Self-management of Ambient Intelligence Systems: a Pure Agent-based Approach*

(Extended Abstract)

Inmaculada Ayala
Universidad de Málaga
Bulevar Louis Pasteur, 35
Málaga, Spain
ayala@lcc.uma.es

Mercedes Amor
Universidad de Málaga
Bulevar Louis Pasteur, 35
Málaga, Spain
pinilla@lcc.uma.es

Lidia Fuentes
Universidad de Málaga
Bulevar Louis Pasteur, 35
Málaga, Spain
lff@lcc.uma.es

ABSTRACT

Ambient Intelligence systems (AmI) are normally composed of networked heterogeneous devices with critical resource limitations. One of the biggest requirements of AmI systems is that they should be capable of self-management in order to adapt their behavior and resources to environmental conditions and variable device resources. Autonomous agents are a good option to endow AmI systems with self-managing capabilities, but current agent platform implementations do not adequately address the heterogeneity requirements of AmI systems, given the impossibility until now of producing pure agent-based solutions. In this paper we present a pure agent-based solution for self-managing AmI systems, with particular emphasis on defining a working solution considering the diversity of devices and communication protocols through which AmI devices must interoperate.

Categories and Subject Descriptors

I.2.11 [**Computing Methodologies**]: Distributed Artificial Intelligence—*Multiagent systems*

General Terms

Design, Experimentation, Management

Keywords

Agent Oriented Software Engineering, Self-management, Ambient Intelligence, Lightweight devices

1. INTRODUCTION

Ambient Intelligence (AmI) environments represent a new generation of computing systems equipped with devices with special capabilities that make people aware of the environment and react to it, in a more natural way [4]. These systems are composed of a large variety of networked heterogeneous devices, such as mobile phones or Wireless Sensors Networks (WSNs). Normally, the majority of AmI devices show symptoms of degradation, such as energy loss or failure of some network nodes, which requires explicit management action, for example saving energy to guarantee the system's survival. Consequently AmI systems demand the reconfiguration of their internal functioning in response to changes in their environment. This means that AmI systems must behave as autonomic systems with a self-managing capacity.

The self-management properties are inspired by the properties of agents [5], such as autonomy, distribution and proactiveness. This leads us to consider agents and Multi-Agent Systems (MASs) as effective metaphors for system design and implementation of AmI scenarios. In this paper we will focus on how an agent-based solution can help to implement the self-management requirement of AmI systems. Several approaches already exploit MAS in the context of self-managing AmI systems [2][3], but the solution proposed by most of them cannot be considered a pure agent-based solution since agents are just used to apply Artificial Intelligence techniques (e.g. learning or planning algorithms), or as autonomic managers of an add-on autonomic system.These solutions are not energy efficient, as the self-management tasks imply an extra traffic between the autonomic agent manager(s) and the managed devices. So, pure agent-based solutions are more energy efficient, since they minimize the self-management traffic, which can be considerable in AmI systems with for example thousands of sensors.

In this paper we introduce *self-StarMAS*, a set of cooperating agents, running in each device of an AmI system, able to communicate and interoperate through heterogenous communication protocols, and with the capacity of self-management adapted to each kind of agent/device.

2. THE SELF-STARMAS SYSTEM

In this section we will present the self-StarMAS system (see fig. 1) focusing on the challenges that pose the use of agent technology to self-manage AmI systems and how they are addressed by our approach. The use of agents to support self-management is not a new research area, but we consider that current solutions do not address all these challenges well.

C1 - Self-management: Much research on self-management is progressing and several self-* properties introduced by IBM can be considered a good starting point (self-configuring, self-optimizing,...). **Achieving:** We propose a MAS composed by a set of cooperating agents with the

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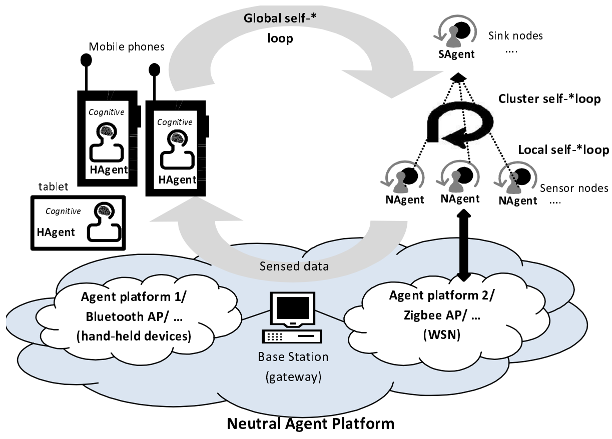

Figure 1: The self-StarMAS global architecture

capacity to provide self-management. Each individual AmI device is endowed with an agent with self-management capacities, so we propose a pure agent-based solution.

C2 - Decentralized adaptation: The highly decentralized and embedded nature of the devices involved makes it hard to enforce some forms of direct control over each of the networked devices [6]. This makes traditional centralized approaches that use one agent, or a fixed set of agents to perform a kind of self-management task, inadequate and economically inviable, leading to a demand for novel decentralized solutions. **Achieving:** Agents in self-StarMAS are structured following a hierarchical organization with different types of agents (see fig. 1), adapted to the resources of each device and its physical organization in the WSN. Firstly, agents running in mote-like sensors include a lightweight implementation of self-managing properties, with only a limited set of previously known reconfiguration actions. They specialize in applying policies to save energy levels but the adaptation is performed locally (*Local self-*loop*). Secondly, sink nodes of the WSN have agents with higher level organization capacities. The policies applied by them have the goal of self-managing a group of agents, representing a group of sensors. Finally, agents running in hand-held devices have the capacity to both self-manage their internal functioning, and act as managers of the self-StarMAS system (*Global self-*loop*).

C3 - Devices heterogeneity: AmI systems are composed of set of heterogeneous lightweight devices, which are continuously being updated. This means that any pure agent-based solution for self-managing AmI systems must consider that agents will be running in different devices, but even so, they must interoperate using the services of a common agent platform (AP). **Achieving:** Self-StarMAS includes different agent designs for different kind of AmI devices, but they are completely interoperable using FIPA-compliant negotiation protocols adapted for self-management in AmI systems. Until now, only a few APs can be executed in mobile phones and only a couple of approaches [1] can be executed in sensors such as Sun SPOT, but in this last case agents in different types of devices are not interoperable.

C4 - Communication heterogeneity: In a ubiquitous environment, agents running in different devices must be able to communicate with each other. The challenge is to support the communication of agents running in devices, using the lightweight devices's own proprietary communication technology. **Achieving:** Self-StarMAS agents are platform-neutral which means that agents are able to support the discovery and interaction between agents running in devices using different communication technologies or APs. As part of our solution, we provide different possibilities in order to support agent interoperation: (i) use an existing AP (e.g. JADE-Leap); (ii) use our infrastructure to support the communication between hand-held devices using WiFi and WSNs using Zigbee; and (iii) use the native communication protocol of the AmI device (e.g. for hand-held devices we implemented an AP using Bluetooth).

To the best of our knowledge, only our work properly addresses all the challenges presented above. We present a workable solution instead of a theoretical one, the results of which sometimes cannot be applied to real AmI systems. The approach proposed here pursues a general goal of making the agent technology a genuine alternative to develop complete AmI applications.

3. CONCLUSIONS

In this paper we present, self-StarMAS, a pure agent-based solution for the self-management of AmI systems. The main characteristic of the self-StarMAS is that it provides an homogenous management of AmI systems, although it is composed of heterogeneous agents running on heterogenous devices, communicating through heterogeneous AP and protocols. The architecture of each type of agent is customized to the resources of each device type, allowing the definition of reconfiguration policies adapted to the role and resources of each agent. Up to now we have defined some control policies focused on energy saving, but the self-StarMAS system is extensible, so new policies can be defined easily.

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