Modular IoT Platform for AAL and Home Care Using Bluetooth Low Energy

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Abstract. This work describes a standard conform Java based modular IoT framework for context-aware applications for AAL and home care. An extensive support of Bluetooth Low Energy personal health devices as well as various home sensor networks is provided.

Keywords: IoT · Java framework · AAL middleware · Home care support · ehealth · Bluetooth low energy · Personal health devices

1 Introduction

During the past decades, consumer driven health care in conjunction with web-based platforms and electronic health records have led to an array of improved health-care solutions. In recent years, also a big amount of smart phone apps for physiological status monitoring became available. However, despite being an important step towards personalized medicine, these solutions often suffer from scalability, security, interoperability and privacy issues. Furthermore, such solutions are only able to provide a snapshot of physiological conditions rather than a continuous view of the overall health status over the course of many years [1].

Despite the increasing number of mobile phones, their supported wireless PAN or WAN technologies are limited, i.e. not all devices support all the available types of wireless PAN or WAN. Therefore interoperability between the sensor devices and mobile phones becomes very restricted. Another common issue when using mobile phones for transmission of data from personal health devices or other sensors is that the application that is receiving the sensor data has to be initiated and cannot always be available for receiving sensor data.

Internet of Things and pervasive computing is becoming more and more important, not only in home care. Furthermore the number of data acquiring devices in households is increasing dramatically. Current systems for the home care and Ambient Assisted Living (AAL) domain available on the market are very often isolated solutions without interfaces for third party applications. In this project, the authors aim to create an inter-operable, standard conform and flexible framework for collecting and analyzing data in the user's home on low-cost hardware. Furthermore, smart home and health related data will be combined and analyzed, to get a continuous and deeper insight into the patient's

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health status, by e.g. comparing smart home activity data with vital parameters. This paper describes the main features and the architecture of the system and how it is integrated in real world scenarios using low-cost hardware.

2 Related Work

In the moduLAAr project [2,3], an NFC-based (near field communication) system was used to monitor vital parameters of older adults in their homes remotely. The system makes use of NFC for both identification via an NFC card and data acquisition via NFC-enabled personal health devices using a smart phone [4]. During the long time field trial a few problems appeared concerning usability (two step approach) as well as robustness of the NFC technology. The users asked for a less obtrusive and simpler solution whereby the system was successfully used in other settings with a different target group. However, the project has shown that there is a demand for cheap, simple to use and non-obtrusive solutions for supporting home care and health care in the AAL domain. Further more, real world use of mobile phone based systems has shown the difficulty to maintain multi-purpose devices.

From the platform perspective, there are existing various AAL middleware solutions as outcome of research projects. The most prominent one is the universAAL open platform and reference specification for building AAL systems [5]. The universAAL project created a reference architecture or an ontology based AAL middleware platform, whereby its core consists of three buses for context, services and user interaction. The reference implementation was done in Java using an OSGi framework.

Beside commercial smart home systems, there exists a number of open source smart home platforms, focusing on the remote control of devices and some AAL platforms providing some more functionality like reminders etc., but a ready-to-use, sustainable, flexible, extensible and modular middleware for AAL providing the whole spectrum of required features like sensing the smart home environment plus the inhabitant, integrated data analysis and context aware multi-modal user interaction which could be used on a large scale is not available so far, even though many research projects attempted to provide certain aspects. The authors aim to close this gap with the provided solution described in this paper.

3 Platform Overview

Our group has developed the HOMER (HOMe Event Recognition) [6] system, a modular software platform, for integration of many kind of devices (smart home environment, body worn and health related devices), data acquisition and analysis of multi-modal data. The platform itself, written in Java, is open source with its core functionalities and makes use of OSGi technology to facilitate modularity and to reduce complexity. Moreover, HOMER runs inside the Apache Karaf framework [7], which is a modern and polymorphic container and supports features like hot deployment, console advanced logging and dynamic configuration.

Besides that OSGi also offers advantages regarding versioning, runtime-flexibility and maintenance. To realize important aspects of such a platform (such as security, modularity, extendibility or interoperability), standards for medical device communication and home automation networks are also integrated. The platform enables integration of other transport types (transport abstraction) as well as device abstraction, that uses a standardized abstraction model (ISO 11073-10471 [8]) in order to enforce interoperability [9]. Based on that hardware abstraction layer deterministic rules, respectively finite-state-machines are configured to trigger various actions. Within the scope of the current work the platform was extended in terms of management and handling of health related data. The implementation is based on the ISO 11073-20601 and accompanying standards for specific health device profiles.

Based on the modular architecture HOMER supports the full signal chain from raw sensor data to abstracted data fusion, connection to remote players and multi-modal intelligent user interaction. This makes HOMER a ready-to-use platform for AAL and home care applications. Even initially designed as a research platform, HOMER can be used for real world applications which require functionalities on top of a smart home like intelligent multi-modal user interaction or human behaviour recognition.

4 Bluetooth Low Energy Integration

Bluetooth Low Energy (BLE) is an emerging wireless technology developed by the Bluetooth Special Interest Group (SIG) for short-range communication. In contrast with previous Bluetooth flavors, BLE has been designed as a low-power solution for control and monitoring applications [10]. Since the BLE communication protocol is well documented and closely related to the ISO 11073 [11] standard and the Continua Health Alliance design guidelines, the creation of standard-conform devices would be quite straight forward, however, the number of standard conform BLE devices on the market is poor. Instead, manufacturers tend to create custom profiles with a custom data encryption even if a device profile exists for their device class.

Within this work a flexible Java framework for integration of BLE enabled devices, both standard-conform and proprietary, was developed and integrated in the platform described above. Due to the aim to create low-cost unmaintained systems for the health care domain the focus was on the Linux operating system using the BlueZ stack. The framework makes use of the Java D-Bus API to connect to the BlueZ daemon and provides generic BLE profiles, services etc. as well as certain proprietary devices. A template class makes the definition of new profiles fast and easy and the integration into the HOMER system provides the connection to an IoT enabled gateway as well as a generic multi-modal data analysis. Moreover, due to the modular architecture the generic BLE library, represented by the Common bundle in the stack of OSGi bundles, is designed to be reused within other applications and operating systems, e.g. Android or Windows. The interconnection of the modules and the data flow from a BLE device up to the application is depicted in Fig. 1.

Even though a small number of open BLE libraries for Java exist, so far none of them is complete in terms of providing all services, characteristics and profiles, and flexible enough to add additional standardized and proprietary devices. The provided solution aims to help to close this gap.

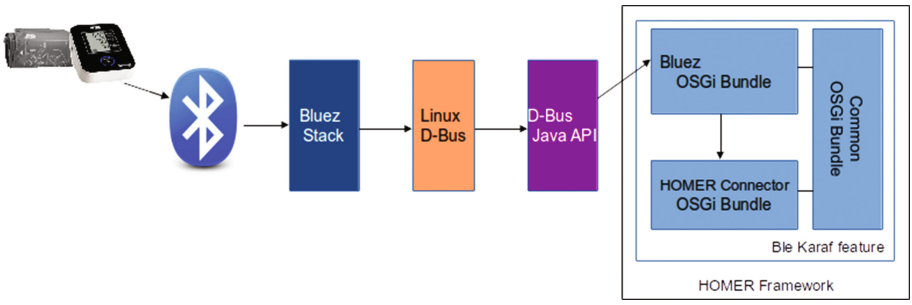

Fig. 1. Bluetooth integration in Karaf feature and OSGi bundle hierarchy

5 Integrated Raspberry Pi Prototype

The whole framework runs on a Raspberry Pi (RPi) which was enhanced with a small LCD display as well as a finger print sensor for user identification in a multi-user setting. Using the newest version 3 of the RPi with on-board Bluetooth and wireless LAN, no additional hardware (in form of USB dongles) is necessary. This allows the construction of a low-cost and stand-alone and non-obtrusive device acting in the background and able to get integrated in the home environment.

6 Applications

The HOMER platform was tested in a few research projects involving extensive user trials. On a larger scale it was used in the moduLAAr project to monitor vital parameters and to detect unusual situations in 50 households e.g. no activity due to a fall [9]. Moreover, a tablet based user interface, which was especially designed for elder users, was provided with functionalities like smart home control. reminders or shared pictures.

In the RelaxedCare project [12] HOMER was used for audio and smart home based activity recognition, and in the Doremi project [13] it was used to design, configure and provide sensor configuration for 40 test flats.

These examples show that our platform is flexible enough and ready-to-use for research projects in the AAL and home care domain on the one hand, and ready for deployment on a larger scale on the other hand.

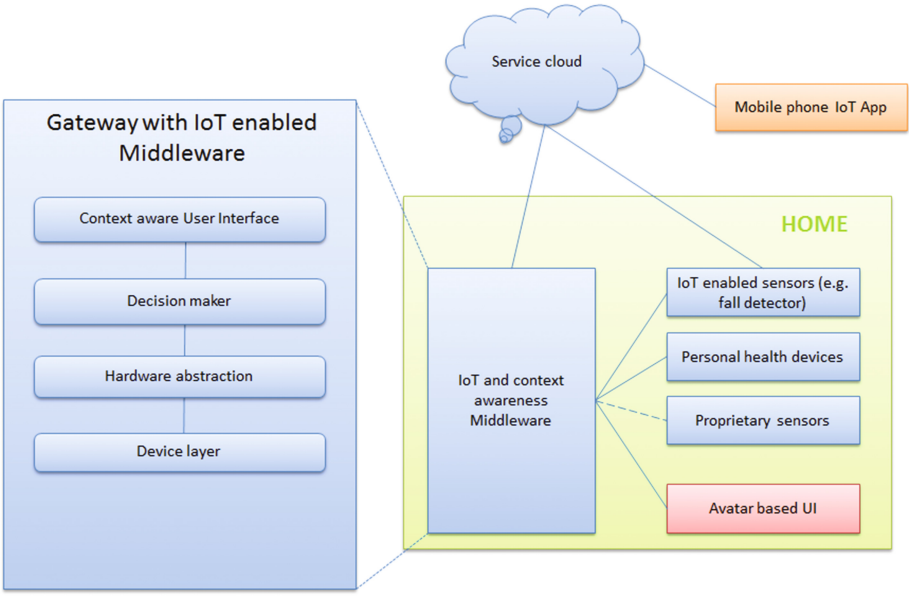

Fig. 2. Overall architecture of the solution

7 Conclusion and Future Work

The solution described in this work forms a flexible and scalable framework for various applications in the AAL and home care domain and is able to run on low-cost hardware. In addition to the original aim to collect data from the home environment, Bluetooth Low Energy based personal health devices were integrated in a modular, non-obtrusive and flexible way. With the ability to collect data from arbitrary sensors and devices, it can and will be used as a context aware middleware platform interacting with the end-user following the ubiquitous computing paradigm. Currently, HOMER platform is being further improved by integrating avatar based user interfaces and a context aware decision making module combing data from the home environment and personal health devices. A detailed architecture of the framework and how it is embedded into a home care setup is depicted in Fig. 2. A service cloud and a mobile app enables the connection to remote players like service provider and informal care givers. Furthermore, unlike mobile phones and tablets, this solution makes it easy to integrate interfaces for different transport types and communicate with sensor devices without having to worry about the underlying transport type and is always available for collecting sensor data.

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