Building a Distributed E-Healthcare System Using SOA

Firat Kart, Louise E. Moser, and P. Michael Melliar-Smith
University of California, Santa Barbara

This article describes a distributed e-healthcare system that uses the service-oriented architecture as a means of designing, implementing, and managing healthcare services.

Effective and timely communication between patients, physicians, nurses, pharmacists, and other healthcare professionals is vital to good healthcare. Current communication mechanisms, based largely on paper records and prescriptions, are old-fashioned, inefficient, and unreliable. In an age of electronic record keeping and communication, the healthcare industry is still tied to paper documents that are easily mislaid, often illegible, and easy to forge. When multiple healthcare professionals and facilities are involved in providing healthcare for a patient, the healthcare services provided aren’t often coordinated.

Countries that have centralized healthcare systems such as the UK have made considerable progress toward electronic medical records and prescriptions, including patient access to them. Despite concerns about security and privacy, such systems provide increased accuracy and efficiency, better communication among healthcare professionals, and reduced risk of prescription errors.

In the US, such record keeping and communication are difficult to establish because of the highly diverse and decentralized nature of healthcare. Physicians’ offices, clinics, hospitals, and
pharmacies use computer systems that, for the most part, aren’t interoperable. In addition, the development of multiple healthcare systems has resulted in data not being easily translated from one system to another. Standards are the key to solving these interoperability problems and enabling collaboration among computer systems. Several organizations, including WellPoint, Blue Cross, and Blue Shield, have initiatives under way to develop electronic prescriptions, but today only 2 to 3 percent of the more than three billion prescriptions each year are submitted electronically.

Typically, a physician writes a prescription on paper and gives it to the patient. The patient carries the prescription to the pharmacy, waits in line to hand the prescription to the pharmacist, and waits for the pharmacist to fill the prescription. The pharmacist might be unable to read the physician’s handwriting; the patient could modify or forge the prescription; or the physician might be unaware of medications prescribed by other physicians. These and other problems indicate the need to improve the quality of healthcare (see the sidebar “The Quality of Healthcare in the US”), ease access to healthcare and healthcare information, and reduce the cost of delivering healthcare.

A distributed electronic healthcare system based on the service-oriented architecture (SOA) can address some of these issues and problems. We developed a distributed e-healthcare system for use by physicians, nurses, pharmacists, and other professionals, as well as by patients and medical devices used to monitor patients. Multimedia input and output—with text, images, and speech—make the system less computer-like and more attractive to users who aren’t computer-oriented.

Service-Oriented Architecture

In our project, SOA, along with Web services and Atom and RSS feeds, provides the opportunity for diverse systems to interoperate without requiring the use of a particular kind of computer system. SOA—an architecture in which the building blocks are services—only encompasses the services from a technology perspective but also includes the policies and practices that govern service provision and consumption.

SOA enables reusability of software components, provides protocol independence, and facilitates application integration. It enforces basic software architecture principles such as modular design, abstraction, and encapsulation. With open standards, such as XML and SOAP, SOA provides interoperability between services operating on diverse platforms and between applications implemented in different languages. It supports diverse processing efficiently and easily, enables cross-platform communication, and adapts dynamically to meet changing needs.

For healthcare in particular, SOA and healthcare standards enable interoperability by encoding healthcare information using one or more common (generally agreed upon) representations (see the sidebar “The Development of Healthcare Standards”). With healthcare standards, diverse but interoperable systems can improve the quality of healthcare delivered to patients.

The Quality of Healthcare in the US

A Washington Post article indicates that as much as 5 percent of the three billion prescriptions filled each year are incorrect, and the US National Association of Boards of Pharmacy reports that as many as 7,000 deaths occur in the US each year because of incorrect prescriptions.

One relevant study suggests that such errors can be prevented by designing systems that can “make it hard for people to do the wrong thing and easy for people to do the right thing.” Although automating systems might sound like a good strategy, a recent whitepaper points out that large healthcare operations face difficulties in managing personal data, standardizing data, extracting content-based knowledge, and federating databases—all of which highlights the issues that many IT professionals face in working to solve problems in the healthcare industry (http://initiative.healthgrid.org/the-initiative/healthgrids-concept/white-paper.html).

References

Distributed E-Healthcare System

Our prototype distributed e-healthcare system uses SOA to enforce basic software architecture principles and provide interoperability between different computing platforms and applications that communicate with each other. The clinic, pharmacy, and patient modules provide the actual services for the distributed e-healthcare system. The devices accessing these modules can be desktop or server computers as well as PDAs or smartphones. They can also be electronic medical devices, such as blood pressure monitors.

Although our distributed e-healthcare system provides user-friendly interfaces for busy healthcare professionals and patients, security and privacy are particularly important in this area, so we designed the prototype with security and privacy in mind. The system authenticates users and logs session information and attaches resources to the resource creator, so that only privileged users can view or modify the data. For applications deployed on devices such as PDAs, the system strictly enforces authentication and session management.

Clinic Module

The clinic module supports routine activities of physicians and nurses at the clinic by maintaining information such as appointments for a specific day or week, the patients that the physician has examined, and notes related to patients. The clinic module exposes a Web server interface and a Web service interface, as Figure 1 shows. We designed the Web server interface for users who prefer to access the healthcare services from a Web browser.

A physician or nurse can use the Web server interface to access the clinic module from a desktop computer or a PDA, and the patient can use the Web server interface to request appointments with the physician for a specific date and time. The Web server uses a Web service to access healthcare data. Applications and devices can use this Web service to communicate with the clinic module. In addition, monitoring devices—such as electronic blood pressure monitors, glucose monitors, weighing scales, pillboxes, and so forth—can transmit information to a desktop or laptop computer via a wired or wireless network and then to the clinic Web service over the Internet.

The clinic module sends prescriptions from the physician to the pharmacy over the Internet using the pharmacy Web service. To locate the pharmacy closest to the patient’s home or the physician’s office, the clinic Web service sends a Web service query to a Web service registry, where pharmacies offering such services have registered. Communication between the physi-
The physician can use a PDA to enter and retrieve information about the patient during or after an appointment and to access the information later. The e-healthcare system currently uses an OQO PC, shown in Figure 2, which is a full-featured 3×5-inch PC with an 800×480-pixel screen that is capable of providing detailed graphical information. The handheld computer can communicate with a desktop or server using a wireless connection.

The use of a small keyboard makes it difficult for the physician to input information, so in addition to the graphical interface, the handheld is equipped with speech recognition and synthesis software that lets the physician enter and retrieve information by speaking and receiving spoken feedback. These speech technologies help the physician complete tasks and encourage the use of the handheld. To ensure accuracy, the physician must confirm the prescribed medication and its dosage upon entry because such information is critical to the patient’s life. Integration with pharmaceutical applications or Web services that warn of interactions between medications can further improve the provided service’s accuracy.

**Pharmacy Module**

The pharmacy module, which provides services to the pharmacist and devices at the pharmacy, keeps a record of the patient’s prescriptions for reference and updates prescription status as the pharmacist fills them. The pharmacy module exposes Web server and Web service interfaces, as Figure 3 shows. The Web server interface lets users access the pharmacy module from a Web browser. The pharmacist can use this interface to view prescriptions as the pharmacy receives them from physicians. The patient can use the Web server interface to determine whether a prescription has been filled and is ready for pick up or delivery.

The Web service interface provides access for applications deployed at the pharmacy. The clinic module sends prescriptions from the physician to

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**Figure 1. Clinic module with Web server and Web service (WS) interfaces.**

**Figure 2. Physician’s handheld displaying a list of medications.**
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The pharmacy over the Internet using the pharmacy Web service. The Web service verifies the physician’s identity, and also checks the patient’s insurance before processing the prescription. Removing human intervention from communication between the physician and pharmacist and maintaining information electronically reduces the possibility of human error.

The Web server interface to the pharmacy module, shown in Figure 4a, lets the pharmacist monitor incoming prescriptions, update their status, and inform the physician and the patient about the status of the patient’s prescriptions. The pharmacist can query the pharmacy module to obtain the status of prescriptions, the records for a particular patient, and other information, with query results shown as a list for the pharmacist to view.

**Patient Interfaces**

The Web server interface to the clinic module lets a patient request an appointment with a physician for a specific date and time using the clinic Web server. In the system, the patient can both see his or her appointments with the physician and access other information. The Web server interface to the pharmacy module, shown in Figure 4b, lets a patient check the status of a prescription, view his or her prescription history, and renew existing prescriptions. If the patient requests a prescription to be filled at the Web site, he or she must make a payment or copayment before the pharmacist can start to fill the prescription. The pharmacy module sends reminders to the patient about the status of the patient’s prescriptions as well as sends messages from the pharmacist to the patient.

To assess and report the patient’s health status, the system supports the use of medical monitoring devices—on wired or wireless networks—to report periodically or, in emergencies, to send an alert immediately. The system doesn’t send any patient-identifying information; rather, it transmits information along with the device’s serial number, and the clinic Web service makes the association with the particular patient. If the patient hasn’t registered the device, the clinic Web service discards the data from the device.

The e-healthcare system is currently enabled with an electronic blood pressure monitor, which transmits blood pressure readings to the patient’s laptop or desktop computer. The data is then communicated over the Internet to the clinic Web service for examination by the physician. The physician
and the patient can see the historical data from the blood pressure monitor as a list or in a chart as a clinic Web service. Figure 5a shows the output from the patient’s blood pressure monitor, and Figure 5b shows the patient’s blood pressure history.

**Underlying Information Technology**

We implemented our prototype e-healthcare system in Java because of its ability to be deployed on small wireless devices as well as on powerful servers. To ease development and debugging of the system, the implementation uses Plain Old Java Objects (POJO) based on the Spring framework.

**Web Services**

Web services are applications that typically execute on a remote computer and can be accessed by clients over the Internet. Web services are based on open standards—in particular, XML and SOAP. These standards aim to achieve interoperability between applications implemented in different languages, running on diverse computer systems, and communicating over a network.

Our distributed e-healthcare system uses the Apache Axis2 framework (the core engine for Web services built on Apache Axiom) and the Apache Tomcat server. Axis2 provides data bindings that enable application developers to generate SOAP messages without being concerned about constructing or parsing them.

Web Services Security (www.oasis-open.org/committees/wss/)—provides a means of incorporating security features in a SOAP message’s header. It supports multiple trust domains, encryption technologies, signature formats, and security token formats.

**Speech Software**

Our distributed e-healthcare system uses SRI’s DynaSpeak speech recognition software (www.sri.com) because it supports multiple languages, adapts to different accents, and doesn’t require training prior to use. DynaSpeak is ideal for embedded platforms because of its small footprint and its low computing requirements. Figure 6a shows the prescription grammar for the e-healthcare system, and Figure 6b gives an example of its use on a physician’s handheld device.

The distributed e-healthcare system uses AT&T’s Natural Voices speech synthesis software (www.research.att.com/~ttsweb/tts/), which can accurately and naturally pronounce words and speak in sentences that are clear and easy to understand. Natural Voices supports many languages, male and female voices, and several speech interface standards.

**Atom and RSS**

Enabling physicians, nurses, and pharmacists to use PDAs or smart phones requires those devices to be able to communicate with the clinic and pharmacy modules on their desktop or server computers using a wireless or wired network. At certain times or places, network communication might not be available—for example, in an emergency, such as an earthquake or a hurricane, a physician can’t expect to have a network connection to his or her desktop or server. Thus, physicians, nurses, and pharmacists must be able to access and modify healthcare information offline.

Atom and RSS are syndication technologies based on XML that enable the sharing and
A major problem in healthcare today is that communication between the physician and the patient typically exists only within the physician’s office: once the patient leaves the office, communication is very limited. However, monitoring the recovery progress is essential to good healthcare. This problem is even more severe for hospitals.

A distributed e-healthcare system can help solve this conundrum. Medical monitoring devices worn by the patient, and frequent electronic communication between the patient and a nurse, can ensure that the prescribed treatment is being followed and that the patient is making good progress.

The e-healthcare system described here can be readily extended to other healthcare professionals, including medical technicians who perform and report tests and analyses requested by physicians. In addition, the system can be interfaced to other applications that provide information on medications and dosages and warn of interactions between medications. Finally, it can be interfaced to drug-delivery devices that prompt and monitor the regular and timely consumption of medications.

References

Firat Kart is a PhD candidate in electrical and computer engineering at the University of California, Santa Barbara. Contact him at firatkart@ece.ucsb.edu.

Louise E. Moser is a professor in electrical and computer engineering at the University of California, Santa Barbara. Contact her at moser@ece.ucsb.edu.

P. Michael Melliar-Smith is a professor in electrical and computer engineering at the University of California, Santa Barbara. Contact him at pmms@ece.ucsb.edu.

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