildings today have various sensors to monitor its energy consumption, and will automatically adjust itself based on occupancy. However, current approaches are optimized for reducing energy consumption while preserving user experience. We believe that proactively modifying occupants' behavior is necessary to further reduce their energy footprint. We built a system to send personalized and detailed energy saving tips to occupants, in order to help them save energy that would otherwise be wasted unknowingly.

1. INTRODUCTION

In many situations, occupants of a building unknowingly consume excess energy. Smart buildings research [2, 3, 4] has yielded systems that give building managers the ability to monitor various aspects of the energy consumption in the building. However, occupants are left in the dark regarding their own energy impact. Furthermore, occupants are often unaware of the possible actions that can lead to major energy savings. In this work, we utilize localization techniques with Bluetooth Low Energy to localize occupants and track their energy consumption at room-level granularity. Occupants then receive suggestions on their mobile devices which describe potential energy saving actions. By notifying occupants, we hope to inform and encourage occupants to save energy. We hypothesize that raising awareness about occupant energy usage, as well as generating meaningful, actionable suggestions will have a substantial impact on the amount of energy saved by occupants.

2. SYSTEM IMPLEMENTATION

The system is composed of four subsystems which communicate with each other as well as with the occupants' mobile devices. The groundwork of our system was set by an earlier work [1], which implements a central database, occupant tracking, and energy monitoring. In addition to these subsystems, we introduce a suggestions engine, which sends personalized energy saving suggestions to a user's mobile device. The occupant's decisions to accept or reject the suggestions are logged by the suggestions engine and are used to improve the quality of the suggestions. The block diagram of the system is shown in Figure 1.

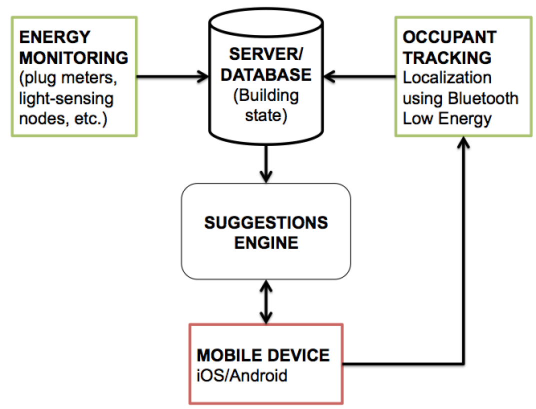

Figure 1: Diagram of the overall system.

2.1 Energy Monitoring

The types of energy consumption in a building vary greatly in their fundamental nature. In order to monitor these different types, the monitoring subsystem requires versatility and interoperability.

Certain types of energy consumption, such as power outlet usage, can be directly and accurately measured via wall plugs. However, some types of energy consumption cannot be so easily measured or is not available in building management systems, such as indoor lighting. In these cases, the energy consumption is measured indirectly, such as by using light sensing nodes to detect light on/off.

2.2 Occupant Tracking

The occupant tracking subsystem uses Bluetooth Low Energy (BLE) beacons, transmitting every quarter of a second, to localize an occupant to a specific room. We gathered location fingerprints for each space that is covered by the system as training data. The user periodically sends RSSI values gathered from the Bluetooth beacons, which are then compared with the location fingerprints to localize a user to room-level granularity.

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2.3 Query System and Data Storage

The database of the system needs to be affordably scalable and capable of supporting various common queries easily. Some queries require near-realtime responses, such as services to user devices. Other queries, such as requests for historical energy data (from web API's) also require near-realtime responses, and may query for a large amount of data. Queries from the suggestion engine, which runs asynchronously, may also request large amounts of data.

To support these queries, we designed a snapshot-based data model that records the dynamic association between occupants and active devices periodically. A variable sampling-rate strategy is used to ensure timely response for footprint change while avoiding large storage space consumption when there is little to no activity in the building.

2.4 Suggestion Engine

By observing the energy consumption and occupant location updates, the suggestion engine generates personalized energy-saving suggestions automatically. The system currently enables four categories of suggestions:

- Movement: to share a space with other users, rather than staying in a room alone.
- Turn Off Appliance: to eliminate wasted energy due to idle appliances.
- Appliance Usage Synchronization: to schedule jobs close together on devices that run on duty cycles.
- User Schedule Synchronization: synchronize occupant schedules to reduce time when building occupancy is low but non-zero.

The system is initialized with certain parameters for rooms and energy appliances. For example, all energy appliances are given an "*actionable*" parameter, which indicates whether or not the energy appliance can be turned on or off. These parameters should be learned eventually by the system. However, we have chosen to set the parameters in order to set a higher quality of suggestions.

Each suggestion can be accepted or rejected by the user. The decision, along with other features such as the suggestion type or time of day, will be fed into a machine learning algorithm to generate both personalized suggestions, but also to extract pertinent patterns about the kinds of suggestions most likely to be accepted.

3. SYSTEM DEPLOYMENT

3.1 Deployment Setup

Areas on two floors of the Northwest Corner Building at Columbia University have been outfitted with various energy monitoring devices. We deployed Aeon Labs plug-load meters to detect power outlet usage, and ESP8266 wifi modules and TSL2561 light sensors to detect whether lights are turned on or off.

In addition to energy monitoring devices, we distributed Bluetooth Low Energy beacons throughout the space for the purpose of indoor localization.

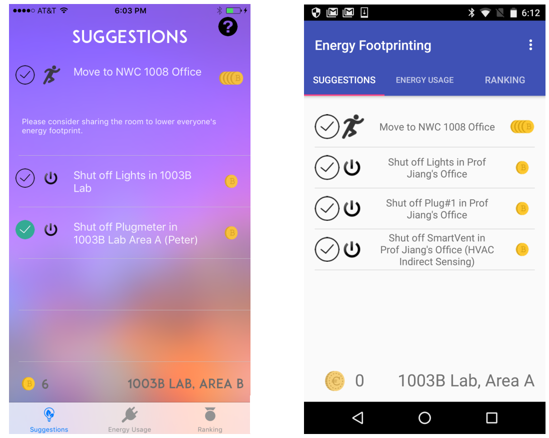

Figure 2: Screenshots of the iOS and Android applications.

3.2 User Experience

We developed a smartphone application for both iOS and Android smartphones. The application allows us to notify occupants of potential energy saving opportunities (and giving the option to accept or reject the suggestion), allows the users to view their personal energy footprint, and shows the users their ranking relative to other application users.

We incentive our users by attaching a reward for each suggestion offered, reflecting the amount of possible energy savings. The user can then decide to take the suggestion and receive the reward, which will reflect in his ranking relative to other application users.

4. CONCLUSION

Actionable feedback is vital in energy saving, as today significant energy is wasted in commercial buildings. Based on energy consumption monitoring and indoor localization techniques, we build a smart suggestion system to notify building occupants about possible energy saving actions.

5. REFERENCES

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