Demo Abstract: Saving Energy in Smart Commercial Buildings through Social Gaming

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Abstract
Energy consumption in commercial buildings is tremendous, resulting in significant monetary cost and waste of natural resources. Designing a low-cost system that serves the goal of saving energy while not forcing people to compromise their personal comfort is important for future smart commercial buildings. Proactive energy saving actions from users in the buildings are the key to achieving this goal. In this paper, we present Mahalo, an energy saving system, which leverages users through social gaming. By incentivizing energy saving actions from end users with a sensing-based feedback control system, the system reduces installation needs and improves understanding of the users preferences.

Author Keywords
Energy Saving, Smart Commercial Building, Social Game

ACM Classification Keywords
J.4 [SOCIAL AND BEHAVIORAL SCIENCES]: Sociology.

Introduction
Energy consumption in buildings costs resources and money. United States alone consumed about 97.8 quads (10^{20} Joules) of energy in 2010. Energy consumption in commercial buildings consisted nearly $1/5$ of the total energy consumption, or nearly 180 billion dollars. Within

this budget, the HVAC systems, lighting and refrigerators consist of more than 55% of the energy consumption in these buildings [2]. With such a high baseline expenditure, saving even only 1% of it would mean saving billions of dollars yearly.

However, energy saving in commercial buildings is difficult to achieve due to misaligned objectives. Since most occupants (office workers) are not directly billed for energy usage, they are less aware of the impact of their energy use. This results in lower motivation for occupants to conserve energy. Instead, without incentives to reduce the bill, they tend to be more concerned about their personal comfort. Systems have been designed to impose energy savings use with centralized sensing and actuation systems. In general, however they require high cost retrofitting of the environment and often fail to accurately incorporate user preferences [5, 6].

In this paper we present Mahalo, a low-cost system that advises and incentivizes people to perform specific actions that saves energy. Mahalo monitors energy usage of devices in the buildings with low-cost smartmeters. Then the system presents to the users both 1) actions that will save energy and 2) incentives if one complete the actions. Mahalo utilizes these incentives to allow users the freedom to balance between the compromising comfort and proactive actions to save energy. By providing incentives and incorporating the users as part of the system, the system automatically internalizes complex user preferences and social situations.

System Overview

The Mahalo system consists of three major modules: monitoring, presenting, and gaming. The monitoring module senses energy usage and user actions. This information is provided to the presenting and gaming modules. The presenting module is designed to organize the information from the monitoring and gaming modules to present the information to the users, which will trigger intrinsic incentives (such as competition). The gaming module tracks the game status and computes extrinsic incentives (such as lottery) for specific tasks.

Monitoring

The monitoring module is used to determine energy waste events in commercial buildings, which are defined as the energy consumed for purposes other than contributing to the user's productivity. Mahalo monitors the energy consumption of the devices and the users' actions. The energy consumption of devices are monitored using SensorAndrew smart plugs [7]. The users' actions are monitored by web application when users confirm their actions. We determine energy waste events using a rule based system (a combination of device energy usage, baseline energy usage, time of day, user actions, user presence). For example, if the light is on for over 3 hours after 17:00 on a weekday would be considered a potential energy waste event.

Presenting

Awareness of energy consumption is a user incentive of our system because it provides the user with an intrinsic incentive to save. Since the incentive methods are critical pieces of the system, intuitive presentation is the key for this module. Therefore, Mahalo provides users with detailed information of their energy consumption through a website and mobile application with graphical data visualization. To preserve privacy, the users' earning statuses are kept to the users themselves. In addition, to motivate users' intrinsic social incentives while preserving privacy, Mahalo allows the users to show statuses and

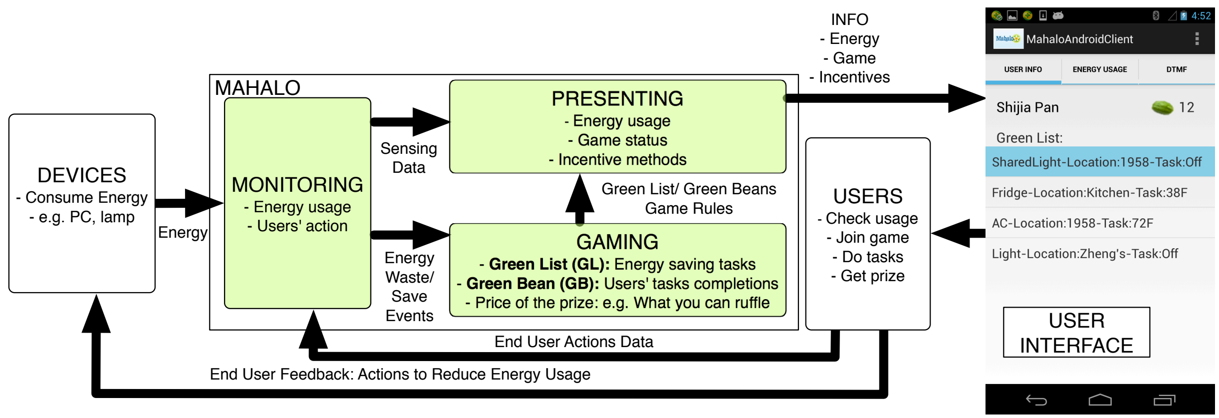

Figure 1: System Overview

actions to the public base on their own preference. To improve on user response, the system also utilizes extrinsic motivations in the form of the lottery, as discussed in the next section.

Gaming
The game is designed to incentivize energy saving actions. Two main sub-modules are designed for this goal: generate the Green List and price of the task.

Generate the Green List – When energy waste events are detected in the monitoring module, Mahalo will place these events as tasks on the Green List, which stores all the tasks that are detected, yet haven't been addressed.

Price of the Task – If a user completes a task in the Green List, he will get a number of Green Beans based on the effectiveness of the task. The Green Beans can be used for entering lottery at the end of each month. Mahalo adopts the lottery as extrinsic incentives due to the effectiveness of lottery shown in prior work [8]. The system sets the jackpot probability with Equation 1, so that the system will save money for the building. J_{value} is the value of the jackpot. J_{prob} is the rate of winning. TD_{num} is the number of tasks that are done. TV_{ave} is the average of the task value. SI is the starting incentive, which we induce from average of the national data.

$$J_{value} \times J_{prob} < min\{TD_{num} \times TV_{ave}, SI\} \quad (1)$$

Mahalo will notify users about new tasks on the Green List through the presenting module. The gaming module records people's achievement for the tasks listed in the Green List by matching their confirmation of completing the task and the task completion status. At the end of each month, participants are allowed to redeem their Green Beans by entering the lottery.

Related Work

Work in developing energy saving systems in smart buildings can be classified into two categories: control systems based on centralized sensing, and feedback control systems based on social feedback.

There have been a number of systems based on centralized sensing [5, 6]. These systems generally require a large effort to retrofit the control system of the deployed buildings to enable fine-grained control. In addition, although some of these systems model general comfort of the users into consideration, the ultimate problem remains: different people have different and changing sense of comfort.

Other work attempts to solve the problem of user comfort through the use of user driven feedback [3, 4]. These user driven approaches rely on information to affect user behaviors with the implicit understanding of cost reductions. While these approaches are effective in the home, in a large commercial shared environment these approaches do not shift the motivation from the management to the users. In addition, even when people have the desire to save energy, they are not clearly told what they can do, and the actions' effectiveness.

Demo Description

To demonstrate the framework of our system, we will set up a mini game at the demo booth. We will install the smartmeters for 5 selected devices consuming energy at the booth. During the demo session, the attendees can get the current energy usage status for different devices set up at the booth. We will set the threshold of detecting energy waste event as when the device is on for the short time demo purpose. The attendees can join the game, get game accounts, complete the tasks on Green List and gain Green Beans. At the end of the demo, we will have a raffle for those who joined the game and took energy saving actions. We would like to observe people's behavior, such as how many people attending the demo session are interested in joining the game and completing the tasks. This information would serve as guidance for our future work.

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