Prototype of a Medical Gateway for Personal Healthcare Systems - Design and Implementation

Mitko Petrov Shopov, Galidiya Ivanova Petrova and Grisha Valentinov Spasov

Abstract **The paper presents design and implementation of a medical gateway prototype for personal healthcare scenarios. The gateway is based on an embedded platform with Linux-based OS and architecture for device integration. Presentation driver for access to HealthVault healthcare platform is presented in the paper. The integration of the gateway with external services and healthcare information systems is based on a REST web service interface. The integration of different medical sensors is based on device drivers implementing CNDEP profiles.**

Keywords – **Personal Healthcare Systems, Medical Gateway, Digi DIA, CNDEP Profiles, Microsoft HealthVault, REST web services**

I. INTRODUCTION

Recent advances in Information and Communication Technologies (ICT) and more specifically in wireless communication technologies and mobile computing have driven new directions in the development of e-Health sector. New and emerging concepts like mobile health (m-Health) and Personal Health Systems (PHS) are expected to revolutionize the way the healthcare services are delivered. They are opening the way for new healthcare and wellness applications by giving the individual person a more central role in its treatment and prevention process, and by giving healthcare professionals an access to data, collected under natural activities and environment.

II. BACKGROUND

A. Personal Healthcare Systems

The PHS are concerned with the individualization of prevention, treatment and well being procedures available through the healthcare system. The patient is placed in the center of the health delivery process. The main their goal is to bring continuity of care at all levels of healthcare delivery through applications for remote monitoring and remote management, spanning from location, to ambiance, and time. This continuity of care is a prerequisite for the delivery of preventive, personalized and citizen-centered health care (figure 1) [1], [2].

B. Body Sensor Networks HUB

Body sensor networks (BSN) are one of the key PHS's components. They often utilize a star topology with a clearly separated master/slave roles. The master node – BSN HUB (figure 1) is a device characterized with higher processing and communication capabilities that acts as a coordinator for the network. It performs multiple functions including sensing, fusing data from multiple sensors, serving user interface, and bridging BSN to higher-level infrastructures [3], [4], [6].

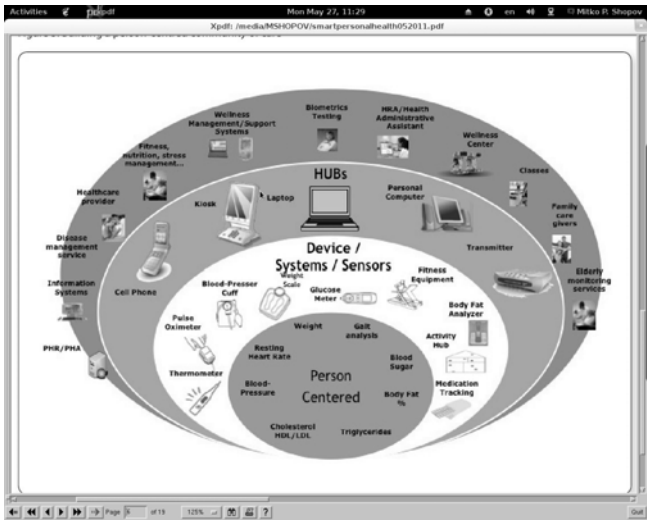

Figure 1. Person-centered healthcare [1]

The BSN HUB is responsible for a number of tasks: transparent interface to BSN, interface to the user, and an interface to the medical server, performing high-level data processing, analysis and temporary local storage. The interface to BSN should deal with network configuration and management. The configuration tasks include sensor node registration, initialization, customization, calibration, and setup of secure communication. The management tasks include channel sharing, time synchronization, data retrieval, processing and fusion. The HUB can also perform a local reasoning to determine user's health status based on data from multiple sensors and provide feedback through a user-friendly and interactive graphical or audio interface. Finally the data is communicated to a Medical server over wireless mobile networks or Internet [4], [5].

C. Healthcare Web Portals

The Web is widely used as an universal access to information resources and it could be used to enable new directions in development of e-health products. Web-based, portal technologies and multi-tiered architectures have proven its advantages in the ubiquitous access to information in device independent manner and provide many benefits over traditional client/server architectures [7], [8]:

M. Shopov and G. Spasov are with the Department of Computer Systems and Technologies, Faculty of Electronic and Automation, Technical University – Sofia, branch Plovdiv, 25 Tsanko Diustabanov Str., 4000 Plovdiv, Bulgaria, e-mail: mshopov@tu-plovdiv.bg, gvs@tu-plovdiv.bg

G. Petrova is with the Department of Electronics, Faculty of Electronic and Automation, Technical University – Sofia, branch Plovdiv, 25 Tsanko Diustabanov Str., 4000 Plovdiv, Bulgaria, e-mail: gip@tu-plovdiv.bg

- Installing and deploying the user interface is virtually instantaneous - only the Web interface in the middle tier needs to be updated ;
- Without a client-side user interface, it is easier to deploy, maintain, and modify applications no matter where the client is located ;
- Instead of managing multiple applications everything is managed under one portal ;
- Satisfy clinicians' requirement for one interface.

An example of healthcare web portals are Microsoft HealthVault (http://www.healthvault.com/), PatientLikeMe (www.patientlikeme.com), Dossia (www.dossia.com), and Google Health (www.google.com/health – discontinued since 2012). They allow individuals to store and manage all of their health information in one central place and give them access to various services and features like: build on-line health profiles, import medical records from hospitals and pharmacies, share health records, and explore third-party health services.

III. Prototype of a Medical Gateway

The prototype of a medical gateway is bases on the hardware platform ConnectPort X4 [10]. It offers Ethernet, Zigbee, WiFi communication interfaces and USB/RS232 serial interfaces. It can be configured to route and filter the traffic between different networks. The gateway comes with a custom version of Linux-based operating system and a python-based framework iDigi DIA (Device Integration Application) [10].

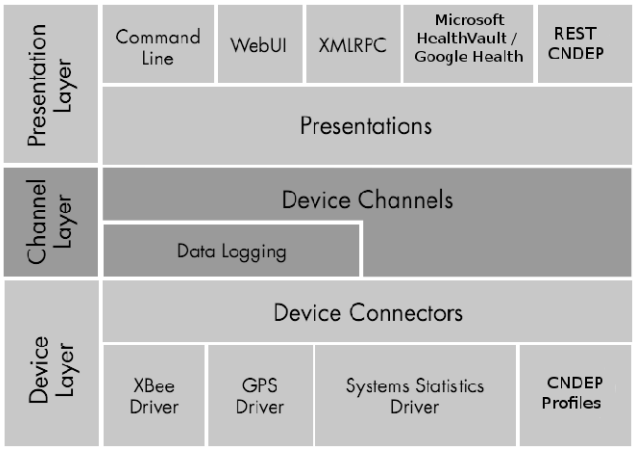

Figure 2. Device integration architecture [10]

DIA framework provides the core libraries and functions for remote data acquisition, control and presentation between devices and information systems. Its functionality is distributed in three layers as shown on figure 2. The function of device layer is to provide connectors that extract real-world data, represent it as a set of properties and publish them to the appropriate channel on the next layer. Channel layer provides and manages publish-subscribe infrastructure that gives ability to create, remove, and publish to a channel, read from channel and subscribe for channel changes. Presentation layer provides the interface with the outside world. It could be as simple, as a telnet connection or a form of web service interface and even device cloud integration [10]. Using DIA as a basis three components are designed and implemented – device drivers for communication with BSN; presentation driver for communication with remote health portal; and application for remote management of the gateway.

A. Sensors integration

The integration of heterogeneous sensors within BSN is based on the application layer protocol CNDEP Profiles [9]. The protocol defines the information model of the communication with sensors and uses XML-based profiles. The introduction of profiles in protocol design aims at providing flexibility and scalability by allowing embedded applications' designers to easily customize and optimize the protocol to their needs. The XML description of the profiles makes it easily processed and written, and along with XML validation makes the protocol definition more error-proof and suitable for automatic generation of the code of its implementation files [9].

B. Healthvault presentation driver

For the synchronization of collected data within MS Healthvault portal a presentation driver is implemented. It is designed as a library model with the following functional groups:

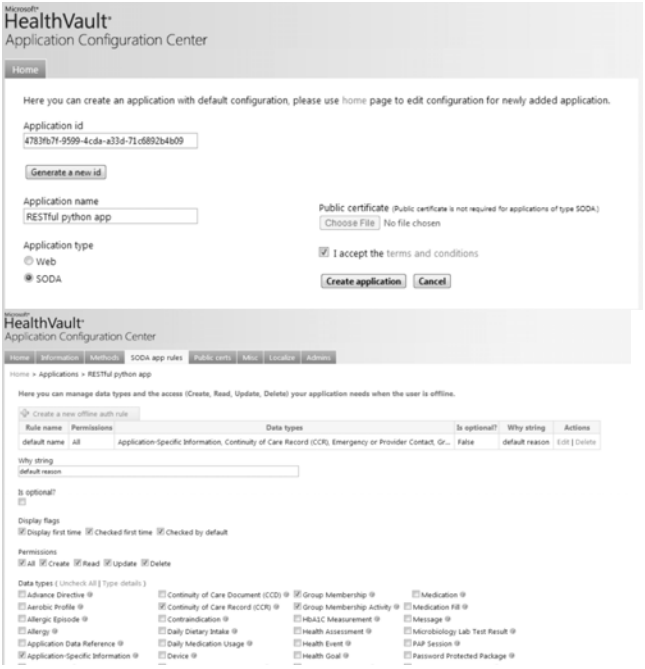

Figure 3. Healthvault authentication and permissions

- Initialization of remote profile connection – authentication and authorization;
- Initialization of publish-subscribe infrastructure and association of sensors-channels-profile relations;
- Formation of corresponding CCR records and their synchronization within remote patient profile.;
- API interface for management of the presentation driver from external modules (including the application for remote management of the gateway).

Like most public health portals Microsoft HealthVault provides web services interface. The presented presentation driver uses Raw XML API Reference (msdn.microsoft.com). The authorization of the presentation driver to access patient profile uses SODA (Software on Device Authentication) – it requires the user to generate new id/password pair that will be used to obtain authentication token without giving the application the actual user credentials (figure 3).

The full functional scheme of the Healthvault presentation driver is given on figure 4.

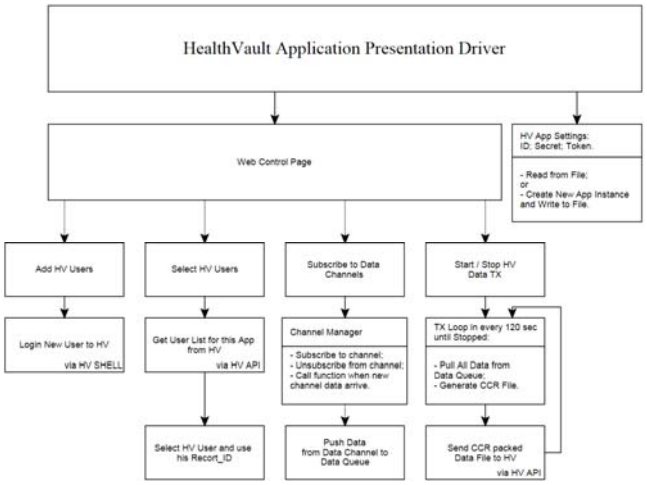

Figure 4. Healthvault presentation driver

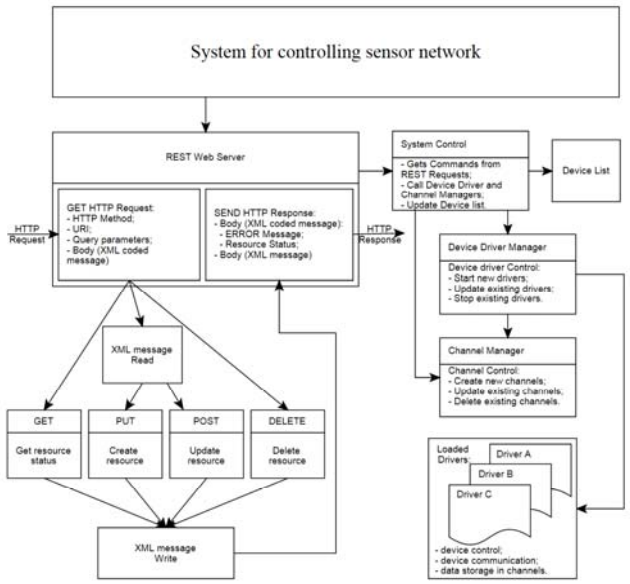

Figure 5. Remote management application

C. Remote management interface

The presented prototype of a medical gateway does not provide interface for local configuration and management. However, it provides an interface for remote configuration and management of BSN, dynamic loading and configuration of device drivers, and dynamic loading and configuration of presentation drivers for remote portals. The interface is based on REST web services and could be used for management of the gateway from a computer in a LAN or for its integration in high-level information systems. The following functionality is provided:

- add a new / remove existing sensor – start and configure / stop corresponding sensor driver;
- Channels management – dynamic creation and association of channels and sensor drivers;
- Selecting of remote health portal/server, dynamic loading its presentation driver and configuring it parameters

The actual functional scheme of the application for remote management of the medical gateway is presented on figure 5.

IV. CONCLUSIONS

Personal Health Systems are envisioned as the future of healthcare delivery process. The individual citizen will have the provisions and handles to be self-responsible for his own health and to manage the health delivery process. On the other side, physicians will be provided with more accurate data from continuous monitoring of patients in their natural environment and will be able to give more accurate prescribes. This will improve the overall quality of healthcare while reducing the costs. ICT technologies are the base for these changes by introducing the new achievements from the recent years in the domain of healthcare.

The paper presented the design and implementation of a medical gateway's prototype, that is one of the key components of a PHS. Its design is based on an open communication technologies and interfaces for a better integration with existing and future sensor networks on one side and healthcare information systems on other.

ACKNOWLEDGMENTS

The presented work is supported by National Science Fund of Bulgaria project “Modern approaches in the design of clinical information system for observation of pediatric surgery diseases. (PedSurgCIS)” under contract DVU-10-0100/2010 and within the framework of the contract № ИУНФ 14000.

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