Smart Home Agents and Energy Efficiency

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ABSTRACT

Smart homes agents are becoming more and more popular. Many IoT devices are not considered smart, as they simply provide a functionality controlled by the user. There exists intelligent agents that can make decisions on their own based on a goal the user has set. Multiple intelligent agents in a smart home can communicate together to accomplish individual as well as larger common goals. One of these goals is energy efficiency. The goal of this paper is to put forth a mechanism to be able to reduce energy usage in a home using these intelligent agents. There are several aspects of energy usage we can look at: the energy used by these intelligent agents and their communication techniques, the energy used by wasted unwanted usage in the home, and the energy cost of completing a task at different times of the day to be most energy efficient. By having a central server for all the houses in a community to talk to it is able to provide a better scheduling algorithm for load balancing and can reduce the cost of energy bills while saving energy.

1 INTRODUCTION

Smart home agents have been becoming more popular recently and different companies have been promoting their collection of devices. Many IoT devices are controlled by the user and are not really smart agents. Some examples of intelligent agents include a smart thermostat, plugs, lights, speakers, locks, and meters. Most of these are independent agents that perform some optimized tasks based on user satisfaction. However, only some are capable to interacting with each other or a central agent for instructions. For example, a Google or Alexa assistant is capable of interacting with other devices and giving action commands based on user input. Multi-agent collaborative systems allow for communication between agents to provide a more informed action. This model can be expanded to have a central control server for a community with each household being a set of agents that interact with the central server. From there we can use these agents to optimize energy usage in a home. There are several different approaches to a smart home energy efficient system. Through the use of intelligent agents and machine learning algorithms, home can be more efficient and can save costs for the consumer.

2 BACKGROUND

A smart home environment usually consists of multiple agents. These agents could be individual IoT devices that perform a particular task on their own or they could be intelligent agents that communicate with each other to perform a larger goal. There can be a multi-level agent system as well where one agent manages a group of agents that then manage another set of agents. With respect to a smart home community, a central server can communicate with a distributed agent in a household that has many IoT devices and other intelligent agents that report to it.

2.1 Intelligent Agents

An Intelligent Agent is an entity that is capable of making decisions based on its environment. This is different than a regular IoT device because those cannot make decisions on their own, they rely on user input and a set of rules. There are different types of intelligent agents including model based, goal based, or learning agents. A simple agent program can be defined as a function that maps every possible percept to an action. There are logic based agents, reactive agents, and belief-desire-intention agents. Simply having an agent is not enough to make much of a difference in a home. The main goal is to allow agents to communicate with each other while being able to make decisions and carry out actions independently.

2.1.1 Simple Reflex Agent. These types of agents take in percepts through sensors to determine a state. Then a set of condition-action rules are applied to determine an action. This is the simplest agent that does not have any learning abilities.

2.1.2 Model-based Reflex Agents. These types of agents take in percepts and combine then with an internal state and model to decide what action to take. This agent needs to know how actions will effect the environment state and is useful in partially observable environments.

2.1.3 Goal-Based Agents. This agent has a goal state it wants to achieve and uses search and planning algorithms to determine the best actions to reach its goal. This agent can also adapt based on its environment and sensor data.

2.1.4 Utility-Based Agents. Ths agent builds on a goal based agent using a utility function to determine likelihood of success for each action based on the current state. This agent keeps track of its environment and builds a model to use to determine how happy or successful the agent should be.

2.1.5 Learning Agents. A learning agent keeps track of how well it is doing, building off a utility agent. A critic will report a value to the agent to let it know if it is on the right path or not. It decides on an action based on past states and tries to maximize performance in real time.

2.2 Multi-Agent System

A multi-agent system is a group of intelligent agents that communicate with each other and exchange information to move towards a common goal. A multi-agent system can have shared resources and distributed tasks. Each agent can have its own agenda while using the information others provide. On the other hand, there can also be a head device or server that is in charge of all the other devices and hands out tasks which each agent carries out, based on information from all the agents.

2.3 Energy Efficiency

These multi-agent systems can be used to optimize energy usage based on peak load times and usage measurements from each household. By having distributed systems in each household, a central server can schedule tasks based on energy usage from each home. Residential loads usually consist of schedulable loads, like heating, washer, dryer, and fixed loads, like refrigerator and stoves. [1] Typical households waste 30 percent more energy than an efficient one. Reduction in energy waste and using energy more efficiently will lower energy bills for the consumer. However, when it comes to devices controlling things like the temperature of your house, it is important to consider the balance between convenience/comfort and savings.

3 RELATED WORK ASSESSMENT

To get a better understanding of how a system can help manage energy usage, we will look into three different papers that provide different approaches to the problem.

3.1 Home Energy Management System with PEA Server

In this paper, the Home Energy Management System (HEMS) was a system in place in each household in a community that then reported to a central PEA server. Each home reports its load profiles to the central server and uses Demand-Response events to schedule tasks. Demand-Response is based on data provided by these load profiles and power grid companies to determine peak load times and how to lower the overall usage at these times. The central server also broadcasts real time tariffs and pricing based on this information for each household. [5]

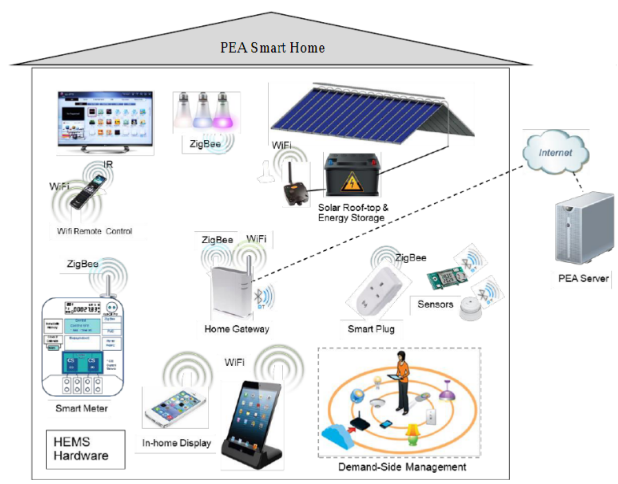

Figure 1: HEMS Smart Home with PEA server [5]

3.1.1 Framework. The HEMS system used an object-oriented framework comprised of states, events, task scheduler, communication protocols, and policies and constraints. States were based on the status of each home appliance. Events could be internal to the home or external from the central server. The task scheduler made decisions based on these events. The communication protocols were in place for reading home states, listening to events, and carrying out resident requests. There was a setting for different policies to take into account user satisfaction including normal, comfort, economy, max-savings, and demand-response. [5]

3.1.2 Assessment. This system uses a central server to which all homes report to. This server can take in load profiles and make decisions that are best for the whole community and schedule tasks accordingly. This system offers different setting and policies to handle the issue of savings vs comfort. It is clear that you cannot have both so you need to find a trade-off. If this trade-off policy is chosen by the user then the user will be more satisfied with the results. Using demand-response is a beneficial technique to incorporate current energy usage and prices into decision making.

3.2 Smart Micro Grid with Intelligent Hierarchy of Agents

This paper also suggested a community ecosystem with a central controller with distributed agents in each household. The centralized agent in this case was in charge of deciding where to draw energy from: wind turbine, battery, or power grid. [2]

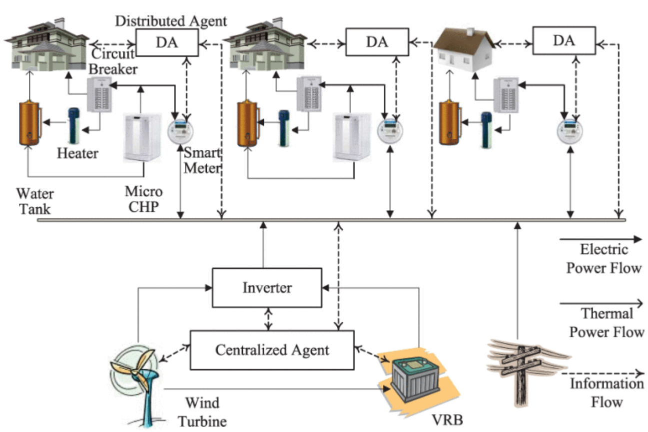

Figure 2: Smart Home Micro Grid System [2]

3.2.1 Three-Level Hierarchical Optimization. The micro grid system consisted of three optimization levels: Distributed Dynamic Demand Response, Centralized Micro-Combined Heat and Power System Optimization, and Centralized Vanadium Redox Battery (VRB) Optimization. [2]

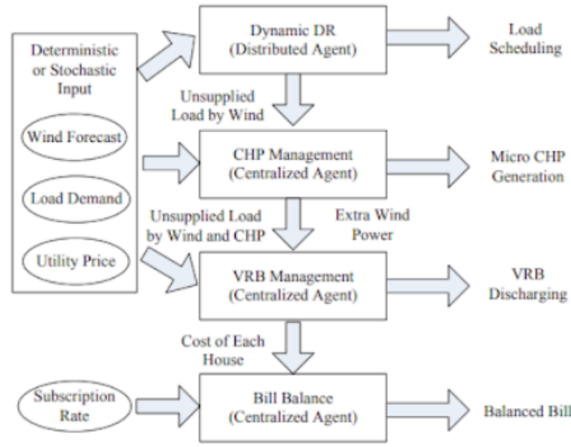

Figure 3: Three-Level Optimization Hierarchy [2]

3.2.2 Algorithms. There were several algorithms used in these agents. Particle Swarm Optimization Algorithm was used for real-time practical operations as it provides a quick way to determine the best action. Q-Learning was used by the battery management system to obtain optimal VRB discharging policy through interactions with the environment. Another agent in the central server used a bill balancing algorithm to ensure each household pays a fair price. [2]

3.2.3 Cost Savings. The paper compared its cost savings results using the proposed ecosystem and a conventional system. A conventional system has a Demand-Response system local to the household while the proposed ecosystem has a central controller to manage the community. Its results showed that the proposed ecosystem reduced costs per day by around 50 percent. [2]

3.2.4 Assessment. The Smart MicroGrid is driven towards a community in which there are multiple sources of energy that can be optimized to offer minimum energy loads and lower costs. It can be very expensive to build such a system in a pre-existing community without multiple energy sources. However, if planned a new community may benefit from such a product. In this case and the previous system, it is essential that all homes in the community have a distributed agent to make decisions accurate and meaningful. If a resident opts out of such a system it can affect the results of other residents in the community. This model also takes advantage of machine learning algorithms to optimize the management of energy sources to determine the best action to take based on prior knowledge. This reduces energy costs by about 50 percent which is very beneficial to the consumer. In addition, this system does not offer as much control over comfort and savings as the previous system so it may be harder to offer user satisfaction.

3.3 Intelligent Smart Home Efficiency Model

This paper proposes a model for a energy efficient smart home focusing more on internal communication within the household without an external central server. The goal is to reduce energy usage and network usage in a household. To learn about the environment sensor boards are put in each room that contain sensors that provide data to determine what a resident is doing if present. Sensor boards take into account motion, sound, and rotary to determine a user being active, resting, sleeping, or not present. [4]

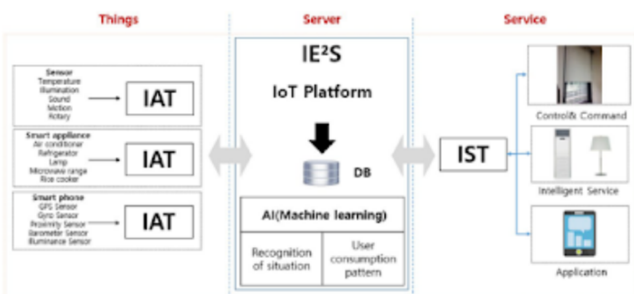

Figure 4: Smart Home Energy Efficiency Model [4]

3.3.1 Model. This model consists of three parts: things (IAT), server (IES), and service (IST). Things like the sensor boards collect environment data and send it to the server. The server uses machine learning to recognize the situation and then interacts with the services to determine an action. [4]

3.3.2 Algorithms. The IAT algorithm takes input from sensors and deducts the situation of the room regarding the resident. the sensor data is filtered and send to the server. The IES algorithm takes in this filtered dataset and uses learning data and user desired data to determine if the room is in the optimal state. It interacts with the IST algorithm which takes in the optimal status and determines an action command for a device and then reports the new status. [4]

3.3.3 Minimal Network Activity. An interesting part of this optimization in the IAT algorithm to filter data s that once the situation is determined there is no need to send all the sensor data to the server. Only necessary data is transmitted to the server lowering network usage. Many IoT devices and intelligent agents in homes can affect network performance and this algorithm attempts to address this problem. [4]

3.3.4 Assessment. This model is focusing on individual home systems without a central server in a community. It still follows the architecture of having a central server within a household and having distributed agents among the home. This system takes advantage of the fact that intelligent agents can offer some computational intelligence on their own. A device can take in sensory percepts and deduct a state and only report that state to the central server for processing and determining an action. This minimizes network activity which is important because many devices on the network can slow it down. This also saves energy among the devices as well as the energy saved by carrying out informed decisions.

4 PROPOSED DESIGN AND ARCHITECTURE

A multi-agent system with a central controller device in a community has shown better results than without a central server in terms of energy efficiency. This system will schedule tasks based on the most energy efficient time for the task. It will reduce its own communication network usage. In addition, distributed agents in each house will report load data to the central server. The central server will be able to balance loads and provide energy from multiple sources with the ultimate goal of consumer satisfaction and cost reduction. Having the user be able to control the policies such as max savings vs comfort would give the user more satisfaction but may have a negative effect of the savings of other members in the community. Regardless, the resident should still have full control of the devices in their home. A central server within a community would only be useful if the majority of the residents participate in the system by having their distributed agents report to it.

5 ANALYSIS

Combining these systems can provide an even better energy efficient system that can successfully lower energy usage through the use of multi-agents and a central control server. The last paper focused more on how to ensure energy efficiency within a household and using sensor boards to determine the situation. This can be sent to the distributed agent for each household which can then communicate with the central server. This communication includes load profiles and can further take into account the schedule of a resident to help schedule tasks around this. The second paper talked about a micro grid which is a good optimization model to balance energy usage and manage different sources of energy based on usage. A community ecosystem was shown to provide significant drops in price of energy bills and energy usage. Less energy is wasted while still satisfying the consumer.

It is important to consider the scalability of such agent systems. To be more efficient, all homes in an area would need to be connected to such a system and this faces a problem of getting everyone on board. Installing distributed agents in every household can get to be expensive and there is a trade-off between the consumer paying or the city paying, especially if it is required in a particular community.

6 SECURITY

Implementing such a start home ecosystem also has many security risks connected to it. Having a central server in the community means that each household distributed agent needs to send their load profiles over the network to this server. The server then has to schedule tasks for each home and possibly send billing information back to the houses. This information must remain secure and unchanged. It is possible for an attacker to perform a man-in-the-middle attack between a distributed home agent and the server. They can learn load profiles for the house as well as modify them or modify pricing to affect the energy bill for that specific household. This would have to be investigated further in future work.

7 CONCLUSION

Home Management Systems for energy efficient communities provides a great benefit for consumers. Not only is less energy being wasted but energy bills are lower. For there to be a considerable difference each home in a community must be part of the system so that load profiles for each house can be taken into account by the central server and provide more accurate data. Implementing such a system is expensive but will pay off for the consumers in the long run. The trade-off between savings and user satisfaction and comfort is important to consider while designing a smart home system. Some related works have looked into this trade-off to determine the best optimized algorithms to satisfy customers. [1] Future work will have to be done to determine more optimization techniques to maximize energy savings while satisfying users. In addition, future work should look into the scalability and setup expenses as this is a major factor in the use of such a system.

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