An Intelligent Management of Lighting in an Ambient Environment with a Multi-agent System

Aouatef Chaib, Boussebough Imen and Chaoui Allaoua

Abstract The home automation is one of the most customers of electrical energy after the industry. Lighting represents on average about 15 % of the annual electricity bill excluding gas and hot water. Different studies have been made to reduce the electrical energy consumption like automatic switching and time programming. But all these techniques have not an important rate in reducing the electrical energy consumption. So we note that an intelligent lighting which varies with the users need remains important source of economy of the energy. The intelligent lighting is obtained by using ambient intelligence (AmI). Multi agent System (MAS) have become the important paradigm to develop an ambient system because they have important characteristics like autonomy, proactivity and mobility to respond better to the main characteristic of ambient intelligence like the adaptability to the context. In this area, we propose an adaptive and intelligent lighting system in which each light source is represented by a software agent and the set of agents compose and coordinate their competences in order to illuminate a region with minimum energy consumption.

Keywords Ambient intelligence · Multi agent system · Intelligent lighting · Home automation · Context-aware

A. Chaib (✉) · C. Allaoua
MISC Laboratory, Constantine 2 University, 25000 Constantine, Algeria
e-mail: chaibaouatef@gmail.com

C. Allaoua
e-mail: chaoui@umc-misc.org

B. Imen
Lire Laboratory, Constantine 2 University, 25000 Constantine, Algeria
e-mail: iboussebough@yahoo.fr

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1 Introduction

Ambient intelligence (AmI) [1] is defined like an environment having the ability to perceive, reason, act and interact to provide services improving the quality of life of persons [2]. The main characteristic of an AmI system is the ability to take into account the context aware of the users and adapt her functionality on this context information [3, 4].

The General mended of AmI is the integration of computer science technologies in the objects of our environment in order to assist person in their everyday activities. It is situated in a junction of different and important fields like: artificial intelligence and distributed artificial intelligence, electronic architecture and nanotechnology, Networks and telecommunications and HMI.

The main objective of AmI is to make our environment [5, 6]:

- Attentive to the specific characteristics of each one;
- Able to adapt her behavior to the users needs;
- Able to respond intelligently to spoken or gestural indications and even to engage in dialogue.

Ambient intelligence is used in several areas like: Crisis management [7], the assistance of the elderly [7–11], intelligent transport, Home Automation: [12–14].

The Home automation includes all techniques and technologies, electronic, computer science and telecommunication means to automate tasks and improve in a house [15]. This automation is carried out with the integration of communicating sensors in the home. This allows knowing the status of the objects of the home at any time: the lamps are lit, the temperature in each room, the state of openings/closures (doors, windows) The main objectives of home automation are:

- Comfort (lights, automation housework...)
- Security (smoke detectors, alarms, video surveillance...)
- Energy savings (heating management, consumption analysis...).

Multi Agent System (MAS) [16] are the more adequate paradigm to develop a context-aware ambient environment. Mainly because they respond more to the main characteristic of ambient intelligence concerning: the adaptability to the context. MAS allows realizing multiple device agents that obtain the context information and they perform their own context inferences to rapidly detect context information changes [4, 17]. More of that, softagents offer several useful characteristics to AmI like: autonomy, reactivity, proactively, reasoning and coordination.

Coordination is one of the main characteristics of MAS for developing an ambient environment. It implements a combination of organizations, interactions, agents and environmental models [16]. Each agent uses its knowledge and resources to solve a sub-problem. The cooperative agents need to avoid as much as possible the conflicting position to solve a problem. Negotiation is a conflict resolution technique. It is considered as a process for improving the agreements.

In this area, we propose an adaptive multi agent system to automate an intelligent lighting system in which each light source is represented by a software agent and the set of agents compose and coordinate their competences in order to illuminate a region with minimum energy consumption. Our system is a context aware, because it take into aucount some context information of the environment like: the location of the user and the intensity of ambient lighting.

The rest of this article is organized as follows: Sect. 2 presents some related works. In Sect. 3 we present our proposed system and the general structure of agents. In Sect. 4 we introduce a case study going from scenario description to it actual execution. Finally, we draw the conclusions and we present some perspectives to extend it in Sect. 5.

2 Related Works

Several projects use MAS in the field of AmI for home automation:

In [12] the authors present a project called MavHome that aims to build a smart home with various functions such as adaptive control of temperature, water, light, clean and multimedia (audio and video) leisure. The authors use a soft ware agent to control the devices in the home. The organization of agents is dynamic because it may change. Agents predict the movements and activities of habitants of the house to automate their activities, assist the elderly, detect anomalies, predict problems and make decisions to solve them. The main inconvenient of this project relates to the structure of agents is not modular (addition or suppression difficult to make) which makes the system closed. Moreover, there is no cooperation between agents then no auto organization in the system.

iDorm [14] is a room for several purposes to: to sleep, to leisure, to work, etc. The piece includes several objects and more sensors are integrated in the room as temperature sensor, occupancy sensor, humidity sensor, etc... iDorm make life easier for residents. The project uses two types of agents. The first one is embarked on static objects; it receives the sensor values, learns user preferences and control actuators. Controlled parameters are the date, the level of indoor and outdoor light, indoor and outdoor temperature, the activities and movements of user and the status of each object in the room. The second one is embarked on a robot that learns and adapts the needs of user. The agents of this project cooperate between them but the system is not fully distributed because the chief agent must wait until the robot has finished its tasks; The system risk of inter locking situation.

In [13], the authors proposed a multi-agent system for intelligent management of home automation context. This intelligent system can fully manage the habitat or simply make proposals for action he thinks is best for management of the real environment. The authors use the approach centered interactions for cognitive agents located. These agents have goals they must solve by acting in simulated environment. These actions are then reflected in the real environment. Three types of agents are used: Active agent: capable of performing interactions, liabilities agent: may undergo

Table 1 The comparison between projects

Project	Dynamicity	Adaptability	MAS	Distribution	Context aware
[12]	−	+	+	+	−
[14]	+	++	+	−	−
[13]	−	+	+	−	+
Our project	++	++	++	++	++

interactions and Artifact agent who can neither suffer nor make any interaction. This project is context aware, because the system is able to plan and perform actions based on the context data; but it is not distributed because there's always access to a central simulator.

Table 1 summarizes and compares these different projects with our proposed system.

3 Proposed System

3.1 General Presentation

We proposed an intelligent lighting system. This later contains several and different light sources. The main objective of our system is to illuminate a region where a user is situated with the desired lighting intensity to satisfy the users lighting need with minimum energy consumption. For example; if we want to light up a region with certain intensity; this intensity can be obtained in different ways.

- 1st way: with a single source light that is close to the region to be illuminated and it has this intensity;
- 2nd way: by the combination of several source lights that are capable together to produce the desired intensity.

Our system must give a solution that should save energy consumption. The system must:

1. Perceive the ambient lighting intensity to calculate the missing need of light to satisfy the user need light;
2. Locate the user to obtain the region to be illuminated and the set of light sources which can contribute to supply the missing need of light.

Figure 1 presents the general representation of our system.

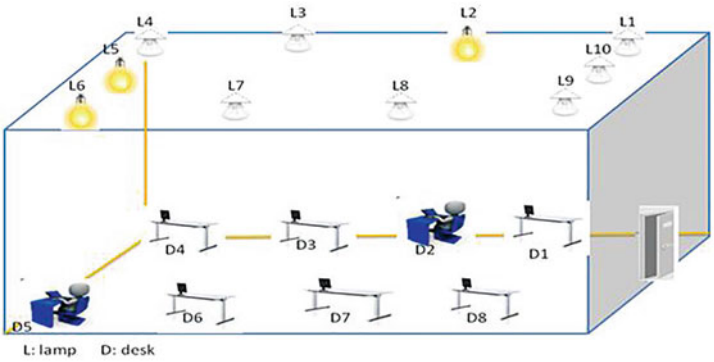

Fig. 1 The general representation of the system

3.2 The Agents of Our System

Each light source is represented by a software agent, the set of agent coordinate between them and compose their competences in order to satisfy the users light need. We have two types of agents:

1. *The initiator agent*: represent the closest light source to the user.
2. *The ambient agent*: represent the rest of light sources which can coordinate with the initiator agent to give de desired light.

The initiator agent sent message to the ambient agents contains her need to supply the desired lighting. Each ambient agent tries to answer favorably alone, if its capacity is insufficient, he becomes another initiator and it sent a message to ambient agent contains as parameters the capacity which misses to satisfy the need of the first initiator. The process of sending messages is terminated if the initial need is satisfied. The ambient agents sent their propositions to the initiator; this later evaluate this proposition and the select the proposition witch satisfy the desired lighting with minimum energy consumption. Figure 2 represents the structure of the agents of our system.

- ***Perception module***: this module perceives the ambient environment, it contains two sub modules and a data bases:
  - The Sensor captures the localization of the user and the ambient lighting intensity and it transmits these values to the interpreter;
  - The interpreter: it interprets the context values and it saves them in a data bases;
  - Context information: it is a data bases for storage of context information for a later use.

We define the context-aware information by a set of (Var_i, Val_i) pairs, Var_i is the variable name and Val_i is the value of Var_i. For example, the context aware information of our ambient environment at a given moment is {(AmbInt, 45 lux), (Loc, D3)}.

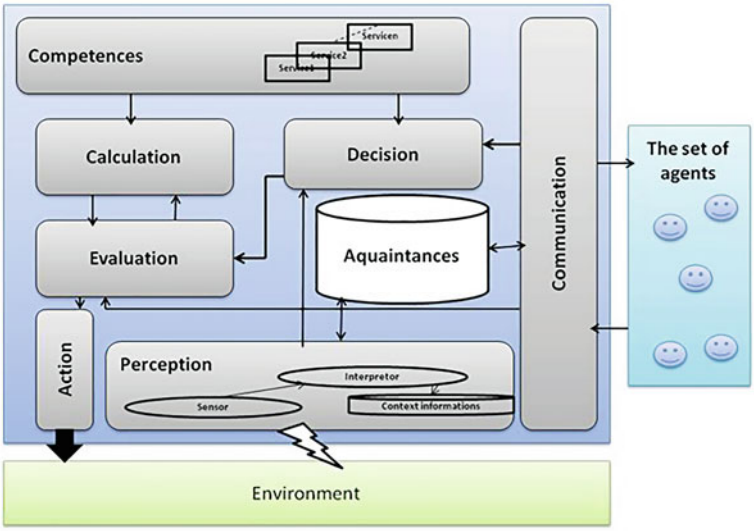

Fig. 2 The structure of the agents

(AmbInt, 45 lux) indicates that the ambient lighting intensity of an environment is 45 Lux.

(Loc, D3) indicates that the user is in the desktop D3.

- ***Communication module***: if this agent is a trigger; this module is responsible for sending/receiving messages to/from the agents of the system.
- ***Evaluation module***: Evaluates the proposals of ambient agents and it selects the best one. The evaluation is done according to certain criteria.
- ***Decision module***: choose the adequate action according to the competences of the agent.
- ***Competences module***: it contains all the services that this agent can perform it.
- ***Calculation module***: calculate the need of the agent.
- ***Action module***: performs the adequate action decided by Decision module.
- ***Aquaintances***: This data base defines the list of the ambient agents which are in the proximity of this agent and which can cooperate with him.

Figure 3 details the operation of the initiator agent and Fig. 4 details the operation of the ambient agent.

4 Case Study

We propose an intelligent lighting system of a room office. This later has the conception showing in Fig. 5 it contains 8 lamps, 2 roof lights and a neon of different power lighting. Table 2 summarizes the dimensions of the room office. Table 3 summarizes

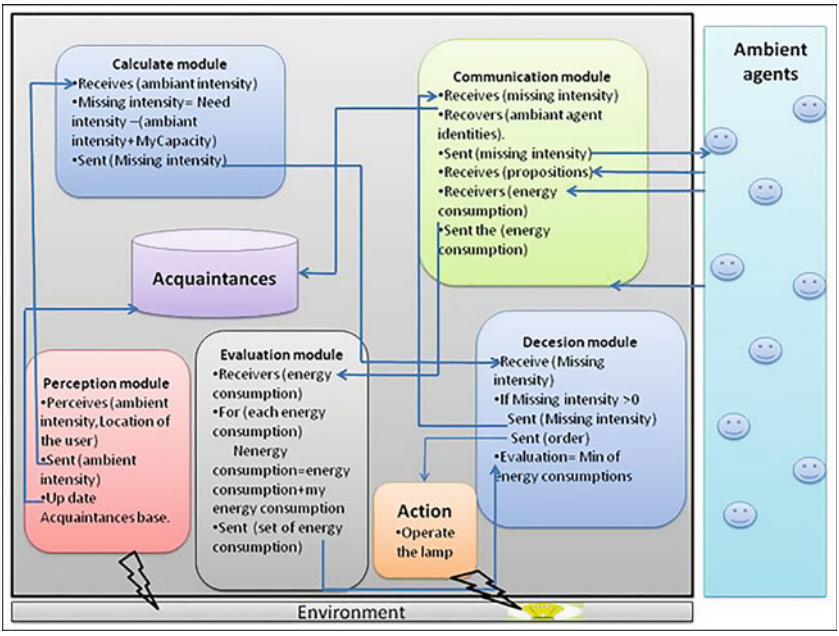

Fig. 3 The operation of the initiator agent

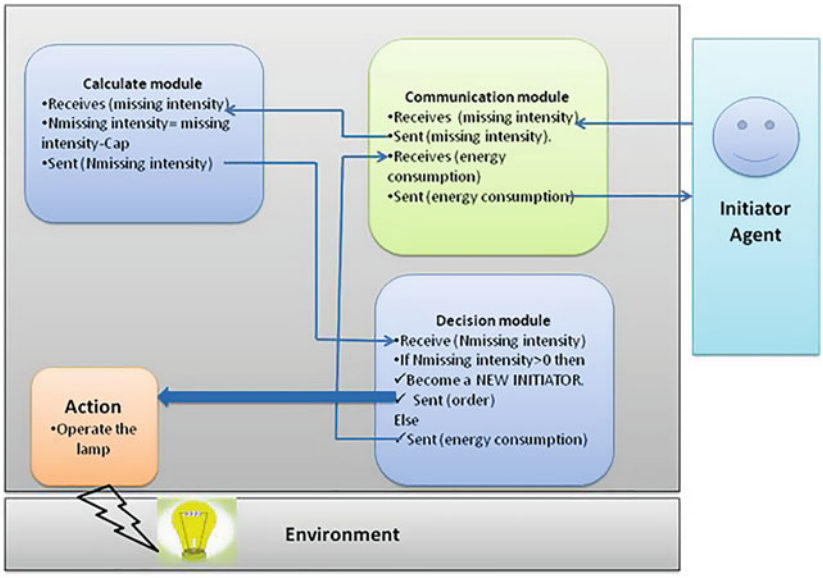

Fig. 4 The operation of the ambient agent

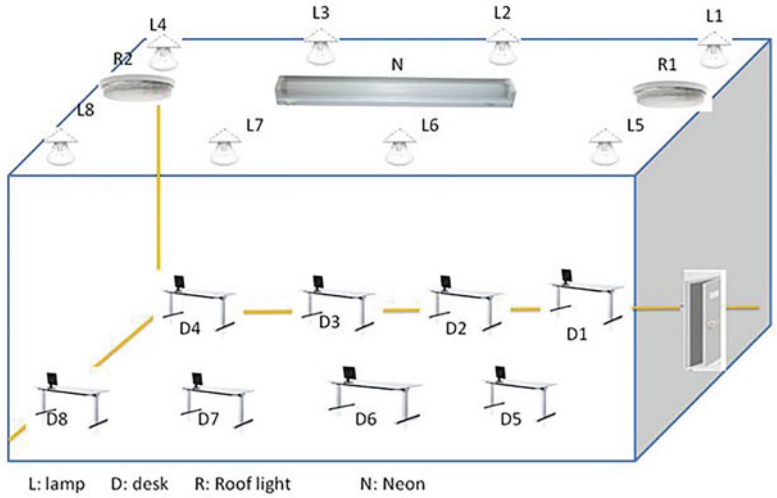

Fig. 5 The conception of the room office

Table 2 The dimension of the room office

Length (m)	Width (m)	Length of desktop (m)	Between desktops (m)	Between lamps (m)	Between roof lights (m)
13.5	5	1.5	2.5	3.3	8

Table 3 The characteristics of the lamps, the roof lights and a neon

	Lighting intensity (Lm)	Surface to be illuminated (m^2)	Amount of light (Lux)	Energy consumption (W)
Lamp: L1, L2, L3, L4, L5, L6, L7, L8	1000	10	100	75
Roof light: R1, R2	1500	50	30	100
Neon: N	2800	70	40	150

the characteristics of the lamps, the roof lights and a neon. Each lamp, roof light and a neon are represented by an agent called a *LampAgent*, *RoofAgent* and *NeonAgent*.

Lumen(Lm): is a luminous power unit indicate the flow of light emitted by the lamp.

Lux: indicate the amount of light received by a surface **1 Lux=1 Lm/**m^2

Assume the following scenario: The user is in the second desktop (D2) and the ambient intensity is 250 lux, According to the **NF EN 12464-1 norm**, the recommended minimum value for Writing, typing, reading and data processing is **500 lux**.

The context information: {(AmbInt, 250lux), (Loc, D2)} The initiator agent is: AgentLamp2 **Missing intensity = Need intensity (AmbInt + MyCapacity)** = 500 − (250 + 100) = 150 lux

- Missing intensity: the intensity wich mises AgentLamp2 to complete the need of the user;
- Need intensity: the intensity needed by the user;
- AmbInt: the value of the ambient intensity;
- MyCapacity: the value of the intensity offered by AgentLamp2.

The founded plans are:

1. Plan1: LampAgent2, LampAgent1, RoofAgent1, LampAgent3.
   Energy consumption = 75 + 75 + 100 + 75 = 325 W.
2. Plan 2: LampAgent 2, LampAgent 1, RoofAgent1, RoofAgent2.
   Energy consumption = 75 + 75 + 100 + 100 = 350 W.
3. Plan 3: LampAgent 2, LampAgent 1, RoofAgent1, NeonAgent.
   Energy consumption =75 + 75 + 100 + 150 = 400 W.

The system must execute Plan 2 because it has the minimum of energy consumption.

4.1 The Implementation of the System

We have chosen Java Agent DEvelopment framework (JADE) platform to implement our system because:

- Jade facilitates the development of multi agent systems
- Jade is easy to use
- Jade runs on all operating systems
- Jade realize the applications conform to the FIPA standard to facilitate communication of Jade agents with non JADE agents.

We have simulated our system by a graphic interface, where a user can indicate her localization and the ambient intensity Fig. 6.

Figure 7 shows the class diagram of the lamp agent if it is an initiator agent and Fig. 8 shows the class diagram of the lamp agent if it is an ambient agent.

Sniffer agent of JADE is useful to sniff, monitor and debug conversations between agents [9]. Figure 9 shows the sniffer agent at the moment of sending of the first message and the sending the propositions.

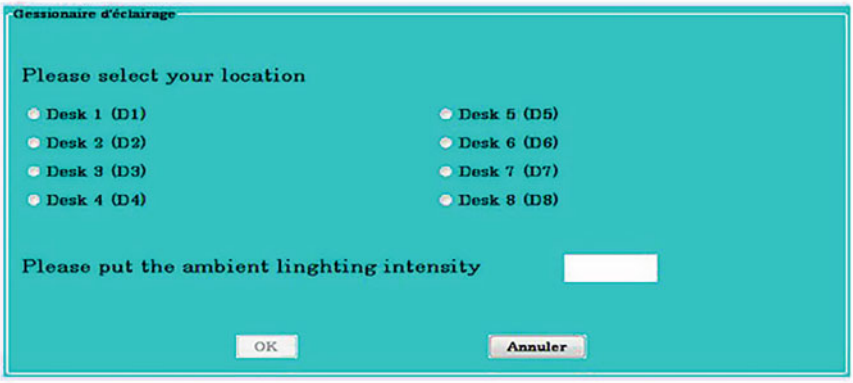

Fig. 6 The interface of our system

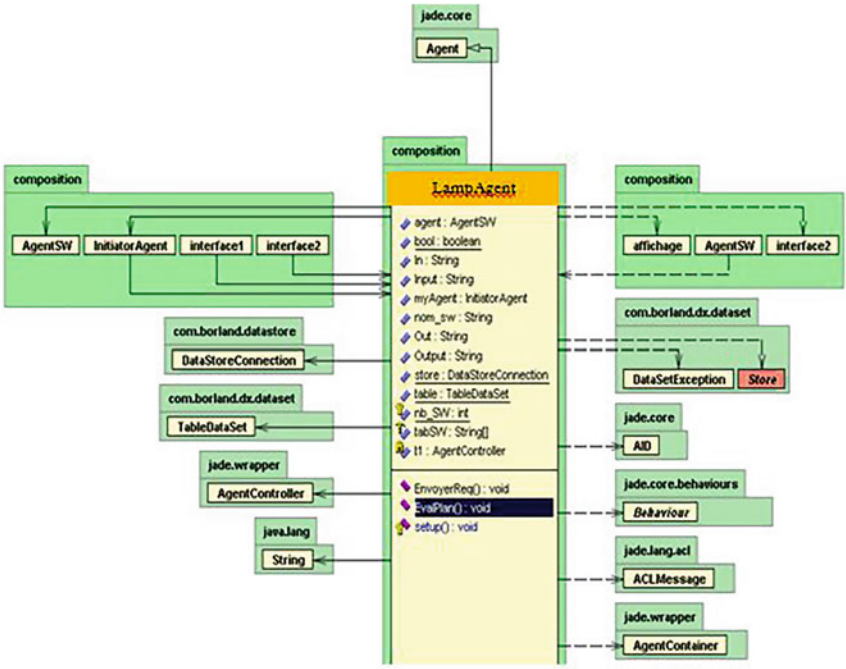

Fig. 7 The class diagram of the initiator agent

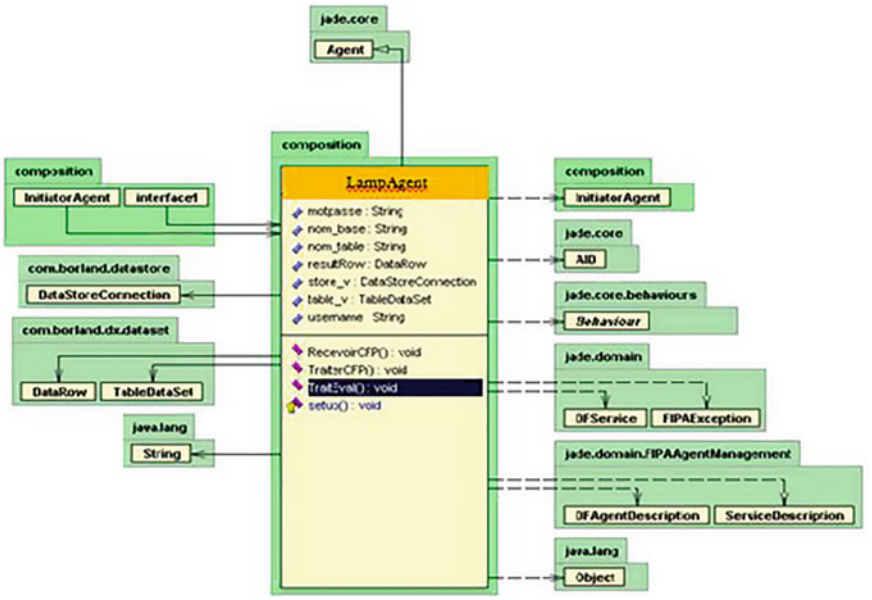

Fig. 8 The class diagram of the ambient agent

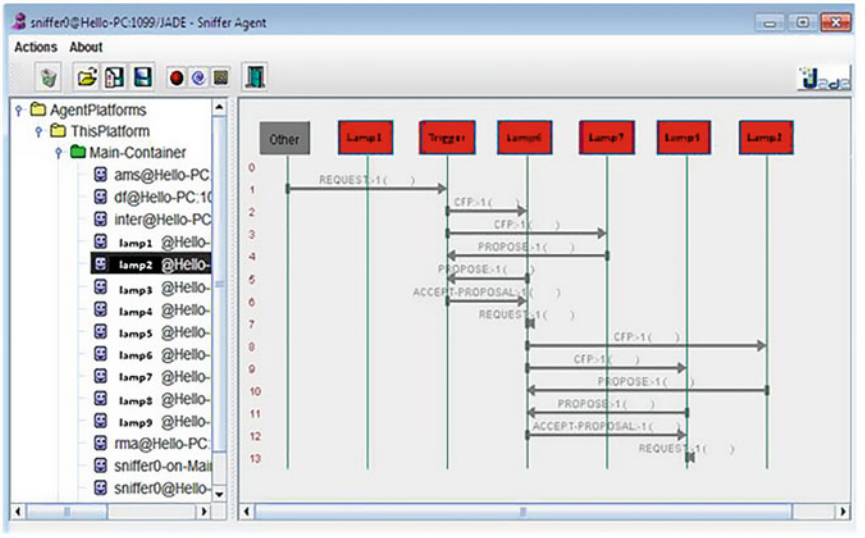

Fig. 9 The sniffer agent at the moment of sending of CFP and resaving of propositions

Table 4 Some obtained results

Localization	Ambient intensity (Lux)	Needed intensity (Lux)	Operates lamps	Energy consumption (W)
D2	250	250	P1: L2, L1, R1, R2	350
			P2: L2, L1, R1, L3	325
			P3: L2, L1, R1, N	400
D1	450	50	P1:L1	75
			P2: R1, R2	200
			P3: L2	75
			P4: N, R1	250
D8	70	430	P1: L8, L7, L3, L4, R1, R2	500
			P2: L8, L7, L3, L4, N	550
D5	300	200	P1: L5, L1	150
			P2: L5, L6	150
			P3: L5, R1, R2, N	425
D6	0	500	P1: L6, L5, L1, L2, L7	375
			P2: L6, L5, L7, N, R1, R2	575
D3	20	480	P1: L3, L4, L2, L7, L8	375
			P2: L3, L4, L2, L7, N, R1, R2	650
D7	360	140	P1: L7, L8	150
			P2: L7, R1, R2	275
			P3: L7, L6	150
			P4: L7, N	225

4.2 Results and Discussion

We have executed our system and we have obtained the encouraging results. Table 4 summarizes some obtained results.

We assume that the desired intensity is 500 lux. Figure 10 presents a histogram that shows schematically the obtained results of the execution of the system.

In each localization of the user and in accordance with the ambient intensity; the system provides several combination of light sources but it executes the combination which consumes less. Whatever light sources used and whatever their characteristics; our system select the combination that uses electrical energy.

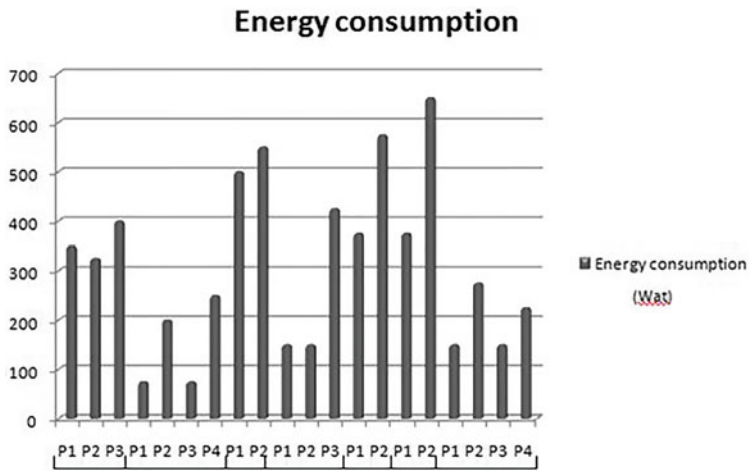

Fig. 10 The energy consumption

5 Conclusion

This paper illustrated how a Multi Agent System can be used in a smart field such as ambient environment. MASs became the principal paradigm for developing an ambient system because they offer several useful characteristics like: reactivity, proactivity, reasoning, autonomy and coordination to create an adaptive environment.

We presented here a MAS for an intelligent management of lighting. The main objective of our contribution is to provide the desired lighting intensity to satisfy the users lighting need with minimum energy consumption.

Our system is context awareness. It uses several contextual information. It must perceive the environment to get the ambient lighting intensity to calculate the missing light and the localization of the user to obtain the region to be illuminated.

Each light source is represented by an agent and the set of agents coordinate and cooperate between them to give the best lighting with minimum consumption of energy.

We have taken the example of the intelligent lighting of a room office to validate our proposition. The room office has several light sources (Lamp, Roof light, Neon) of different power lighting and different energy consumption. We have implemented our system in JADE platform because it facilitates the development of multi agent systems. We have executed the system and we have obtained encouraging results.

As future work, we plan to adapt our system to other complex domains like a health-care, compare the obtained results and create a general framework for service composition in ambient environment using the paradigm of Multi Agent System.

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