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Service oriented centered e-health solution for monitoring and preventing chronic diseases

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Service Oriented Centered E-Health Solution for Monitoring and Preventing Chronic Diseases

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Abstract
The modern and continuously changing lifestyles in almost all parts of the world resulted in an increase in the incidence of chronic diseases (CDs). To reduce risks associated with chronic diseases, health professionals are studying various clinical solutions. As a result of recent advances in sensing technology, wireless communications, and distributed communication, the monitoring of patients' health condition and the elaboration of prevention plans are considered the most promising solutions for the treatment of chronic diseases. In this paper, we propose a novel framework for monitoring chronic diseases and tracking their vital signs. The framework relies on the service orientation concepts and standards to integrate various subsystems. Monitoring of subjects' health condition, using various sensors and wireless devices, aims to proactively detect any risk of chronic diseases. The system will allow generating and customizing preventive plans dynamically according to the subject's health profile and context while considering many impelling parameters. As a proof of concept of our monitoring and tracking schemes, we have considered a case study for which we have collected and analyzed preliminary data.

Keywords-component; E-health, Chronic Diseases, Monitoring, Tracking, SOA.

I. INTRODUCTION

With the recent advances in healthcare services, many earlier mortal diseases have been turned into chronic diseases. Also, the increasing and continuous changes of lifestyle in almost all parts of the world resulted in an increase in the incidence of chronic diseases. This is leading to growing demand for care, especially for elderly, and growing costs for both the society and caretakers.

Over the last decade, deaths caused by chronic and cardiovascular disease (CVD) in all countries over the world are increasing. According to the statistics, from the United Arab Emirates' (UAE) Ministry of health, published in 2010, over 25% of fatalities in the UAE are caused by cardiovascular diseases [1][2]. Multiple and various risk factors can cause these diseases. They include: cholesterol, diabetes, high blood cholesterol and other lipids, physical inactivity, smoking, overweight and obesity. Also, according to the World Health Organization, the UAE has the second highest rate of diabetes in the world while other research studies conducted at the UAE University estimate that up to 29% of the population over 30 years old have diabetes.

To address the rising incidence of chronic diseases and their associated complications, a prevention approach can contribute to reducing the risks of their occurrence. Furthermore, continuous monitoring of subjects' health condition is vital for detecting the diseases' symptoms as soon as they occur and mitigate the impact and the consequences of these diseases. Subject tracking is also essential for monitoring and locating subjects with hazardous conditions while they are on the move.

The implementation of monitoring, prevention, and tracking mechanisms is becoming possible due to the integration of different technologies, systems, and communication infrastructures. These technologies include sensing, pervasive computing, and wireless and mobile computing technologies. They are greatly impacting the healthcare industry, which is undergoing fundamental changes by:

1) Shifting from hospital-centric services to ubiquitous and ambulatory systems (with homecare, daycare clinics, remote healthcare)
2) Providing support for the treatment of chronic diseases through active involvement of patients.
3) Providing patients and healthcare professionals with easy access to important health information anytime/anywhere.
4) Optimizing healthcare costs.

Inline with the above goals, we propose in this work a framework for monitoring and prevention of chronic diseases. The system relies on the concept of Service Oriented Architecture (SOA). SOA has been proven to be an adequate solution for integrating heterogeneous systems and technologies, allowing application-to-application communication over the internet, reducing cost of integration, and making data available to different stakeholders. The system will allow deploying various services for continuous data gathering, automatic monitoring, and taking proactive measures to identify risk factors and prevent subjects from severe heath consequences. These services can be made accessible from diverse mobile devices, such as smartphones and tablets. Besides, the system can be easily integrated with other healthcare systems; which allows high interoperability and dynamic integration between heterogeneous systems.

The monitoring approach in our system involves efficient use of sensing technologies and communication infrastructures to sense and collect important physiopathology measures of a subject under observation. Discrepancies in measured data trigger immediate analysis and assessment of subject's case to determine whether the subject has, or not, a chronic disease.

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The preventive approach to reduce the incidence of CDs and control the spread of these diseases, aims to address the factors causing mainly obesity, hypertension, smoking, diabetes, overweight, dyslipidemia, physical inactivity and unhealthy diet and lifestyle. Collecting, analyzing, and mining of data are key elements in addressing the problem. It consists of extracting patterns to build prediction models that greatly help taking rational decisions to prevent and decrease the risk factors. Healthcare systems should be organized on the basis of locally derived data to provide adequate affordable care to the increasing groups of patients with these diseases.

The remainder of this paper is organized as follows: Section 2 discusses related work on various e-Health systems with the same goal as our project. Section 3 presents our proposed architecture and describes its main components and actors. Section 4 illustrates our approach using a case study for the monitoring mechanism of subjects with chronic diseases and presents preliminary results. Finally, Section 5 concludes the paper and highlights some future work.

II. RELATED WORK

To improve healthcare services and optimize medical resources, several e-health centers have been created and many initiatives have emerged in USA, UK, EU, AU, and in some developing countries. At the core of all these initiatives is the investment in modern ICT infrastructures to make possible the exchange of medical data between hospitals, clinics and healthcare organizations, and to implement e-Health services.

The increasing demand for e-Health services has led to many research efforts [5]. Different architectures have been proposed for e-Health systems and other healthcare related systems. Some of these systems are used in special areas, such as trauma [6], cardiology [7], neurosurgery, and pathology treatment. Others are used for specific purposes, such as emergency and patient monitoring [8]. With the advent of wireless and mobile technologies, many wireless-based e-Health systems (i.e. m-Health system) have also been developed [9]. Most of these systems, however, provide only limited services to their users.

Several research works and initiatives have investigated the challenges of building e-health solutions. These solutions differ on how they tackle the integration issue given the heterogeneity of systems, middleware, and architectures used to build an e-Health system. S.H. Hsieh et al. [13] proposed a distributed framework for a Web-based telemedicine system, which addresses two types of servers, i.e. Web servers and data servers. This framework uses CORBA technology and a database fragmented on different sites. The system is not flexible enough to allow the integration of non-CORBA systems. It requires an intermediary middleware to handle the heterogeneity of heath systems and huge development effort to adapt the system to the integrated system requirements.

In [11], the authors proposed a multi-layer SOA-based e-Health services architecture, which has six main components that define the interactions among the layers. The system is generic. However, it describes only the architectural design without detailing the implementation and its challenges. In addition, their proposed system hasn't been implemented. Kart, F. et al. [12] described a distributed e-healthcare system that uses SOA as a mean of designing, implementing, and managing healthcare services. The users of the system are physicians, nurses, pharmacists, and other professionals, as well as patients. The system includes a clinic module, a pharmacy module, and patient's interfaces, which are implemented as Web services. Various devices can interact with these modules, including desktop and server computers, Personal Digital Assistants and smart phones, and even electronic medical devices, such as blood pressure monitors.

The authors in [14] described the design, the implementation, and the deployment of a multi-tier Inpatient Healthcare Information System based on SOA and on the HL7 message exchange standard at the National Taiwan University Hospital (NTUH). The services-tier includes Computerized-Physician Order Entry (CPOE), Billing, Pharmacy, and Diet. The authors in [15] investigated how healthcare organizations, using SOA, can leverage their shared services to automate multiple business processes and reinforce overall interoperability. The authors in [16] designed and developed a SOA-based platform for home-care delivery to patients with chronic diseases. This work shares some of the goals with our project with regards to monitoring patients with chronic diseases.

To promote interoperability among healthcare organizations that are seeking to develop SOA-based architectures, a joint collaboration effort among standards groups, specifically HL7 and the Object Management Group (OMG), was formed under the name: Healthcare Services Specification Project (HSSP). This effort intends to develop health industry SOA standards. The intent of HSSP is to produce standard services that define services' responsibilities, behavior, and interfaces so that ubiquity can be achieved across implementations and vendor products [16].

Our solution is aligned with the above initiatives and addresses mainly the chronic diseases monitoring and prevention. It also addresses some difficult issues in the design of an e-health system and protection of medical data. Our solution relies on SOA to integrate different systems, data, and make it available for CDs monitoring, and prevention. The net implication of using SOA in our solution is that it facilitates interoperation among various systems that typically do not speak the same language. Using a common SOA reduces the complexity of the integration of heterogeneous systems. New services can be developed to satisfy the needs of integration, and existing system capabilities can also be organized into services. Redundant processing, which is normally developed and used by several units, can be structured and represented as a separate service or set of services. Each service becomes, then, available to the entire stakeholders through a standard interface. Furthermore, services can be orchestrated and aligned with users' workflows.

In addition to the challenges of developing and implementing the above model, the related research issues are still open. Indeed, the integration of different technologies and systems to solve the interoperability issue is a challenging research area.

III. FRAMEWORK OVERVIEW

Figure 1 depicts our proposed framework for the monitoring and prevention of chronic diseases. The framework relies on the service-oriented architecture and integrates various sensing and monitoring technologies. The ubiquitous communication and coordination among stakeholders including physicians, hospital surveillance center, and laboratory, permit to respond to new conditions of chronic diseases' subjects with effective intervention plans. The framework includes several management entities with different responsibilities and roles: Sensing devices, Subjects, the managing server of measures, the Surveillance Center (SC), the Hospital Information System (HIS), the services knowledge base (KWS), and physicians.

The following is a brief description of the main responsibilities of each management entity of the model.

Sensing Devices (SD): Sensing devices, deployed at the subject's location, measure continuously different physiopathology parameters and make the readings available via Web services. Different sensing technologies might be used to monitor the subject's health condition. Examples of these devices include Heart Smart Diagnostic (HSD) machine, which collects data on heart rate variability, central blood pressure, ECG, oxygen utilization, endothelial function and other measurements. Parameters related to body composition are assessed using a body analyzer, which outputs data on regional adiposity and overall fat content. Most of these devices generally have Application Programming Interfaces (API) that allow accessing collected data.

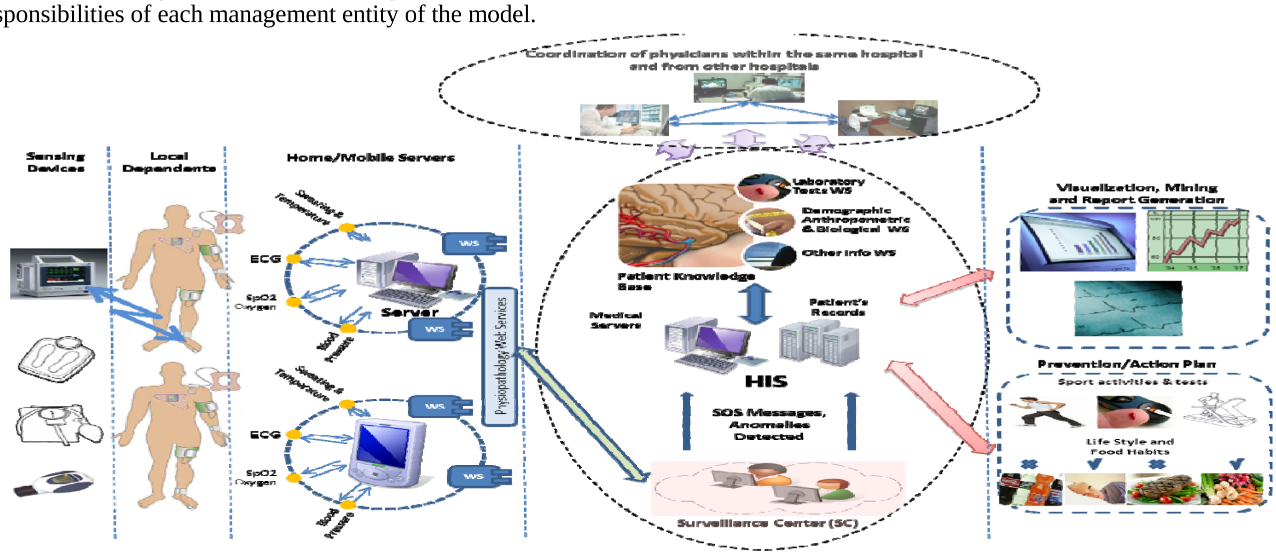

Figure 1. SOES E-health/M-health Model for Chronic Diseases Monitoring and Prevention

Subject (R): A subject can be a person suffering from a chronic disease or even a healthy person who uses the system to benefit from continuous monitoring of her/his chronic disease, and to get fast assistance and intervention by physicians whenever needed.

Home/Mobile servers (HMS): These servers are responsible for storing sensed data and making it available to SC via Web services. They can be deployed on computers as well as on mobile devices.

Surveillance Center (SC): is in charge of observing subject's collected data via continuous invocation of Web services that expose these data by invoking a variety of service operations. The SC receives and analyses notification messages that might be sent by the HMS if the SC was in a pause situation and an expected heath condition of a subject has occurred. The SC also handles SOS notification messages to the HIS when an emergent situation is detected by transmitting the details of the situation and the monitored heath data of the subject.

Hospital Information System (HIS): The HIS includes various software and hardware resources within hospitals that might include medical servers hosting a variety of applications (e.g. registration, scheduling, and patient billing), database servers storing patient's records and other relevant data. Once receiving SOS messages from the SC, the HIS triggers necessary actions and notifies physicians about the current conditions of the patient under observation and provide them with the necessary data. Physicians can be selected based on the case, and can be from the same hospital or other hospitals.

Knowledge base Web services (KWS): They represent knowledge information exposed as Web services and made available to physicians and to the patient's assistance team. These expose data such as laboratory tests, demographic, anthropometric, and biological data. This information serves as decision support for physicians to take appropriate prevention and action plan as shown in figure 2.

IV. CASE STUDY: MONITORING SCHEME

In addition to the above roles, our SOES model exhibits two key features that concern (1) visualization of assistance and prevention data, statistics and report generation, data mining and patterns detection, (2) prevention and action plan generation to respond to the occurrence and treatment of chronic diseases. A prevention plan may recommend, for instance, practicing regular sport exercises, following a diet plan, changing food habits, and/or the lifestyle. An action plan, however, consists of a series of actions that might include medications, chemotherapy, reeducation, etc.

Figure 2 shows the sequence of exchanged messages between five key SOES entities for the sake of conducting initial health assessment, generating action plans, and monitoring and controlling the patient's heath parameters. The following phases summarize the interactions among the system actors:

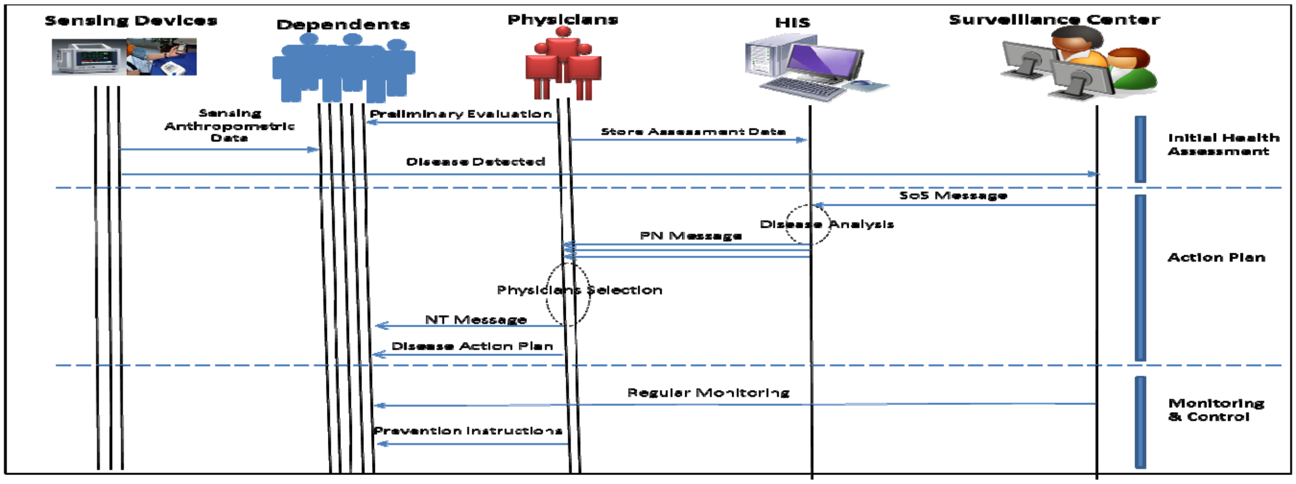

Figure 2. Sequence diagram of exchanged messages between main SOES entities

Initial health assessment: Upon conducting a preliminary assessment of the subject health conditions by physician(s) and storing the assessment data at the HIS, the sensing entities start sensing the subject anthropometric measures and report to the SC if anomalies are detected.

Action Plan: Once an anomaly is detected, the SC sends immediately an SOS message to HIS along with the data collected from sensors. This represents the first operation of the action plan phase. Then, the HIS prevention team analyses the data and sends a notification message (PN) to appropriate physicians. The selection of suitable physicians is based on their availability, on the type of disease detected and its accompanied complications, and maybe on the subject's physician preferences. After analyzing and studying the subject's situation, physicians send a notification message to the subject for a consultation during which an action plan is provided and explained to the subject.

Monitoring and Control: While the patient is following an action plan, a monitoring and control phase is triggered by conducting regular monitoring of the patient situation and his reaction to the execution of the action plan. Finally, prevention recommendations are made to the patient whenever the monitoring process detects anomalies in the measurements.

V. PROTOTYPE IMPLEMENTATION

In this section, we describe the implementation of the architecture developed based on the Enterprise Service Bus (ESB). We also describe the implementation of monitoring blood sugar, and blood pressure prototypes. The core business logic of the application is developed as Web Services.

A. Entreprise Service Bus

Figure 3, depicts the SOES architectural implementation which is based on the SOA paradigm and involves various sub-systems. These sub-systems can be divided into four layers: (1) Service consumers, (2) SOA infrastructure, (3) Web services interfaces, and (4) Systems implementation. Service consumers include inpatient system, outpatient system, pharmacy system, and many others. The SOA infrastructure is typically using an ESB that allows interoperation and exchange of data among the different sub-systems. The Web services interfaces represent the interfaces of common services that can be invoked by the service consumers in order to carry out their tasks. Finally, systems implementations include the EMR system, physician record system, laboratory system, surveillance and monitoring system, visualization and data mining system.

B. Web Services Implementation

We have implemented Web Services that expose their interfaces to any client application to invoke and get the BS and BP readings through a set of implemented methods as described in the below table:

TABLE I. WEB SERVICES INTERFACES

Blood Sugar	Blood Pressure
getReadingsThisWeek(patientID)	getReadingsThisWeek(patientID)
getReadingsLastWeek(patientID)	getHighestSystolicInCurrentMonth(patientID)
getReadingsLastMonth(patientID)	getBPReadingsPerDay(patientID,date)
getUnControlledSugarList(patientID)	getBestDay(patientID)
…	….
setLifeStyleAdvices(patientID,doctorID)	getTreatmentPlan(patientID)

C. Experimentation Setup

Figure 4 describes the environment setup and components we have used for the evaluation of our solution as follows:

- Wireless Body Sensor Network that integrates two types of sensing devices (BS and BP). It also includes communication protocol and a set of APIs.
- An SQL database server to store the sensed data.

- OpenESB for SOA integration and Web services integration. In addition, to a two implemented Web Services interfaces for BS and BP monitoring implementation.
- Samsung mobile Galaxy Note running Android 4 to host the mobile application.
- A Non-Invasive Mobile application developed to parse the sensed data, generates, visualizes, and interprets monitoring's results.

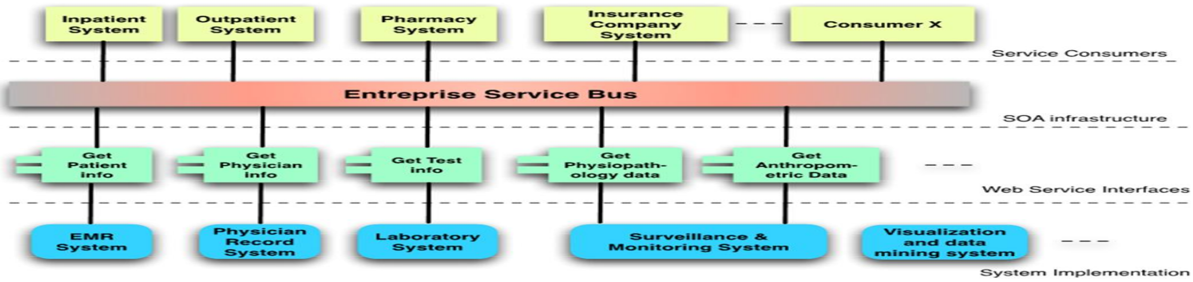

Figure 3. SOA-based data and services integration in SOES

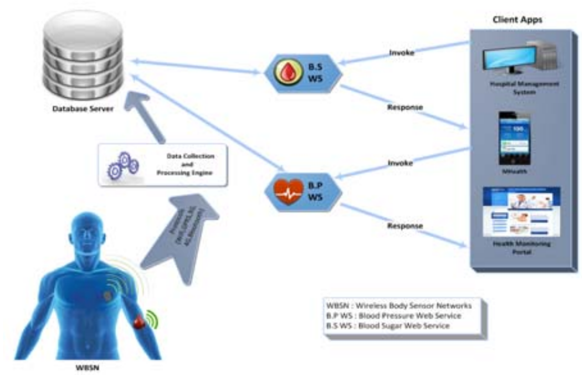

Figure 4. Experimentation Setup

D. Monitoring Scenarios

Two main scenarios were used to evaluate the monitoring features of our solution. These include monitoring two vital signs as following:

1) ***Monitoring patient's blood sugar***: readings are taken in different period and in different situations. For instance, while fasting, 2 hours after meals, and while the patient is under stress situation.
2) ***Monitoring patient's blood pressure****:* readings of blood pressure include two metrics: systolic and diastolic. Also, as of the BS, the BP is taken at different times and patient's situation.

E. Results and Discussion

We present here the results we obtained from monitoring the BS and BP parameters for a subject under observation. The observed subject is diabetic and under medication. The monitoring has been triggered to observe the variation of these parameters in different subject's contexts.

Figure 5 shows the monitoring results obtained from monitoring a subject in three difference situations mainly: fasting, after meal, and at bedtime. The BS readings show a considerable fluctuations and non-stable readings with some abnormal values that exceeds largely the BS threshold of a patient under medication. Therefore, an alert is triggered to notify the patient and physician to take necessary actions. Also, a detailed supportive plan is generated to the patient and includes: a diet program, sport practices, and lifestyle adjustment program.

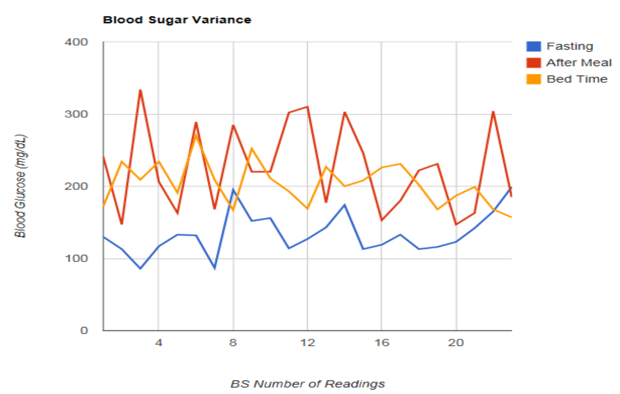

Figure 5. Blood Sugar monitoring results

Figure 6 describes the variation of results from monitoring a subject's BP. The readings depict some slight abnormal diastolic and systolic readings which makes it subject of interpretation, however it does not lead to assure the apparition of BP related disease.

Using data that have been collected in the above scenarios, in addition to other data we have sensed; we draw a deep analysis and interpretation of these data with heavy consultation with health professionals, we draw the following conclusions:

- Continuous monitoring is a challenging operation that needs not only a well-defined monitoring process but also requires an advanced system to collect, process, filter, and structure this data for better exploitation and analysis.
- Preventive plans cannot be fully automated and should definitely involve physician(s) intervention and analysis.
- In some complex health cases, data collected might not be enough to make an appropriate treatment/operation

decision. Therefore, some other alternative practices need to be investigated as well.

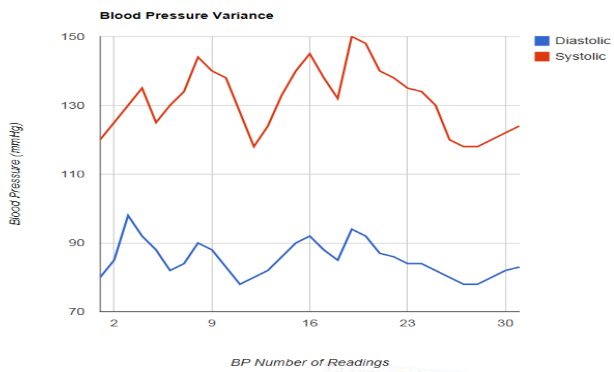

Figure 6. Blood Presure monitoring results

VI. CONCLUSION

As chronic diseases represent the main cause of deaths in all parts of the world over the last decade, many efforts have tried to mitigate the impact of these diseases using information and communication technologies-based solutions. Monitoring of subjects, for instance, helps to early detect these diseases and to establish prevention plans for them. In this work, we have proposed a solution for dealing with chronic diseases that relies on proactive monitoring and automatic prevention schemes that are supported by an open, flexible, and interoperable SOA-based architecture. The architecture allows integrating subsystems from various stakeholders.

A prototype of the system is under development using open source software. The portal of the system includes a set of portlets used to display the monitoring results, statistics, and prevention plans. Patients, physicians, and nutritionists can access the portal using various devices, such as laptops, PDAs, and Smart Phones. As a future work, we are planning to conduct extensive monitoring of a large population of chronic diseases' subjects in the UAE, and mine the collected data to draw conclusions about the nature of chronic diseases in the UAE and evaluate our system with regard to handling large datasets.

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