Agents for Energy Efficiency in Ubiquitous Environments

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ABSTRACT
In ubiquitous environments a vast amount of mobile human and software entities, each with limited resources and knowledge, needs to interact with each other to achieve common and/or individual goals within a specific context. Due to their autonomy, proactiveness, mobility, social capability, and the successful implementation of agent mediated applications and services over the Web, different scenarios have been proposed in literature for the use of agents in ubiquitous environments for a wide range of applications such as user interfaces, mobile computing, information retrieval and filtering, smart messaging, telecommunication and m-commerce. In this paper, we address the problem of energy efficiency in ubiquitous environments from customer satisfaction, customer awareness and energy savings points of view. We propose an agent-based information system in which agents act on behalf of the users, are situated within the appliances, sensors and actuators, or represent different stakeholders in the energy market. Different scenarios have been proposed as the basis for the proposed information system.

Categories and Subject Descriptors
I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence – intelligent agents

General Terms
Algorithms, Performance, Design, Theory

Keywords
Management, Intelligent Agents, Expectation Maximization Algorithm, Wireless Sensor Networks

1. INTRODUCTION
Energy efficiency can be defined as the use of less energy to provide the same level of energy service to the user. Energy efficiency, Customer satisfaction and Customer awareness can be considered as the three criteria for evaluating the performance of an energy service. With advances in agent technologies, wireless sensor network and open standards, it is now feasible to build such an intelligent system for energy efficiency that can motivate and empower people to become active energy consumers.

Smart home environment as an example of a ubiquitous environment is becoming as synonymous to sustainability as it is to convenience. Incorporating smart home technologies into a new or existing environment makes it easier to reduce energy consumption [1], and at the same time guarantee user satisfaction and awareness.

Agent technology has gained increasing attention in developing intelligent building environment. An Intelligent Building can autonomously manage the building environment via computer techniques to optimize energy consumption, resident wellbeing, safety and work efficiency [8]. By its nature, agent technology makes possible the implementation of scalable, flexible and distributed systems. Thus, MAS is able to address many of the problems of energy management. Three main dimensions of energy efficiency in ubiquitous environments intermingle, in addition to energy saving, user satisfaction and user awareness as depicted in Figure 1.

Figure 1: Three main dimensions for Energy Efficiency and their interrelationship

Energy saving is realized through automatic control of lighting and heating devices according to the presence of occupant, programmable climate control systems, automated irrigation systems, power strip, automatically detects when you have turned an item off and completely cuts power to a device so it stops drawing electricity and provides surge protection, programmable thermostats, solar powered products that use clean energy (instead of coal or nuclear powered electricity), smart motion detectors that control lights and appliances, Occupancy Sensors that automatically turn on/off lights and other items when one enters/leaves the room, and Lighting and power timers which turn loads on/off at the optimal and designated times

At the same time, customer satisfaction is realized through adapting light intensity, room temperature and many other devices according to resident personal preferences, providing feedback to the device manufacturer regarding the customer satisfaction with products and also for further enhancements, the use of mobile and ambient system to configure the building in the most efficient way from the energy point of view, and customer satisfaction, application of Ambient Intelligence techniques to design intelligent control systems to reduce energy consumption in buildings. According to this, the intelligent control systems will be enablers and responsible for the energy savings. In this way, the energy saving process will become more independent of users' behavior, keeping the comfort levels desired by users, and The small size of wireless sensor networks that is achievable with wireless technology is desirable for buildings because it allows sensors to be embedded in building materials and furnishings without causing aesthetic problems [2].

While Customer awareness is realized through Real Time Power Cost Monitor, where customers can measure how much electricity an item uses, or find out how much electricity the whole household uses. Many electricity companies offer lower rates during off-peak hours, such as nights and weekends. Using appliances like washers, dryers, air conditioners and dishwashers during these off-peak hours can lead to substantial savings on the electricity bill and by integrating the device to confirm this, it can be programmed to reflect two rates one for off-peak periods and one for peak periods—so customers know how much money they are spending on electricity at any given time. Once they determine these facts, they can reduce usage or replace energy hogs with more efficient items. These real-time energy usage meters will help customers to understand their habits and can help them to become more efficient with their energy consumption needs, Taking advantage of the possibilities offered by ICT technologies regarding energy consumption metering and intelligent control of buildings. ICT networks play a strategic role in the deployment of eco-efficient systems via linking the customers to a database where they can find solutions for their problem and also on the best way on how to use their home appliances, or the system can suggest solution or policy based on the customer energy usage and Digital communication capabilities in the network, including in end-use devices, provides increasingly feature-rich, mobile, and customizable ways to create consumer awareness about electricity consumption, electricity expenditure, and the environmental impact of that consumption. It also provides ways to change electricity consumption, either manually or automatically, in the home or remotely [3].

2. AGENTS FOR ENERGY EFFICIENCY

This research from which this paper stems is aiming at designing an agent system in which agents act on behalf of the users, are situated within the appliances, sensors and actuators, or represent different stakeholders in the energy market. The research shall evaluate how MAS approach can enable controlled; secure coordination of all distributed system functionality (including user interactions), and contributes to Reinforce Government management on using energy efficiency and conservation. Organize controlling system on energy saving, Strengthen education, training, propagandize and mobilize community, upgrade their awareness, promote them using energy efficiency, protecting environment, Creation and maintenance of the system ontology, including flexible management, storage, manipulation, and selection of the actual instance sets describing the current set up of the environment and devices in the system, Creation and management (storing, activating) of policies that reflect the preferences and constraints regarding the energy consumption and system control, Multi-objective policy-based reasoning for energy-efficiency, Investigate on how various environmental sensors, as well as other system information can be delivered and used to achieve the most energy-efficient platform. Sensing and analyzing both external and internal information allows the platform to make better decisions about the use of energy, Smart monitoring the automated home for eldercare, childcare, and pets care through using multitude of different sensors to monitor activities in a smart home and use the results to control the home environment to meet the objectives of energy efficiency, Help the customers to identifying Programs and devices that Support Energy Efficiency and also provide the consumer with database or web application to Get Additional Help on energy efficiency, Minimising the low consumer awareness of the benefits of specific energy efficiency technologies and practices, and the small apparent consumer interest in buying these technologies or adopting these practices, To increase the accessibility of technical information in the application of energy efficient technologies, To keep energy users and building designers informed and motivated to include energy efficiency good practices in their activities, and To encourage policy makers and managers to become more aware of the potential and benefits of energy efficiency, and capable of establishing pragmatic conservation policies.

3. APPLICATION SCENARIOS

Different scenarios are proposed her to show the need and feasibility of an agent-based system for energy efficiency in ubiquitous environments.

Assuming that a smart home can have a home area network (HAN) that connects its appliances, its heating and cooling, its water heater, its laundry, its entertainment (stereo, TV, DVR, game console), and its lighting into one communication network, accessible either through a computer screen in the home or a web-based portal that can be accessed via a computer or a web-enabled mobile device. Through this communication interface, the customer's electricity retailer can communicate real-time information about the quantity of electricity consumed; the price the consumer is paying, and even the type of generation resources being used to generate the power being consumed. The retailer can also communicate price signals to the customer, and the customer can program the different devices in the HAN to change their settings in response to price changes – if the price increases from 9 cents to 12 cents, reduce the temperature in the water heater by 5 degrees, and increase the thermostat air conditioner setting by 5 degrees. Moreover, the consumer can have remote web access to the HAN, and can change settings, monitor energy consumption, and analyze data on the home's electricity consumption.

An example, you are on the train to work, and you get an SMS notification that due to unexpected weather, there will be a higher-than-normal electricity price in the 9:00-10:00 hour. You may have already programmed your devices to respond to price signals, but what if the price is high enough that you want to change your settings? You can log in to your HAN from your mobile device, or from your computer at work, and change the device settings in the home through the web portal.

Another example, you are away for vacation and you would like to check on your property constantly? You can log into your LAN from your mobile device and see whether if there is an intruder in your property or if there is any change in your property electricity usage status "lights had been on or off" or view your remote camera; in case of any problem you can call the neighbours or the police.

A third example, you are working in your office and the temperature dropped immensely or you heard the news of an ice storm hitting the city, while your elderly parents or your children at home alone? You can easily access the heating Intelligent devices, have their settings changed remotely via your mobile device, and can be programmed to respond autonomously to data, including temperatures signals or adjust the temperature manually.

Furthermore, if the home has distributed generation installed, such as solar photovoltaic rooftop panels, you can program the network to reduce electricity usage once the home's consumption reaches the generation capacity of the solar resource, thereby reducing the use of energy overall and reducing the use of fossil-fuel-generated power, even if you were outside or overseas. Thus these digital communication technologies enable new value creation, reduction in environmental impact, and decentralized coordination in the electricity industry [4].

4. ENERGY EFFICIENCY INFORMATION SYSTEM

To achieve all the above scenarios we need to construct an energy-efficiency information system containing the following parts:

4.1 The monitoring and information system

The monitoring component includes a load-survey meter (LSM) that measures electric-power consumption for the entire house, and an end user meter (EUM) that measures electric-power consumption for each home appliance "agents which can communicate through the use of WLAN or WHAN (Wireless Home Area Network)". Both measure power consumption at predefined intervals. The measured data were sent to the network control unit (NCU) through "WLAN or LAN" throughout the house. Data were then collected through the network, by a server in the energy company premises [5]. The distribution component includes a laboratory-based computer which distributes data to the information terminal in each house by E-mail or short messages "SMS". The logs of operation of the information terminal and responses of the consumers to the energy tips were sent to the distribution server periodically. Here, operation of the information terminal means pressing of buttons on the screen of a terminal, by the customer, and also information also the "NCU" sent the consumption information to the user mobile devices "UMD" where users are able to interact with agent system and be aware of their consumption measurement, allowing the Users to modify, change, and adjust their usage to the energy at home, as it is represented in figure 2, the information terminal will also send the tips advices or how to use instructions which it receive it from the energy efficiency company distribution server. These information which its collected and moved in two direction between the consumer home and the monitoring base (Figure 2) will help to determine the generation and consumption of energy for both side energy companies, Government and the consumer as well. Another added advantage to this system is the prediction of short term and long term between the demand and generation of electricity and help to enhance the energy consumption through information exchange and advice and notification to the user especially in times of electricity peak load or environmental disaster to save the company side from overloading, shutting down and also to keep the user satisfied with service they receive.

4.2 Design of the information terminal

Although various display methods can be considered effective for providing energy-consumption information, conciseness has a big influence on the overall effectiveness of the display methods. Hence, the composition of the display needs to be designed carefully. A few factors should be taken into consideration during the design of the information terminal display: Simple access to the detailed data. A number of buttons should be properly located on a single display picture; only a mouse or click is required in order to access various functions and more detailed data. The main graph area is located at the centre of the display picture, while windows displaying energy-saving tips and information on electricity charge are located below and to the right of the main graph area, respectively.

The web-based system is made up of a group of modules containing information, data, and hyperlinks for a set of topics of energy efficiency in buildings. The web-based system is intended to give people a manageable subset of the information available on the WWW and to allow them to start working with practical guidelines and data. Information is drawn from related web sites, both within and outside the University, so as to make the best use of the resources on the WWW to supplement the content. In-house information and external links are organised in a logical way to guide beginners to the best sources and to provide directions for guided explorations. Information about products and services, technology, applications, legislation and regulations will help people in the planning, designing, operating and maintaining of their building and energy systems.

4.3 Energy management system

Energy management system plays crucial rules in encourage policy makers and managers to become more aware of the potential and benefits of energy efficiency, and capable of establishing pragmatic conservation policies [7].

Typically, energy management is ensured by a central controller in which a program is implemented. This program is based on some long series of control flow like ''if else if'' (e.g. ''if the battery is empty then charge it''). Even if this solution achieves a constant supply of the load, it cannot fulfil easily other objectives such as fault tolerance of an element. This centralized management is also based on a ''top–down'' approach and requires the designer of the control system to be exhaustive in the control flow written in the program. If an event not covered by the system occurs it is unable to respond adequately. Moreover, if the configuration has to be changed (addition or removal of an element), the program must be completely redesigned. That is why a bottom–up approach seems preferable, although little used so far for this type of problem. Indeed, the designer knows, in most cases, how each element must respond separately. With the bottom–up approach, power management emerges from relatively simple rules established according to the constraints of each element. This approach can be structured around the Multi-Agent Systems (MASs) paradigm. In energy management three fields of application can be distinguished as explained in figure 2.

MAS allows to get a system that adapts to faults and improves performance by selecting the shortest path between sources and loads. A long series of rules must be thoroughly prepared in order to obtain an answer for all states of the system. If a case is omitted, the system is unable to respond adequately. The field of ''soft computing'' has also brought its share of solutions with neural networks, genetic algorithm and fuzzy logic [6], [7].

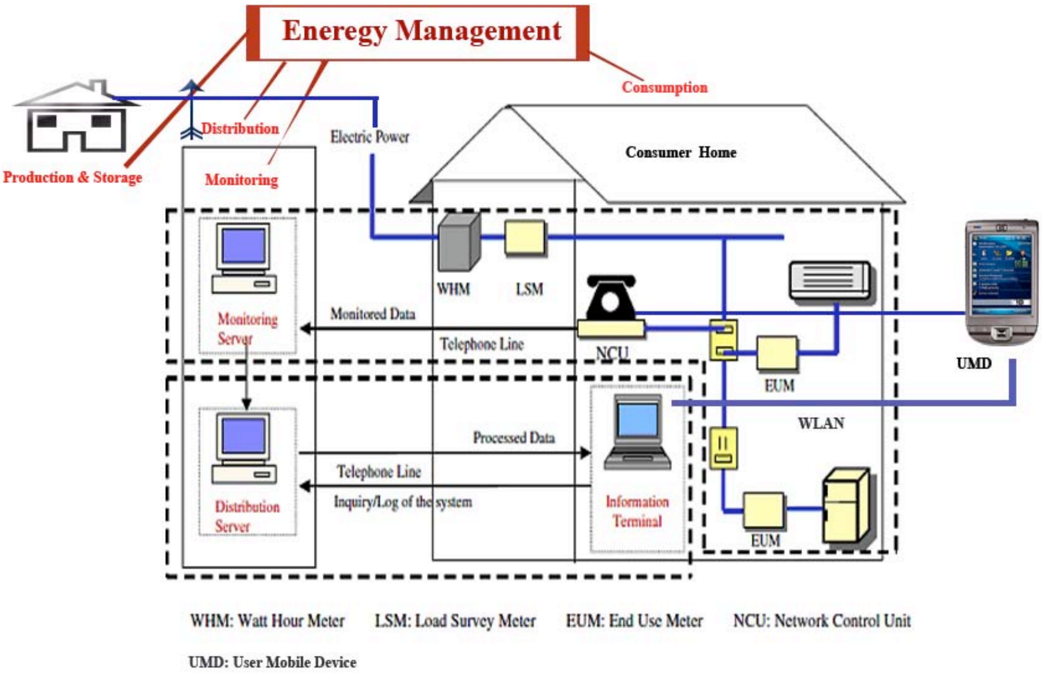

Figure 2: Energy Efficiency Management System

5. CONCLUSIONS AND DISCUSSION

Many regulatory and market barriers still exist that discourage greater reliance on Energy Efficiency such as 1) Rate structures and the price of electricity also often fail to encourage efficiency. The cost of power varies by season, time of day, weather, type of power and location, as well as by the economy and politics, 2) Custom, practice, and utility expertise also results in less reliance on efficiency and conservation to meet power needs. If more power is needed, the general practice has been to build a new generation plant, purchase more power, and build more transmission capability to meet those needs. These are what electricity suppliers know best how to do, and it is often the first or only solution proffered, 3)Most utility regulation also fails to reward efficiency. Traditionally, electric utility rates are a function of the cost of providing electric service to customers. A rate proceeding establishes the revenue requirement for the utility to meet electricity needs in its service territory, and sets rates based on that revenue requirement. A utility's profit is then linked to the amount of electricity it sells. As soon as rates are set, the utility's actual revenues and profits are driven by sales. The more electricity a utility sells, the more money it makes and 4) The structure for buying and selling power does not reward efficiency. Most consumers and utilities are "rational" beings and act to minimize costs and maximize profits.

While there are many barriers to having efficiency and conservation resources meet more of our energy needs, these barriers are not insurmountable and there are many tools available or under development to use less power. Further research is required to consider all of the following requirements: Energy efficiency and residents' comfort, Preferences learning in a shared environment, Personalized control and feedback, Human readable and accurate knowledge representation, Sophisticated agent platform and techniques.

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