SmartMeter+

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The Problem we are trying to solve:

"How could the consumption of non-renewable energy sources be controlled in order to provide for a sustainable future."

Introduction

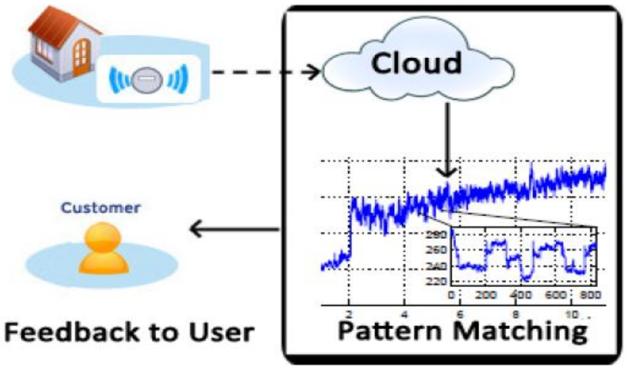
There are many **opportunities for reducing electricity consumption in buildings**, **but identifying and quantifying** them is often perceived to be too time-consuming or too expensive to justify, particularly in small homes. The average consumer currently receives a monthly bill as an indicator of his or her consumption. However, the energy-metering hardware has become cheaper and is more easily available. Even the "smart meter" installations proposed by many utilities have started to provide much higher-resolution electricity consumption data than monthly bills currently do. This creates an opportunity to provide accurate and **building-specific energy conservation recommendation** and verification without costly submetering hardware or expert assistance.

Which conservation opportunities have the most impact may seem obvious, but most building owners don't have a good sense of **how much energy different appliances and activities consume**. Recent researches on energy metering has shown that targeted feedback can be an effective way to remedy this problem, by providing specific and timely information (Darby 2006; Parker et al. 2006; Fischer 2008).

Energy audits are one way to obtain accurate and objective assessments of how to achieve savings. **An energy audit is a process by which a building is inspected and analyzed by an experienced technician to determine how energy is used in it, with the goal of identifying opportunities for reducing the amount needed to operate the building while maintaining comfort levels**. Such audits can be done for homes and public buildings alike. These audits, particularly when focused on electricity, can identify two different types of conservation opportunities: **equipment upgrades** and **altering usage patterns**.

There is a clear need, and a good value proposition, for providing building owners, professional energy auditors, and other interested parties, including homeowners, with simpler tools that would result in motivating them to reduce electricity consumption and use appliances employing greener and cleaner technologies. SmartMeter+ does just that and helps regulate and reduce the consumption of electricity (which in turn reduces the usage of non-renewable energy resources)

The Solution



SmartMeter+ uses an **extremely simple architecture**. It is derived from the regular smart meters which **monitor instantaneous loads** to bill the customers selectively based on the time slot in which the energy is drawn. Smart Meter+ not just possesses all these features, but also **provides customers with insights** on how they can actually reduce their electricity consumption. When the meter is installed at a home, the **inmates fill up a questionnaire**. The meter then continuously monitors the instantaneous current drawn. This data collected at the user's endpoint is then **transferred to the cloud**, wherein a **two-dimensional signature space technique coupled with pattern matching algorithms** is used to find signature patterns for each of the appliance switched on.

The algorithm follows 3 simple steps:
->Finding the **Higher Harmonics** by using phase-locked short-time fourier transform to compute "**spectral envelopes**"
->Identifying **transients** by matching events in the incoming aggregate power stream to previously defined **transient signatures**
->**Disaggregating** Continuously Variable loads, like VSDs used in HVAC fans

Once the exact usage pattern for each of the appliance is known, our intelligent software proposes changes which can be adopted by the household to achieve lower levels of energy consumption. The **energy savings in this case would be user dependent**, but it is estimated that it might help **reduce electricity bills by upto 30%.**The data collected by this system can also be used to **charge customers differentially** on the basis of the **type of appliance** being used. Electricity for appliances **using CFCs and other harmful gases can be priced higher** than appliances which use greener technology.

Given the recent surge of activity in *smart grid* technology and standards, it bears some discussion as to how this would benefit consumers' ability to understand and manage their electric energy consumption. It is first necessary to clarify that the term ***smart meter*** has been used, traditionally, to **refer to the ability of these devices to establish communication with the electric utilities and exchange information about the building's energy demand, pricing, and so on**, as opposed to obtaining the relevant information from building owners. To some extent it means **making the grid—rather than the consumer—smart**. The term does not generally imply providing feedback to the users or any other direct interaction with users, despite consumer expectations for the technology.

Much of the forthcoming investment toward the smart grid will be focused on infrastructure in the transmission and distribution systems, and many homes will be outfitted with **advanced metering infrastructure** (AMI) equipment, which facilitates **two-way communication** between the meter and the utility. This will save on meter-reading costs, much as many one-way communicating automated meter reading (AMR) systems already have. It will also facilitate the **implementation of demand response** (DR), an idea that relies on this two-way communication. However, while AMI systems will allow utilities to send **real-time pricing signals and demand-response requests to homes**, they will not necessarily provide real-time power level readings to consumers or otherwise help people to understand and reduce their consumption. On the other hand, the AMI hardware and variable pricing plans can potentially alter both the available information about energy use as well as the **motivation to alter those usage patterns**, and **this is what SmartMeter+ aims** to do.

A Prototype

A standard prototype would be required to perform the following operations:

- Data Acquisition
- Event Detection
- Appliance Signature
- Classification
- Training

Data Acquisition

To accurately measure a home's consumption and distinguish between 120-V and 240-V loads, the **electric current on both legs** of the main electric supply are to be measured with split-core current transformers. To compute complex power, the voltage is also measured after attenuating it with a voltage transformer to fit the input range of the DAQ. Both **current and voltage are simultaneously and continuously sampled** at a comparatively lower sampling rate of 50-500 Hz. The software used varies from proprietary softwares provided with the CTs to simple data acquisition systems like labjack.

Event Detection

The algorithm used for the prototype is focused on the **classification of "events"**, or points in the time series of power measurements that correspond to abrupt changes. These events are assumed to be the result of an appliance changing its state. We also **assume that the aggregate power metrics for the building quickly settle to steady-state levels** after each **state transition**. This is a reasonable assumption for many, but not all, of the loads in modern buildings.

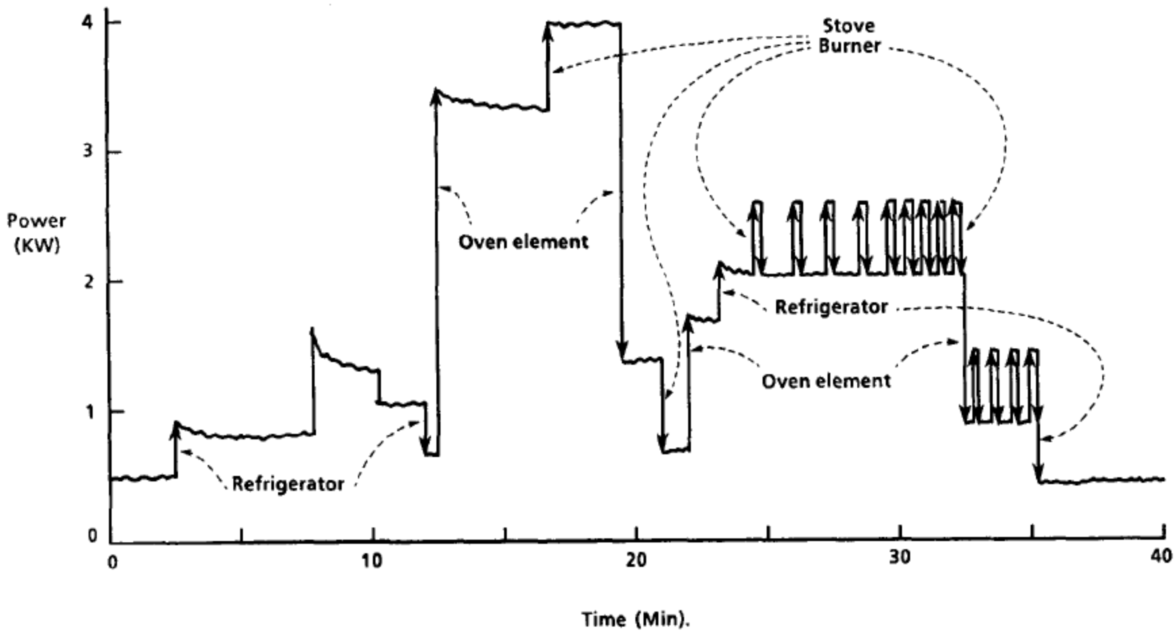
The events are detected in such a way that:

(1) Instead of assuming fixed values for the standard deviation, it is **continuously computed** from the samples. This makes the system adaptable and dynamic

(2) There exists a voting scheme such that **each sample receives**, at a maximum, as many **votes as the number of samples** in the detection window.

The algorithm can be implemented over open source statistical software like **R** or over proprietary software like **MATLAB**.

Appliance Signatures



Once an event is identified, a fixed-size window of samples surrounding it (ie. the **"transient"**) is compared with previously labeled examples in order to classify it. Several **different features** can be used to **characterize the signature** of these transients. Similarly, there are several different approaches for comparing them. One simple signature to compare would be the **difference in average real power before and after the event**. This typically yields unique signatures for many of the larger appliances in a home (as shown figuratively in the figure above), but it is likely that two or more appliances will have power levels that are indistinguishably close, and including other metrics may be necessary. Other possible features are **slope and offset, first and higher order derivatives, the whole transient itself**, and so forth.

Our prototype system implements the above reasoning in a series of **R scripts** that extract features from the real and reactive power transients for the two legs. **Regression** can be used to capture the transient in a better way. Different basis functions can be tested for the regression: Fourier, polynomial, radial, and so forth.

Classification

The crux of the SmartMeter+ appliance recognition process is **a machine-learning algorithm** that takes the **signature of a newly detected event** and **automatically classifies** it based on a corpus of known appliance state transitions.

Training

The classification algorithm in the system relies on an **instance-based learning approach**, where a new unlabeled event is compared with existing, labeled events using a **distance**

metric. The algorithm **determines which "class" the new event belongs** to, based on the set of examples that are closest to the new one

Typically, to obtain the set of examples that will compose the **training set**, a human observer **assigns labels to specific events** in a time series of power values recorded in a building. This approach is scalable to a greater number of appliances in the house and does not require that an appliance be on a dedicated circuit or otherwise make special allowances for any other submetering equipment.

The Impact

As explained above, such a system can/will be used for following purposes:

a) For Conducting **Energy Audits**
b) To **rectify energy usage pattern** at homes
c) To **create awareness** about saving electricity
d) To **reduce consumption of non-renewable energy sources** (indirectly)
e) To **charge differentially** on the basis of live demand and supply
f) To charge differentially on the basis of **type of appliance** being used

The Plan of Action

Once the hardware and the software are tried and tested in the laboratory, it would take a few basic steps to set the device up for Smart Insights. The basic steps which would need to be taken to implement such a scheme are:

Setting up a Smarter Grid if Realtime Differential Energy Rates are to be followed

The grid will have to spew data regarding the current energy rate dependent on the expected demand and availability of electricity, at constant interval.

Filling up a questionnaire on the number/type of appliances in the house (valid only for households)

To increase the speed of calculation and enable disaggregation of overlapping signature patterns, all household users will have to fill a questionnaire up front regarding the type of appliances they use.

Enabling Networking

- Wifi Based
- 2G Wireless Telephony Technology

A big infrastructural challenge would be to enable networking so that data collected at the consumer's site can be passed on to the cloud.

Setting up the meter at the power supply junction

Providing the Users with an Android/Java/iPhone app

With the kind of boom that is being seen in mobile technologies, providing real time data on user's cellphones seems like a viable option to increase awareness and save more electricity.

Probable Challenges

The most important problems/issues with the proposed system can be:

Security

With the whole distribution system being dependent on the data obtained over wireless/telephony network, ensuring secure connections can be a big challenge. The system has to be foolproof and have some latency introduced into it to ensure that hackers don't compromise the security of the system

Privacy

The system can detect what types of appliances people have and their behavioral patterns. Patterns of energy use may indicate behavior patterns, such as routine times that nobody is at home, or embarrassing or illegal behavior of residents. Though useful to the authorities, collection of such information may be considered a breach of privacy unless otherwise specified.

References

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