AmI Open Source System for the Intelligent Control of Residences for the Elderly

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Abstract. The IoT has an enormous potential to dramatically improve the quality of life and health of elderly population. In this sense, Ambient Intelligent (AmI) environments focused on the domains of Assisted Living (AAL) represent one of the most promising IoT areas to explore and exploit. We present an intelligent AmI open-source system that aims to monitor and control smart homes and residences for elderly people in order to enhance the safety, health and comfort of the elderly people. For achieving an interoperable interface for collecting, storing and retrieving data from very heterogeneous sensors it integrates a Sensor Observation Service of the Open Geospatial Consortium and follows open standards. Our system is validated from a practical perspective as it is implemented in a pilot residence in Spain.

Keywords: Interoperability · Ambient intelligence · Ambient assisted living Open source system · Sensor observation service · Sensor web enablement

1 Introduction

The steep increase of elderly population in modern society [1] alongside with the special caring needs that they require, it has recently promoted a strong interest in the Ambient Assisted Living (AAL) domain of IoT [2]. AAL constitutes an area of Ambient Intelligence (AmI) [3], and comprises areas such as e-Health [4] and Elderly Smart Home [5]. These areas may be assisted and boosted through the utilization of IoT technologies. An instance of this is the use of Body Sensor Networks (BSN) in e-Health [6], which enable the remote monitoring of human bodily signals for medical purposes by means of IoT wireless sensors.

Ambient Intelligence involves the employment of sensor networks in order to collect information from the environment in a way that is transparent for the end user. However, underlying that final clearness there is inbuilt, occult, multilayered complexity. IoT Sensor networks usually feature a marked heterogeneity, as different sensors have different specifications, come from diverse providers and present distinct measurement patterns. Besides, those sensors may present mobility instead of being located in a fixed spot. The data that the sensors gather is transmitted by means of very

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diverse technologies and protocols. As a consequence of this heterogeneity, the integration of sensors and their data is not trivial, as well as the access and management of that data [6, 7].

Another interoperability issue posed in AAL and AmI is the need of addressing sensor mobility and geospatial data support. Even for fixed sensors, the position of a smart object may be relevant for the analysis of data. Many sensors are mobile, and this characteristic enables sorts of environment monitoring that could not be addressed otherwise. Mobile phones are a good example of the pervasive presence of mobile smart objects in IoT. The mobility aspects of smart objects should be addressed bearing in mind potential roaming across different networks and seeking to more thoroughly interpret monitoring information. In special environments, mobile sensor networks may even require the utilization of mobile gateways [8]; in such IoT systems, information about gateway and sensor position is evidently crucial for system operation and the analysis of monitoring data.

We present an innovative open source AAL system that solves this interoperability issues through the use of open standards and Sensor Web Enablement components from the Open Geospatial Consortium standardization initiative. Our system intends to improve the life quality of elderly people living in smart homes and nursing houses and has been validated through its implementation in a pilot residence.

This paper is laid out as follows. Section 2 expounds open OGC standards and the SWE framework. Section 3 explains our architecture proposal. Section 4 expounds a use case of our system in a pilot residence. Finally, Sect. 5 puts forth conclusions and outlook.

2 Sensor Web Enablement

There are few standardized initiatives that address the interoperability issues mentioned in the introduction section and put forth solutions. The most relevant initiative is probably the Sensor Web Enablement (SWE) [9] framework of the Open Geospatial Consortium (OGC), which permits the integration of sensors and their data. The Sensor Observation Service (SOS), as a component of the SWE specification, plays a major role in that integration by defining an interface for accessing sensor data and metadata [10]. The SOS offers a standardized web service interface that enables customers to interact with registered sensors and their measurement data [10] and also to register new sensors and types of observations or to erase them.

Mobility aspects may be especially relevant in AAL, given that information stemming from location and tracking can be critical for the proper functioning of many services in a nursing home or in the smart homes of the elderly. The employment of geospatial metadata can solve the aforementioned issues. In this sense OGC provides geospatial standards that support the geolocation of sensors and their measurements, allowing the use of sensor data and metadata.

We employ components of the Sensor Web Enablement framework in our system to solve the interoperability issues posed by the high heterogeneity of sensors in order to collect and manage their data, and by the need of addressing additional geospatial information for this data.

3 System Architecture

The architecture of our system is shown in Fig. 1 and it is explained in this section from a component perspective. Conjointly, it is also detailed the general software architecture of the central system, that only has open-source components.

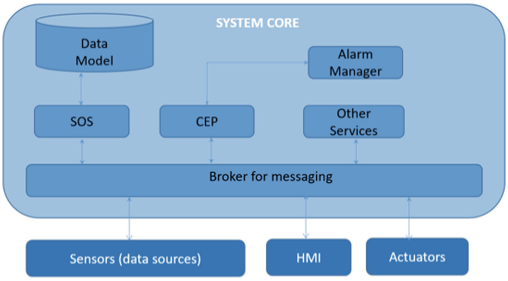

Fig. 1. System architecture of the AmI open source system

Our system is composed by a Human-Machine Interface a Central System, an Actuator Module and a Sensor Module. Their functionality and role within the system are described in the following paragraphs.

The Sensors Module is a set of sensors that are placed in a residence as a part of an Ambient Intelligence environment (together with the system intelligence and the actuators). They send monitoring data to the system through the local network to a Sensor Data Acquisition Module, that is responsible for collecting and sending the data to the central system.

The Actuator Module is composed by a set of actuators that are placed in the residence. They respond to the orders of the central system.

The Central system is the core of our system, and it is able to collect and store data from the sensors and analyze it. In case its intelligence considers that an action must take place in response to a specific situation, the system will create notifications visible through the HMI, send orders to the actuators and/or launch alarms. This system will handle alarms as events with the highest priority.

The Human-Machine Interface (HMI) can be accessed on-line through a web interface. It shows to authorized users relevant monitoring information, alarm notifications and provides access to real-time sensor information as well as records. Administrator users can configure the system and perform control actions.

The Central System is composed by a SOS, that enables standardized sensor data management, a Complex Event Processor (CEP) that provides analysis intelligence to the system, a Sensor Alarm Service, to handle alarms and events of high priority, and a broker that allows for the communication among the aforementioned components. These system core components are described in more detail in the following paragraphs.

The Sensor Observation Service collects and stores the data from the sensors following the Open Geospatial Consortium (OGC) standards, and provides a standard interface for managing and retrieving the meta-data and observations from the sensors system [11]. The OGC SOS accomplishes the specification O&M [12] for sensor observation modelling, the specification SensorML [13] for modelling sensor metadata, and follows the Sensor Web Enablement [9] framework. SOS is based on widely accept-ed web technologies like XML, JSON and SOAP. The OGC SOS has geospatial support for sensor observations. The SOS requires a database with geospatial support for storing the sensor data using a specific data model designed for registering SOS observations and sensors. Our system uses 52º North SOS implementation [14], and a PostGreSQL database with PosGis support.

The broker allows for the communication of the different elements of the Core system. It is as well the interface between the core system and the external sensor information sources. We use RabbitMQ broker, that employs AMQP protocol for messaging [15].

The Complex Event Processor (CEP) processes events that are registered and through the SOS. The CEP has several rules that define specific patterns of events, and the actions to be triggered if those patterns are detected. Auxiliary tables, such as schedules for performing specific actions, can be used in CEP rules. The set of rules is adapted to the specific needs of a residence. In this sense, an administrator of the system can add, change or remove CEP rules, and modify or create auxiliary tables, through the system HMI. Rule definitions can entail high complexity. The CEP engine used is ESPER, an Event Stream Processing (ESP) [16].

An Alarm Manager that handles alarms and certain incidences of high priority detected by the Complex Event Processor. The Alarm Manager used is Sensor Alert Service (SAS) [17], a component of the 52º North SOS and the SWE framework. Alarms are handled separately from other events due to its high priority.

4 Use Case

In this section we describe a use case of our system in a residence for the elderly.

A pilot of our system has been deployed in a nursing home in the area of Valencia (Spain). The main features of the pilot are the following: it has 136 residents, 42 caregivers that work on three daily shifts and 80 rooms (66 bedrooms for elderly people and 12 regular rooms). The services that are currently implemented within our system are Intruder detection, Fire alarm, Medical Emergency, Access Control, Air Conditioning and Lighting Intelligent Service.

It integrates the human actors (caregivers and residents) of the nursing home in our system through a set of sensors, actuators and the Human-Machine Interface (HMI).

For the residence monitoring, we use 1378 sensors (room alarm buttons, terminals, access control points, air conditioning sensors, smoke detectors). All the residence area offers internet connectivity to the sensors. Thus, sensors communicate with the central system using wired LAN connectivity, in the case of fixed sensors, and WiFi, in the case of mobile sensors.

Our system receives the data produced from the sensors, stores and analyzes it. As a result of the analysis performed by the intelligence of the system, some control actions may take place. Notifications are sent to caregivers, alarms are launched if their trigger conditions are accomplished, and actuators receive orders. These type of actions can also be performed as a result of a previous programming and configuration of the system. For example, the automatic activation of the intruder alarm at a specific hour at night.

Caregivers can interact with the system through the HMI. As a consequence of the awareness of relevant monitoring information, the Caregivers can be more effective, faster, efficient, and have a better coordination in the service that give to the elderly people.

The main services offered in the pilot residence are intruder detection, fire alarm, medical emergency, access control, air conditioning regulation and intelligent lighting system. Those services are described in more detail in the following paragraphs.

Intruder detection is a service that protects certain access points of the residence at specific hours from unauthorized access, launches alarms if there is any attempt of trespassing and maintains the doors remotely closed. It is programmed to be active at some specific hours (i.e. at night) in the central system.

The fire alarm service detects if a concentration of CO2 or CO is higher than regular and launches a fire alarm, allowing for rapid dislodgment and or other measures for fire suffocation. As a matter of fact, to have a quick response is critical in fire situations. Smoke sensors are distributed in the whole area of the residence, including all rooms, and inform the central system of the existence of a potential fire in their specific location, and an alarm is automatically launched. This alarm can be deactivated manually, through the HMI of the central system, or after a timeout period if smoke sensors are not triggering it.

Medical Emergency is a service that aims to give the residents and caregivers a quick way to trigger an alarm in case of emergency, to immediately alert the system and the other caregivers in order to achieve the most rapid and efficient reaction possible. It is specially thought for medical emergencies. To this end, many rooms in the residence are provided of emergency buttons or handlers that can be easily pushed and activated by residents or caregivers in case of emergency. Then, the central system will receive information about the existence of an emergency and its location. The alarm will be active in the system until a caregiver informs the system that the emergency is being attended. The alarm will be then in a standby state until finally, a caregiver closes it when it is resolved. If it were necessary, health services will be called. Actually, each of the common rooms (i.e. a gym, a dining room, lounges and bathrooms), the bedrooms and private bathrooms contain at least one emergency button or handler in addition to a voice communicator. This service allows for a rapid response of caregivers and health services in case of accidents, medical emergencies or any other risk situations.

Access Control: this service restricts the entrance to different areas of the residence to only authorized people, for security and privacy reasons. The doors that limit certain areas of the residence have a card access control system that only allows the access of people with valid access permissions. The system has a registry of residents and caregivers, the access points that they are able to open with their access cards, and the end date of those permissions. If the access is authorized the door will be unlocked and opened. This system guarantees the privacy of residents in the rooms in which they live, that can only be accessed by them, caregivers or personnel of the cleaning service. As well, this service avoids the entrance of intruders in other residence areas.

Air Conditioning: Temperature is automatically regulated by the system to provide the most appropriate environmental conditions for the comfort of the ancient residents. It is critical to offer an appropriate temperature as a measure to prevent health problems in elderly people. Air conditioning devices have several sensors and actuators connected to the system. These sensors measure the current environmental temperature, the air velocity and the target temperature registered in the device, and send this information to the central system. Actuators can change the target temperature of the device and the velocity of the air. From the central system it is possible to set the target temperature of all the residence or to particularize it for specific devices (for example, some rooms could be empty and do not need to be warm). Also, it is possible to program times, air velocity and temperatures for a set of air conditioning devices, or specific ones, through the HMI as an administrator user.

Lighting Intelligent Service: this services allows luminaries of common rooms in the residence to be automatically switch on and switch off by the system. System administrators can program the start and end time of the lighting time. When the start time

5 Conclusions and Outlook

We have presented our system as an AAL open source solution with the goal of maximizing the comfort, safety and service effectiveness for aged people in smart homes and residences. For this aim, it utilizes a set of sensors and actuators to gather relevant information, applies intelligent data analysis to decide and perform the best course actions and it provides the caregivers a Human-Machine Interface to facilitate management and monitoring.

Our system aims to be adaptable to any type of sensors, services and building topology. The use of data from a very heterogeneous range of sensors poses an interoperability problem in IoT systems in other to collect, store and retrieve their monitoring data. Moreover, the mobility of sensors and the use of geospatial information, which is required in our system services, extends this interoperability problem. We solved both issues through the use of open standards (O&M and SensorML) for data management and the incorporation in our system of an OGC SOS that offers an interoperable interface for the collecting, storing and retrieving sensor data from heterogeneous sources.

The core of the system is composed by four main elements: the SOS that stores sensor observations in a database with geospatial support, a CEP that processes events and provides intelligence to the system, a Sensor Alarm Service that handles alarms from the CEP, and finally a broker that enables communication among the different elements. Our system is open source as it only uses open source components and its code will be released in the short future.

The main functionalities of our system have been validated not only from a theoretical scope, but in practice as it has been deployed in a pilot residence in Spain, covering a variety of services such as access control, medical emergency alarms and intruder detection.

In the short future, we will increment our system functionality, and integrate it into public emergency services, to increase the safety of residence and decrease the reaction time to any medical emergency.

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References

1. European Centre. http://www.euro.centre.org/search_index.php. Accessed Jan. 2017
2. Rashidi, P., Mihailidis, A.: A survey on ambient assisted living tools for older adults. IEEE J. Biomed. Health Inform. PP(99), 1 (2013)
3. José Bravo, V.V., Hervás, R.: Ambient assisted living. In: Third International Workshop, IWAAL 2011, p. 236 (2011)
4. Yang, G., et al.: A health-IoT platform based on the integration of intelligent packaging, unobtrusive bio-sensor, and intelligent medicine box. IEEE Trans. Industr. Inf. **10**(4), 2180–2191 (2014)
5. Cicirelli, F., Fortino, G., Giordano, A., Guerrieri, A., Spezzano, G., Vinci, A.: On the design of smart homes: a framework for activity recognition in home environment. J. Med. Syst. **40**(9), 200:1–200:17 (2016)
6. Gravina, R., Alinia, P., Ghasemzadeh, H., Fortino, G.: Multi-sensor fusion in body sensor networks: State-of-the-art and research challenges. Inf. Fusion **35**, 68–80 (2017)
7. Fortino, G., Giannantonio, R., Gravina, R., Kuryloski, P., Jafari, R.: Enabling Effective Programming and Flexible Management of Efficient Body Sensor Network Applications. IEEE Trans. Hum. Mach. Syst. **43**(1), 115–133 (2013)
8. Aloi, G., Caliciuri, G., Fortino, G., Gravina, R., Pace, P., Russo, W., Savaglio, C.: Enabling IoT interoperability through opportunistic smartphone-based mobile gateways. J. Netw. Comput. Appl. **81**, 74–84 (2017)
9. OGC SWE Project Website. http://www.open-geospatial.org/ogc/marketstechnologies/swe Accessed Jan 2017
10. Na, A., Priest, M.: OpenGIS sensor observation service implementation specification. In: Open Geospatial Consortium (OGC), Wayland, MA, OGC, pp. 1–104 (2006)
11. Bröring, A., Stasch, C.: OGC® Sensor Observation Service (2012)
12. Cox, S.: Observations and Measurements - Part 1 - Observation schema. in Open Geospatial Consortium (OGC), Wayland, MA, pp. 1–85 (2007). OGC Document, OGC 07-022r1
13. Botts, M., Robin, A.: OpenGIS Sensor Model Language (SensorML) implementation specification. In: Open Geospatial Consortium (OGC), Wayland, MA, pp. 1–180 (2007). OGC Document, OGC 07-000
14. 52 North: 52 North. Sensor Web Community. http://52north.org/communities/sensorweb/index.html. Accessed Jan 2017
15. RabbitMQ https://www.rabbitmq.com. Accessed Jan 2017
16. Esper: http://www.espertech.com/esper. Accessed Jan 2017
17. Simonis, I., Echterhoff, J.: OpenGIS sensor alert service implementation specification. In: Open Geospatial Consortium (OGC), Wayland, MA, pp. 1–144 (2006). OGC Document, OGC 06-028r5