

# Virtual Organizations of Agents for Monitoring Elderly and Disabled People in Geriatric Residences

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**Abstract**— This paper presents the use of PANGEA platform applied to improve healthcare and assistance to elderly and dependent people in geriatric residences. PANGEA is based on Virtual Organizations of agents (VO) and integrates a set of autonomous deliberative agents designed to support the carers' activities and to guarantee that the patients are given the right care. The system makes use of Wireless Sensor Networks and a Real-Time Locating System for providing autonomous responses according to the environment status. Agents are a suitable alternative to manage the enormous quantity of data provided of sensors because they can represent autonomous entities by modelling their capabilities, expertise and intentions. This approach facilitates the inclusion of context-aware capabilities when developing intelligent and adaptable systems, where functionalities can communicate in a distributed and collaborative way. Several tests have been performed to evaluate this framework and preliminary results and conclusions are presented

**Keywords**— *multi-agent systems; virtual organizations; deliberative agents; real-time locating systems; wireless sensor networks, information fusion process, health care.*

## I. INTRODUCTION

The importance of developing new and more reliable ways to provide care and support to people is underlined by the ageing of world population, especially in industrialized countries [16], and the creation of secure, unobtrusive and adaptable environments for monitoring and optimizing health care will become vital. Therefore, tomorrow health care institutions (public or private) will be equipped with intelligent systems capable of interacting with humans. Research areas such as Ambient Intelligence (AmI) and Ambient Assisted Living (AAL) propose new way to interact between people and technology, where this last one is adapted to individuals and their context [17]. The objective of AmI and AAL systems is to develop intelligent and intuitive systems and interfaces capable to recognize and respond to the user's necessities in a ubiquitous way, providing capabilities for ubiquitous computation and communication, considering people in the centre of the development, and creating

technologically complex environments in different fields, such as medical, domestic or academic, among many others.

On the one hand, Agent Technology [18] has become increasingly relevant for developing distributed and dynamic intelligent environments and therefore fulfils the requirements and goals of Ambient Intelligence and Ambient Assisted Living. These intelligent systems aim to support people in several aspects of their daily life, predicting potential hazardous situations and delivering physical and cognitive support. In this sense, it is important to integrate intelligent and dynamic mechanisms to learn from past experiences and therefore provide users with better tools for supplying healthcare.

On the other hand, Wireless Sensor Networks (WSNs) allow us to obtain information about the environment and act on this, expanding users' capabilities and automating daily actions [19]. One of the most interesting applications for WSNs is Real-Time Locating Systems (RTLS). Although outdoor locating is well covered by systems such as the current GPS (Global Positioning System), indoor locating needs still more development, especially with respect to accuracy and low-cost and efficient infrastructures [5]. In this sense, the use of optimized locating techniques allows obtaining more accurate locations using even fewer sensors and with less computational requirements [20].

Agents are a suitable alternative to manage the enormous quantity of data provided of sensors in this kind of system because they can represent autonomous entities by modelling their capabilities, expertise and intentions. In this sense, virtual organizations of agents are an interesting possibility because they can provide the necessary capacity to handle open and heterogeneous systems such as those normally found in the information fusion process. In this case, information fusion is understood as a process that assembles assessments of the environment based on its goals. The integration of sensors is not an easy task. Therefore, it is necessary to develop innovative solutions that integrate different approaches in order to create open, flexible and adaptable systems.

This paper presents an intelligent multi-agent system aimed at improving healthcare and assistance to elderly and dependent people in geriatric residences. The system is based on the PANGEA (Platform for Automatic coNstruction of orGanizations of intElligents Agents) [13]. Moreover, the system makes use of Wireless Sensor Networks and a Real-Time Locating System for providing autonomous responses according to the environment status and integrates a set of autonomous reactive and deliberative agents designed to support the carers' activities and to guarantee that the patients are given the right care in both the residence and their homes.

The article is structured as follows: Section 2 makes a review of the state of art of multi-agent system (MAS) and Virtual Organizations of Agents, including a description of PANGEA platform. Section 3 and 4 introduce a description of the system infrastructure specifically adapted to assist elderly and dependent people in geriatric residences. Finally, some conclusions are given in Section 5.

## II. VIRTUAL ORGANIZATIONS OF AGENTS

The usefulness of any technology, including multi-agent systems (MAS), can be judged by two criteria: (i) its ability to solve new types of problems and (ii) its ability to improve the efficiency of existing solutions [2]. With this in mind, agents and multi-agent systems provide a natural method of characterizing intelligent systems. Intelligence and interaction are two concepts that are inextricably joined, a fact that is well established in agent technology. When discussing MAS, the idea of a single agent is expanded to include an infrastructure for interaction and communication. Ideally, MAS include the following characteristics [1]: (i) they are typically open with a non-centralized design; (ii) they contain agents that are autonomous, heterogeneous and distributed, each with its own "personality" (cooperative, selfish, honest, etc.). They provide an infrastructure specifically for communication and interaction protocols. Open MAS should allow the participation of heterogeneous agents with different architectures and even different languages [2]. MAS agents based on organizational concepts coordinate and exchange services and information; they are capable of negotiating and coming to an agreement; and they can carry out other more complex social actions. At present, research focusing on the design of MAS from an organizational perspective seems to be gaining most ground. The emergent thought is that modeling the interactions in a MAS cannot be related exclusively to the actual agent and its communication capabilities; instead, organizational engineering is necessary as well. The concepts of rules [4], norms and institutions [5] and social structures [6] are rooted in the idea of needing a higher level of abstraction, independent from the agent, that explicitly defines the organizations in which the agents reside.

Virtual organizations [7] are a means of understanding system models from a sociological perspective. A VO is an open system formed by the grouping and collaboration of heterogeneous entities and there is a separation between form

and function that requires defining how a behaviour will take place. The dynamics of open environments is one of the reasons that have encouraged the use of Virtual Organizations of Agents (VOs).

Agent organizations depend on the type of coordination and communication among agents, as well as the type of agents that comprise the group. There are several different organizational approaches [11] [10] [9] [2] [8] [12].

Currently, there are no virtual organization-based applications oriented to fusion information. However it is possible to find some approaches that try to propose advances in this way. For example, the e-Cat System [23] focuses on the distribution and integration of information. This system is based on enhancing the skills or abilities of members of the organization by defining the different types of skills and relationships that exist between them. This organization aims to ensure the maximum independence between the different partnerships created, and information privacy. Another example, perhaps more centralized in the fusion of information, is the KRAFT (Knowledge Reuse and Fusion / Transform) architecture [24], which proposes an implementation of agents where organizational aspects are considered to support the processes of heterogeneous knowledge management.

From our perspective, an open platform has been created and allows any type of configuration, adaptation mechanisms, reorganization, search services, etc. All the artifacts that make up a virtual organization can be developed with PANGEA platform. MAS and VO are combined to obtain a system especially specifically oriented to manage information obtained of the environment, including sensors.

### A. The PANGEA Platform

PANGEA (Platform for Automatic coNstruction of orGanizations of intElligents Agents) [13] is an agent platform to develop open multi-agent systems, it can manages roles, norms, organizations and suborganizations that facilitate the inclusion of organizational aspects. The services offered by the agents are included completely separate from the agent, facilitating their flexibility and adaption. PANGEA incorporates reasoning mechanisms available for the agents [29]. The basic agent types defined in PANGEA can be seen in Fig. 1, they are:

- **OrganizationManager**: the agent responsible for the actual management of organizations and suborganizations. It is responsible for verifying the entry and exit of agents, and for assigning roles. To carry out these tasks, it works with the **OrganizationAgent**, which is a specialized version of this agent.
- **InformationAgent**: the agent responsible for accessing the database containing all pertinent system information.
- **ServiceAgent**: the agent responsible for recording and controlling the operation of services offered by

the agents. It works as the Directory Facilitator defined in the FIPA standar.

- NormAgent: the agent that ensures compliance with all the refined norms in the organization.
- CommunicationAgent: the agent responsible for controlling communication among agents, and for recording the interaction between agents and organizations.
- Sniffer: manages the message history and filters information by controlling communication initiated by queries.
- DiscoveryAgent: implements an intelligent mechanism to discover services.
- MonitorAgent: interacts with the platform to show the information to the end user.

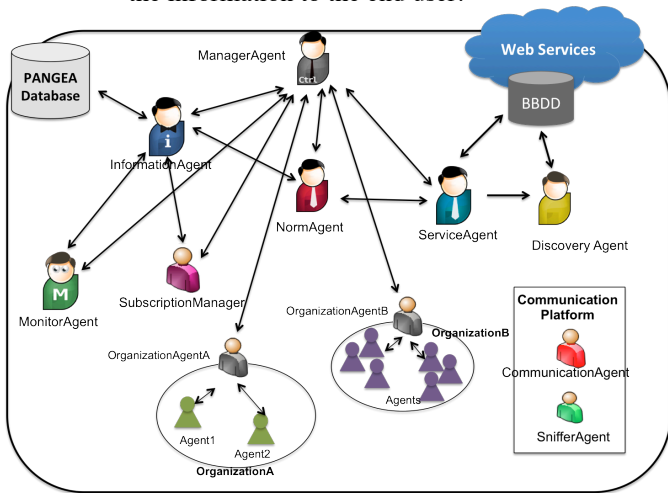


Fig. 1. Basic agent included in PANGEA

PANGEA is a service-oriented platform that can take maximum advantage of the distribution of resources. To this end, all services are implemented as Web Services. This makes it possible for the platform to include both a service provider agent and a consumer agent, thus emulating a client-server architecture. The provider agent (a general agent that provide a service) knows how to contact the web service, the rest of the agents know how to contact with the provider agent due to their communication with the ServiceAgent, which contains this information about services.

Using Web Services also allows the platform to introduce the SOA architecture (Service-Oriented Arquitecure) into MAS systems. SOA is an architectural style for building applications that use services available in a network such as the web. It promotes loose coupling between software components so that they can be reused. Applications in SOA are built based on services. A service is an implementation of a well-defined functionality, and such services can then be consumed by clients in different applications or processes. SOA allows for the reuse of existing services and a level of flexibility that was not possible before in the sense.

One of the most important features that characterize the platform is the use of the IRC protocol for communication among agents. The IRC protocol was used to implement communication. Internet Relay Chat (IRC) is a Real Time Internet Protocol for simultaneous text messaging or conferencing. This protocol is regulated by 5 standards: RFC1459, RFC2810, RFC2811, RFC2812 y RFC2813 [14][15]. The use oh the protocol facilitates the implementation process and provides a flexible and robust communication, already tested by many users. Using IRC involves the ease in implementing communication. The platform's code generating tool makes it possible to easily create an outline of an agent, with the communication code requiring few lines of code. Moreover, it is an open standard protocol that is continuously evolving. There are also IRC clients for all operating systems, including mobile devices. Then, it is important to remark that PANGEA admits mobile agents deployed in Smartphones or tablets and agents in any programming language, it is not necessary to learn a new language in order to use it.

### III. SYSTEM OVERVIEW

This is an Ambient Intelligence based multi-agent system aimed at improving healthcare of dependent people at the geriatric residences and their own homes. An essential aspect in this system is the use of Wireless Sensor Networks (WSN) to provide the agents with automatic and real-time information of the environment and allow them to react upon it. This way, the system makes use of several WSNs in order to gather context information in an automatic and ubiquitous way. The system enables an extensive integration of WSNs and provides a greater simplicity of deployment, thus optimizing the reutilization of the available resources in such networks. The agents in the system are implemented within the agent platform, PANGEA (Platform for Automatic coNstruction of orGanizations of intElligents Agents).

The two key concepts that come together in this system are: first the use of virtual organizations of agents for the overall management and control system for high-level sensor data. Furthermore, the sensors themselves itself, which will have to be managed and analyzed to extract information from them and apply them to the case study in question (healthcare and assistance to elderly and dependent people in geriatric residences).

The context includes information about the people and their environment. The information may consist of many different parameters such as location, the building status (e.g. temperature), vital signs (e.g. heart rhythm), etc. Each element that forms part of a sensor network is called a node. Each sensor node is habitually formed by a microcontroller, a transceiver for radio or cable transmission, and a sensor or actuator mechanism [25]. Some nodes act as routers, so that they can forward data that must be delivered to other nodes in the network. There are wireless technologies such as Wi-Fi, IEEE 802.15.4/ZigBee and Bluetooth that enable easier deployments than wired sensor networks [26]. WSN nodes must include some type of power manager and certain

smartness features that increase battery lifetime by means of having offering worse throughput or transmission delay through the network [26].

The combination of agents and WSNs is not easy due to the difficulty in developing, debugging and testing distributed applications for devices with limited resources. The interfaces developed for these distributed applications are either too simple or, in some case, do not even exist, which even further complicates their maintenance.

The way in which information fusion is held together is the key to this type of system. In general, data can be fused at different levels [27]: (i) sensor level fusion, where multiple sensors measuring correlated parameters can be combined; (ii) feature level fusion, where analysis information resulting from independent analysis methods can be combined; (iii) decision level fusion, where diagnostic actions can be combined.

At the level sensors, the basis of the WSN infrastructure of the system is made up of several ZigBee nodes (i.e., readers and tags). ZigBee standard is specially intended to implement WSNs and allows operating in the frequency range belonging to the radio band known as Industrial, Scientific and Medical (ISM), specifically in the 868MHz band in Europe, the 915MHz in the USA and the 2.4GHz in almost all over the world. The underlying IEEE 802.15.4 standard is designed to work with low-power and limited computational resources. The ZigBee standard allows more than 65,000 nodes to be connected in a star, tree or mesh topologies. These features make ZigBee and ideal supporting wireless technology for building indoor Real-Time Locating Systems. The possibility of working with low-power nodes that do not need large computational resources allows designers to reduce hardware costs when implementing the systems. In addition, these kind of low-power nodes can reach battery life-time even of several years, regarding the transmission range (transmitted power), the time resolution and the accuracy of the system. ZigBee-based Real-Time Locating Systems can use different locating techniques in order to estimate the positions of the tags in the environment. In the proposed system, each ZigBee node includes an 8-bit RISC (Atmel ATmega 1281) microcontroller with 8KB of RAM, 4KB of EEPROM and 128KB of Flash memory and an IEEE 802.15.4/ZigBee transceiver (Atmel AT86RF230). These devices, called n-Core Sirius B and Sirius D are shown in Fig. 2 [28].



Fig. 2. n-Core Sirius B/D devices

At higher levels (features and decision), it is possible to detect changes in the environment and its consequent action in the system. This consequent action can be managed on the PANGEA platform as a result of the services and functions that comprise the agents of the organization. For example, if a change within a node (a change of light for instance) is detected at sensor level, the agents at a higher level can decide to send a warning message or perform an action.

This scheme provides for the potential inclusion of a variety of sensors as well as other devices of diagnostic relevant information that might be in the form of maintenance records, monitoring and observations. The framework provides for information synchronization and high-level fusion [21].

The principal objective of the high level fusion is to transform multiple sources of several kinds of sensors and performance information into a monitoring knowledge base. Embedded in this transformation process is a fundamental understanding of node of WSN functions, as well as a systematic methodology for inserting services to support a specific action according to information received by the node.

The operation of the system is as follows. Each user or object to be located in the system carries a n-Core Sirius-B acting as tag. Each of these tags broadcasts periodically a data frame including, among other information, its unique identifier in the system. A set of n-Core Sirius D devices is used as readers throughout the environment, being placed on the ceiling and the walls. The broadcast frames sent by each tag are received by the readers that are close to them. This way, readers store in their memory a table with an entry per each detected tag. Each entry contains the identifier of the tag, as well as the RSSI (Received Signal Strength Indication) and the LQI (Link Quality Indicator) gathered from the broadcast frame reception. Periodically, each reader sends this table to the coordinator node connected to the computer. The coordinator forwards each table received from each reader to the computer through the USB port.

Then, services of PANGEA platform offer the location data to remote client interfaces as web services. Through different interfaces as it is shown in the next section, users can watch the position of all users and objects in the system in real-time. This way, if some user enters in an area that is forbidden to it regarding its permissions, the system will generate an alert that is shown to the administrator through the client interfaces. In addition, user can manage the different information provide for other kind of sensors.

#### IV. CASE STUDY

The case study consists of a telemonitoring system for elderly at a geriatric residence where elderly can be monitored not only at the residence, but also at their own homes.

Infrastructure currently available:

- Locating platform: system for locating elderly or dependant people and staff.
- Home automation platform: system with different kind of sensors that fusion the information obtaining knowlegment and alerts.

- Caregivers' system support: system that allows the caregivers to get alarms and plan daily tasks and routines to take care of the elderly.

There is a locating infrastructure at the geriatric residence for positioning patients, medical personnel and assets within the building. The configuration used in the system consists of a ZigBee tag mounted on a bracelet worn on the users' wrist or ankle, several ZigBee readers installed over protected zones, and a central workstation where all the information is processed and stored. These readers are installed all over the facilities so that the system can detect when a user was trying to enter a forbidden area according to the user's permissions. The ZigBee network also allows obtaining information of the environment from different sensors, such as temperature sensors, light sensors, as well as smoke and gas detectors. In addition, it can be used different locating techniques using these devices as readers and also as tags carried by patients and medical personnel. These devices are small enough to be carried by a patient, a caregiver or even an object, and provide a battery life of up to six months. The location of users is given as coordinated points obtained from the locating techniques provided by a locating engine [22]. All information obtained by means of these technologies is processed by the PANGEA agents. The system allows users to keep track of any tag in the system as well as receive distinct alerts in real-time coming from the system in any Web-based device, such as PC or a smartphone carried by doctors and nurses. Among the different alerts there are panic button alerts (when a user press a panic button on its tag or in a fixed device including such a button), forbidden area alerts (when a user enter into a forbidden area according to its permissions), as well as low-battery alerts (if some tag in the system should be recharged).

The ZigBee infrastructure has been deployed in a 600 m2 area within the residence where live dependent people with distinct dementias such as Alzheimer's disease. The locating infrastructure is intended to provide the real-time position of people (i.e., patients and medical personnel) and assets (i.e., wheelchairs and lifters) with an average accuracy of 2 meters within the monitored area. Fig. 3 shows one of the Web-based interfaces of the telemonitoring system in the monitored area.

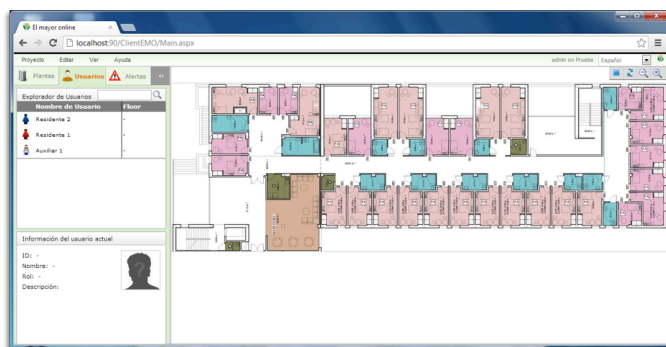


Fig. 3. Software interface of the locating system.

There is deployed a home automation in each patient's home for telemonitoring the environment where he or she lives from a remote control center installed in the own geriatric residence. The home automation infrastructure for the remote

telemonitoring of the elderly at their homes is formed by a ZigBee wireless sensor network fully integrated on the environment. For the pilot of the system, this network has been deployed in a typical bedroom in the own residence (simulating the patient's home), as shown in Fig. 4.

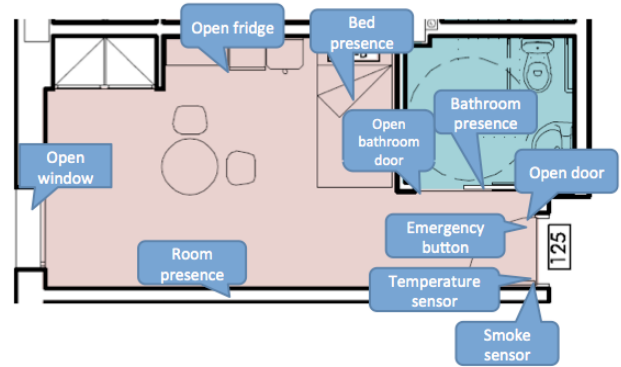


Fig. 4. Map of the room with the installed sensors

The alerts generated by the sensors are reported to a central server, where there will be an agent dedicated to each of the sensor types. The platform will merge the data from all the sensors installed to generate the appropriate alerts. The system will have a "daily activity plan" and a library of "rules" that generate alerts in case something gets out of typical daily plan. For example: "If the sensor is on bed for more than eight hours, generate alert one."

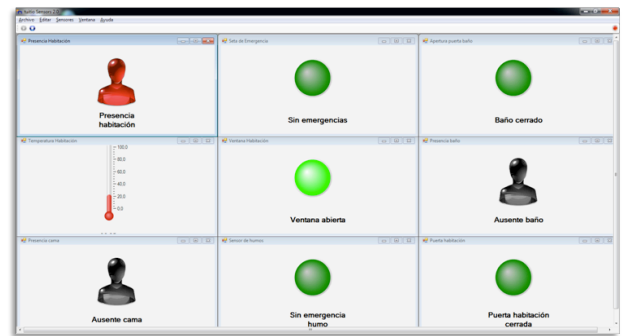


Fig. 5. Software interface of the central control point

The third part of the system deployed is the caregivers' system support. Thanks to all the information obtained by the sensors the caregivers and doctors can get statistics to monitor the patient's health status through a web tool.

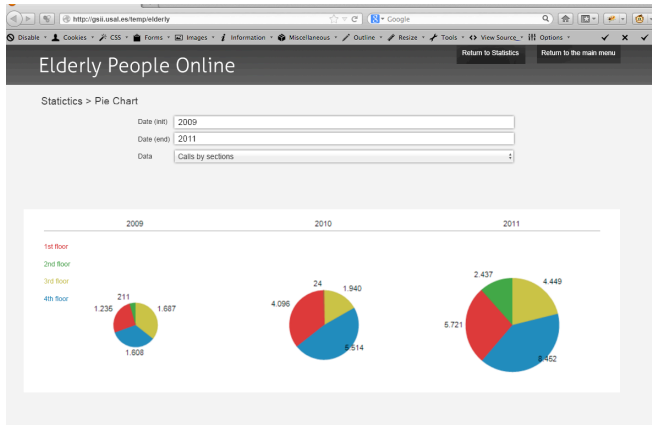


Fig. 6. Web application to consult statistical data, in this case, Number of calls by sections.

Also the caregivers through their smartphones can:

- Locate the patients in real time.
- Planning their daily tasks using artificial intelligence mechanisms specially designed for that.
- Quickly respond to alarms.

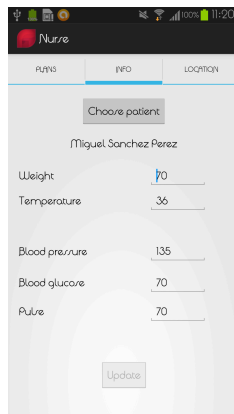


Fig. 7. Screen of the Smartphone application.

### A. Integration in PANGEA

In PANGEA four suborganizations have been created. In this platform, all the suborganizations are managed by an *OrganizationalAgent*, which helps the *OrganizationManager* to control the correct functioning. Each suborganization is specialized according to the tasks carried out. In Fig. 8, the four suborganizations can be seen, they are:

- **InformationProviderOrganization:** enables the interaction with the user. As three different interfaces have been developed, there is an agent for each one of them.
- **HomeAutomationOrganization:** it is formed by all the agents that control the different sensors of the spaces (presence, smoke, temperature, etc.). All the information collected by them is sent to the *ZigbeeSupervisorAgent*. After a previous evaluation, this agent communicates it to the

*InformationAgent*. The *InformationAgent* is the interface with the database

- **LocatingOrganization:** it is formed by all the agents that control the Zigbee sensors and tags, which allows locating the people (caregivers or patients). All the information collected by them is sent to the *ZigbeeSupervisorAgent*. This information is used by the *MonitorAgent* and the *LocatingAgent* in case that the user wants to track a person.
- **CaregiverOrganization:** each caregiver (doctor or nurse) is represented by an agent that collects information of their interventions. Each intervention has a representative collection of information that allows extracting knowledge. This information is the key for the *RulesAgent* functioning. For example, it can create the routine of a patient. When the information provided by the caregivers and sensors is out of the routine of the patient or shows any dangerous situation, the *AlarmAgent* extends the alarm through the system. The *MonitorAgent* can receive the alarm thanks to its communication with the *SnifferAgent* and show it on the screen.

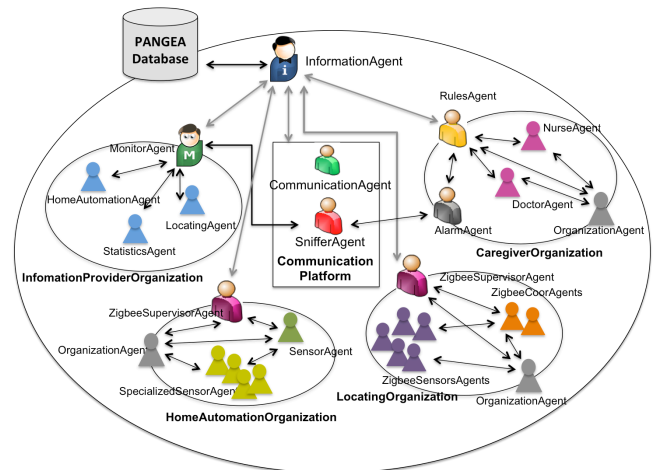


Fig. 8. Overview of the deployed agents in PANGEA.

## V. CONCLUSIONS

As result of the dynamic features of PANGEA platforms and the WNSs, the presented system can be easily enhanced with new sensors without be redeployed and it can be adapted to new scenarios as even whole medical centers with many patients, whilst other approaches cannot. The system incorporates intuitive interfaces which facilitate usability and interaction to the user. The core of the system is a group of deliberative agents acting as controllers and administrators for all applications and services, including manage of the sensors. The functionalities of the agents are not inside their structure, but modeled as services thanks to PANGEA platform. This approach provides the systems with a higher ability to recover from errors, and a better flexibility to change their behavior at execution time. The agents in the organization can carry out

complex tasks as well as react to changes that occur in the environment.

Finally say that healthcare, surveillance or work safety applications are only some examples of the possible environments where RTLS can be exploited. There also are different wireless technologies that can be used on these systems. The ZigBee standard offers interesting features over the rest technologies, as it allows the use of large mesh networks of low-power devices and the integration with many other applications as it is an international standard using unlicensed frequency bands.

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