Insert-coin: turning the household into a prepaid billing system

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Abstract

Energy awareness is the ability to perceive the role of energy in daily activities. We combine appliance-level consumption information with prepaid billing so as to turn appliances in pay-as-you-go devices. We expect a greater awareness of energy available and demand to arise from the interaction with such a system. In this paper, we introduce the key principles of pay-as-you-go devices and report about the implementation of this strategy as an energy management system consisting of a cloud-based webservice and a mobile application.

Categories and Subject Descriptors

H.5.m [**Information interfaces and presentation**]: Miscellaneous

General Terms

Design, Experimentation

Keywords

energy consumption, persuasive interface, prepaid billing

1 Introduction

Classical billing mechanism make it hard to get an understanding of how energy was used because of their excessively coarse-grained information and the large delay between consumption and billing. In contrast, prepaid billing alone is shown leading to average savings of 11% regardless of disconnections from the grid [5]. Interactive systems need to support users in understanding their use of energy. Displaying real-time consumption information has been shown leading to savings of up to 15% [2]. To enable learning, and consequently, long-term change of the user's behavior, indirect information can be derived from consumption information. Consumption information can be also enhanced by a positive feedback, such as a reward, which can be monetary or social when the consumption is compared to other people within a community. Goal setting and commitment strategies act as reinforcement mechanisms and are meant to prevent users to take a certain behavior in future. Beside providing an effective feedback, appliance-level information allows for extracting a model of residents' behavior. Models can be used to offer tailored services, such as personalized recommendations, which were shown leading to more effective strategies, with estimated savings of around 20% [1]. In the MONERGY project we seek for solutions to lower the energy consumption in the Austrian region of Carinthia and the Italian region Friuli-Venezia Giulia. In [4], we outlined typical scenarios and identified devices most responsible for residential energy consumption. Driven by the findings, we reported existing conservation strategies and designed a home energy management system to assess specific solutions. In this paper, we discuss the principles behind the implementation of a prepaid billing system for household appliances.

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2 Approach

The approach underlying this study combines prepaid billing to disaggregated consumption information. Users can specify the amount of money they intend to spend per device, so as to get charged when using it according to the current cost of energy. An event for a device is a tuple $\langle start, duration, consumption, price \rangle$ described by a timestamp, duration, the overall energy and the tariff, respectively. The cost of operating a device is given by the energy for the event and the cost of energy for the time period, as follows:

$$Cost_{event} = price \int_{t_{start}}^{t_{end}} P(t)\, dt$$

with t_{start} and t_{end} as beginning and end of the event. Intuitively, dynamic pricing can increase awareness of operating devices under different energy availability. While not yet available for Austria, this is already partially true for Italy, where price changes over different periods of the day. We assign a credit to each device which is decreased according to an hourly pricing scheme. Money can be used as non-technical measure unit for energy. The availability of a wallet for each resident might help tracking individual expense for energy and thus enable self-learning. Besides, this would also provide an understanding of most expensive devices, which might promote their replacement with more efficient ones. In addition, a monetary value required to operate appliances can be used to prevent specific users to operate them. For instance, children might have a different energy awareness. The presence of a wallet tracking energy usage can support parents in monitoring and educating them. This allows for the classification of appliances and users. Classification of devices (e.g., by importance) is needed to schedule their operation in autonomous demand-response strategies [6]. This requires detecting devices, to identify and control them even when moved and plugged to a different position. We are working on disaggregation algorithms to solve the mapping [3]. In this work each sensing unit is associated to a code, and the user can name connected devices. On the other hand, we need to identify users when operating devices. We are considering of using relays to force users log on devices and prevent them from operating without credit. The version described in this document implements a soft policy, which serves as a testbed for the effectiveness of pay-as-you-go devices in single-user environments.

3 Implementation

The system is based on three elements. The OpenEnergyMonitor[1] platform collects active power measurements using a network of wireless embedded nodes. A Raspberry Pi acts as a gateway. From the samples collected on the nodes, it uses a threshold to detect on/off events, and enhances events with context information such as the overall energy consumption, the current cost of energy, and the starting time and duration. We collect power samples each three seconds. The event consumption is the sum of consumptions of two consecutive samples, computed as the average power of the samples multiplied to the sampling period. These events are then sent to a scalable cloud-based application running on the Google App Engine[2] at *http://monergy-advisor.tk/*, which manages the billing mechanism and offers basic analytics, such as a wallet and the visualization of domestic activities and their cost on a timeline (Fig.1). The interface is implemented using the template engine Jinja2 and exploits the Google chart[3] and Chap links[4] chart libraries. All functionalities are exposed through a REST API, using a JSON protocol and a token to authenticate requests. In addition, an android application[5] allows users to quickly access the functionalities, along with a smart notification mechanism which is part of our contribution (Fig.2). Accordingly, mobile terminals can register to the Google Cloud messaging infrastructure so that they can receive push messages triggered by our application server. This solution offers a reliable eventing mechanism to reach mobile devices, while keeping low the cost of battery and network communication needed. Whenever a device runs out of credit all user's terminals are notified for the event, enabling the user to react accordingly. This increases the resolution of the feedback, thus potentially improving user's energy awareness.

[1]http://openenergymonitor.org

[2]https://appengine.google.com/

[3]https://developers.google.com/chart/

[4]http://almende.github.io/chap-links-library/timeline.html

[5]https://play.google.com/store/apps/details?id=at.aau.monergyapp

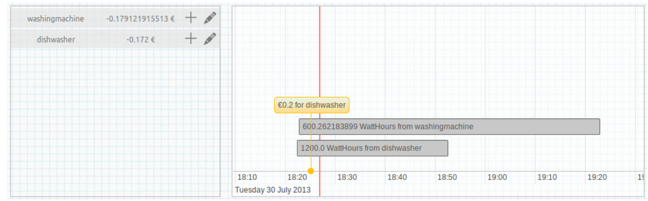
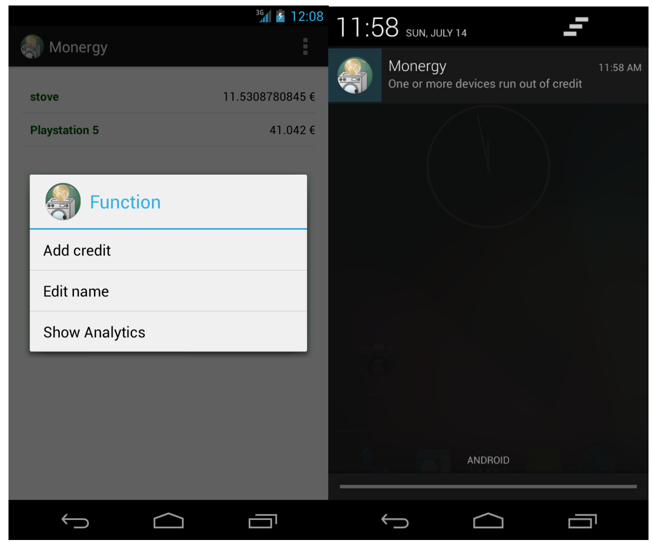


Figure 1: The timeline view



(a) (b)

Figure 2: The Android application

4 Conclusions and future works

Pay-as-you go devices can contribute in lowering energy consumption. Preliminary user tests showed a clear perception of cost of daily activities, and low intrusiveness rates for the smart notification system. We are currently planning to observe long-term acceptance and effectiveness of the strategy in terms of savings.

5 References

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