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An Integrated Architecture for Remote Healthcare Monitoring

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***Abstract*—Remote healthcare monitoring has attracted the interest of many research projects during last years. The need to address the issue of ageing population has lead to the exploitation of modern communication and software technologies in this domain too. This is instigated by related technological evolutions such as the evolutions in sensor networks which can now support self organization. This paper presents the INCASA architecture that provides advances towards mainly two directions. To start with, by using the appropriate middleware, it manages to transform the network of devices to a network of services following a Service Oriented Architecture. In this way, it turns the implementation of applications (e.g. clinical applications) on top of the middleware to be easy and efficient. Furthermore, INCASA architecture provides an integrated solution for profiling user habits. This is particularly important in case of elderly people who tend to follow daily activities in a repeating manner. In the proposed architecture, the procedure of modeling user habits is the necessary step in order to generate alert actions in case of divergence.**

***Index Terms*— Remote healthcare monitoring, Home Sensor Network, Body Area Network, Device and Service Discovery, Service Oriented Architecture**

I. Introduction

The demographic change is one of today's major issues; ageing population is a challenge that should be faced with priority. In parallel, networked technologies focused on the healthcare monitoring sector have attained a great penetration in the ICT market during recent years and they certainly are a key factor for improving elderly people's quality of life.

There are several research activities related to remote monitoring of patients and elderly people. MobiHealth [1] is a platform allowing patients to be fully mobile whilst undergoing health monitoring. The patients wear a lightweight monitoring system - the MobiHealth BAN (Body Area Network) - which is customized to their individual health needs. Therefore, a patient who requires monitoring for short or long periods of time doesn't have to stay in hospital for monitoring. An innovative project which easy the development of health monitoring architectures is Hydra [2]. The Hydra middleware allows developers to incorporate heterogeneous physical devices into their applications by offering easy-to-use web service interfaces for controlling any type of physical device irrespective of its network technology such as Bluetooth, RF, ZigBee, RFID, WiFi. Hydra incorporates also means for Device and Service Discovery, Semantic Model Driven Architecture, P2P communication, and Diagnostics.

Based on Hydra middleware a bundle of e-health projects were developed expanding the provided capabilities. The AAL (Ambient Assisted Living) project [3], [8] is mainly addressing the needs of the elderly people, with healthcare applications built on top of the Hydra middleware, while CAALYX (Complete Ambient Assisted Living Experiment) [4], [9] is an IST project that develops a wearable light device able to measure specific vital signs. These signs are communicated in case of emergency to the personal caretaker or to the appropriate emergency service. The proposed middleware is responsible to establish and manage the communication between the portable device and the monitoring system.

Other significant ongoing research activities in this sector are: OLDES (Older people's e-services at home) [5] and TAS3 (Trusted Architecture for Securely Shared Services) [6] which is not involved directly with the healthcare domain; its significance lays in the fact that TAS3 aims to implement a generic architecture with trusted services to manage and process distributed personal information generated over a person's lifespan. The aforementioned cross-domain architecture could be very helpful in the healthcare sector where personal health parameters are collected from distributed locations and analyzed through a process that takes also into consideration medical history data.

However, previous approaches have not succeeded in integrating procedures capable of profiling user habits in the proposed solutions/services mechanism in order to implement customized intelligent multilevel alerts/ communication services for elderly people. This paper follows a completely different approach from previous efforts. It presents the INCASA architecture, which is focused on citizen-centric technologies and a services network to help and protect frail elderly people, prolonging the time they can live well in their own home. This goal is achieved by integrating solutions/services for health/environment monitoring to collect and analyze data in order to profile user habits and implement customized intelligent multilevel alerts/communication services. Data are made available to care services through a Smart Personal Platform with an embedded Habits Analysis Application which include: access policies to preserve

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privacy; planning for day-by-day activities and therapies with multiple alerts.

INCASA takes advantages of the Hydra middleware which offers web service interfaces for managing any type of connected physical device regardless of its physical layer technology, while it enhances the provided services by incorporating a number of e-health related technologies like Home Sensor Networks (HSN), Human Monitoring Sensors (HMS) and Habit Applications.

The rest of the paper is organized as follows: Section II gives an overview of the INCASA architecture, presenting the main components and their functionality. The main components, namely the Telemonitoring system, the Smart Personal Platform and the Hydra Middleware are described in more detail. Section III summarizes the parts of the overall INCASA platform. Finally, conclusions and directions for future work are given in Section IV.

II. THE INCASA ARCHITECTURE

A. Telemonitoring system

The Telemonitoring system is able to perform real-time measurements of critical metrics like skin temperature, pulse rate, heart rate etc in order to reassure immediate actions in emergency situations. It communicates via radio waves with a Base Station located in elderly person's residence. The Base Station may identify abnormal situations (e.g. thermal disorder) and inform accordingly the headquarters

Key components of the Telemonitoring system are the Body Sensor Network (BSN) and the Home Sensor Network (HSN). The body sensors are portable / wearable wireless sensors, while the HSN is consisted of environmental sensors and actuators with wireless connections too. It is worth mentioning that both BSN and HSN may include various sensors which may be manufactured by different vendors and may use different communication protocols and technologies. Furthermore, the sensor devices may operate in different radio frequencies. Consequently, it is difficult to achieve integration and self-organization of such sensors. In the proposed architecture, the use of Hydra Middleware makes possible for the sensors to work together in a single BSN/HSN through remote adaptation and reconfiguration.

B. Smart Personal Platform (SPP)

The Smart Personal Platform is an EPR (Electronic Patient Record) system able to share, collect and analyze data extracted from hospital software and present them in a patient oriented view. One of EPR's major goals is to build a continuous patient record in order for care efficiency to be improved. In Fig. 1, it is presented the data sharing procedure where it is shown the role of the EPR system.

In particular for the INCASA architecture, this solution will be enhanced to manage also the user habits learning system. The desired target is that the application will provide alerts related to significant changes in activities of daily life. For example, supposing that someone has had a significant change in sleeping, eating or toileting, this will start evaluation workflows that lead to multiple actions (like alerts or automated calls). These early indicators could be used by caregivers for early interventions, and by social and healthcare professionals for care-plan purposes or direct interventions.

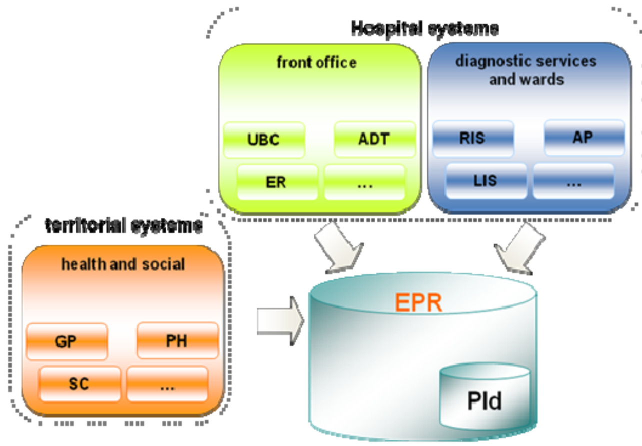

Fig. 1 EPR data sharing

C. Hydra Middleware

The developed Hydra middleware [7], [10] offers web service interfaces for managing any type of connected physical device regardless of its physical layer technology such as Bluetooth, RF, ZigBee, RFID, WiFi.

The Hydra middleware will be considered a building block for the Socio-Medical platform in INCASA architecture, to support the self discovery and self configuration of inter-connected devices. On top of the middleware, developers may add INCASA related applications utilizing device and sensor networks.

Hydra middleware takes care of selecting the appropriate software component, called proxy, which is able to perform low-level communication with each device. Moreover, it exposes device's available services as web services in a standard way, something that allows the service discovery at the local network. After local service discovery is achieved, device's services are exposed to the overall Hydra network, a P2P network, where anyone having the appropriate rights can discover and consume them. Through its unique combination of Service-oriented Architecture (SOA) and Model Driven Architecture, the Hydra middleware will enable the development of generic services based on open standards. In particular, Hydra aims at creating middleware, which operates with limited energy or memory resources.

The Hydra middleware is an intelligent software layer placed between the operating system and applications. The middleware is built of many software entities (called managers) which make possible the cost-effective development of intelligent applications for networked embedded systems. Fig. 2 shows how the different middleware managers are embedded in gateways and devices to create the SOA in which devices' services appear as web services and UPnP services. In the figure, the grey triangles, that represent physical devices, are discovered by the

Discovery Manager and software proxies take care of the communication with them.

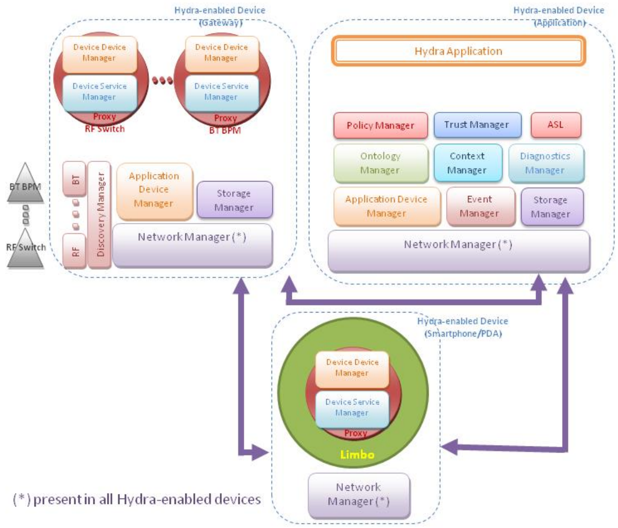

Fig. 2 Hydra managers, runtime view

In Hydra based applications, each participating entity (e.g. physical device, sensor, subsystem) can be represented as a unique web service. This transformation is fundamental for the "easy-to-use and consume" character that all Hydra implementations aim to achieve. A major novelty in the Hydra approach is that the middleware supports interconnected devices' usage both by embedding services in devices and by proxy services for devices. The middleware takes also care of handling device-dependent and network-dependent details allowing developers not to get involved with such low-level issues.

The Hydra middleware is even more responsible to establish communication in the Hydra network, route data, perform session management in the communication and synchronize the different entities that are parts of the network. A novel implementation in the Hydra middleware is the use of peer-to-peer (P2P) network technologies to identify and utilize the services available in the network, even if they are protected by firewalls or they lie behind NATs. P2P pipes are used as an alternative to Web Service communication between Hydra-enabled devices. The Hydra P2P network is illustrated in Fig.3, where devices D0-D4 are network devices classified by their processing capabilities and the communication technology they use. As already mentioned, the network devices appear to the application developer as services since the middleware exposes them in a transparent way.

In order to perform efficient and reliable network and device discovery, the middleware uses semantic description of each entity where advanced ontologies technologies like OWL and SA WSDL play a significant role. Finally, the combination of web services and ontologies techniques strengthens the system on a security point of view [11], in which major goals are confidentiality, authenticity and non-repudiation.

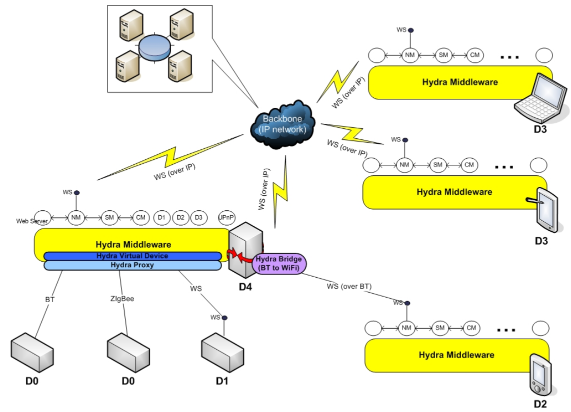

Fig. 3 Hydra connections

III. INCASA PLATFORM

The INCASA platform takes advantages of the aforementioned technologies and targets to integrate them to create an enhanced socio-medical platform able to monitor both user habits and user clinical conditions and creates a user habits model. Alerts are generated in case of anomalous situations in respect to the created user habits model.

INCASA Platform is composed by a home infrastructure and a remote service provider infrastructure.

The home infrastructure is consisted of the following parts:

- A Home Base Station enriched with the Hydra middleware. The Home Base Station automatically collects and stores sent data from body and environmental sensors. Due to the fact that Hydra middleware is enabled, various wireless communications technologies are supported including Bluetooth and ZigBee. The Home Base Station should also be able to perform basic checks and detect anomalies. On such detection, it will inform a group of people and/or the headquarters based on the defined escalation procedure. Finally, it periodically sends collected data to the headquarters for the analysis and the population of the person habits model.
- A user habit monitoring system where user's habits will be recorded through small wireless motion/contact sensors. These sensors are placed in key places such as bed and bathroom that are expected to be visited in a periodical way by the elderly person
- A pre existing domotic system which allows remote control for domestic applications

On the other end, the remote service provider infrastructure is consisted of the following parts:

- The Smart Personal Platform (SPP) able to store, retrieve and analyze the available personal data. The SPP should be able to update accordingly the dynamic habits profile of each user. Moreover, it should be able to compare current information with the already created user habits. If significant diverges are detected, the SPP will proceed on generating alert actions.

- Web services interface for consumer applications like clinical applications or statistic oriented applications.
- The integrated hydra middleware component for easy access to monitor data in case of need

The overall architecture overview of INCASA platform is illustrated on Fig.4.

Fig. 4 INCASA platform overview

IV. CONCLUSION

In this paper, the INCASA platform has been presented, with special emphasis to its network architecture and infrastructure. The crucial role of Hydra Middleware in INCASA architecture has been explained in detail. Concisely, this middleware allows the self discovery and self organization of interconnected physical devices and is responsible for exposing devices as services in the overall network. Its Service Oriented Architecture facilitates the development of applications on top of it since it hides device-dependent and network-dependent details. Moreover, the rest of INCASA platform's essential elements are presented; the Telemonitoring system which performs automatic measurements of critical variables like body temperature and the Small Personal Platform which analyzes collected data and forms each user's habits profile in order to generate alerts when abnormality is detected.

This paper presents INCASA architecture and its perspectives on building a citizen-centric technology able to protect elderly people and reinforce their autonomy. Nevertheless, it will be challenging to further evaluate the performance and the interoperability of INCASA components. Towards this effort, the impact of the different wireless communication technologies, like Bluetooth, WiFi, ZigBee etc, used in the Body Sensor Network and in the Home Sensor Network could be examined. Furthermore, since Hydra Middleware architecture is generic, it would be fruitful to propose other sectors that it could be used apart from the healthcare monitoring sector.

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