Digital Healthcare Empowering Europeans
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Internet of Things For an Age-Friendly Healthcare

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Abstract. In healthcare applications a large cohort of recent implementations utilises IoT-oriented infrastructures (XMPP) as well as smart mobile devices as communication gateways. IoT characteristics such as Ubiquitous Communication/Connectivity, Pervasive Computing and Ambient Intelligence, are all highly related to Active and Healthy Aging environments. This paper presents a new idea, that of IoT enabled devices which are directly connected to the IoT (a glucose meter is used as an example herein), complying with the XMPP messaging protocol and the incorporation of a recently released Controller Application Communication (CAC) framework for distributed, cross-platform communication. A web based exergaming platform and a disease management tool, provide the vehicles for the demonstration of the feasibility and the successful implementation and integration of the aforementioned infrastructure.

Keywords. Internet of Things, Active and Healthy Aging, Exergames, Cross device communication, Elderly care

Introduction

The continuously growing aging population over the last decades led to an equivalent increase in Ambient Assisted Living (AAL) technologies [1]. Following this evolution, physical components used in AAL have been transformed to smart components, before they ended up as connected objects [2]. Architectures and implementations in this domain utilise either Internet of Things (IoT) oriented services, like XMPP, or service-oriented architectures and intermediate gateways [3][4][5][6], based on Restful services. Due to this, the road to the Web of Things (WoT) has been open allowing developers to create applications without having specific knowledge about physical devices or networking environments [4].

In healthcare applications a large cohort of IoT implementations utilizes smart mobile devices or PCs as communication gateways. The recently introduced terms, m-health and m-health Internet of Things “m-IoT” [6], reflect the essential role of these devices in the realm of IoT. A typical m-IoT scenario includes the integration of wearable sensors, coordinated by a gateway node, typically a smartphone, capable of transmitting biosignals [3][5][6][7]. However, the sensors in these implementations are not considered as IP enabled devices, but rather as remote sensors of the smartphones. To this end, it is argued that one of the most important factors for the realisation of the

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IoT is to allow IP addresses to each of the embedded devices in the world (by means of IPv6??) [8].Some of the IoT main characteristics such as Ubiquitous Connectivity, Pervasive Computing and Ambient Intelligence [9], are all highly related to Active and Healthy Aging (AHA) environments. Monitoring health status or chronic diseases progression, wellness interventions, reminder and awareness services are examples of how IoT is involved in the promotion of AHA [9]. IoT can overcome many of the challenges, especially in acceptance and usability for the ageing population [10].

This work presents an innovative approach in the sense that the user is not required to carry a smartphone device 24x7 [11][12]. The implementation presented herein as a feasibility of the idea is an IoT enabled Glucose meter, connected directly to the Internet, contrary to the vast majority of glucose meters presented so far, which are connected to smartphones [6]; what is more, the paper describes a distributed framework for sharing sensing device data in the realm of an AHA environment. The exploitation of the proposed solution is presented by two use case scenarios. The latter illustrate how serious games could be revolutionised in this way and contribute to promoting of health self-awareness.

1. Methods

The architecture of the proposed system consists of two distinct components, namely the recently released Controller Application Communication (CAC) framework (http://www.cac-framework.com) [13] and an XMPP network. Both components align with the IoT paradigm and enable real-time communication between different entities. The CAC framework integrates multiple controllers and provides input to systems and applications such as exergaming platforms. On the other hand, medical devices, software components, disease management and elderly support services, such as decision support systems (DSS) communicate with each other using the XMPP protocol.

Figure 1. Architecture design of the proposed solution for IoT enabled AHA environment

1.1. Adoption of the xmpp protocol and its extension

XMPP, a real-time communication protocol used for instant messaging, file transfer and IoT, uses TCP as a transport layer, but can also communicate over HTTP using Bidirectional-streams Over Synchronous HTTP. In order to integrate medical devices into our system, we have adopted the Sensor Data XMPP Extension protocol (XEP-

0323) which provides a framework for sensor data communication taking into account hardware limitations of sensors and peripheral devices.

1.2. The IoT enabled Glucose meter sensor

The Glucose meter sensor consists of an off-the-self glucose meter device, the Lifescan OneTouch Vita [14], and an intermediate hardware IP ready device. The intermediate hardware is responsible for the connectivity of the glucose meter to the XMPP server by acquiring measurements of the glucose device (wired connectivity) and transforming them to XMPP (XEP-0323) compatible messages. The intermediate hardware scans the glucose meter periodically for any updated measurement. In case a new one exists, it is transmitted to the XMPP server. The user follows the usual walkthrough for a glucose measurement, without the need for additional actions.

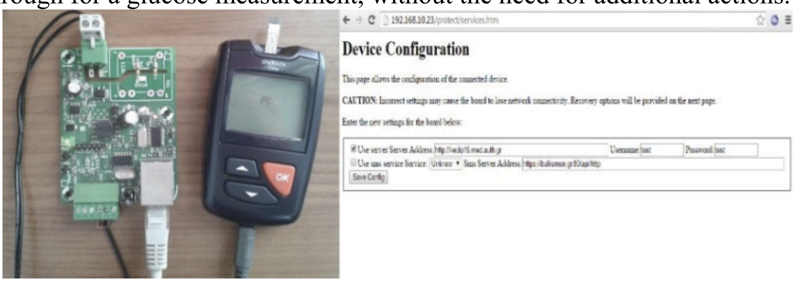

Figure 2. The glucose meter device adapted to the intermediate hardware device for XMPP compatibility (left). Configuration of XMPP server, username and password (right).

2. Results: Scenarios of Use

The USEFIL system [15] was conceived as a platform utilizing low cost, off-the-shelf sensors and devices. A set of applications, including the Disease management system and the cognitive and physical training (exergaming), were developed on top of the USEFIL core infrastructure. Elderly users are able to navigate through their own medical measurements collected by the appropriate sensor as well as to improve their wellbeing.

2.1. Physical Training

FitForAll [16] is a web-based exergaming platform which utilizes IoT in terms of controllers though the CAC framework. This framework integrates diverse controllers such as Wii remote, Wii Balance board, Microsoft Kinect, Neurosky Mindwave and communicates the data to multiple software components [13].

Additionally, the exergaming platform communicates with an XMPP server using Strophe.js, an XMPP library for JavaScript, in order to gain access to any currently available medical measurement device, such as the glucose meter. Commonly, a diabetic senior regularly measures her blood glucose levels. The exergaming platform takes advantage of the IoT enabled glucose meter by prompting the user to postpone the exercise until glucose in blood is in the appropriate levels. In contrast to the previous version of FitForall, where the elderly had to manually communicate their heart rate to the computer (through a touch screen), this approach enhances unobtrusiveness through the imperceptible manipulation of sensor data.

In our approach, prior to starting an exergame, the system checks if a glucose meter is connected to the XMPP server. If it is connected, then it makes a request to the glucose meter and in the case of a successful response the measurement is shown to the user along with some suggestions. For example, if the blood glucose level is too high, a message is shown to the user suggesting them to continue the exercise later on. Moreover, it requests for a new glucose level if the date of the last measurement exceeds a defined time interval. Furthermore, FitForAll incorporates provisions towards increasing the seniors' health self-awareness by rewarding the seniors with game achievements when they have a health measurement as part of the game.

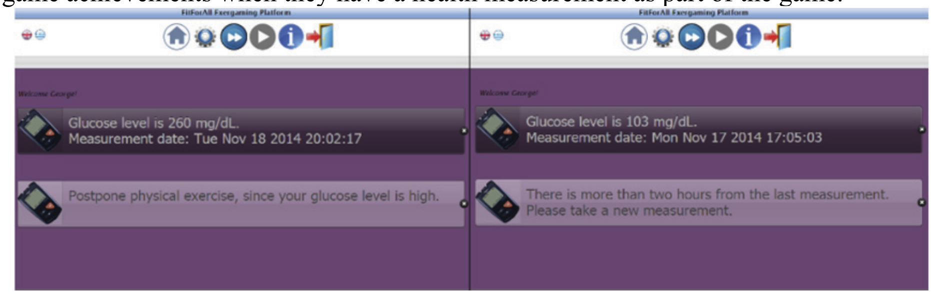

Figure 3. In case of a diabetic user, the FitForAll exergaming platform consults the glucose device in order to postpone physical exercise or to suggest a new glucose measurement (if the existing one is too old).

2.2. Disease management

On the server side, a service is constantly connected to the XMPP server and collects the users' available measurements by querying periodically (or listening to incoming messages) the medical devices through XMPP messages. The implemented service is responsible for pushing the measurements to a database in order to make them accessible by the USEFIL components. The USEFIL DSS [17] was designed as a spatio–temporal model consisting of artificial intelligence methods manipulating data related with user activity and physiological classification. Various soft computing, probabilistic and data mining techniques are applied on the sensors' signals/data to provide decision support and personalized recommendations for improved lifestyle. An indicative example is presented in Figure 4, where data gathered by the implemented IoT-enabled glucose meter are uploaded to the central USEFIL repository, allowing for their visualization in terms of health evolution and interpreted by the DSS as personalised suggestions for improved lifestyle.

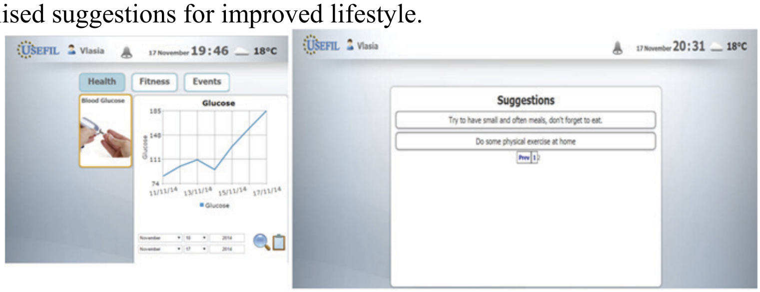

Figure 4. Personalized recommendations for improved lifestyle according to the measurements.

3. Discussion

This paper describes innovative efforts to foster IoT concepts towards the development of applications for the promotion of Ageing well and Active Ageing, by introducing an unobtrusive IoT infrastructure. The main building blocks of the latter have been an IoT-enabled glucose meter device, the extension of XMPP messaging protocol and the incorporation of the CAC framework for distributed, cross-platform communication. For purposes of demonstrating the feasibility of the approach, two applications, an exergaming platform and a disease management tool, were used as test case scenarios. Further scenarios, applications and device exploitations are underway to accumulate evidence for the successful implementation and exploitation of the infrastructure.

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