Home Lighting System Managed by Practical Reasoning Agents Society

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***Abstract*—The Agent-based Home Lighting Systems have shown good results decreasing electricity consumption and enhancing user comfort. However, there are certain characteristics of agent theory that have not been implemented, or even so, they are done in an inappropriate way. The main goal is to embed intelligent agents on this systems, so that they are capable of automatically decide over household resources use. The collaborative and cooperative decision-making behaviors are aspects of agent theory that may deal with the system management. Unlike regular lighting control systems, agents go beyond inputs refinement and output procurement. Agents have autonomous behavior, which, in the near future, will bring about what is called a Home Automation System as a Multi-Agent System. Previous approaches have designed solutions that divide the control of a lighting system into functional stages and thus assign specialized agents to perform each of them. These approaches distribute the solution but does not apply agent's society approach. This paper describes the functionality and composition of a Home Lighting System Managed by Practical Reasoning Agents and how it improves the weaknesses of other approaches. It does not present implementation results as it is just the architecture, and the implementation is let as future work phase.**

Keywords–agent; decision-making; energy use rate; home lighting system; user preferences.

I. INTRODUCTION

Nowadays, an inefficient use of resources in a house is typical. Electricity, water, LP gas and more, are used in an inappropriate way by home appliances, equipment, infrastructure and residents themselves. Some examples include usage of home appliances and entertainment systems for long periods of time, excessive use of water by garden irrigation systems, and improper use of air conditioning systems, among others. Home lighting is not the exception for this kind of waste, as an inappropriate distribution and selection of lighting sources (bulbs, lamps, luminaries, etc.), as well as, the misuse of them can be found.

In the recent years, agent-based home lighting systems have been developed with the purpose to optimize energy usage. The intelligent agents in those approaches, monitor, control and take decisions upon the system's state, mostly based in user preferences [1]–[5]. Also, these approaches distribute the management of the home lighting system into functional stages. Through this, they assign specialized agents to perform over each one of the stages. In general, those stages can be categorized mainly in perception, action and decision layers. The perception layer provides the current state of the system by means of agents administration of different sensors types. Actuation layer is quite similar to perception, but the intelligent agents control actuators to change the system state. Finally, in the last layer, decisions are performed through the implementation of algorithms or control mechanisms in agents, using the system's state obtained from perception layer as input and sending an action to action layer as output.

The scope of this document is to detail the proposal of a new agent-based home lighting system architecture, in which state-of-the-art implementations advantages, disadvantages, and main characteristics were taken into account for its design. The proposed model is based on the interaction of an agent society directly with the environment, something that other architectures do not have. Also, the agent society is in charge of managing the state of the system according to user preferences, plus energy consumption. Therefore, the environment is used to provide a representation of the physical world to the agents.

This document is structured as follows. In Section II, a comparison between agent-based home lighting systems is presented in terms of how perceptions and actions are performed, what decision-making algorithms have been used, and how these approaches manage user preferences and energy consumption rate. In Section III, the proposed architecture is described in terms of how the system's state is represented, shared and changed, the organization of the agent society, the process to reach a decision and how it performs an action plan. Section IV discusses how the weaknesses of previous designs can be improved by the proposal here presented, as well as, it describes the differences between approaches. Finally, the conclusions of the proposal and future work are discussed in Section V.

II. INCLUSION OF AGENTS IN HOME LIGHTING SYSTEMS: A COMPARISON BETWEEN APPROACHES

Because of the agent's paradigm nature, many of the systems that implement these approaches for lighting management can be described, in general, in a three-layer basis: perception, action and decision [1]–[6]. Some of these approaches are clearly divided in three layers [5]. In others, these layers can be merged in different combinations [1]–[4]. The purpose of the following comparison between approaches is to identify their main characteristics, and take them as a basis to develop a potentially improved architecture. Such comparison is summarized in Table I, and is described in following paragraphs.

 ISBN: 978-1-61208-459-6

TABLE I. AGENT-BASED HOME LIGHTING SYSTEMS FUNCTIONALITY DISTRIBUTION.

Author	**Sandhu, et al. [1]**	**Bielskis, et al. [3]**	**Mady, et al. [2]**	**Wang, et al. [4]**	**Paulauskaite-Taraseviciene, et al. [5]**	**Damián A. González N., et al.**
			Perception layer			
What does the system sense?	-Light -Occupancy -User preferences	-Temperature (indoor/outdoor) -Carbon dioxide -Light level -Users' ElectroDermal Activity (EDA) -User's electrocardiogram (ECG) -User's skin temperature signals	-Luminance -Occupancy -Light intensity -User luminance preferences	-Light intensity -Solar radiation -Infrared camera data -PIR data -User preferences -Energy data	-Luminance -Occupancy -Light intensity -User luminance preferences	-Residents occupancy -Residents preferences -Energy consumption -Light intensity -Light ignition
Who is/are in charge of system perception?	-Supervised learner agent -Reinforcement learner agent	-Thermo_measurer agent -CO2_measurer agent -Light_measurer agent -AV_FIA agent	-Person Movements agent -Daylight Intensity agent -Window Blinding Occlusion agent	Sensor agent	-Lighting Sensor agent -Resident Location Sensor agent	Environment
How do sensations are gotten?	-Occupancy sensor -Photosensor	Embedded system administrators of digital thermometers, carbon dioxide sensors, light level sensor and instrumentation amplifiers	-RFID detector -Light sensor	Multi-sensors	-Lighting Sensor -Hybrid Ultrasound and Radio Frequency (RF) technology	-Occupancy sensor -Light intensity sensor -Power meter -User Interface
What does/do it/they do to achieve system perception?	NIA	Analysis, storage and propagation of sensor measurements	Analysis and propagation of sensor measurements	Analysis and propagation of sensor measurements	Analysis, interpretation and propagation of sensor measurements	Analysis, storage and propagation of sensor measurements
			Decision layer			
Who is/are in charge of system decision?	-Supervised learner agent -Reinforcement learner agent	Radial Basis Neural Network component	Control agents	Local Lighting Agent via a Data Fusion Center	Decision agent	Agent society
How does/do it/they do to achieve system decision?	Via supervised and/or reinforcement learning	Radial Basis Neural Network	PI-Controllers	ANFIS	ANN, Fuzzy Logic and Bayesian approaches	Worth-Oriented Negotiation process
How does the system obtain decision data?	Sensors	-Thermo_measurer agent -CO2_measurer agent -Light_measurer agent -AV_FIA agent	-Person Movements agent -Daylight Intensity agent -Window Blinding Occlusion agent	Sensor agent	-Lighting Sensor agent -Resident Location Sensor agent	Perceiving environment
Who performs decision deliberation?	-Supervised learner agent -Reinforcement learner agent	EnvironmentCon-troller agent	-Daylight Intensity agent -Window Blinding Occlusion agent	Local Lighting agent	Control agents	Agent society via Environment
			Actuation layer			
What does the system actuate?	Lighting ballasts	-Fans -Lamps -Air-conditioners	-Sunblinds -Bulbs	-Lamp -Sunblind	Bulbs	-Dimmer -Switches
Who is/are in charge of system actuation?	-Supervised learner agent -Reinforcement learner agent	EnvironmentCon-troller agent	-Daylight Intensity agent -Window Blinding Occlusion agent	Local Lighting agent	Control agents	Environment
Where do actions are gotten from?	-Supervised learner agent -Reinforcement learner agent	AmbiantComfort agent	Control gents	Local Lighting Agent via a Data Fusion Center	Decision agent	Agent society

A. Perception Layer

The perception layer, as its name indicates, is where the state of the system is sensed, and is made up of a set of descriptive parameters. From "Perception layer" column in Table I, it can be observed that all the approaches differ in the type of measurement units in which the system state is sensed. These measurements are obtained by different types of sensors, from physical states to user physiological sensations. For readings of physical states, lighting and occupancy sensors are mainly used. In the case of user sensations, instrumentation amplifiers are used to obtain occupant's bio-signals in order to compute them. The installation of all these sensors in the house infrastructure brings minor inconveniences, because there exist diverse network protocols to interconnect several types of devices [7]–[9]. However, when users are required to wear sensors, it may become an issue, because of inherent human behavior misconception or fear to changes. In particular, for an office area, described by Sandhu et al. [1], two approaches of sensors installation are suggested, the workspace-based and the user-based configurations. The first of them uses static occupancy sensors located at strategic places where users sit, and the second require that users wear badges in order to locate them and identify their preferences. Workspace-based approach is appropriate for spaces such as offices where employees have specific places to sit. Otherwise, for a house environment, the user-based approach is more feasible but limited by some considerations. Residents may tolerate to carry a wearable sensor or even its own smart device but always taking into account comfort and personal information security and privacy.

Actually, in all approaches, the perception functionality is accomplished by one or multiple agents that, by means of sensors measurement, analyze, interpret and propagate sensor's readings to those other agents who may require them. Authors such as Paulauskaite-Taraseviciene et al. [5] emphasize the fact that agents responsible of perception layer, must only share data when there exists a request or when a significant and useful change occurs.

B. Action Layer

This layer interacts with the environment in order to change the perceived state of it. As shown in Table I, actuators are the instruments used to change the quantity of light provided by natural or artificial light sources (sunblinds, bulbs, lamps, etc.). The tasks of agents in this layer are quite similar to those performed in perception layer, they include analysis, interpretation and propagation of actuators measurements. But, these agents are able to change the state of affairs on the environment. All actions made by agents in this layer come from the decision layer.

It is noteworthy that not only agents manipulate actuator devices, but also its occupants. Their actions are taken as a feedback to measure the performance of the system. Thus, they are used by the decision layer in order to improve system's response, either with an energy decrement or with the profiling of user preferences.

C. Decision Layer

The decision layer determines the actions to be performed, based on user preferences and/or energy consumption. Thus, if a change is required, an action is to be decided by this layer. For this, one or a variety of algorithms are performed by specialized intelligent agents.

Other approaches differ in the selection of algorithms used in the decision layer. The decision-making of Paulauskaite-Taraseviciene et al. [5] has a “Decision Agent”, that is capable to operate in two modalities: decision-making and learning or re-learning. In the first, a ”Decision Agent” executes an algorithm based on Artificial Neural Networks, Fuzzy Logic and Bayesian approaches to make a decision. It uses data received by sensor agents, establishing actions to be sent to ”Control Agents”. The learning or relearning takes place when a resident adjusts an already computed solution, in order to set up the next status of the actuator. This adjustment is taken as user's feedback for later learning purposes.

Sandhu et al. [1] describe two approaches when the system needs to execute an action: supervised and reinforced learning. In the first, training data are obtained from sensors and recorded actions, where sensor readings are the inputs and user actions are the target values. Then, a mapping between sensor and target values is made, in order to perform an appropriate control of lights. Thus, the task of a supervised learner is to minimize the difference between its action and user's action.

A reinforced learner merges user location and lighting reading to represent the environment's state, in order to generate actions that lead to an appropriate illumination setting. Reinforcement is based on how agent's actions approximate to those of the user. The absolute value of the difference between the illumination reading after an agent's action, and the illumination reading after the user action in the same state, is used as negative reinforcement, or punishment. In contrast, when an action performed by the agent and the user does not change anything (i.e., user is pleased with illumination setting), the agent receives a positive reinforcement, or reward.

The system developed by Bielskis et al. [3] is based on a index called Ambient Lighting Affect Reward (ALAR), which expresses human comfort. The system predicts the indoor RGB LED illumination conditions by measuring the ALAR index that reflects the sense of comfort of the resident.

Mady et al. [2] describe a ”Control Model” that is comprised by a ”Centralized Controller” that takes as inputs the user's illumination preferences, user's location and light intensity readings. The outputs are the illumination level and blinding position. The ”Centralized Controller” is integrated of an ”Optimization Engine” and a ”Refinement Controller”; PI-Controllers sub-compose the ”Refinement Controller”. For the representation of the ”Control Model”, two types of agents were used: control and environment agents.

The proposal of Wang et al. [4] is a multi-agent system applied to the control of household illumination. The system focuses on the user and communicates to him/her through a wireless network and a system terminal, that can be a personal computer, smarthphone, wearable device, etcetera. The system takes into consideration different variables, such as ambient illumination, occupancy, energy limitations, user preferences among other information, in order make a decision. By using an Adaptive Neuro Fuzzy Inference System (ANFIS), they estimate environment's visualization and occupancy of users, which are used by the control host in conjuction with user preferences and energy data for the decision-making process. The multi-agent system consists of three types of agents: central agent, local light agent, sensor agent and person agent.

From above implementations, common patterns of agent societies can be detected and described as follows. Agents have specific tasks that contribute to the main goal of the whole system. A communication is established to exchange information and/or goals. The decision-making task takes place in a dedicated part of the system. Algorithms used to select actions can be seen as processes that ingest several inputs to accomplish a goal. Also, another point to note is the importance of home residents preferences and energy consumption. User preferences can be considered very important, almost as a “law” [1], for others they are only one parameter to make a decision [2] [4] [5] and even some others do not take them into account, they focus on user physiological senses [3]. In the case of energy consumption, implementations consider it as an important parameter without leaving aside user preferences [4].

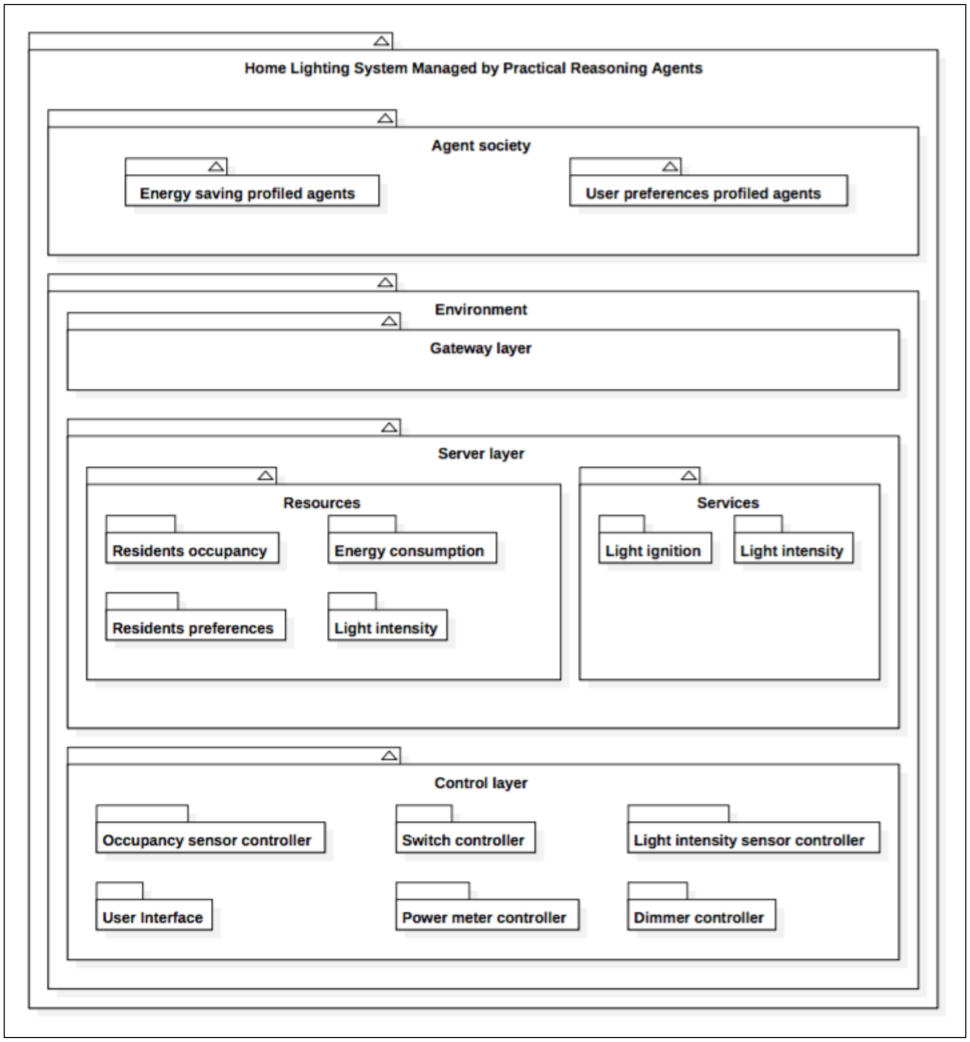

Figure 1. Home Lighting System Managed by Practical Reasoning Agents architecture.

III. Home Lighting System Managed by Practical Reasoning Agents

As mentioned above, the base of our model of a Home Lighting System (HLS) managed by Practical Reasoning (PR) agents is the interaction between the environment (an abstraction of the physical world) and a contoured society of agents (agents with guidance to energy saving and satisfaction of preferences). The structural distribution of the system consists of the environment, made of three layers, and the society of agents. Functionally, the environment is responsible for perception and action, and agents carry out the decision process. Overall system's architecture is shown in Figure 1.

A. Physical representation

In the proposed model, the administration of the entire system is divided into workspaces that correspond to every room of a house. Each workspace has an occupancy sensor, a light intensity sensor, a power meter, a switch and a dimmer. These are used to monitor the location of residents, measure the consumption of power, and to control the intensity of the light. Also, they are connected over a network. In the case of resident preferences, they are established by means of an User Interface (UI) and indicate the desired brightness in a particular workspace.

B. Environment

The environment is the component that abstracts the physical environment, allowing to obtain and modify the state of the system. This environment is made up of each workspace and controls all the sensors and actuators within the house.

1) Structure: The environment is composed of three layers: Control, Server and Gateway. The Control layer is responsible for the management of sensors and actuators and its divided into Control components. The Server layer has Resources and Services to consistently obtain the state of the environment and assign actions from and to Control layer. And, Gateway layer is the interface between the agent society and the environment itself (see Figure 1.)

2) Functionality: The Control layer of the environment manages different types of sensors and actuators. Control components assigned to sensors constantly monitor the state of power consumption, the location of the residents, the luminous intensity. Also, when required, the components share these signals to an specific resource belonging to the Server layer.

 ISBN: 978-1-61208-459-6

The Control components dedicated to handle actuators carry out almost the same tasks, but also they are capable of change the states of the switches and intensity regulators. States of actuators and sensors are updated on-demand by the Server layer or when a substantial change is detected.

The Server layer is divided into two types of components, Services and Resources. Resources aim to record the state of the environment through constant requests to the Control layer, and to translate it to perceptions for agents. Services component performs the same type of tasks, but its also capable to assign actions to modify the state of the environment to the Control layer. Figure 2 represents the interaction between Control and Server layer, when an update of the system's state happens.

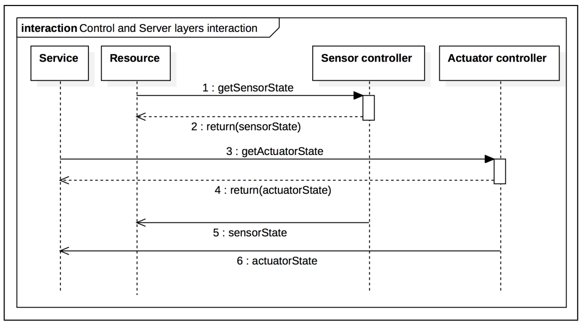

Figure 2. Control and Server layers interaction.

The Gateway layer is the interface between the agent society and the environment. The Gateway receives requests to get the status of the system and sends actions to modify it, both signals come from agent's society. Perceptions and actions are exchanged on-demand only. The message passing between Gateway layer, Server layer and a profiled agent is pictured in Figure 3.

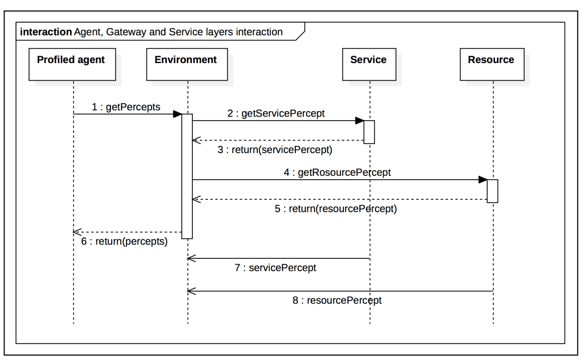

Figure 3. Agent, Gateway and Service layers interaction.

C. *Profiled agent society*

The approach allocates PR agents to the management of a HLS. The PR agent's *Beliefs*, *Desires* and *Intentions* determine the way it behaves [6].

- *Beliefs*, represent the current state of the environment.
- *Desires*, reflect an agent motivational state. They represent the objectives that an agent would like to accomplish or bring about.
- *Intentions*, are something that an agent wants to achieve or a state of affairs that the agent wants to maintain or avoid.

The society is composed of a number of agents with two types of tendencies: to save energy and to the fulfill the preferences of residents. These behaviors are observed in the *desires* of each type of agent, and they determine the way in which the management of the state of the environment is done. Agents which want to satisfy the user's preferences, tend to change the state of the environment according to the resident's desired light intensity. Similarly, agents devoted to the decrease of energy consumption prefer to modify the environment with the aim of reducing electricity consumption. Regarding to the distribution of the agents, in every workspace two agents are placed for the achievement of activities of decision, one of every category. For the stage of problem solving, the distribution in the workspaces is not a limitation, all the agents are capable of modify and of perceive the complete state of the environment.

1) Perception: Agents are able to perceive the current state of the system (a compilation of percepts) by means of the environment. Each type of percept corresponds to a property of the system: resident's occupancy, energy consumption rate, light intensity level, light ignition state and resident's preferences. The environment's state is only shared on-demand and can include one, many or all types of these percepts, depending on the request of a agent. Figure 3 shows the interaction between a profiled agent and the environment to share the system's state.

2) Reaching Agreement: The proposed approach for the decision mechanism is to have a Worth-Oriented Negotiation Domain (WOD) [6].

> *"...the goals of an agent are specified by defining a worth function for the possible states of the environment. The goal of the agent is thus implicitly to bring about the state of the environment with the greatest value. Reaching agreement involves the agents negotiating not over a distribution of tasks to agents, as in task-oriented domains, but over the collection of joint plans. It is in an agent's interest to reach agreement on the plan that brings about the environment state with the greatest worth."*

When a change in the state of the environment is detected by the agents belonging to a workspace, a process for construction of a *joint plan* begins. This type of plan is intended to change the environment to a better value and goes in accordance with the desires of the agents. *Joint plans* include from doing nothing (no plan change the environment to a better value), to a series of actions that require several agents. Once a *joint plan* is identified, a negotiation process begins. When two agents negotiate, they exchange proposals in series of rounds where the only way to continue is giving a *joint plan* that brings the environment to a higher value than received. Otherwise, negotiation stops and the latest proposal is accepted. Figure 4, shows an interaction diagram of the negotiation process.

3) Problem solving: The problem solving phase is conducted by a Cooperative Distributed Problem Solving (CDPS) process [6].

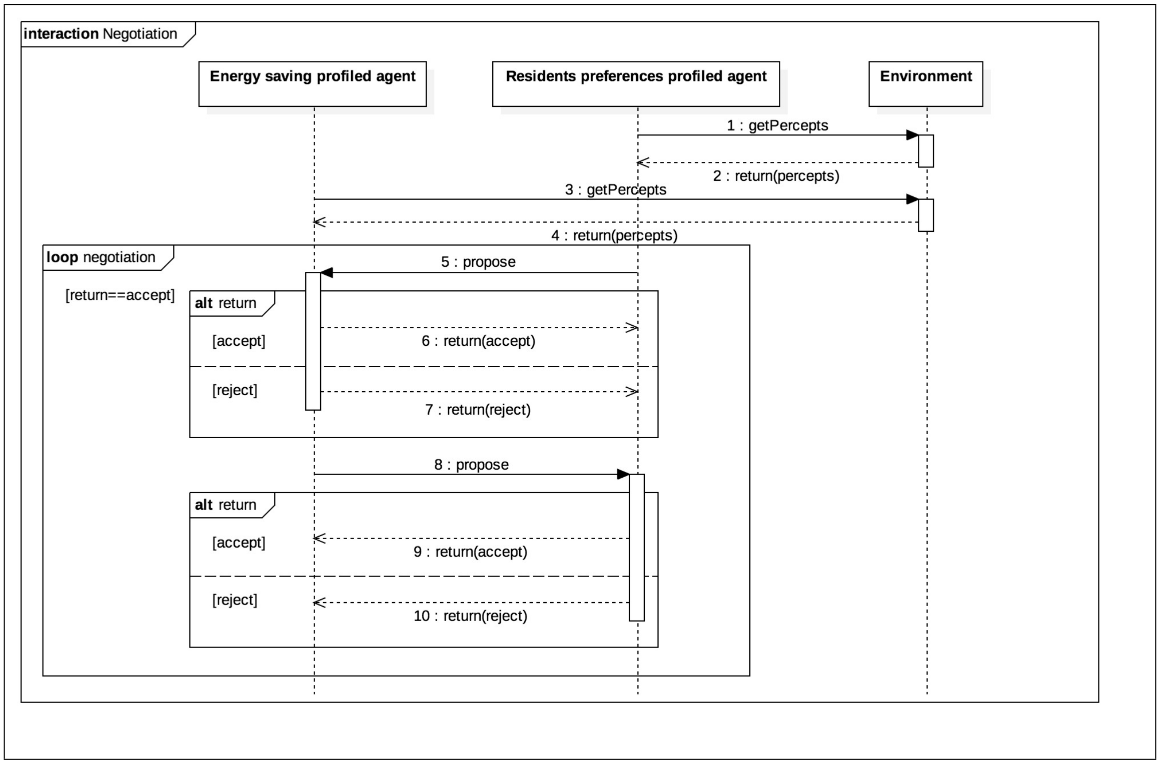

Figure 4. Worth-Oriented Negotiation process.

The CDPS process has three stages, which are summarized as follows.

1) Problem decomposition stage decomposes the overall problem into smaller sub-problems.
2) Sub-problem solution stage solves sub-problems individually.
3) Solutions to individual sub-problems are synthesized into an overall solution.

Specifically, ContracNet protocol was selected to perform CDPS process. This protocol requires an initiator and a sort of participants. In a first phase, the initiator requests agent's proposals by issuing a "call for proposals", where initiator specifies a task and conditions upon the execution of it. Subsequently, participants reply with a refusal or a proposal. Then, initiator selects the participants to perform the offered task and rejects the remaining agents. The selected participants acquire a commitment to perform the task. Once participants complete the task, they reply result to the initiator, this message can be a failure, task done or a result. ContractNet protocol is shown in Figure 5 [10]. In our approach, the initiator is an agent that previously have won a negotiation process in a workspace domain, and the participants are the rest of the agents in the system that are not performing any activity.

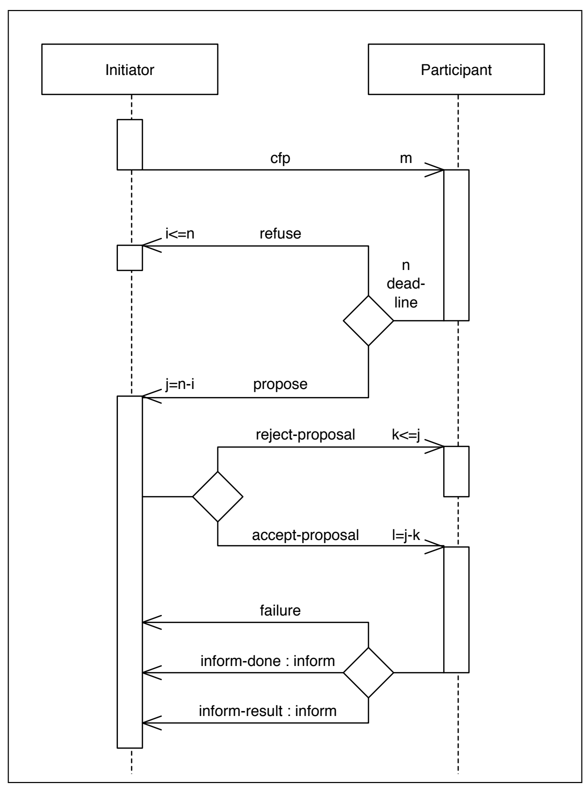

Figure 5. FIPA-ContractNet-Protocol. Adaptation of image found in FIPA Contract Net Interaction Protocol Specification [10]

IV. DISCUSSION

Section II described how different lighting systems treat the coming energy problem of improper use of lighting resource, guiding their behavior towards the preferences of users. Such description denoted the structure, operation and the role of agents in each of the systems. Section III described the proposal of this research work in terms of the structure and the interaction between components. Where the novel approach is the representation of the physical world's sensing and modification, by means of the environment. Also, it presents the way in which the agent society manage the condition of the system. By comparing the previous approaches, certain patterns were identified with respect to their operation and structure:

- Every agent fulfills, in a specialized manner, a specific function of the system.
- The communication that is established between agents is performed in order to exchange information and/or to assign tasks.
- The decision-making in order to change the state of the system is centralized.
- The design of the systems is very specific to the management of illumination.
- A major emphasis exists for the satisfaction of the preferences of the users, versus the decrease of electricity consumption.

The fact of splitting the functionality of the system into pieces is naturally more like a distributed system, than a MAS. As shown in Figure 6, an agent is abstractly modeled in two internal subsystems: perception and action. Where perception aims to provide the ability to observe its environment, and action, represents the decision process [6]. For the sake of the previous argument, the fact of to assign an specific task to an agent limits the essence of its definition, so the agents have specific capabilities, which cannot be to sense, decide and act, but only one of them. The agents who manage the sensors are just capable of perceiving a property of the environment, and to communicate such property. The agents dedicated to act, perceive and modify a property of the environment, nevertheless, they are not capable of determining the action that the actuator realizes. Finally, the decision-making agents, establish the actions to execute to modify the environment but, perceiving and acting are done by other agents.

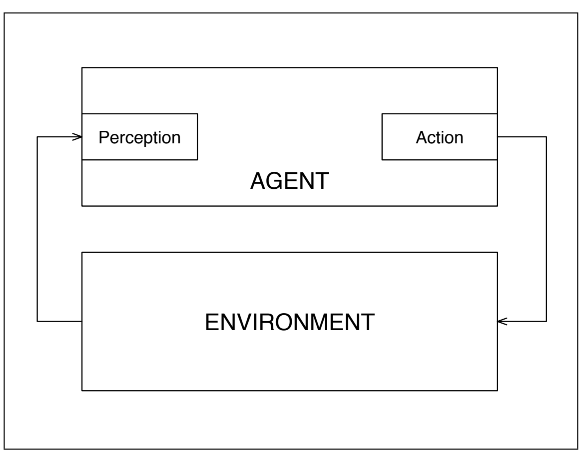

Figure 6. Perception and action subsystems. Adapted from [6]

In a MAS, the social ability goes beyond the binary exchange of information [6]. It involves the understanding and reasoning on the goals of others. Also, the accomplishment of actions to cooperate in order to reach own and other goals. For this, the agents must be capable of negotiate and cooperate. Nevertheless, in the discussed approaches this is not the case, the interaction between agents is merely to exchange perceptions and actions across a predefined protocolm and with a slightly clear sense of conscience of the goals of other agents. Likewise, the execution of an algorithm must be a part of the decision-making of the system, but not the whole process. In a MAS, the action must be agreed between the agents and established by means of a *joint plan* instead of the pure implementation of an algorithm.

Morganti et al. [11] say that a HAS is the collection of devices and appliances connected to a network, and its aim is to manage the resources in a house. The design of the previous approaches denote a high speciality in the management of home illumination. The agents are dedicated to a specific task, so these systems expose little or few scalability in terms of different services. In other words, the management of other types of resources would need the implementation of another different system.

Most of the approaches are based on the preferences and actions of the residents for the learning process of the agents, relying that information coming from them is trustworthy. This behavior may be not the best for decision-making process.For example, the residents can change their preferences and actions depending on emotional states, which not always complies with energy saving, thus in consequence this may lead to system's "corruption."

The architecture was designed to solve the issues stated above. First, each type of agent in the system shares the same capabilities for perception and action. Thus, every agent perceives an abstraction of the physical world and performs actions to modify it by means of the environment layer. Also, the decision-making process is a worth-oriented negotiation between agents in the society. So, social ability of the profiled agents is observed when reaching-agreement and problem-solving processes are done by agents interaction. Also, simple negotiation for a *joint plan* demonstrates that agents believe in other's goals. Therefore, when a decision is made, the agreement of a general task for system's state improvement and the distribution of the problem solving process are achieved by cooperation.

On the other hand, the architecture was designed with the aim of allowing scalability, regarding the structure of the system. As other agent-based HLS, this proposal takes as a principal goal the management of illumination of the house, but unlike them, it has the ability to extend the number of properties to sense. Thus, the three-stages structure of the environment allows the increase of the number of resources that can be managed in the house. Which is done by the increase on Services and Resources in the Server layer, and the variety of devices controlled in the Control layer. Also, the agent's architecture must be modified just in the type of tendencies (*desires*) and perceptions (*beliefs*). Finally, Negotiation and ContractNet protocols would be kept in essence, they would only change in the type of *joint plans* and their execution.

Another thing to note is that the agent society manages illumination over two types of profiles. As explained before, the energy saving is favored in a great manner. It is noteworthy that agents are conscious of the preferences of the users and direct their actions to fulfill them, to a certain extent. But, as the appropriate administration of the energy is the main goal, it has more importance on the proposal presented here.

Finally, some considerations must be taken when trying to implement a HLS. For example, the electrical, electronic and mechanical aspects of this type of systems influence the compatibility with others that exist in a house. Leaving aside the administrative aspect of the system, the selection and placement of light sources and luminaries in a home is an important issue when it comes to energy savings. A large part of the electrical waste comes from an inadequate placement of light sources. In many cases, with only replacing the light sources with those that consume less energy and taking advantage of the natural light resolves the excessive use of electricity. Another thing to consider is the compatibility between the rest of an existing HAS in the house, because there are many communication protocols to interconnect devices, which ones differ in the manner they perform connections. Some examples include: X10 [7], ZigBee [8] and Z-Wave [9].

V. Conclusion

This paper presents how agent-based HLS energy waste is caused by inappropriate light management, by giving blind confidence over preferences of the user. Their design, strengths and weaknesses were exposed. As said before, previous approaches take advantage of some properties of agent paradigm, such as collaborative behavior and task distribution. However, not all agent's characteristics have been fully applied. The approach proposed in this paper attempts to implement the correct agent's society paradigm over HLS requeriments. Therefore, it gives all importance to energy saving, without neglecting on user preferences, which seems to be a difficult task.

As future work, two goals have been identified. In the short term, the proposal will be implemented in collaboration with the Department of Renewable Energies of the Autonomous University of Guadalajara. The prototype will include the deployment of the agent society, the abstraction of the physical environment, and the electrical and mechanical aspects of a HLS. This prototype will be subject to a set of use cases to demonstrate its functionality, which will include scenarios to observe its energy saving performance and its behavior towards the user. A fact that it is expected to see, is that even when the user preferences are not fulfilled, partially or completely, He/She will appreciate an increasing performance in energy saving. Finally in the medium term, the house resources that the system can manage will be scaled with the purpose to achieve a prototype of a HAS as a fully MAS, for the sake of energy saving.

Acknowledgment

The authors would like to thank to the National Council of Science and Technology (CONACyT), for the scholarship No. 362650 given to Damián, in order to obtain Master's degree.

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