SAPHIRE: Intelligent Healthcare Monitoring based on Semantic Interoperability Platform - Pilot Applications*

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Abstract

As a response to the challenge of providing high quality healthcare services with reasonable costs while the elderly population and the associated chronic diseases increase, the SAPHIRE architecture provides an intelligent healthcare monitoring architecture. The monitoring of patients is achieved through a clinical decision support system based on clinical guidelines. SAPHIRE provides the necessary interoperability layers to access the patient's vital signs from wireless medical sensors and the electronic healthcare records of the patient in order to exploit them in the decision process seamlessly. This paper presents this architecture through two pilot applications, one for the bedside monitoring of cardiac patients at hospitals, and the second for homecare monitoring of the cardiac patients rehabilitated after a revascularization therapy.

1 Introduction

The World is facing the challenge of delivering high-quality healthcare at affordable cost while the greying population continues to grow at an increasing pace. According to recent studies, the proportion of the population over 65 is expected to almost double from 16.4% in 2004 to 29.9% in 2050 in Europe [1]. Due to aging population, chronic diseases and their management costs are also on the rise. The current healthcare delivery model is far from ideal to address the challenges ahead [2]. On the other hand, Information Technology combined with recent advances in networking, mobile communications, and wireless medical sensor technologies offers great potential to support healthcare professionals and to deliver remote healthcare services, hence providing the opportunities to improve efficiency and quality and better access to care at the point of need.

In this paper, we will present the SAPHIRE architecture, which provides an intelligent healthcare monitoring platform. To be able to assist medical practitioners efficiently, the healthcare monitoring platform is enriched with a clinical decision support system (CDSS) based on computerized clinical guidelines. Through the SAPHIRE system, the intelligent monitoring architecture is able to access seamlessly the medical history of a patient stored in medical information systems as well as the vital signs of the patients through wireless medical sensors. In this way, not only the observations received from wireless medical sensors but also the patient medical history is used in the reasoning process.

In the following we will present the basic features of the SAPHIRE architecture by emphasizing how it is extending the state of the art healthcare monitoring research:

- The healthcare monitoring system needs to access the vital signs of the patients through wireless medical sensor devices. The SAPHIRE architecture provides a Sensor and Data Point abstraction in order to seamlessly present the sensor data to the applications exploiting it.

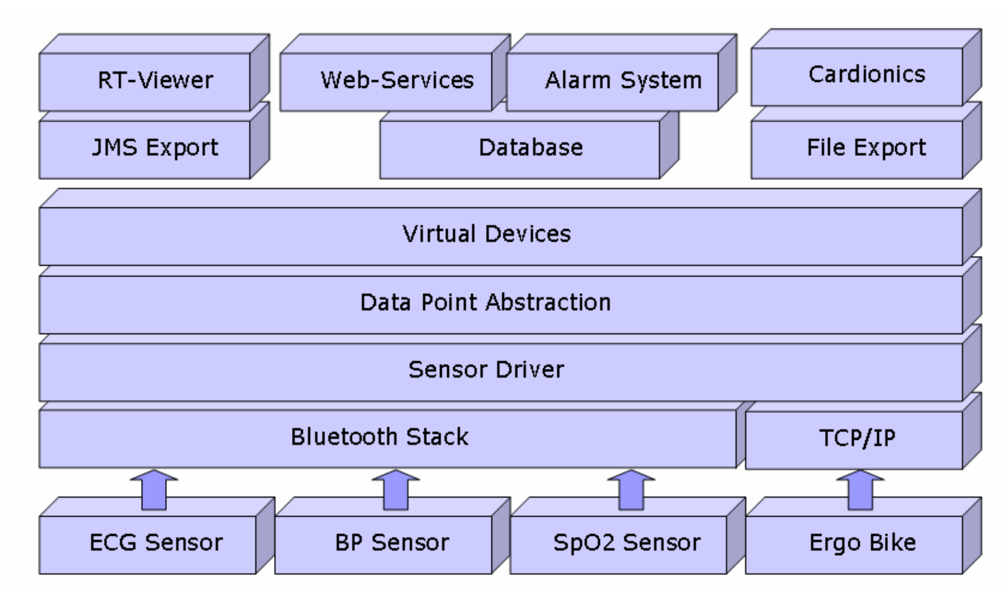

Figure 1 Sensors and Data Point Abstraction

Figure 1 shows the data layers used in the SAPHIRE system. The bottom layer represents the actual sensor hardware. Above that, the networking layer is comprised of a Bluetooth stack and a TCP/IP stacks. The sensor driver layer implements the communication protocol that determines the sensor's data structure and how it is transmitted through the network layer. If a new sensor is introduced to the system, the Data Point Abstraction layer ensures that only the proprietary sensor driver needs to be adapted. A Virtual Device, as it can be seen in the layer above the Datapoint Abstraction can – but does not necessarily have to – correspond to a physical device. A Virtual Device can also receive its data from an algorithm that derives data from other (possibly also virtual) devices. In the SAPHIRE context, an example for a Virtual Device without a hardware representation is the virtual device for the respiratory rate, where the respiratory rate is derived from multi lead ECG device [3]. Data from the Virtual Devices are stored in the database (where they are exposed as semantically enriched web service so that the CDSS can use it and where the alarm system access it), exported as file (for the sensor data analysis software such as Cardionics). Also, the data can be published using the publish/subscribe mechanism of the Java Message System (JMS) [4]. The Real-Time Viewer (RTViewer) for Sensor data subscribes to the sensor data topics through JMS to display the data on the physicians' display.

- The Healthcare Monitoring system needs to access the Electronic Health records of the patient so that the vital signs of the patient can be put into context while giving recommendations/decisions. However patients' healthcare records are usually physically dispersed in disparate medical institutions which usually do not interoperate with each other. SAPHIRE architecture uses the IHE Cross-Enterprise Document Sharing (XDS) [5] architecture to tackle this interoperability problem. In this architecture, the EHR documents are stored in local EHR repositories, however they are also registered to an XDS Registry along with a set of metadata so that the documents then can be discovered and accessed wherever they are actually stored. Through this architecture, we have solved the discovery of and access to relevant EHR documents, however in order the CDSS to exploit the data stored in these EHR documents, they need to be represented in a machine processable format. In SAPHIRE architecture we use HL7 CDA Level three documents [6] where both the entries and the sections are annotated through coding schemes.

- In SAPHIRE, the behaviour of the CDSS is defined through Clinical guidelines. Clinical guidelines are the definitions of medical plans for the study of medical problems and regimens for therapy. As the clinical guideline representation formalism we use the GLIF language [7]. Computerized clinical guidelines have been previously used for implementing CDSSs such as GLEE [8], however it has been a well accepted fact that wide adaptation of computerized clinical practice guidelines has yet to be achieved even in a single healthcare institution [9]. One of the reasons for this is complexity of fully integrated decision support systems due to the nature of heterogeneous set of clinical applications need to be involved in the decision process and the lack of commonly agreed electronic healthcare standards and set of interpretable interfaces to proprietary medical information system. The previous approaches automating guidelines have addressed this problem through local adaptation where the interfaces of the guidelines to EHRs and medical applications are usually manually bound [8][10]. To tackle this problem we have extended the GLIF model semantically as detailed in [11]. In this extension we have annotated the external interfaces of the guideline definition such as references to EHR, vital signs, or clinical applications. In addition to this, as discussed in Section 2, we have provided a semi-automatic deployment architecture, to process this extended guideline definition and dynamically discover the resources needed in the guideline execution. In this way, the manual deployment effort needed to create interfaces with the underlying EHR systems and clinical workflows is avoided.

A more detailed discussion of SAPHIRE architecture can be found in [11]. The SAPHIRE has two pilot applications: in the hospital pilot we address the bedside monitoring of subacute phase of the patients suffering from myocardial infarction; in the homecare scenario we address the homecare monitoring of the rehabilitation of the cardiovascular patients undergone a revascularization therapy. In the following sections we will present how SAPHIRE architecture is exploited to model and automate these pilot applications.

2 SAPHIRE Hospital Pilot Application

One of the pilot applications of SAPHIRE project is the hospital pilot application which is being developed for the Emergency Hospital of Bucharest (SCUB). This pilot application aims to demonstrate that the SAPHIRE system can provide bedside intelligent monitoring of patients with subacute coronary syndromes in a wireless fashion to provide computer-generated clinical decision in accordance to the latest European Cardiology Guidelines. In this pilot application, the guideline execution environment will provide continuous feedback to the physicians that will be patient-specific and guideline-oriented, to provide optimized medical care in accordance with medical standards.

In the following subsections we will introduce the steps of the guideline used in our pilot, and explain how its semantics have been modeled so that it can be deployed and executed automatically through the SAPHIRE architecture.

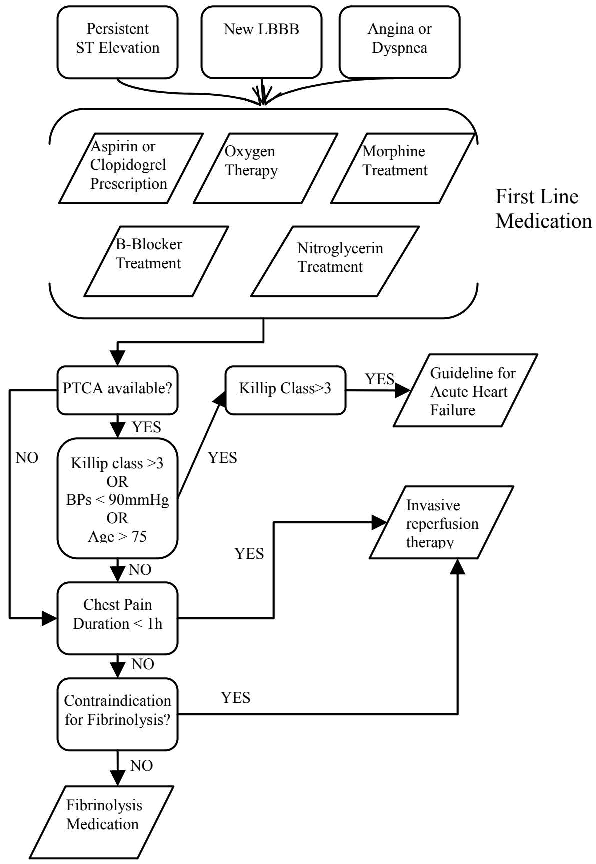

Figure 2 Management of Acute Myocardial Infarction Guideline [3]

2.1 Guideline Definition and Requirements

In our pilot application we are using the "Management of Acute Myocardial Infarction" guideline defined by the European Society of Cardiology [12]. It should be noted that the patients with acute myocardial infarction on admission is not our target population. We are addressing patients who are in subacute phase who can still have acute Myocardial Infarction during hospital stay. For these patients, the use of the system is safe and rapid enough.

We have modeled the guideline in the extended GLIF model we proposed in SAPHIRE [13] using the Protégé Tool [14]. While the guideline is represented in Computer Interpretable

Language, the physicians and the medical informatics professionals should collaborate. Although Protégé tool is quite user friendly being developed by Stanford Medical Informatics department, especially in the definition of expression scripts, the expertise of medical informatics professionals is required.

The guideline is triggered by a sensor alarm indicating "Persistent ST Elevation[2] and/or new LBBB[3]" coming from the ECG sensor. This initiates the "First Line Medication" step, where depending on the current medication and medical history coming from Electronic Healthcare Records (EHR), and also vital signs coming from sensor devices, medications and therapies are proposed by the guideline. After the first-line medication (such as giving aspirin, applying nitroglycerin therapy), based on the vital signs coming from sensors and patient's medical history, either another Guideline for Acute Heart Failure is followed, or a Fibrinolysis[4] therapy or an appropriate "invasive reperfusion therapy" is applied to patient. A more detailed flow of the guideline is presented in Figure 2. The parallelograms indicate sub-flows that are not detailed in the figure.

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[2] ST-segment elevation is usually associated with looming infarction, but can also be due to pericarditis or variant angina and it directly comes as an alert from the ECG.

[3] LBBB means left bundle branch block and usually indicates widespread cardiac disease. When the left bundle is blocked, activation of the left ventricle proceeds through the muscle tissue, resulting in a wide (0.12 msec) QRS complex.

[4] Fibrinolytic drugs are given after a heart attack to dissolve the thrombus blocking the coronary artery, experimentally in stroke to reperfuse the affected part of the brain, and in massive pulmonary embolism.

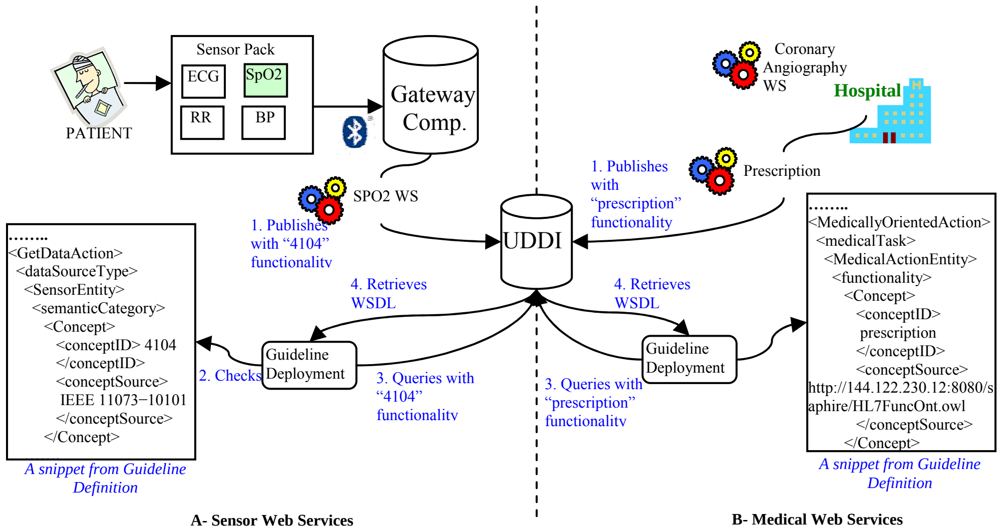

Figure 3 Sensor and Medical Web Services Architecture

To model the guideline definition in the extended GLIF, we have identified the external resources that we need to interact with while the guideline is being executed. These requirements and how they have been realized can be exemplified as follows:

- The guideline execution needs the vital signs of the patient: for example the oxygen saturation of patient's blood is needed to decide whether to apply oxygen therapy or not. As presented in Figure 3-A, the sensor data coming from wireless sensors to the gateway computer are exposed as Web services. These Web Services have been published to the UDDI Registry [15] together with their functionality semantics. For semantic annotation we use the nomenclature codes defined by the IEEE 11073-10101 standard [16]. In the guideline definition, whenever a vital sign of the patient is needed, the nomenclature code from IEEE 11073-10101, is assigned as the semantic category of the data needed. When the guideline is to be deployed, first of all the relevant Web services are discovered from the UDDI registry through their semantics, and saved to the guideline definition to be used in the guideline execution.

- The guideline execution requires data usually stored in the EHR of the patient, such as a possible contraindication to fibrinolysis. In SAPHIRE the EHRs of the patient are represented as HL7 CDA Level three documents [6]. An example CDA document used in SAPHIRE is presented in [17]. As presented in Figure 4, these EHR documents are shared through IHE XDS Registry/Repository architecture [5], where the EHR documents are registered/queried to/from the XDS Registries through their metadata. In the guideline definition whenever an EHR document is needed, the document metadata is specified through LOINC Document type codes [18]. When the guideline is to be deployed, the references to the related EHR documents of the patient stored in XDS repositories are discovered from the XDS Registry through this metadata.

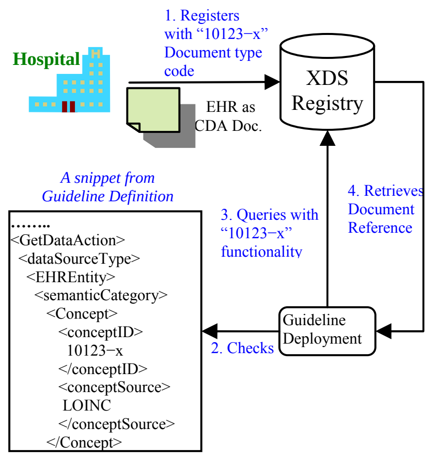

Figure 4 SAPHIRE EHR Architecture

- While guideline is being executed, it needs to interact with the underlying clinical workflow. For example, in our guideline, the guideline execution orders a coronary angiography to derive functional parameters of the patient's heart and blood supply, and needs to receive the results to continue its operation. Such interactions are facilitated through the Medical Web Services exposed by the Hospital Information Systems (HIS). In our pilot, the coronary angiography order is implemented as an asynchronous Web service since gathering the result may take some time but the execution can go on with the rest of the guideline, while operations such as saving the medication recommendations back to HIS are implemented as synchronous Web services. Such Web services are also published to the UDDI registries through their functionality semantics. We are using an HL7 based service functionality ontology [19]; such service requirements are represented through the nodes of this ontology in the guideline definition as presented in Figure 3-B. When the guideline is to be deployed, first of all these Web services are discovered from the UDDI registry through this metadata, and started to be used in the guideline execution.

- During the execution of guideline, several alarms, reminders may need to be issued to medical practitioners, and when necessary to the patient relatives. In such cases, the alarm message and the role to whom the message should be delivered are sent to an agent, the Alarm Distribution Agent, which is specifically designated to distribute these messages to the necessary recipients in the most efficient and reliable way. According to the urgency of the message to be delivered, one or more of the supported messaging means which are namely email, SMS and instant messaging (MSN, GTalk) are selected by the agent. The alarm distribution mechanism is reliable, i.e. the acknowledgements of the messages are tracked, if the original receiver is not available, the message is routed to an alternative user specified previously.

2.2 Execution of a small portion of Guideline

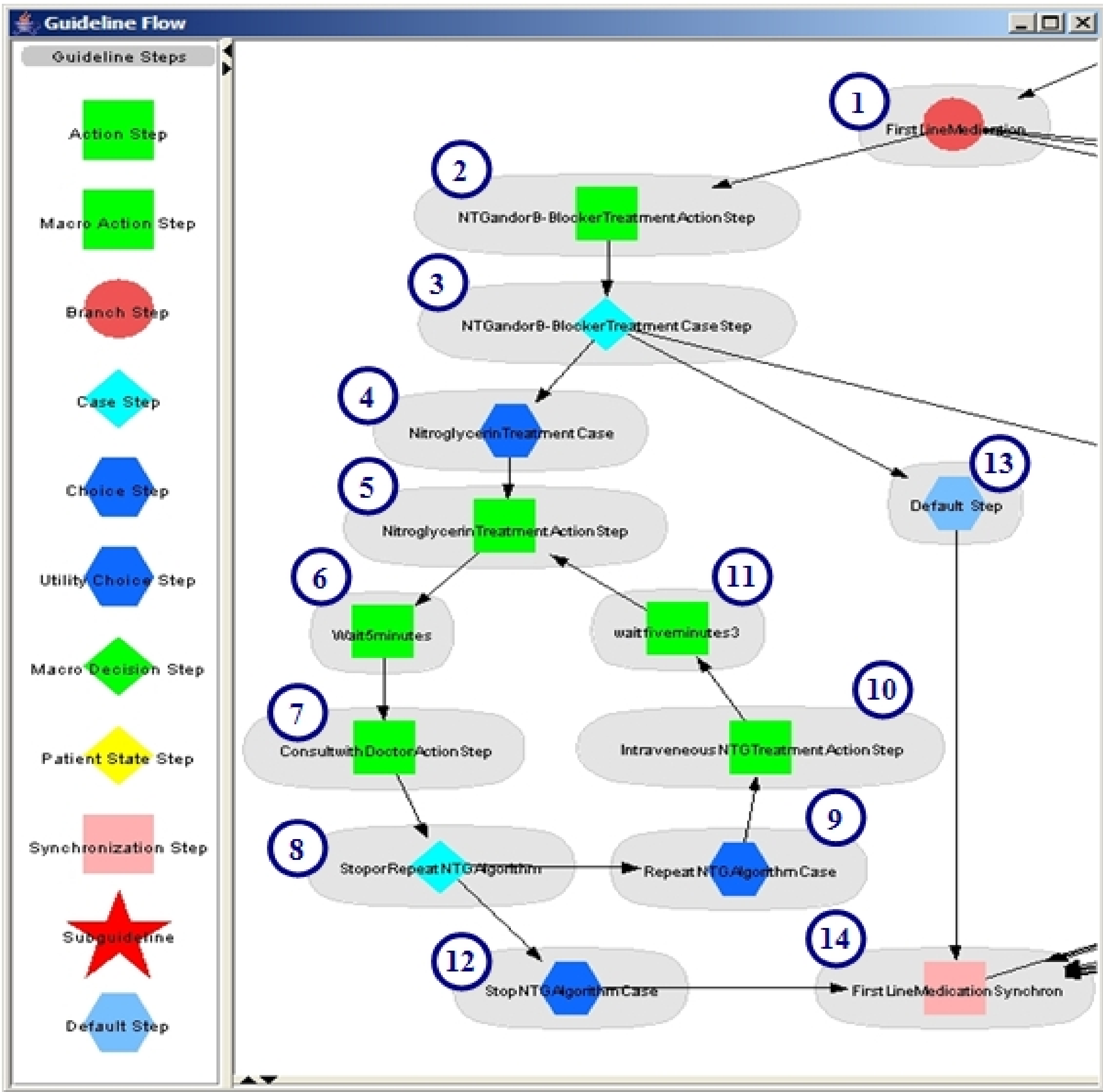

Figure 5 Flowchart of a small portion of the Guideline

In this section, execution of a small portion of the guideline is explained. This portion is responsible of applying Nitroglycerin (NTG) treatment to patient and it has been selected since it is rich enough to demonstrate all kind of services, namely the EHR, Sensor, Medical Services and delivering alarm to the clinician.

The flowchart of this guideline portion can be seen in Figure 5. This flowchart is automatically generated by the SAPHIRE Guideline Monitoring Tool and the execution is monitored on it by changing the underlying colors of guideline steps.

The first step is *First Line Medication Branch Step*. In order the guideline execution to decide whether to apply Nitroglycerin or B-Blocker treatment, it needs to access the EHRs (Baseline Bloodpressure, AnginaStatus) and the vital signs of the patient through sensors (Systolic Blood Pressure, Heart Rate). In Step 2, first of all the vital signs are gathered through invoking the Sensor Web Services identified in the deployment phase. For accessing the EHRs of the patient, the EHR documents are retrieved through the document references located from the XDS Registry in the deployment phase. The necessary pieces are extracted from the retrieved HL7 CDA documents to be used in the guideline execution. Example input, output structures for these Web Service calls and EHR accesses are represented in Table 1 and 2.

Table 1 Retrieval of Heart Rate

Service Type	Sensor Web Service
Input	<Data> <Patient_Data> <Id>10000006</Id> </Patient_Data> </Data>
Output	<Data> <Observation> <Id_OB>HeartRate</Id_OB> <Index_Value> <Index_IV>85.0</Index_IV> </Index_Value> </Observation> </Data>
Description	Value of “HeartRate” variable is retrieved from the sensor.

Table 2 Retrieval of Baseline Blood Pressure

<table>
<tr><td>Service Type</td><td>EHR</td></tr>
<tr><td>Input</td><td>10000006 (The reference to the EHR Document located in the deployment phase)</td></tr>
<tr><td>Output</td><td><Data>
  <Observation>
    <Certainity_OB>0</Certainity_OB>
      <Mood_Cd_OB>
        <Symbol_Value_S>EVN</Symbol_Value_S>
      </Mood_Cd_OB>
    <Service_Cd_OB>
      <Concept_Id_C>C0428880</Concept_Id_C>
      <Concept_Name_C>
        SystolicBloodPressure
      </Concept_Name_C>
      <Concept_Source_C>UMLS</Concept_Source_C>
    </Service_Cd_OB>
    <Severity_OB>0</Severity_OB>
    <Text_Value>100</Text_Value>
  </Observation>
</Data></td></tr>
<tr><td>Description</td><td>Value of "BaselineBP" variable is extracted from the HL7 CDA document retrieved from the XDS Repository.</td></tr>
</table>

After collecting the necessary input, in Step 4, the criterion presented in Table 3 is checked to decide whether Nitroglycerin Treatment is applicable to the patient.

Table 3 The Evaluator Script of *Nitroglycerin Treatment Criterion*

<table>
<tr><td>JavaScript Code</td><td>function NitroglycerinTreatmentCriterion(SystolicBP, BaselineBP, HeartRate, AnginaStatus) {
    if (!((SystolicBP.getValue().getIndex() < 90) ||
            (SystolicBP < (BaselineBP.getValue().getIndex() - 30)) ||
            (HeartRate.getValue().getIndex() < 60)) &&
        (AnginaStatus.getValue().getText() == "true") &&
        (HeartRate.getValue().getIndex() <= 100))

        return true;
    else
        return false;
}</td></tr>
<tr><td>Description</td><td>This criterion has 3 main blocks of conditions: if(not(E1) and E2 and E3). In E1, it is checked whether Systolic Blood Pressure (BP) of the patient is less than 90 mmHg, or Systolic BP is less than Baseline BP minus 30 mmHg or Heart Rate is less than 60 bpm. In E2, it is checked whether the patient has Angina and in E3, it is checked whether Heart Rate is less than or equal to 100 bpm.</td></tr>
</table>

In SAPHIRE, the decision criteria of the decision options should be defined with JavaScript as in the format shown in Table 3. The JavaScript executor module has been implemented using Rhino library [20]. With the retrieved values, this script evaluates to *true* and execution continues with *Nitroglycerin Treatment Action Step* (5). In this step, the doctor of the patient is informed that it is urgent to provide 0.4 mg nitroglycerin to the patient. This message is delivered to the doctor via SMS through the SAPHIRE alarm distribution mechanism as presented in Figure 6. Based on this message, the doctor can check the guideline execution monitoring tool to see why such a decision is taken. In addition to this, this medication recommendation is stored to the HIS, through a Web Service call as presented in Table 4.

Figure 6 NTG Treatment Alarm Message

Table 4 Prescription of 0.4mg Nitroglycerin to the patient

Service Type	Medical Web Service
Input	<storeMedication> <medication> <application> <route>sublingual</route> </application> <dosageQuantity>0.4</dosageQuantity> <notes></notes> <person> <PID>10000006</PID> </person> <service> <conceptID>C0017887</conceptID> <conceptName>Nitroglycerin</conceptName> <conceptSource>UMLS</conceptSource> </service> </medication> </storeMedication>
Output	"Medication inserted successfully"
Description	0.4mg Nitroglycerin medication recommendation is saved to HIS

After this step, through similar mechanisms presented the status of the patient is monitored and it is decided to stop the Nitroglycerin Treatment algorithm, and continue with the *First Line Medication Synchronization Step* (14).

As it can be seen, our guideline execution seamlessly accesses the necessary patient data and the underlying clinical workflow through widely accepted standards, Web Services, IHE XDS architecture and HL7 CDA.

3 The Homecare Application

In the homecare scenario, the SAPHIRE platform is used to implement services that benefit patients at a later state of their treatment. The hospital scenario deals with the patient in the subacute phase of myocardial infarction, while the homecare scenario deals with physiological recovery and training in secondary prevention [21]. Another difference between the two scenarios is the patient's role. After being discharged from the (rehabilitation) clinic, the patient must assume an active role in the treatment, and the SAPHIRE system empowers the patient to do so. It allows the patient to advance from simply being the recipient of care to being an important partner in the endeavor of tackling the disease. The daily feedback can be mutual, i.e. the patient can easily inform the doctor about problems that require attention but aren't deemed severe enough to warrant an immediate visit. Also the doctor can involve the patient more directly by giving feedback to the patient, and informing them about the progress the patient is making.

The key component of the homecare scenario is a modified bike ergometer that is shown in Figure 7-b. A panel PC has been mounted to the bike and serves both as a gateway for the sensor network and as a user interface for the patient. Adding this component to the SAPHIRE system allows the patient to emulate a supervised training at home. Being able to perform training with medically sound guidelines and automatic supervision in effect without having to travel to the rehabilitation clinic is already an improvement compared to the current state of the art, where supervision after discharge is sketchy at best and patient compliance is relatively low. Patients living in rural areas without quick access to the resources of the rehabilitation clinic will be the ones benefiting the most from the SAPHIRE system.

a) b)

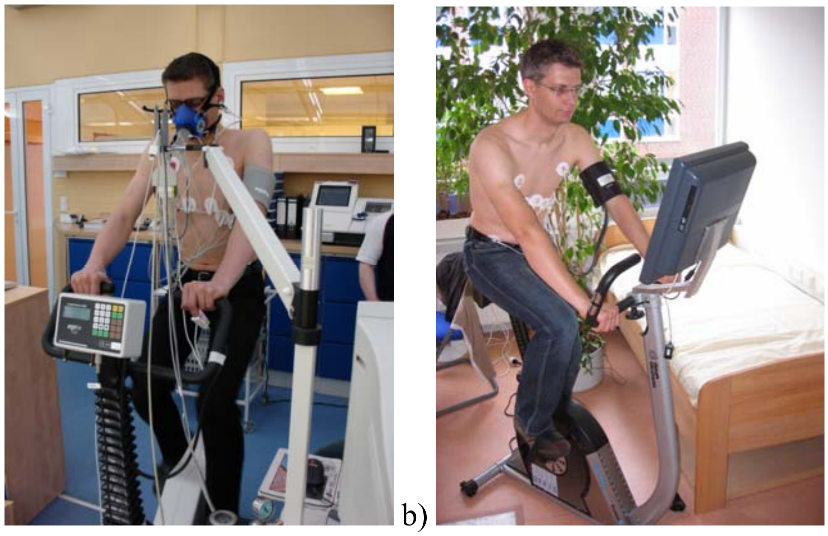

Figure 7 a) Training during the inpatient phase at the clinic, and b) the modified bike ergometer for the training during the outpatient phase at home

Although there are no suitable clinical guidelines for the fitness training, it is considered as one of the most important building blocks of a successful treatment of patients who have undergone a coronary angioplasty (PTCA). Assisted home-based training, as it is envisioned for the homecare application will generally be composed of two consecutive phases, the inpatient phase and the outpatient phase.

In the inpatient phase, after a successful revascularization procedure, patients will train in the rehabilitation clinic using the homecare equipment under the supervision of a physician. During this phase, the patient will become acquainted with the equipment (ergometer bike and sensors, see Figure 7-a). In this phase, which lasts approximately three weeks, the parameters (training program) and reference data for the home-based training will be acquired using spiroergometry.

In the outpatient phase, the patient will proceed with the training at home. The results of each training session are summarized in a report that will be reviewed by a physician once per day. If there’s an event requiring immediate assistance, the physician will be notified at once.

Most of the software used in the homecare application is implemented as bundles for the OSGi-framework [22]. As Figure 8 illustrates, the homecare application consists of several components with several dependencies among the components. The OSGi framework allows an easy management of these highly interconnected components. As some components, such as the training program and the patient GUI are very likely to require updates, using the ability to update bundles remotely will make it easier to offer maintenance for systems deployed at the patient’s homes.

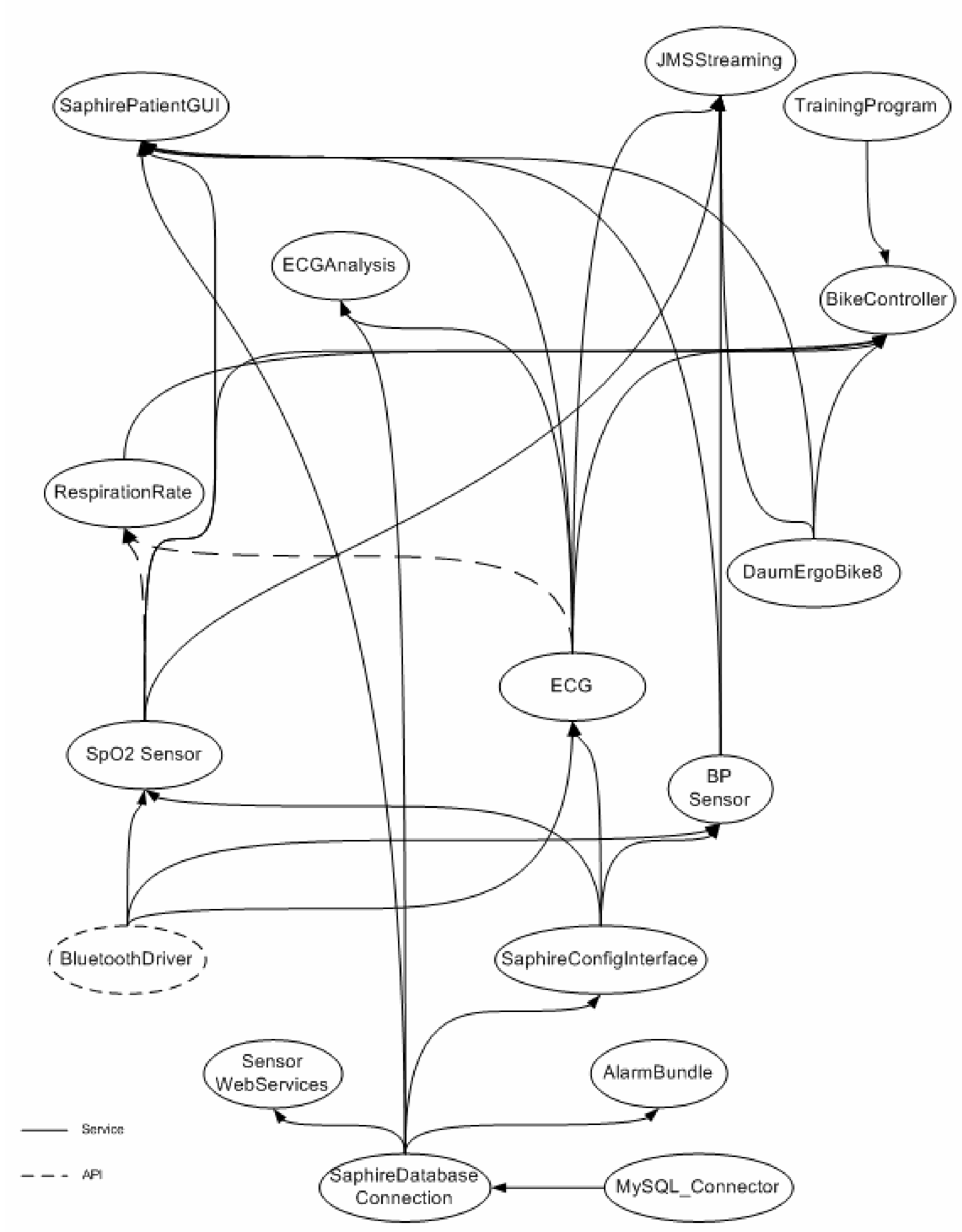

Figure 8 SAPHIRE OSGi bundles

As in the hospital pilot application, homecare scenario employs several aspects and variants of decision support to facilitate a safe and efficient training session

3.1 Sensor Placement Support

The correct placement of the sensors is vital for the functioning of the SAPHIRE system. The hospital application can rely on nurses and doctors being able to attach the sensors correctly on a patient, but in the homecare scenario, no such professional help is available, leaving this important task to the patient. Although the patient has been instructed during the inpatient phase in the rehabilitation clinic, it is likely that the system will have to instruct the patient on how to attach the sensors, and to detect missing or incorrectly positioned sensors. Missing ECG electrodes for example are detected easily, but in order to detect switched or misplaced leads, reference ECGs have to be used for comparison.

3.2 Patient Status and Stabilization

Before the actual exercise begins, the patient's vital parameters are acquired from the sensors, and the patient has to answer a number of questions. These questions cover the patient's current status (i.e. "Do you have breathing difficulties?") but also the patient's experience after the last training session (i.e. "Did you experience chest pain after the exercise ended?").

Based on the patient's answers, and taking the sensor data into account, the system determines whether or not it is safe for the patient to commence the ergometer training. Several options are available as a result:

- The patient's vital parameters are only temporarily outside the 'safe corridor', without being critical. If this is the case, the system will instruct the patient to wait for a few minutes. During this, the acquisition of data by the sensors and monitoring will continue.
- The patient's vital signs are within the 'safe corridor', but the answers given indicate that the patient should not continue the training session. An example for this case would be a patient experiencing pain after the last training session that faded and is not felt in rest. The system will instruct the patient to contact the rehabilitation clinic.

- The patient's vital parameters are critical. In this case, the patient is asked to contact the rehabilitation clinic right away. The SAPHIRE alert system allows an alert to be sent to the clinic, or to an emergency dispatcher.
- The patient's vital parameters are within the 'safe corridor', but the patient indicates that the medication has been changed. In this case, the training might commence, using a more conservative guideline. Information regarding the medication would be sent to the rehabilitation clinic, so it can be taken into account for a new training program.

Once the patient begins the exercise, leaving the state of rest, monitoring the status becomes even more crucial. During the training, the patient can signal events (such as pain and dyspnoea) at any time using the touch screen. This action will abort the training and trigger an alert that will be sent to the clinic. Sensor data are used to determine the patient's status during the exercise session. Depending on the patient's recommended training program, the ergometer bike needs to control the resistance in order to maintain target wattage or a target heart rate. Adapting the resistance to maintain a set heart rate is a feature offered by most ergometers. We believe that taking into account the patient's breathing frequency, blood pressure, the oxygen saturation, and the ECG - in addition to the heart rate - allows for a much safer training, creating a combination of fitness training and ongoing diagnostics.

Figure 9 shows a simplified state machine that describes the states of an early experimental system during a training session where the ergometer's power is regulated by a PI (proportional-integral) controller to maintain a target pulse. In the homecare application, more sensors will be used, but the pulse will remain as the main variable used to control the resistance.

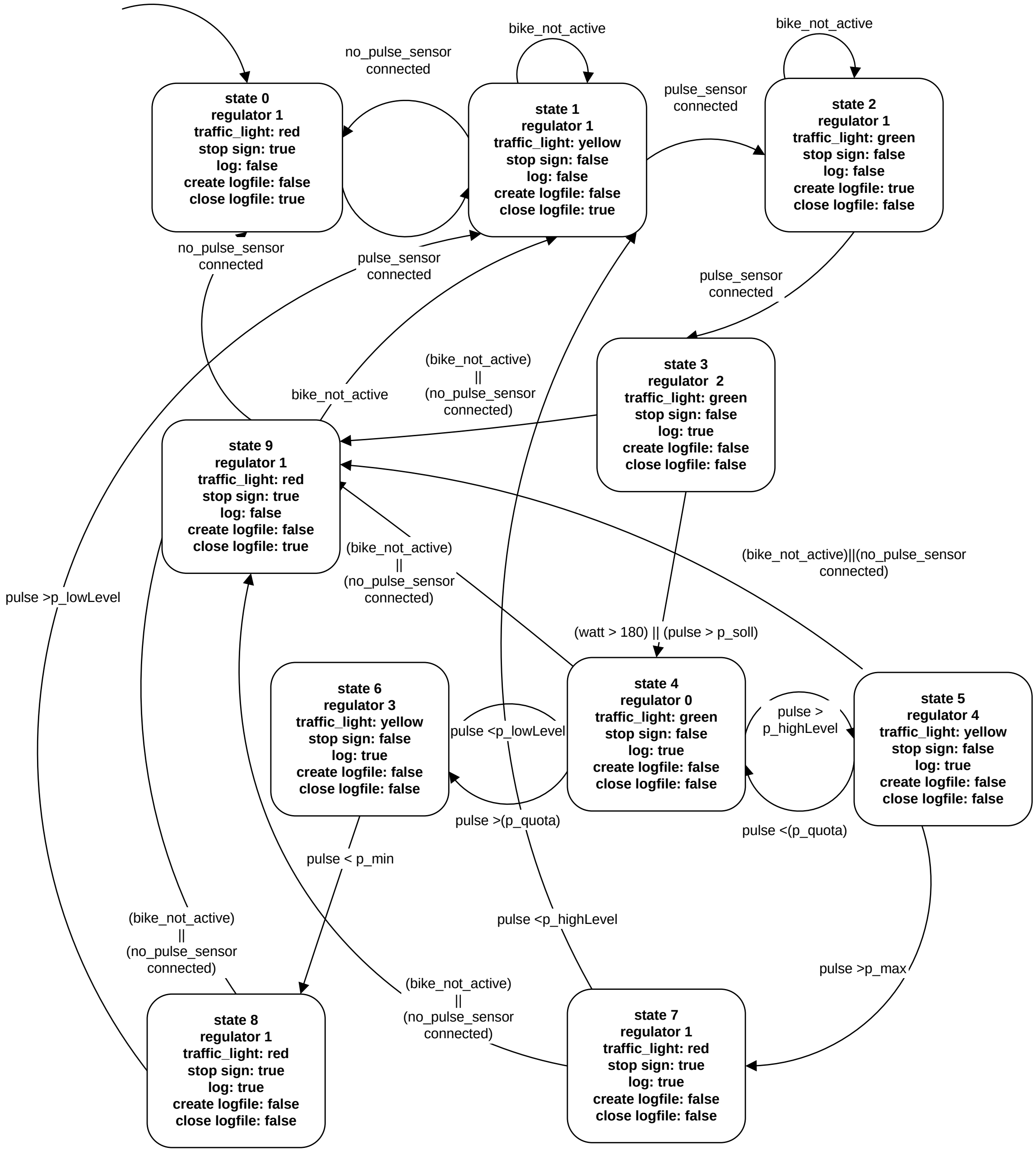

Figure 9 State machine describing the training

After the training session, while the patient is cooling down, and while the sensors are still acquiring blood pressure and other data, several questions are asked to determine how the patient is feeling. Although sensor data reveals a lot about how the patient was able to cope with the training program, having this additional input is very helpful. Among other things, the system asks the patient about the perceived exertion. The dialog shown in Figure 10 maps the degree of exertion to the Borg scale [23]. This perceived exertion ranges between "very, very light", which is usually the case in rest, to "exhaustion". The American College of Sports Medicine (ACSM) has recommended RPE (rate of perceived exertion) since 1986 for both fitness and Cardiac rehabilitation purposes [24]. Guidelines of the ACSM recommend a RPE range of 12 ("fairly light") to 16 ("hard") as the perceived exertion range associated with a cardiovascular training effect; roughly corresponding to 60%-85% of the Maximal Heart Rate (HR_{max} = 220 – age).

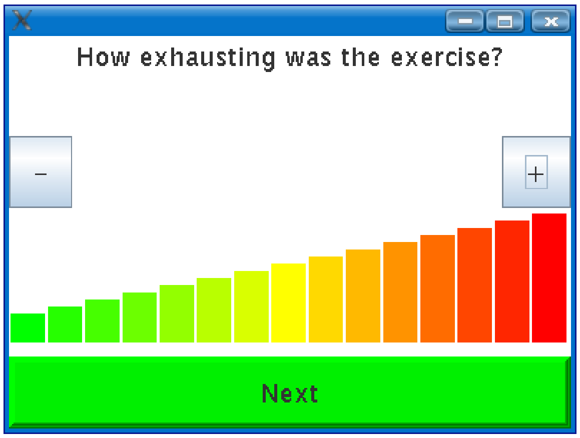

Figure 10 Example dialog querying the Borg value

Capturing the sensor data and correlating it with the patient's answers (especially the RPE) allows the physicians to determine the efficiency of the training.

For the pilot application, patients after an acute myocardial infarction have been chosen. However, the system can be used for other patient groups as well. For example, by providing scales, the system would be suitable for patients with chronic heart failure, who would benefit greatly from light exercise and a thorough monitoring of the weight. It would also be possible to turn the SAPHIRE system into a tool for prevention. A setup consisting of an ergometer, weight scales, and a glucose meter could be used to manage diabetes while aiding the necessary change of lifestyle and combating risk factors for heart infarctions. The feedback that can be provided through a system like SAPHIRE makes it a powerful tool for people who wish to actively pursue the goal of personal health.

4 Conclusions

The SAPHIRE system proposes an intelligent healthcare monitoring architecture based on clinical guidelines. The architecture is supported with a semantic interoperability platform in order to access the Electronic Healthcare Records and vital signs of the patients seamlessly, which was presented as a major reason for the failure of adoption of clinical guidelines by the hospitals. The system is tested with two pilot applications, one in homecare, one in hospital environment. Through these pilot applications, the system aims not only to reduce the workload in the hospital and to diminish probability of human error, but also in future aims to reduce the medical costs by cutting down intensive care days and complex diagnostic investigations or therapeutic approaches where these are not necessary and supporting remote rehabilitation at homes. The SAPHIRE system in the homecare scenario can be seen as one step towards p-Health (personal health) applications as well as an extension of healthcare services to the patient's home. With some modifications of the sensor setup and new computer-executable guidelines, the system can be adapted for other diseases easily.

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