STANDARDIZED DATA ACCESS FOR TELEMEDICINE DEVICES

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Abstract: Currently, there is a great number of telemedicine devices that can be connected to a computer in order to collect medical data of a patient, but these devices usually use proprietary protocols with a low level of interoperability. This paper proposes the use of a standardized protocol like UPnP to enhance the diffusion and utilization of a telemedicine device. This work presents an UPnP wrapper that allows announcing, discovering and managing of those telemedicine devices into an UPnP network. Additionally, the integration of this wrapper into an OSGi service platform allows the use of a telemedicine device by other services/applications that can need the medical data.

1 INTRODUCTION

Telemedicine is growing fast for different reasons as the progressive increase of dependent people (elderly or disabled people) or the need of reduce the cost of hospitalization. The integration of key healthcare actors is required to offer an efficient service but these systems often lack of adequate interoperability which slow down the acceptance and usage of the system. Additionally, ehealth applications and technologies are usually proprietary and unreasonably complex for embedded systems.

For example, John is 80 years old and lives with his son, Benn, who is 55 years old. John has been sent to Benn's home after an operation but he has to be visited by a doctor. As some of the visits are only to take different measurements of his state, it has been decided to provide some telemedicine devices that, with the help of Benn, John has to use to take that measurements and automatically send it using an Internet connection. The set of devices includes a thermometer, a blood pressure monitor and a personal scale. Additionally, there are some devices to create a videoconference between patient and doctor when it is necessary. All of them use different protocols to communicate with a computer where has been installed different applications to manage those devices. Benn is familiarized with computers and Internet but the installation of new software and devices is too complex for him.

Therefore, we have an scenario where lots of devices and protocols, some of them proprietary, appear, making the interconnection and interoperability very difficult. Our approach describes a system architecture that reduces complexity combining a central management device with a service platform to integrate different telecare services. The main service of this architecture will be an UPnP (UPnP Forum, 2010) wrapper that provides transparent connectivity and discovery of telemedicine devices.

According to the description of our approach, the main device of the architecture will be the Residential Gateway (RGW) (Hofrichter, K 2001) that provides connectivity between Internet and the local network and provides a place for installing the OSGi service platform (OSGi Alliance, 2010), which provides an execution environment as well as a remote control architecture for services.

Figure 1 shows a scenario that presents all the elements involved in our work and includes the patient surrounded by multimedia devices for videoconference and the eHealth equipment for monitorization, and, as a central control point, the

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RGW with the OSGi platform. This service platform includes services for health data transmission, videoconference and other not related. However, the service that is in the target of this paper is a service for wrapping telemedicine devices to serve them in an UPnP network.

The wrapper consists of an OSGi service that creates different UPnP devices for each telemedicine device managed by the residential gateway. The service has to announce each device and provides the information to communicate a telemedice device with those that requires their data. This data are encapsulated following medical standards like HL7 (Hutchison, A. et al., 1996) and the ISO/IEEE Health Informatics (ISO/IEEE, 2004).

In resume, we propose an architecture for a home ehealth system based on OSGi that provides capabilities to integrate different telecare, telemedicine and home automation services for dependent people in a RGW. This system provides transparency of installation and utilization using the widely use UPnP protocol and medical data transmission standards.

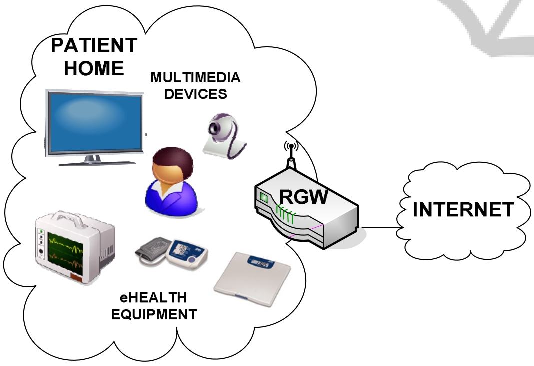

Figure 1: Environment description.

The next sections are organized in the following way: Section 2 presents the state of the art as well as protocols and standards. Our proposal is presented in Section 3 while Section 4 describes implementation details and Section 5 shows the testbed and results obtained. Finally, the last section concludes the paper and gives some future outlook.

2 STATE OF THE ART

This section presents the work and research lines related to telemedicine and similar developments followed by a brief introduction to the technologies and standards used in the system.

2.1 Related Work

Healthcare is a very important topic as reflects the high number of projects that describes a telemedicine environment and solves related problems. A brief sample of this projects are HEALTHMATE (HEALTHMATE, 2010), Personal intelligent health mobile systems for Telecare and Teleconsultation, TELECARE (TELECARE, 2010), A multi-agent tele-supervision system for elderly care or PIPS (PIPS, 2010), Personalized Information Platform for Life and Health Services. They provide different solutions but they use to work with compatible devices and proprietary solutions.

There are some works that attempt to provide a non proprietary solution defining a generic architecture to interconnect telemedicine devices. This is the case of (TIA, 2003), (Parkka, J. et al., 2002) and (Hui-Bing, Z. and Jing-Wei, Z. 2009). All of them describe architectures to provide a homogeneous management system. All work do not present a definitive solution because they are not oriented to telemedice devices or because they do not define the kind of services and data that an UPnP telemedicine specification has to provide. Apart from those work there are other ones that present a complete solution for the integration of different telemedicine devices. Wen-Wei, L. and Yu-Hsiang, S., 2008, presents a solution to manage zigbee telemedicine devices as UPnP devices but it is limited to the zigbee protocol and to a subset of telemedicine devices. Toninelli, A.; et al., 2009, presents a solution based on the MIDAS protocol that is a non standard protocol.

To end this section and justified the use of UPnP and OSGi to provide interoperability, as well as the ones mentioned before, it is possible to cite Reina, Á. et al., 2009) and (Martinez J. et al., 2007). Both present solutions for the management of different devices using UPnP and OSGi but in different environments.

2.2 Technologies

The main technologies describe in this section are related to the health informatics standards, the OSGi framework and the UPnP standard.

2.2.1 Health Informatics Standards

Home telecare requires that patient data must be transmitted following messaging standard. Currently, HL7 (Hutchison, A. et al., 1996), (Hammond, W. E., 1993) is a widely applied protocol to exchange clinical data that provides open source tools like (HAPI, 2010), (Mirth Corp., 2010).

Furthermore, there is a standard under development, the ISO/IEEE 11073 (also known as x73) standard (ISO/IEEE, 2004), to transmit medical information among devices, but there are hardly eHealth devices yet in the market supporting the standard.

2.2.2 OSGi Framework

The OSGi framework (OSGi Alliance, 2010) is a Java-based open architecture for network delivery of managed services. Services are added through software components (bundles). The platform carries out a complete management of bundles' life cycle: install, remove, start, stop and update.

2.2.3 UPnP Standard

The Universal Plug & Play (UPnP) (UPnP Forum, 2010) protocol is used to exchange services between the devices attached to a local network (LAN) and a control point (CP). An UPnP network can be deployed over any kind of TCP/IP network, including the most common access technologies like WiFi or Ethernet.

Additionally to this specification, the UPnP Forum has release a document with the definition of a security (UPnP Security Ceremonies, 2009).

3 UPNP/HL7 WRAPPER FOR TELEMEDICINE DEVICES

The objective of this work is to describe a wrapper that allows the integration of any kind of telemedicine device into a common network to provide interoperability. For this reason, UPnP has been chosen because of its capabilities of autodiscovery, autoconfiguration and adaptability as well as being a well known standard. This protocol is combined with HL7 to provide a medical data structure and management. This section shows the software architecture defined and the hardware architecture where the software is deployed.

3.1 Type of Devices

As it is depicted in Figure 2, the working environment is composed of four types of devices: non-UPnP telemedicine devices connected directly to the RGW (USB, RS-232, Bluetooth, …) or using the Home Network, UPnP telemedicine devices, UPnP Control Point (Mobile, Tablet PC, …) and the RGW which acts as the coordinator device

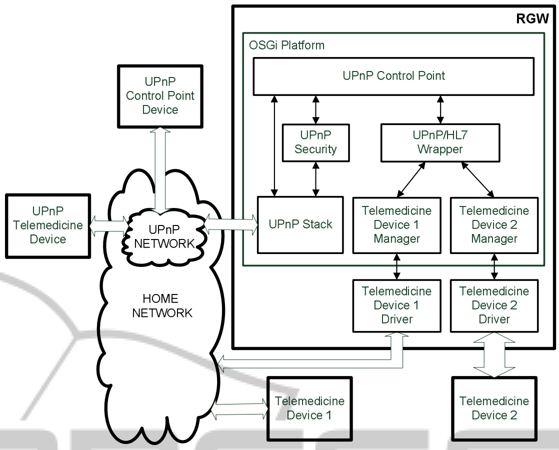

Figure 2: System Architecture.

3.2 UPnP Wrapper and Medical Data Management with HL7

The UPnP/HL7 wrapper is the main part of this work. It is in charge of mapping the non-UPnP telemedicine devices that can be accessed from the RGW, the interaction with the modules that communicates with the telemedicine devices, providing an easy way of accessing data for the internal control point and announce the telemedicine devices in the UPnP network as well as manage communications with devices that want to use data of the devices supported by this system.

This medical data follow the HL7 standard in order to be integrated and exchanged using UPnP. It enables the communication with the largest possible number of Electronic Health Record (EHR) servers, making possible the use of our telemedicine platform with many providers involved in patient care. Our approach follows the described De Toledo, P. et al., 2006.

3.3 Telemedicine Device Managers

These modules are in charge of managing the communications with the medical devices in a middleware-compliant way (OSGi bundle in case of the proposed architecture). They must be provided by the device manufacturer who owns the knowledge about how they work (data types, acquisition methods, sampling modes, etc.).

A common interface between the telemedicine device managers and the wrapper is needed to read the device descriptive information like type of measurements, units, bounds and sampling frequency . Afterwards, an instance of a UPnP device that represents such telemedicine device in the home network can be created.

3.4 System Security

Medical data is highly sensible so that discovery of devices and distribution of data have to be done in a secure manner. For that, a module based on the UPnP definitions has been defined. This module encrypts data generated by the wrapper before sending any device description.

4 UPNP TELEMEDICINE DEVICE DEFINITION

The UPnP allows the definition of different devices depending of the requirements of each situation, and additionally, it defines some basic devices. As there is not a standard definition for telemedicine devices, one has been developed one for this work.

This proposal states how to describe an UPnP telemedicine device and the services provided.

4.1 Device Model

Two types of devices are covered by this model depending on the way of collecting data. On-demand devices that collect data sporadically for example the temperature or the weight of the patient, and event-triggered devices that continuously monitor the patient.

Table 1 shows the devices and their services. OnDemandTelemedicineDevice:1 communicates with the on-demand devices and has 4 services named to start or shutdown the device, to access the buffered data and to access the measurement units.

Table 1: Devices and services.

Device Type	Service Type	Service ID
OnDemandTelemedicineDevice:1	SwitchPower:1	SwitchPower
	GetMeasurement:1	GetMeasurement
	GetUnit:1	GetUnit
Event-triggeredTelemedicineDevice:1	SwitchPower:1	SwitchPower
	StartMeasurement-Stream:1	StartMeasurementStream
	StopMeasurement-Stream:1	StopMeasurementStream
	GetUnit:1	GetUnit

Event-triggeredTelemedicineDevice:1 service differs with the previous one in the way of collecting data. In this case it is needed to start and stop the measurement stream.

4.2 SwitchPower Service Description

This service defines a basic power switching for telemedicine devices. Table 2 shows the State variable for this service which is in charge of storing a value of false to request for a power-off or true to request for a power-on state. This variable has to be monitored to detect changes.

Table 2: State variables for SwitchPower service.

Variable Name	Data Type	Allowed Value	Events
Status	boolean	true/false	YES

Finally, the actions associated with this service are listed in Table 3. These actions respectively write and read the status state variable.

Table 3: Actions for SwitchPower service.

Name	Arguments	Direction	Associated Variable
Set-Status	NewStatus-Value	IN	Status
Get-Status	RetStatusValue	OUT	Status

4.3 GetUnit Service Description

This service defines the type of value managed by the device. A datum is defined by a name, the number of bytes needed to store one measurement, and a range where this datum moves. Table 4 shows the list of variables associated with this service requiring name, size and minimum and maximum.

Table 4: State variables for GetUnit service.

Variable Name	Data Type	Allowed Value	Events
Name	string	n/a	NO
Size	int	>0	NO
MinValue	float	n/a	NO
MaxValue	float	n/a	NO

As the variables described above only depend on the specific device they cannot be changed so the allowed actions for the service GetUnit, see Table 5 are used to read the values of the state variables

Table 5: Actions for GetUnit service.

Name	Arguments	Direction	Associated Variable
Get-Name	RetName	OUT	Name
Get-Size	RetSize	OUT	Size
Get-Min-Value	RetMinValue	OUT	MinValue
Get-Max-Value	RetMaxValue	OUT	MaxValue

4.4 GetMeassurement Service Description

GetMeasurement provides data obtained by the intervention of a patient. This data is stored in the telemedicine management bundle till is required by a UPnP device. The state variables for this service are described in Table 6. The variable Values is an array of floats that stores values while the variable Dates stores the instant when those values were captured. MaxElements and CurrentElements determine the maximum and current number of values stored.

Table 6: State variables for GetMeasurement service.

Variable Name	Data Type	Allowed Value	Events
Values	set	>= MinValue, <= MaxValue	NO
Dates	set	Dates, format: yyyymmdd-hh:mm:ss	NO
CurrentElements	int	>= 0, < MaxElements	NO
MaxElements	int	n/a	NO

Table 7 shows the actions available for this service. They provide a way of accessing to the stored values getting the value (getValue) and the associated date (getDate). These methods always return the oldest values erasing them from the internal buffer. GetCurrentElement provides the number of elements in the buffer.

Table 7: Actions for GetMeasure service.

Name	Arguments	Direction	Associated Variable
GetValue	RetValue	OUT	Values
GetDate	RetDate	OUT	Dates
GetCurrent-Elements	RetCurrent-Elements	OUT	Current-Elements
GetMax-Elements	RetMax-Elements	OUT	Max-Elements

4.5 StartMeassurement Service and StopMeassurement Description

These services are related with the event-triggered devices which are constantly generating measurements. Values are generated in the physical device with a certain frequency and send to the device manager with the same rate. MinRate and MaxRate determine the limits of the Rate one. Table 8 shows detailed information of the state variables.

Table 8: State variables for StartMeassurement service.

Variable Name	Data Type	Allowed Value	Events
Values	set	>= MinValue, <= MaxValue	YES
MinRate	float	n/a	NO
MaxRate	float	n/a	NO
Rate	float	>= MinRate, <= MaxRate	NO

The actions for these services are resumed in Table 9. They allow starting and stopping the acquisition process as well the setting of rate.

Table 9: Actions for StartMeassurement service.

Name	Arguments	Direction	Associated Variable
StartCapture	n/a	n/a	n/a
StopCapture	n/a	n/a	n/a
GetMinRate	RetMinRate	OUT	MinRate
GetMaxRate	RetMaxRate	OUT	MaxRate
SetRate	NewRate	IN	Rate

4.6 Errors Considered for all Services

Table 10 shows a compilation of all the errors that can be returned by the system in case of failure.

Table 10: System error compilation.

Error Code	Error Description	Description
401	Invalid Action	See UPnP Device Architecture section on Control.
402	Invalid Args	
403	Out of Synch	
501	Action Failed	

5 RESULTS

Currently, we have developed and tested a prototype with the functionality described above. First experiments are being implemented in a laboratory with a simulated RGW and a blood pressure monitor and a personal scale.

The RGW is running in an embedded computer with limited resources using an Intel Pentium Celeron CPU, 512 MB memory and Debian Linux. Apache Felix (Apache Software Foundation, 2010) an OSGi R4 Service Platform compliant implementation released under an open source license has been chosen as service platform.

The software made for this work includes a Telemedicine Device Manager that communicates with the eHealth equipment via Bluetooth and the UPnP/HL7 Wrapper. UPnP development is based on a branched version of Cybergarage (Satoshi, K., 2010) Java libraries. HAPI, (HAPI, 2010) an open source libraries, are used to implement the HL7 part of the wrapper following the HL7 version 2.6 standard.

6 CONCLUSIONS AND FUTURE WORK

An "UPnP/HL7 wrapper" for providing interoperability in an e-health environment has been presented and developed. Our approach is based on well-known standards as OSGi, UPnP and HL7. It supports discovering medical devices that use different protocols as well as the management of the health data provided by those devices. Additionally the presented architecture is open to incorporate future devices.

Future work is directed in three ways. The first working line tries to increase the functionality of the system incorporating home sensors. The second line of action has relation to the usability of the application, so it is needed to test the interface with real patients. Finally, UPnP defines a security protocol module that has to be implemented.

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