New development in Anticipatory Agent System used for Power Management in Smart Home Simulator

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Abstract

In recent years, there is a global evolution in the way energy is generated and consumed due to climate change, energy independence and the impending decay of fossil fuels. It has seen a rise of interest in the deployment of multi agent systems in energy domains that inherently have uncertain and dynamic environments with limited resources. In such domains, the key challenge is to minimize the energy consumption while satisfying the comfort level of occupants in the buildings under uncertainty (regarding agent negotiation actions). This paper presents the new development for enhancement the performance of Power Management in Smart Home simulator. This development is based on the anticipatory and multi agent systems that used in this simulator.

Keywords: *Anticipatory System, Multi Agent System, Power Management, Smart Home.*

1. Introduction

Power systems are widely used as an example of Multi Agent system (MAS). In such systems, each consumer can be considered as an agent. Each agent in this MAS must learn an intelligent behavior in order to maximize its own personal gain. In this case, the gain from the consumer's perspective is the ability to satisfy the user's consumption and preferences. [4]

There are many benefits of applying MAS in power management as: [9]

- Flexibility: the ability to respond to dynamic situations.
- Extensibility: the ability to easily add new functionality and augmenting or upgrading existing functionality.
- Fault tolerance: the ability of the system to meet its design objectives in case of failure.

Anticipation is one of the most important behaviour for power management system. Basic definition of *Anticipatory Systems* (ASs) was published in 1985 by cyberneticist R. Rosen in his book Anticipatory Systems [8]. Anticipatory system contains *a predictive model of itself and/or its environment, which allows it to change state at an instant in accord with the model's predictions pertaining to a latter instant*. [5]

Home Energy Management (HEM) is a hot topic for several good reasons:

1- Consumers want to reduce the amount they spend each month on electricity.
2- Utilities want to switch from a model of getting people to consume more to one of getting them to consume less.
3- Societies would like to stop being dependent on fossil fuels (much of which go to generating electricity).

The remainder of this paper is organized as follows: section 2 gives a background of Anticipatory Agent System (AAS). Overview of Power Management in Smart Home (PMSH) simulator is presented in section 3. In section 4, the proposed development of the simulator is shown. In Section 5, the results of performance for the original and proposed simulator are presented. Finally a conclusion is briefly described in the last section 6.

2. Background of Anticipatory Agent System (AAS)

More sophisticated ASs are those which also contain its own model, are able to change model and to maintain several models, which imply that such systems are able to make hypotheses and also that they can comprehend what is good and bad. One can infer from this statement that true agent systems are only those that have a clear anticipatory ability, both at the level of the individual agents themselves, and also at the whole MAS. [6]

The framework for *anticipatory agents* is based on the concept of ASs as described by Rosen. It is a hybrid approach that synthesizes low-level reactive behaviour and high-level symbolic reasoning. As illustrated in Figure 1, an anticipatory agent consists of three main entities: [1] [2]

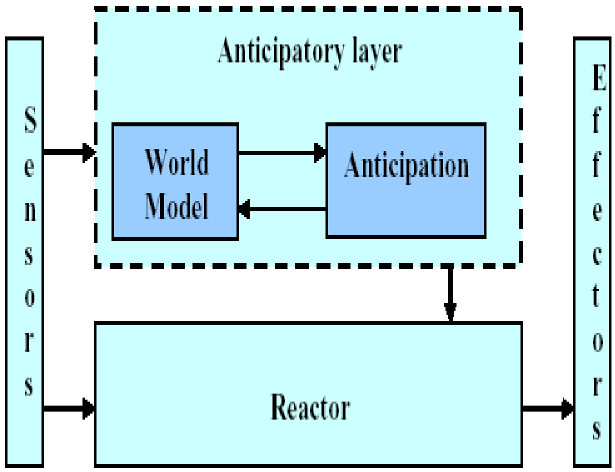

Fig. 1 The Basic Architecture of an Anticipatory Agent System.

1- *A reactive system*, which is referred as Reactor. The reactor controls the low-level behaviour. The reactive component is modified according to the predictions from Anticipator. Every time the *Reactor* is modified, the *World Model* should be updated accordingly.
2- A world model includes the description of the agent's environment, the reactive part of the agent and of all other agents in the environment.
3- *A meta-level*, which we will refer to as the *Anticipator*, makes use of the world model to make a sequence of predictions of future states. The *Anticipator* guides the agent's behaviour on a high-level.

To summarize: The sensors receive input from the environment. This data is then used in two different ways: *(1) to update the World Model and (2) to serve as stimuli for the Reactor*. The *Reactor* reacts to these stimuli and provides a response that is forwarded to the *effectors*, which then carry out the desired action(s) in the environment. Moreover, the *Anticipator* uses the *World Model* to make predictions and on the basis of these predictions the *Anticipator* decides if, and what, changes of the dynamical properties of the *Reactor* are necessary. Every time the *Reactor* is modified, the *Anticipator* should, of course, also update the part of the *World Model* de-scribing the agent accordingly. [1]

There are different developments to the basic *Anticipatory Agent System* (AAS) which depended on the principle of distribution of anticipation [3] [7]. These are as follows:

1- *New Multi Agent System* (NMAS), it included *Anticipatory Module* (AM), which depended on the principal of central of anticipation. (as a facilitator in MAS).
2- *Anticipatory Multi Agent System* (AMAS). This system combined the principles of central and distributed anticipation from the two previous systems. .
3- *Adaptation Anticipatory Multi Agent System* (A2MAS). The adaptation behaviour is included to the previous system.

Figure 2 presents the system's architecture. The explanation of its components is as follows:

1- Environment is the description for the particular component of the environments, e.g. for the power consummation control, it gives the numbers of the devices that found in the place that I need to control their power.
2- Interface is the groups of the sensors that take the statues of the environment component and gives to the system as an input for it.
3- MAS is the group of agents that have the architecture as in the following figure.
4- Anticipation module is used for anticipating of a new situation.
5- Effectors take its inputs from anticipation module and send to MAS and environment to change their statues.

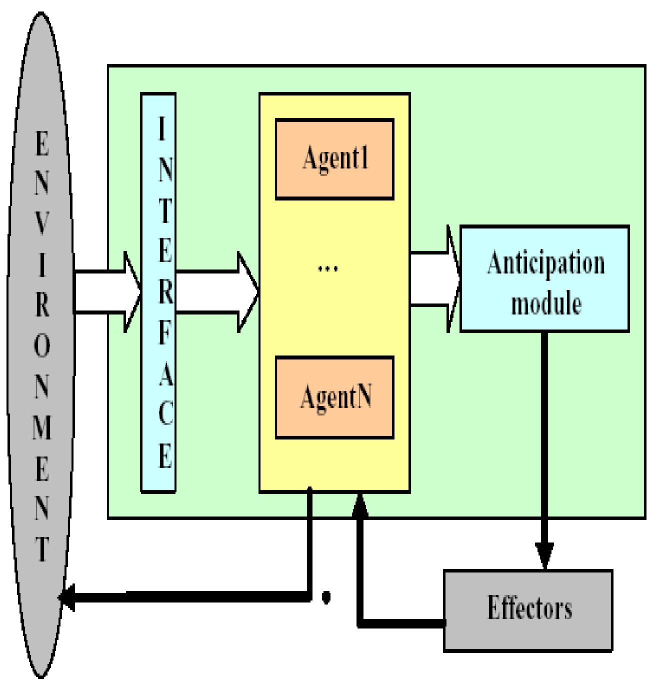

Fig. 2 The Structure of New Multi Agent System (NMAS)

Figure 3 illustrates the internal structure of used Agent in the Adaptation Anticipatory Multi Agent System (A2MAS).

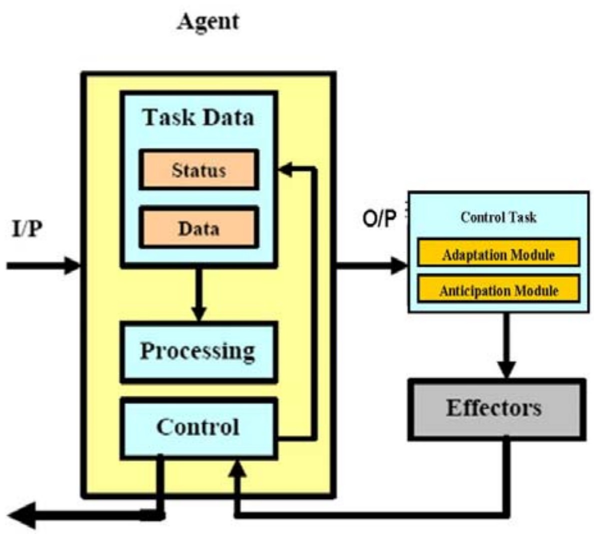

Fig. 3 The Architecture of Agent in *Adaptation Anticipatory Multi Agent System* (A2MAS)

3. Overview of Power Management in Smart Home (PMSH) simulator [3]

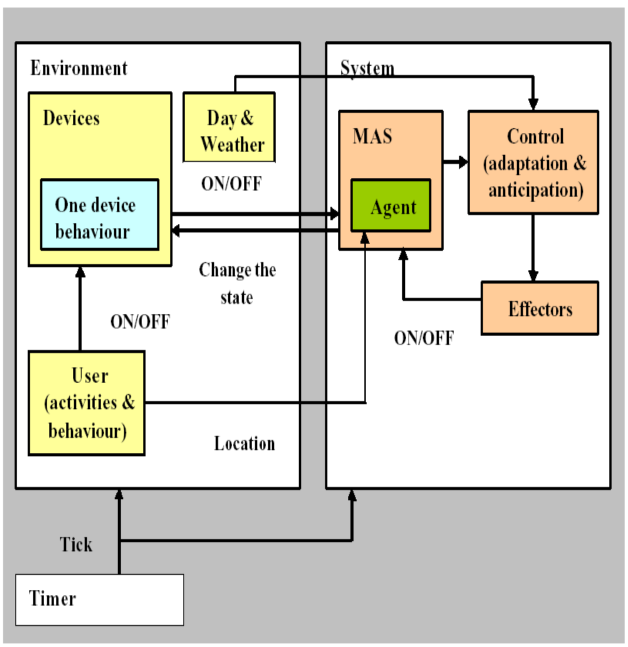

Fig. 4 The architecture of *Power Management in Smart Home* (PMSH) simulator.

The Adaptation Anticipatory Multi Agent System (A2MAS) is used in a daily life application that is called Power Management in Smart Home (PMSH) simulator as in figure 4.

The scenario of working the *Power Management in Smart Home* (PMSH) simulator is as follows:-

1-The sensors try to collect the statues of the devices in the environments and send them to the system.
2-Each agent is used for an each room for particular devices.
3-When each agent receives the new data from the sensors, it begins their processing to calculate the power for its group of devices and then sends its data to anticipation module.
4-The anticipation module collects the data from all agents and according to particular rules for controlling of the power it can anticipate if it will be overload or not. Then it sends its results to effectors.
5-If there is no overload then there is no change in the system and the agents wait for a new data from environment.
6-If there is an overload then the effectors send notification to all agents to see which devices can be stopped. The system tries reducing the total power by switching some devices OFF, and then uses it as a new data and goto step3.
7-The system continues in this loop until it reaches to the case of no overload. In this case, each agent sends the names of the devices that change their statues to environment to make a real change in their statues for avoiding the overload.

Power Management in Smart Home (PMSH) simulator depends on the following things:-

1- User activities as cleaning, cooking, sleeping, washing, outdoor, relaxing, etc …
2- User behaviour according to its status as a student, as a worker either in job or during his free time.
3- The particular part of day as morning, noon, afternoon, evening or night.
4- Weather in different sessions as autumn, spring, summer or winter.

All these things must be considered by the control task in both adaptation and anticipation module. The anticipation module uses one of the machine learning algorithms. But, the adaptation module depends on the group of if-then rules.

4. The Proposed Development

According to the A2MAS's structure, the anticipation is done for all agents' outputs. In some cases, this gives unwanted state. It is suggested to add some modifications on this structure especially in the internal structure of the agent. The anticipation module is removed from control task and added with each agent. So each agent has its own AM that will avoid the undesirable state.

Figure 5 illustrates the suggested internal modifications in the structure of the Agent that is used in the system.

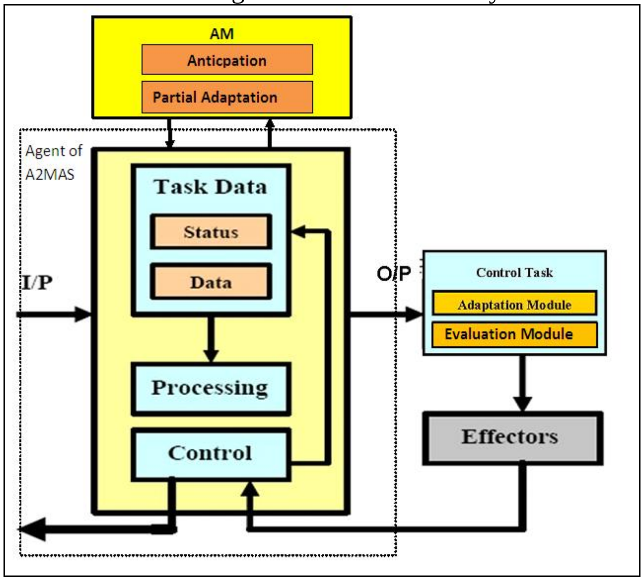

Fig. 5 The Architecture of the modified A2MAS.

Also, the PMSH simulator's structure will be modified as in figure 6, according to the suggested modification in A2MAS.

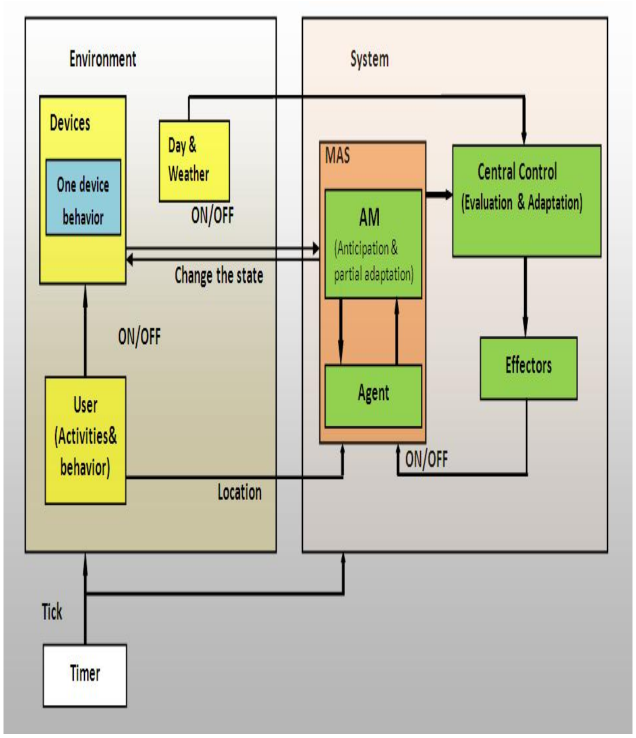

Figure 6: Proposed Architecture of PMSH Simulator.

5. Evaluation

Many experiments will be presented using our PMSH simulator. In each case, the system was run once original A2MAS and another time with modified A2MAS using one of the evolutionary algorithms (Island, OET and Team algorithms). In each experiment, the same conditions were applied to the simulator for all algorithms but the simulator was run over different time for 500, 1000, and 5000sec. But, the results were presented for only one case when the time is 500 sec. In every second of this time, there were one or more devices which are switched ON or OFF. The total electricity consumption in the home was changed finally. The simulator read the average power in home every 5 sec. then I had 100 values as shown in following figures.

5.1 Island Evolutionary Algorithm

By using the previous Smart Home Simulator for the power control, the results are presented. The following figure illustrates the relation between the time and the average power in the home during 500 sec. when it uses the previous MAS depending on Island algorithm for anticipation.

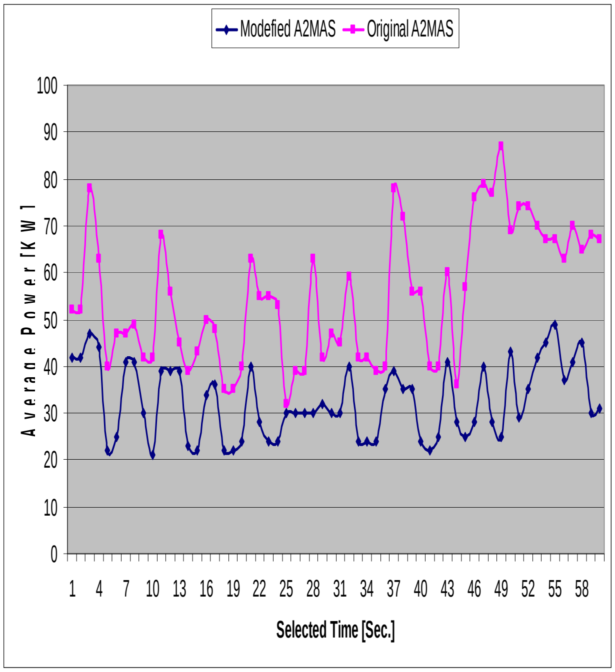

Fig.7 Power consumed in home during 500 Sec. using island evolutionary algorithm.

Figure 7 shows that the simulator using original A2MAS where it had an average power about 55 kw over 100 sec. In the case of using modified A2MAS in the simulator, the average consumed power was 32.5kw.

5.2 OET Evolutionary Algorithm

In OET algorithm evolution pressure is applied on both team and individuals level to produce strong agents that they cooperate well. Also, the previous experiments are repeated under the same condition but using OET algorithm for AM.

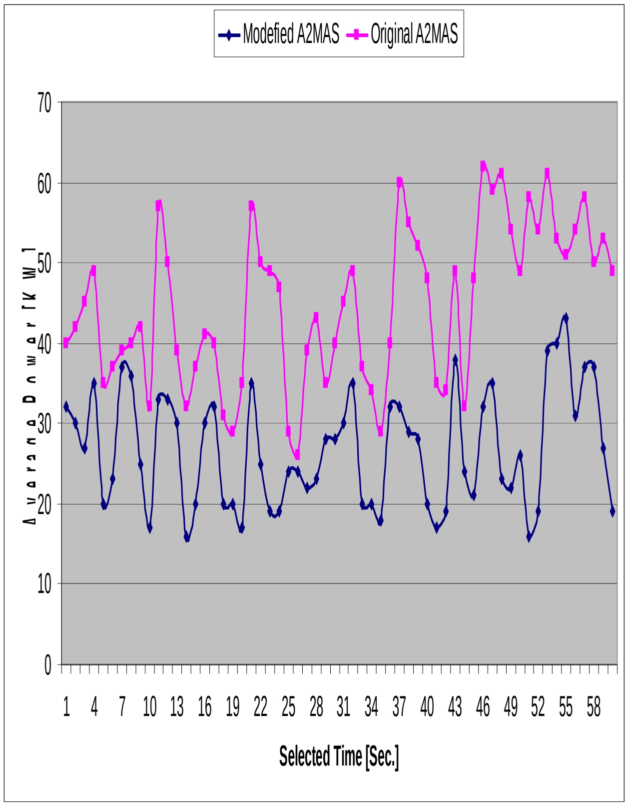

Fig. 8 Power consumed in home during 500 Sec. using OTE evolutionary algorithm.

Also, figure 8 presents that the performance of the simulator with modified A2MAS is better than the performance with original A2MAS in all time values. For example, at 60 sec., the simulator modified A2MAS read about 19 kw of average consumed power. In the case of using original A2MAS, the simulator read 49 kw of average consumed power.

5.3 Team Evolutionary Algorithm

In Team evolutionary algorithm all of the evolution pressure is applied on the team level with no regard to all individuals' level. Anticipation on team level is used to be consistent with the algorithm. The same experiment is repeated on the simulator again under the same condition as in the previous algorithms.

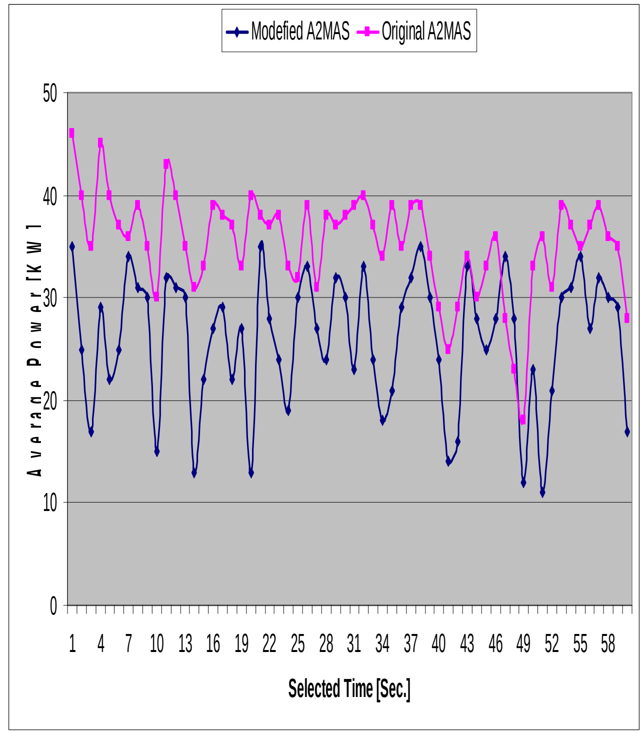

Fig.9 Power consumed in home during 500 Sec. using team evolutionary algorithm.

As it is seen in figure 9, the performance of the simulator with modified A2MAS is better than the performance with original A2MAS in all time values. For example, at 50 sec., the average consumed power with modified A2MAS was 23 kw. In the case of using original A2MAS, the simulator read 33 kw of average consumed power.

Table 1: Summary for the Performance Evaluation of PMSH.

	Modified A2MAS			Original A2MAS		
	Ave.	Max.	Min	Ave.	Max.	Min
Island	32.5	49	21	55	87	32
OTE	27	43	16	45	62	26
Team	26	35	11	35	46	18

Table 1 summarized the performance evaluation of the simulator with modified and original A2MAS using the previous evolutionary algorithms for anticipation according to the total average consumed power over the time interval (500 sec.), max and min consumed power's value in this interval.

6. Conclusion and Future Work

From the previous figures and table, it is shown the importance of modification in the A2MAS that used in

PMSH simulator. Also, it is concluded that the system with team evolutionary algorithms for anticipation has the best performance according to average, min. and max. consumed power values. The order of three used evolutionary algorithms in the system according to their performance is Team, OTE and Island.

The anticipatory behaviour is most important to be included in many simulators. The future work will focus on two branches. The first one is to enhancement the performance of Island evolutionary algorithms which has the lowest performance values by suggestion a modification in it. The second is to use machine learning algorithms rather than evolutionary algorithms for anticipation to have a good performance.

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