Monitoring Architecture to collect measurement data and medical patient control through mobile devices

Vladimir Villarreal , Gabriel Urzaiz , Ramon Hervas , Jose Bravo
Technological University of Panama, Panama, Republic of Panama
Universidad Anahuac Mayab, Merida, Yucatan, Mexico
MAmI Research Lab, University of Castilla-La Mancha, Ciudad Real
vladimir.villarreal@utp.ac.pa, gabriel.urzaiz@anahuac.mx, {ramon.hlucas,jose.bravo}@uclm.es

Abstract—**Patients constant monitoring is considered one of the most relevant aspects in healthcare. The development of a framework to communicate information between mobile and biometric devices allows constant monitoring of the patient, is viewed as a solution to healthcare issues. In this paper, we define an important element in framework design like that: a group of ontologies called MoMOntology that represent the ontologies of mobile monitoring process and allow collecting data from biometrics devices. An overlay-based solution is implemented between network elements in order to build an efficient and highly functional communication platform. In order to develop mobile monitoring applications, we define a MobiPattern for each module generation; and finally, we develop a framework compounded by an application for the patient on the mobile phone and an application for doctors on the personal computer.**

Keywords- MobiPattern, Mobile Monitoring, Development Framework, MoMOntology Definition, Application Development, Mobile Visualization.

I. INTRODUCTION

In order to facilitate people lives, we are working [1] [2] on a mobile monitoring system which allows patients to have a constant control of their vital signs tendency as well as direct communication with their doctor. Furthermore, we aim to educate these people in their disease; so that, we are elaborating an educational component meant to allow them to know more about the disease and how to make their daily routine more comfortable.

The goal of this work is create architecture for the development of patient's mobile monitoring applications of any disease.

In order to improve the communication between patients and doctors, this architecture provides additionally, continuous patient monitoring and supports an automatic architecture of each patient for the individual profiles, self-control and education modules for their condition. This architecture is compounded by 3 important elements: patient profile, modules definition, and the communication structure.

First of all, the profile defines each patient's characteristics. The architecture defines initially a common structure for every patient´s data (ID, Name, Address, Phone Number, and others). Next, the generated data of the common structure are customized for each patient´s profile, which can correspond with each patient's measurements data (disease, doctor, and others).

Secondly, the architecture allows definition of all modules which will be deployed, via pattern definition; these patterns establish relations among each module and they are part of the required data of the individual patient profile. Modules information is defined by patterns embed in the individual profile of each patient. The modules definition, the relations among all of them, and the individual profile, make possible the generation of the applications for the doctor and the patient in a mobile phone.

In third place, the communication structure defines the communication platform to enable functionality of the measuring devices for each kind of condition, the tendencies management and the doctor and patient modules.

An overlay-based solution is implemented between elements in the network (mobile phones, desktops, servers, etc.) in order to build a solid and versatile communications platform. The measuring device will send via Bluetooth to the local device (mobile phone) the data collected from its sensor. If the mobile phone doesn't have this communication technology, the patient writes through the device keyboard. However, most of the other devices in the network may be connected by means of different technologies. The communications platform allows the connection of a wide variety of devices and technologies, and serves also to perform additional functions, such as the possibility to perform some processing in the network that may help to improve overall performance.

II. BACKGROUND RESEARCH

Some research's seeks to provide a solution to each problems related to diseases control patients. Some in the mentioning's field and others in the medical self-control.

METABO [3] is a diabetes monitoring and management system which aims at recording and interpreting patient's context, as well as, at providing decision support to both the patient and the doctor. In our architecture the information is obtained through the ontologies. This information is use to generate future information based in the information saved in the patient profile (diet, pharmacological prescription, etc.)

A mobile u-healthcare system [4] with multiple physiological signs measurement capability in real time is designed and developed. Our architecture has the capability to capture the measurement from the biometric device through the mobile phone in real time. This information is use to update the different control modules in the application.

In [5] aims at extending home care services delivery by introducing a novel framework for monitoring the patient's condition and safety with respect to the medication treatment administered. We are development diet, suggestions, alert, education, medical treatment modules with exercises and medication self-control.

In [6] believe that in the use of rule-based paradigm within the network for a mental health setting. And, In [7] present a tool for evaluating the health of patients who suffer from mobility-affecting chronic diseases such as MS, Parkinson's, and muscular dystrophy is assessment of how much they walk.

III. MoMo FRAMEWORK MOTIVATION

In order to facilitate people lives, we are working on a mobile monitoring system which allows patients to have a constant control of their diseases as well as direct communication with their doctor.

Patient monitoring represents one of the key elements in the progress and control of his illness. This monitoring should offer patient and doctor constant data regarding the disease´s status (vital signs, pulse glucose, etc) so that, the doctor can accordingly readjust the initial treatments and prescriptions.

This is our motivation in developing framework architecture for patient monitoring via mobile phone. Mobile phone is characterizes the technologic advance majorly used and which we execute more than a 60% of our daily activities along.

For this work, we are defined a group of ontologies called MoMOntology that represent the ontologies of mobile monitoring process and allow to collect data from biometrics devices. To facilitate the communication between elements we are defined layers for each device (mobile phone, biometrics devices and server). To development a mobile monitoring applications we are defined a MobiPattern for each modules generation.

A. Using MoMONTOLOGY to collect data

We are development a complete ontology about the information of diseases, patient profile, mobile devices, modules control, and other called MoMOntology (Mobile Monitoring Ontologies).

The **MoMOntology** is formed by 3 key elements:

- *PatientProfile*,
- *ModuleDefinition*, and
- *CommunicationStructure*.

PatientProfile defines each patient's data; *ModuleDefinition* elements generated according to each patient's profile and *ComunicationStructure* define a communication between mobile devices and the framework. As show in the figure 1, the doctor and the patient are the actors who interact with the framework.

The patient has defined a profile that offers information to the framework (classified under *CommonProfile* and *IndividualProfile* ontologies). This individual profile allows the modules definition (*MedicateTreatment*, *ActiveCare* and *ClinicalSituation* ontologies).

In addition, the modules definition obtains information of Diseases and *Food* Ontologies. These ontological elements is part of the architecture of Mobile Monitoring, which then they will be used for the patterns and relations definition.

The patient uses a glucose meter "*GlucoTel*" with Bluetooth communication, which transfers the value of the blood glucose to the mobile phone "*GeeksPhone One*" with an Android 1.5 operating system.

The glucose measurement is sent to the mobile phone, which interprets it according to the ranges established for diabetes and shows the recommendations and suggestions for the patient. It is here that the mobile application starts interacting with the patient by offering timely advice to monitor and control the disease.

The patient can see the list of recommendations for diet, exercise, medications, and preventive care activities by only touching the mobile phone screen. Also, they keep glucose levels under control by constantly viewing certain sections of the table and graph for the measurements obtained earlier.

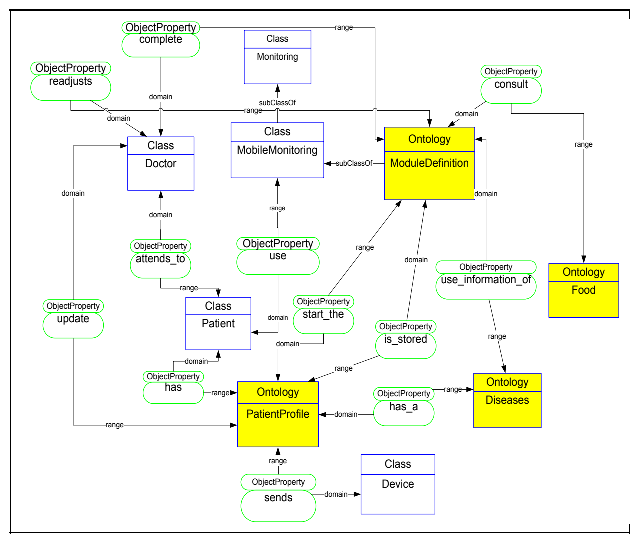


Figure 1. A general diagram of the mobile monitoring Ontologies (MoMOntology).

B. Framework Layers Distribution

The definition and development of layers in the framework allows the design. In some cases more orderly and standardized interpretation aspects of communication and data transmission.

In different areas [8] [9] has been implemented layers architecture allowing for greater interoperability of all architecture and facilitating standardization in development.

In our research, as shown in Figure 2, we have defined and developed layers architecture of our framework.

This architecture is distributed through the three main elements: patient's mobile phone, doctor's personal computer and a central server as show in figure 3. The framework server layers defined the design layer, which establishes the communication with elements of the ontologies and the module's generation.

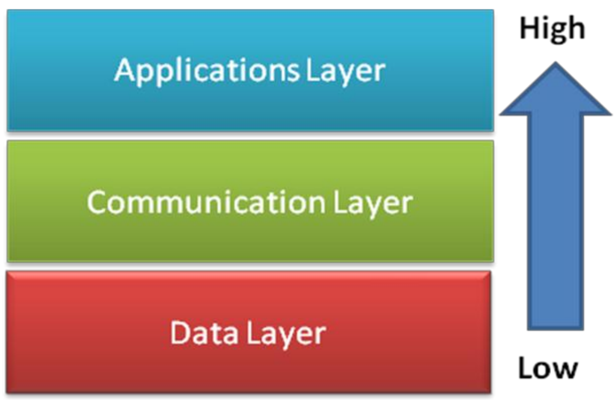


Figure 2. The three layers of the MOMO model

A communication layer parameter established the data transmission/reception to/from the mobile phone. And a security layer provides encryption for data transmission. After embedding the application on the patient mobile phone, we defined the layers that compose it. At the top we have the applications layer, which contains all modules generated by the framework corresponding to the elements of the final application.

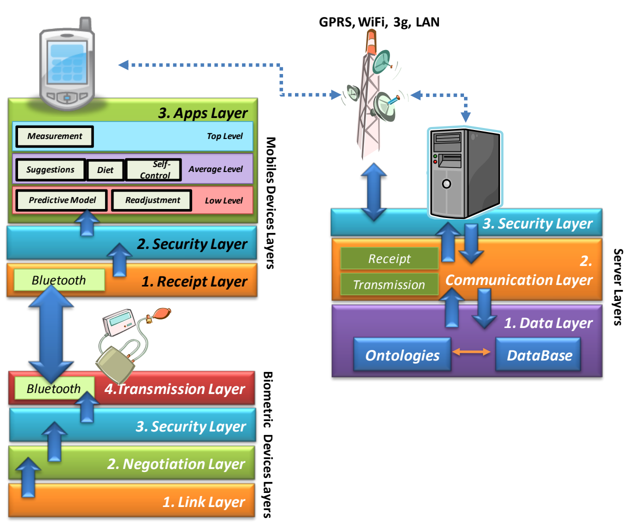


Figure 3. Distribution of the framework architecture layer.

The next layer defines the security levels to prepare the receipt layer in the collection of data from the biometrics devices.

And finally, the biometric devices are composed by the link layer that established the parameter to connect with the mobile phone, the negotiation layer, to select the type of connection (Bluetooth, NFC, etc.), the security layer to establish the type of data encription, and the transmission layer to allow the transfers of each measure.

C. The Communication Layer

The communication platform is one of the most important elements to be considered in modern Ambient Intelligence (AmI) applications, and it implies enormous challenges from the technological point of view. Some of these challenges are the following: heterogeneity, versatility, high demanding, and efficiency. A wide variety of devices should be connected [11]. Several other inherent issues (for instance energy consumption [12]) must be also taken into account. Devices may be connected by means of a wide variety of technologies, either with a traditional network infrastructure or throuth an ad-hoc network environment. Flexibility [14], scalability, and other requirements may also be considered. High demanding multimedia applications [15] should be supported with Quality of Service (QoS). Process time is always important but in some cases may be critical. An efficient use of network resources should be also taken into consideration.

Not much communication platforms exist specifically designed for AmI, and the existing ones are based on traditional communications schemes. Fuentes and Jimenez present AOPAmI [11]. They describe an internal platform structure and how service is provided to support AmI devices, emphasizing the dynamic nature of Ami applications. Their proposal is based on Aspect Oriented Programming (AOP) that provides a solution for the problem of managing the evolution in different levels, and therefore it may be applied to develop an AmI platform. An "ad-hoc service grid" (ASG) infrastructure is described by Hermann in [13] to support interaction between mobile users with remote resources along with their current physical environment. An adaptive, dynamic end decentralized service location algorithm for AmI environments is proposed, that generates a global location pattern that minimizes communication costs without the necessity of a central controller.

Our proposal is based on the Virtual Quality-of-service Network (VQN) model [16], a semantic overlay network implemented as a distributed application by means of an object oriented middleware for distributed systems. The originality of VQN is based on the fact that it is focused to enhance the network. Existing approaches are focused to enhance performance and/or functionality of a specific application.

VQN was designed to support a heterogeneous environment. This means that a wide variety of devices (such as mobile phones, PDA's, portable computers, servers, etc.) could be connected transparently.

The overlay network is divided in three sub layers. This division helps to maintain an order thru the enhancement process, and gives independence between the functions that each one of the sub layer performs. VQN includes three major components: object-oriented multi-layer routing, network functionality, and semantic functionality (figure 4).

The object-oriented multi-layer routing [17] function is used to provide an end-to-end transport service that is independent of any network technology or protocol. The implementation of the object-oriented multi-layer routing as a coupling element between the overlay and the underlying network, gives advantages in performance and functionality when compared to conventional TCP/IP mechanisms.

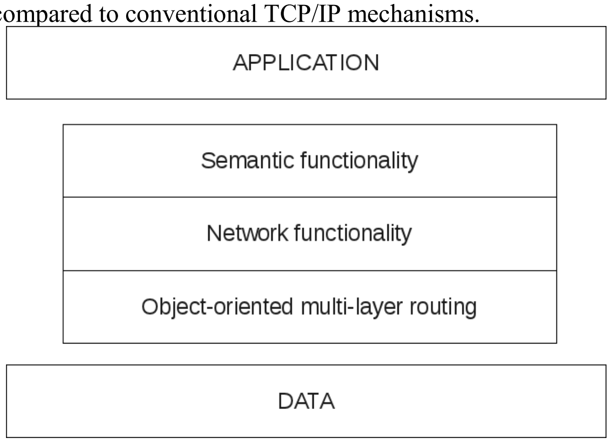


Figure 4. Major components of the VQN model

The network and semantic functionality layers offer the possibility for the participating nodes to perform additional functions depending on their characteristics and circumstances. This additional functionality is not restricted to just network-type operations but it could also be extended to address additional requirements even at the semantic level.

A simple application is here presented in order to illustrate the functionality provided by VQN. Consider a mobile phone that requires some process done in a remote location, probably by means of a heterogeneous connection dealing with different technologies, such as Bluetooth, Ethernet, Wifi, GPRS, TCP/IP, etc.

Consider the case of patient which is constantly monitored the following vital signs: temperature, blood pressure, physical activity, and insulin level, by means the appropriate measurement devices, all of them provided with probably a Bluetooth connection to connect to the mobile phone. All these variables and periodic measurements are sent to the mobile phone, which has an application that receives and stores all this information, and based on a diagnosis and if possible it gives directions to the patient locally. But in some cases there may be a need to call a doctor or an ambulance, or ask to a pharmacy for a medicine, etc.

Figure 5. Server process requirement traditional solution

A traditional solution to this situation (figure 5) would include some servers in the cloud to provide the required process function. The application running in the mobile phone needs to know every service in the network and how to reach each one of them. Somehow it decides which specific server to connect with and sends to it the request. Then the server performs the required process and sends the answer back to the application at the mobile phone.

Once the VQN platform is established (figure 6) between devices, the local application running at the mobile phone does not need to know anymore which server to connect with for a specific service, and just need to invoke an object instead. For instance, the application at the mobile phone just need to invoke an ambulance object, and the network is in charge to find the ones that are available at any given time, and even to decide which is the nearest, or the cheapest, or the most appropriate based on semantic similarity, etc. and establish the connection accordingly.

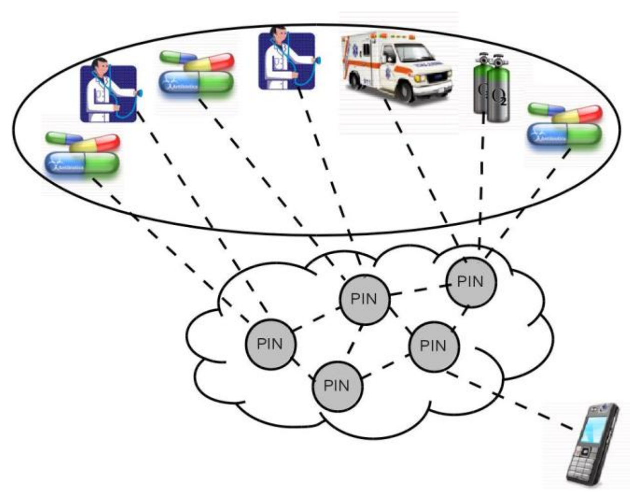


Figure 6. Alternate solution with PIN functionality

VQN also opens a wide variety of network services that could be easily implemented, such as the possibility to perform some Process-In-Network (PIN), as an example of the additional functionality that could be provided. PIN should be understood as the possibility of performing some processing as information passes through the network. The processing is done directly in the network nodes that are found between the origin and destination, taking advantage of waiting times in queues of routers, idle processing capacity in the intermediate nodes, and the information itself. This means that some process (or even the whole process) may be performed before the requirement arrives to the server, and therefore a lower requirement of time and process at the destination end nodes. PIN is distributed, but it offers additional advantages compared to a traditional distributed scheme. No additional servers are needed for PIN given the fact that processing is performed in existing network nodes. Due to the fact that PIN is network-aware, it is also possible to make decisions based on real-time network conditions.

D. Using MobiPattern to modules generation

This section discusses the generation of mobile applications for monitoring patients within a high level of abstraction. In our study we have development of specific modules with functions defined for each of the requirements. These requirements allow creating an application for mobiles devices.

For the creation of these modules and integration of each of them and for the generation of mobile applications have defined and developed a set of patterns called "MobiPattern", classified in the following items listed in Figure 7.

For the definition of any MobiPattern we have to consider all the interpretations made are generated after the measurement. All measurements obtained for the biometric device will have five levels of ranges alert, low, acceptable, ideal and high according to each disease.

In our structure based on MobiPatttern we are defined two classification related to a definition and the functionality of framework. First, we are development a Definition MobiPattern.

These defines the two most important elements of our architecture these are the Profile MobiPattern, which defines how to collect the data related to each patient and Measure MobiPattern that established the structures to capture measurement from biometrics devices.

Below is defined Functionality MobiPattern, referring to the actual structure of each module medical supervision functional. The Functionality MobiPattern is classified for mobile and for server functionality. In the mobile we defined the structure for Readjustment and Execution MobiPattern. Readjustment MobiPattern has the function of generating modules changes or adjustments to the application previously generated for the mobile device, so that if you need to make changes to the original application, it knows where to make these changes.

In other hand, the Execution MobiPattern allows to define which elements are related after generated application for mobile device. You must define which modules are considered for analysis, for processing and for display information. In the framework server we have Construction MobiPattern and the Design MobiPattern.

The Construction MobiPattern have the Visualization MobiPattern, that defines the visual parameters of the application at the time of being generated for the various types of mobile devices, the Accommodation MobiPattern that defines the location of each module or element on the application structure.

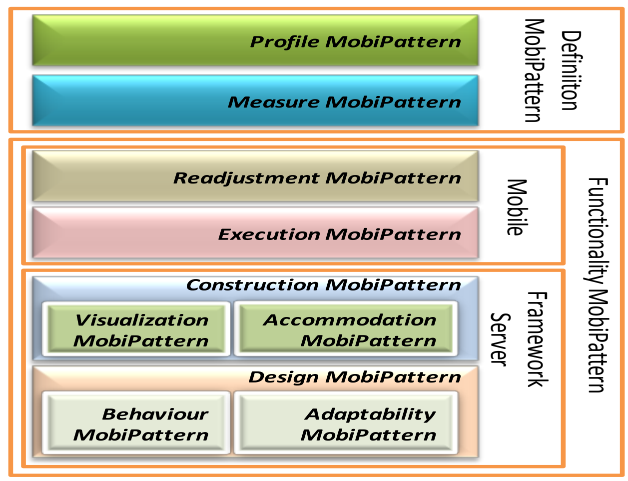


Figure 7. MobiPatterns used for generating mobile monitoring final application.

The Design MobiPattern is compounded by Behavior and Adaptability MobiPattern. The Behavior MobiPattern defines the various features of each module. It is establish what parameters are required for a module, which processes are running and wish is the result of each output.

The Adaptability MobiPattern defines the possibility to adapt news capabilities to applications, for interact with existing ones.

E. MoMo Framework Applications

Architecture developed in this paper is compounded by two specific areas: the first one, corresponding to development of the application for doctor and the second one, corresponding to the application of the patient.

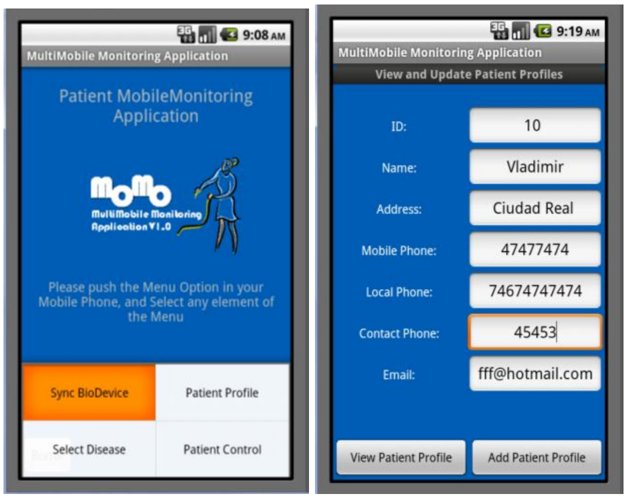
The application for the doctor is installed on your PC; from there it controlled all records of their patients, organized by the profile of each one, the historical control of their measured data and specifications of the disease(s).

As shown in Figure 8, the doctor application is developed in Microsoft Visual Studio .Net, with remote connectivity through MySQL. Database and all the specifications of the framework are distributed on the main server; the doctor and the patient have access these data every time you use the application for each of them.

In the patient application, the implementation is installed in your mobile phone. We are developed the application using Android Operating System with remote connectivity through MySQL.

As shown in Figure 8a, the patient has a screen with a menu that lets you access all functions of the application.

In Figure 8b, the patient can update information in your profile, if the patient needs to update your information, just need to change each data about the specific profile.



(a) (b)

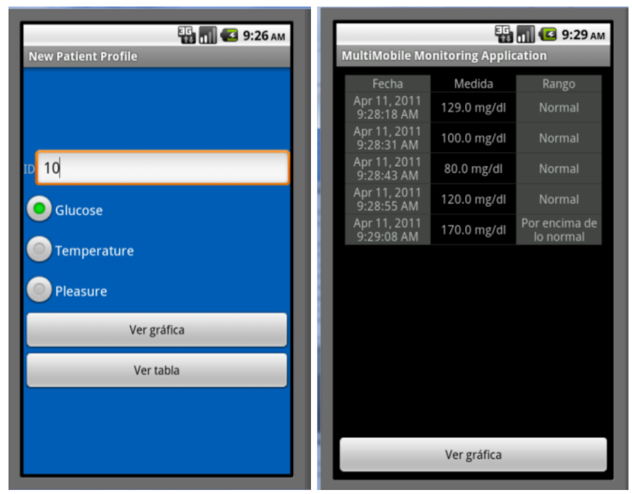
Figure 8. a. Main menu, b. Updating Patient Profile

As show in figure 9 each collects measure data is associated with a specific patient id, this allows the update to the server for the doctor to interpret the measurements of each patient without confusing them with others. The reading of the measurements can be manual, where the patient enters through the keyboard obtained measurement and automatic reading of the measure is obtained directly from the biometric device via Bluetooth technology

Figure 9. Adding a measure for patient disease.

In Figure 10a, the patient can select the type of disease that want to graph, from data captured from the biometric device. Our architecture can display graphs of different diseases. In our first assessments were captured measures of diabetes, blood pressure and temperature.

As shown in Figure 10b and figure 11, these graphics or table of measures depend on the type of disease(s) the patient has (in some cases may be more than one) and the changes obtained during a time.



(a) (b)

Figure 10. a. Type of disease to graphic, b. Show table, c. Show graphic

The patient can see his latest measurement obtained either through a chart showing the extent and period of time was taken, or through a table that stores information about the day, time, as numerical value, analyzed range from the application (low, normal, high).

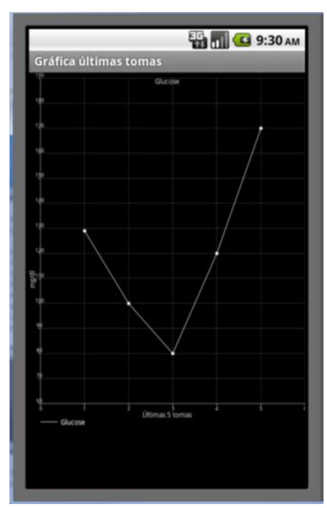


Figure 11.Show graphic of measuremement sel-fcontrol

IV. CONCLUSIONS

Our main goal with this project is to promote the easy day-by-day life of people with a chronic condition. This architecture provide a continuous patient monitoring, to improve the communication between patients and doctors allowing the generation of an automatic architecture for the individual patients' profiles of each patient, self-control and education modules for their chronic diseases.

This has been developed for the patients mobile monitoring via biometric devices and a mobile phone.

An architecture intervening elements ontological classification has been built up. These elements are the patient profile, where the personal details of the patient are specified; and the definition of the modules for the mobile phone as well as for the doctor. Diet definition, medical treatment, care activities, patient profile are some of the aspects that have been modelled in the ontologies and that allow the framework an accurate interpretation to generate the right applications.

The communications layer design is inspired on the VQN model, an overlay-based solution which is used to build a solid and versatile communication platform between network elements, and to provide additional functionality such as PIN. We are sure this architecture will help to doctors and patient to take decision in different situations of conditions.

ACKNOWLEDGMENT

This work has been financed by TIN2010-20510-C04-04 project from Ministerio de Ciencia e Innovación (MICINN) and supported by Secretaría Nacional de Ciencia y Tecnología (SENACYT) and Instituto para la Formación y Aprovechamiento de los Recursos Humanos (IFARHU) (Panama). This work has been also partially funded by Fundacion Carolina and Universidad Anahuac Mayab.

REFERENCES

[1] Villarreal, V., J. Bravo, and R. Hervás, MoMo: A Framework Proposal for Patient Mobile Monitoring, in 5th Conference of the Euro-American Association on Telematics and Information Systems. EATIS 2010.

[2] Villarreal, V., J. Bravo, and R. Hervás, Towards Ubiquitous Mobile Monitoring for Health-care and Ambient Assisted Living, in International Workshop on Ambient Assisted Living, 2010. Valencia, Spain.

[3] Georga, E., et al. Data mining for blood glucose prediction and knowledge discovery in diabetic patients: The METABO diabetes modeling and management system. in Engineering in Medicine and Biology Society. EMBC 2009. Annual Conference of the IEEE. 2009.

[4] Wan-Young, C., L. Seung-Chul, and T. Sing-Hui. WSN based mobile u-healthcare system with ECG, blood pressure measurement function. in Engineering in Medicine and Biology Society, EMBS 2008. 30th Annual Conference of the IEEE. 2008.

[5] Koutkias, V.G., et al., A Personalized Framework for Medication Treatment Management in Chronic Care. Information Technology in Biomedicine, IEEE Transactions. 14(2): p. 464-472.

[6] Blum, J.M. and E.H. Magill. The Design and Evaluation of Personalised Ambient Mental Health Monitors. in Consumer Communications and Networking Conference (CCNC), 2010 7th IEEE.

[7] Ryder, J., et al. Ambulation: A Tool for Monitoring Mobility Patterns over Time Using Mobile Phones. in Computational Science and Engineering, CSE '09.

[8] Barbarán, J., et al. RadMote: a mobile framework for radiation monitoring in nuclear power plants. in XXI International Conference on Computer, Electrical, and Systems Science and Engineering CESSE 2007. Vienna, Austria.

[9] Crossbow-Technology-Inc. http://www.xbow.com.

[10] H. Goto, Y. Hasegawa, and M. Tanaka, "Efficient Scheduling Focusing on the Duality of MPL Representatives," Proc. IEEE Symp. Computational Intelligence in Scheduling (SCIS 07), IEEE Press, Dec. 2007, pp. 57-64, doi:10.1109/SCIS.2007.357670.

[11] Fuentes, L. and Jiménez, D. 2005. An aspect-oriented ambient intelligence middleware platform. In Proceedings of the 3rd international Workshop on Middleware For Pervasive and Ad-Hoc Computing (Grenoble, France, November 28 - December 02, 2005). MPAC '05, vol. 115. ACM, New York, NY, 1-8. DOI= http://doi.acm.org/10.1145/1101480.1101482.

[12] Aarts, E. and Roovers, R. 2003. IC Design Challenges for Ambient Intelligence. In Proceedings of the Conference on Design, Automation and Test in Europe - Volume 1 (March 03 - 07, 2003). Design, Automation, and Test in Europe. IEEE Computer Society, Washington, DC, 10002.

[13] Herrmann, K. 2010. Self-organized service placement in ambient intelligence environments. ACM Trans. Auton. Adapt. Syst. 5, 2 (May. 2010), 1-39. DOI= http://doi.acm.org/10.1145/1740600.1740602.

[14] Basten, T., Benini, L., Chandrakasan, A., Lindwer, M., Liu, J., Min, R., and Zhao, F. 2003. Scaling into Ambient Intelligence. In Proceedings of the Conference on Design, Automation and Test in Europe - Volume 1 (March 03 - 07, 2003). Design, Automation, and Test in Europe. IEEE Computer Society, Washington, DC, 10076.

[15] Iglesias, R. and El Saddik, A. 2008. A glimpse of multimedia ambient intelligence. In Proceeding of the 16th ACM international Conference on Multimedia (Vancouver, British Columbia, Canada, October 26 - 31, 2008). MM '08. ACM, New York, NY, 1159-1160. DOI= http://doi.acm.org/10.1145/1459359.1459616.

[16] Urzaiz, G., Villa, D., Villanueva, F., Moya, F., Rincon, F., Lopez, J.C., and Munoz, L.A. (2009). A novel communication platform to enable the collaboration of Autonomous Underwater Vehicles. The 2009 International Conference on Wireless Networks (ICWN '09), Las Vegas (USA), July 13-16, 2009.

[17] Villa, D., Villanueva, F., Moya, F., Urzaiz, G., Rincon, F., and Lopez, J. C. (2008). Object oriented multi-layer routing with application on wireless sensor-actuator networks. 16th IEEE International Conference on Networks (ICON2008). New Delhi, India, 12-14 December 2008.