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A Framework for Anomaly Diagnosis in Smart Homes Based on Ontology

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Abstract

Smart homes are pervasive environments to enhance the comfort, the security, the safety and the energy consumption of the residence. An ambient intelligence system uses information of devices to represent the context of the home and its residents. Based on a context database, this system infer the daily life activities of the resident. Hence, abnormal behavior or chronic disease can be detected by the system. Due to the complexity of these systems, a large variety of anomalies may occur and disrupt the functioning of critical and essential applications. To detect anomalies and take appropriate measures, an anomaly management system has to be integrated in the overall architecture. In this paper, we propose an anomaly management framework for smart homes. This framework eases the work of designers in the conception of anomaly detection modules and processes to respond to an anomaly appropriately. Our framework can be used in all heterogeneous environments such as smart home because it uses Semantic Web ontologies to represent anomaly information. Our framework can be useful to detect hardware, software, network, operator and context faults. To test the efficiency of our anomaly management framework, we integrate it in the universAAL middleware. Based on a reasoner, our framework can easily infer some context anomalies and take appropriate measures to restore the system in a full functioning state.

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Keywords: Context-aware Framework ; Anomaly management ; AAL ; Smart home ; Ontology

1. Introduction

Smart homes refer to residences equipped with technology to monitor the environment and provide advance services based on the context of daily life activities of the inhabitants. Devices (i.e., sensors, actuators, computers...) are scattered everywhere in the residence and an ambient intelligence system uses the information they send to offer a better quality of life. The ambient intelligence system proposes automated appliance control and assistive services to the residents. Hence, smart homes enhance personal comfort, security, safety and energy consumption [1].

However, smart homes are composed of heterogeneous networks and device's capacities [2]. Devices differ in terms of both communication technologies and capabilities (software and hardware). Indeed, these devices often use dif-

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ferent communication technologies where the interoperability cannot be ensure. Moreover, these devices range from high-end PC devices to low-end battery-less devices. The heterogeneity of networks and device's capacities increase the complexity to exchange information between them. The ambient intelligence system need a same representation of the information to monitor the context appropriately.

Semantic Web technologies such as Web Ontology Language (OWL) are good candidates to provide data interoperability between these devices. Semantic Web ontologies can be used to classify information and formally describe concepts. Indeed, ontologies describe the relations between objects that represent the domain of interest. Hence, ontologies increase the inferring power of the ambient intelligence systems. Due to the limitless interoperability possibilities proposed by Semantic Web ontologies, researchers propose context-aware middlewares[10 11], frameworks[3 4 5 6 7] and architectures[8 9] in order to propose a generic platform to ease the development of applications based on the context of daily life activities of the residents. These researches can increase the comfort and safety of the inhabitants while enhancing the energy consumption of the residence.

Smart homes can propose a large variety of applications. One of the most important application is the health care of residents[12]. People ageing occurs in every country all over the world. Indeed, the expected population of the EU-28 around 2050 will reach 525.5 million inhabitants while 28% will be over 65 years and 11% over 80[13]. Population ageing raises the dependency level of the elder people. Smart home is convenient to monitor the health of dependent people and offer healthcare services remotely. In the same way as for generic smart home infrastructure, context-aware middlewares[14 15], frameworks[16 17 18] and architectures[19 20] are proposed to manage the health of the residents. All these approaches use Semantic Web ontologies such as OWL to ensure interoperability of information and infer the daily activities of the residents. These methods can detect changes in the behavior of residents or chronic diseases and inform caregivers of health problems.

Due to the large variety of applications, anomalies in smart homes can put at risk the life of the residents. For example, caregivers cannot detect chronic diseases if the sensors worn by the residents send false information. In the same way, in case of a broken human fall detection sensor, emergency workers may be informed about the problem after a long time while causing an excessive stress or increasing the suffering of the fallen resident. Hence, an anomaly management system becomes an indispensable part of the overall architecture.

In this paper, we propose an context-aware anomaly management framework. Our framework uses the semantic web ontologies to represent the anomaly information. So, our framework can be uses in all types of heterogeneous environments such as smart homes. Our framework eases the design of anomaly detection modules and anomaly management services. it incorporates a reasoner to infer misbehavior or context problems. Our framework is designed to manage hardware, software, network, operator and context faults.

The remainder of this paper is organized as follow. We present in section II, a fault model for smart homes and the design of the anomaly ontology. In section III, we present our anomaly management framework. In section IV we provide the details of its integration in the universAAL middleware. Finally, we conclude with some insights and related perspectives, in section V.

2. Smart home anomaly

Before delving into the smart home related faults, it matters to define what a fault is. Fault, failure, error… are many words used to refer to a system in an undesired configuration. Instead of classifying these words in a hierarchy, the higher level concept of anomaly will be used. An anomaly is an abnormal, or unexpected, situation or behavior of a part of a system. This is a "should not/never happen" phenomenon.

2.1. New anomaly model

From "Multi Agents Systems" (MAS) to "Service Oriented Architecture" (SOA), Distributed Systems vary in forms and aspects / concepts. As with anything, distributed systems are not perfect, and present some troubles. Whether they are human controlled or not, potential anomalies may originate from their conception, their usage, or malevolence. An anomaly in Distributed Systems can be of four types[21]: hardware anomaly, software anomaly, network anomaly and operator anomaly. Hardware anomalies concern the problems encountered by physical devices. Software anomalies concern the problems encountered by the logical program executed on the physical device. Net-