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AN USER PROFILING SYSTEM BASED ON WIRELESS SENSORS FOR SAVING HOME ENERGY

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ABSTRACT

The high energy required by home appliances (like white goods, audio/video devices and communication equipments) and air conditioning systems (heating and cooling), makes our homes one of the most critical areas for the impact of energy consumption on natural environment. It present a work in progress within the European project AIM for the design of a system that can minimize energy waste in home environments efficiently managing devices operation modes. In our architecture we use a wireless sensor network to monitor physical parameters (like light and temperature) as well as the presence of users at home and in each of its rooms. With gathered data our system creates profiles of the behavior of house inhabitants and through a prediction algorithm is able to automatically set system parameters in order to optimize energy consumption and cost while guaranteeing the required comfort level. When users change their habits due to unpredictable events, the system is able to detect wrong predictions analyzing in real time in- formation from sensors and to modify system behavior accordingly. By the automatic control of energy management system it is possible to avoid complex manual settings of sys- tem parameters that would prevent the introduction of home automation systems for energy saving into the mass market

Keywords

Energy saving, Home automation, Smart monitoring, User profiling, Wireless sensor networks

1.INTRODUTION

According to recent studies [1] energy consumptions are increasing year after year, and if effective energy saving poli- cies will not be adopted, in 2030 they will double with re- spect to 1980 level and will increase by 28% on 2006 level. The residential sector accounts for an increasing percentage of the total consumption which is now above 27.5% (source Earthtrends). In other sectors like the industrial one the introduction of strategies for the reduction of energy consumption have been stimulated by the urgent need to improve production efficiency, while residential users have a low awareness of the problem and usually lack of tools for measuring and optimizing the energy consumption of their daily activities. The top four residential end-uses of en- ergy (as a percentage of primary energy) are: space heating (26.4% of total primary energy end use), space cooling (13% of total primary energy end use), water heating (12.5% of to- tal primary energy end use), lighting (11.6% of total primary energy end use).These predictions have recently increased the interest of the research community as well as of the industry world in the use of new generation home automation systems for energy saving.

The general goal is to use monitoring and con- trol devices to measure in real time the energy consumption of home appliances and to set them to low power modes when possible in order to save energy. It reviews previous work on home automation focusing on energy saving systems and present the basic characteristics of the sys- tem

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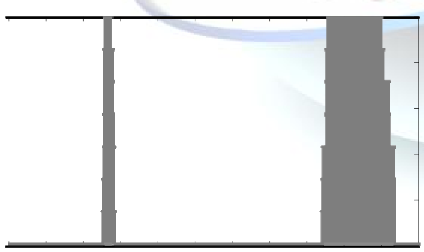
under development within the AIM project. It presents the wireless sensor network architecture adopted and the middleware MobiWSN that we designed and devel- oped to manage data gathering and processing in a flexible and efficient way. It presents the user profiling mechanisms focusing in particular on presence sensors. In some numerical results are presented to provide ex- amples of possible advantages achievable with the proposed system in terms of energy consumption.

2. HOME AUTOMATION FOR ENERGY MANAGEMENT

In recent years, several research efforts have been carried out to design the so called *smart home* [4]. One of the most attractive potentiality of this kind of environment is the possibility to reduce the energy consumption managing intelligently the devices into the house.

3. WIRELESS SENSORS FOR SMART ENERGY MANAGEMENT

In the AIM architecture, the wireless sensor network (WSN) provides the basic tools for gathering the information on user behavior and its interaction with appliances from the home environment. Some physical parameters like temperature and light that can be used by the system to perform some automatic adjustment of the energy management sys- tem. The sensor network can be implemented using several available communication



DAILY PRESENCE PROFILE

The proposed middleware archi- tecture requires some basic services to the network layer, namely: *best-*

4. USER PROFILING

technologies. Christo Ananth et al. [7] discussed about Reconstruction of Objects with VSN. By this object reconstruction with feature distribution scheme, efficient processing has to be done on the images received from nodes to reconstruct the image and respond to user query. Object matching methods form the foundation of many state- of-the-art algorithms. Therefore, this feature distribution scheme can be directly applied to several state-of- the-art matching methods with little or no adaptation. The future challenge lies in mapping state-of-the-art matching and reconstruction methods to such a distributed framework. The reconstructed scenes can be converted into a video file format to be displayed as a video, when the user submits the query. This work can be brought into real time by implementing the code on the server side/mobile phone and communicate with several nodes to collect images/objects. This work can be tested in real time with user query results.

In the proposed architecture for home energy management, besides the temperature and lighting information for every room, Then need to create a user profile through presence detection. This has been obtained using a low-cost technology based on multiple infrared sensors deployed in all rooms. To filter the motion events captured by the infrared sensors and to process this raw information within the motes of a group, implement a high level functionality which has the task to report to the gateway only information on the presence users in the room, reducing the number of long path messages. *effort delivery*, *discarding duplicate packets*, *unicast and broadcast addressing*. The routing protocol we adopted for WSNs, called *Hierarchical Addressing Tree* (HAT), allows the creation of a network with a tree topol- ogy and a hierarchical addressing. The network address is divided into levels according to the number of hops from the root of the tree, each of which has the same number of bits that represents the maximum number of sons for every node in the hierarchical tree topology. The routing tree is created with a node association procedure and maintained through the exchange of periodic beacon messages.

Two different ways: *Off- line mode* and *Real-time mode*. This is used to collect the data of the house using sensor.

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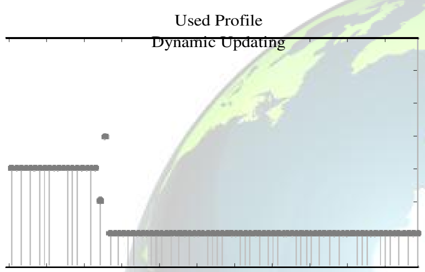
Off-line mode information collected by the WSNs is aggregated providing inputs for user profiling. The basic function of the user profile is the characterization of users behavior so that some settings of the energy management system can be made automatically. In the user presence profiling the sen- sor network collects 24 hour information (here called *"daily profile"*) about users presence/absence in each room of the house in a given monitoring period (i.e. week, month). At the end of the monitoring time the cross-correlation between each couple of 24 hour data presence is computed for each room of the house in order to cluster similar daily profiles.



Real-time mode the sensor network collects real time measurements of physical parameters that can be used by the system to perform some automatic adjustment of the energy management system (like e.g. regulating lighting sys- tem according to the level of natural light from windows, control the heating/conditioning system to set temperature in the rooms according to the user profile, etc.). The real time user presence information is also used to dynamically update the predicted profile during the day, through the *Lo- cal Updating Algorithm* (LUA), tracking the user behavior (Figure 2): for each room the cross-correlation between the stored presence profiles and the real time detected one $s(t)$ is calculated dynamically during the day. A switch from a predicted profile $x(t)$, to another one $y(t)$, is performed if:

$$r(y, s) - r(x, s) > C(r(y, s) + r(x, s))$$

5 NUMERICAL RESULTS

Simulation performed a monitoring period of 30 days has been used; in the first monitoring period the system just collects information on user behavior. After the first 30 days the system begins to work using always the last 30 days like monitoring period to generate, for example, the presence profiles. The presence prediction algorithm has been sim- ulated in three user behavior exceptions cases: exceptions spike (there are 20 isolated exceptions in the users behavior), exceptions burst (there are 4 sequences of 4 contiguous ex- ceptions in the users behavior) and changing behavior (user changes his behavior two times during the year, for exam- ple as we move from winter to spring/summer the user goes to sleep later). The results of the 300 days simulation are presented in Table 1.

	1	2	3	4	5
Exceptions	88.00%	90.33%	87.67%	88.67%	87.00%
Exceptions	94.00%	92.00%	93.67%	91.67%	93.33%
Behavior	90.00%	91.00%	90.00%	91.67%	90.67%

CORRECTLY PREDICTED PROFILES FOR EACH ROOM OF THE HOUSE

	1	2	3	4	5
LUA	2.05%	2.55%	1.78%	0.58%	0.79%
GUA	1.38%	1.67%	1.54%	0.36%	0.66%

WRONG USER PRESENCE PREDICTION PROFILE OF THE DAY IS NOT CORRECT

The dynamic profile updating has been tested in all three cases and the average values have been computed for the LUA and GUA Table 2. Considering all the simulating pe- riod (300 days) the percentage of time with a wrong user presence prediction is very small. The home temperature management has reduced the working time of the cooling system by nearly 28 percent. Obviously, the working time reduction and the resulting energy saving are strictly related to the specific scenario considered since they depend, for example, on the presence/absence periods in each room of the house.

6 .CONCLUSION

A home energy management system under development within the European project AIM. We proposed a heterogeneous hierarchical sensor network architecture to gather physical parameters and to monitor user behavior. It designed and implemented a middle ware able to deal with network heterogeneity and dynamics, as well as to greatly simplify application development. Data collected by the sensors are used to create user pro- files. Based on user profiles and real-time information provided by the system, It predict user behavior and optimize the energy consumption controlling in an automatic way home appliances. The proposed a new approach to implement a self adaptive prediction algorithms to set several parameters (light intensity, temperature, etc.) according to user estimated preferences. The presented solution is simpler than other profiling systems, which rely on complex learning techniques: just replicating a previously observed set up that satisfied the user in a similar context pro- vides good results and requires shorter training periods. We implemented a prototype version of the propose sensor net- work architecture based on off-the-shelf devices. Moreover, It simulated our prediction algorithms over long time periods and showed their effectiveness in estimating user presence in normal conditions and their ability to quickly detect anomalous conditions and to correct estimations.

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