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Development of Distributed E-Healthcare System Using Service Oriented Architecture

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Abstract—*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 are not often coordinated.*

1. INTRODUCTION

Countries that have centralized healthcare systems such as the UK have made considerable progress toward electronic medical records and prescriptions, including patients' excess 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, are not 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 collaborations among computer systems. Several organizations including WellPoint, BlueCross and Blue Shield, have initiatives under way to develop electronic prescriptions, but today only 2 to 3 percent of the more than 3 billion prescriptions each year are submitted electronically.

Typically, a physician writes a prescription and gives it to the patients. The patient carries the prescription to the pharmacy, waits in line to hand the prescription to the pharmacist, and waits for the pharmacists 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, 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 are not computer- oriented.

2. SERVICE-ORIENTED ARCHITECTURE

In our project, Service – Oriented Architecture (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-not only encompasses the services from a technology perspective but also includes the policies and practices that govern service provision and very attractive consumption.

SOA enables reusability of software components, provides protocol independence, and facilitates application integration. It enforces basic software architecture principles and 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 representations. With healthcare standards, diverse but interoperable system can improve the quality of healthcare delivered to patients.

3. 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 Smartphone. 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.

4. 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 Fig. shows. We designed a web server interface for users to prefer the 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 PDA, and the patients can use the web server interface to request appointment 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 a 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 physician and the pharmacy occur after the physician receives a response from the registry. Although, we used our own message data format in our prototype, an actual e-healthcare system would follow electronic prescription standards once they are adopted and widely used.

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, as shown in Fig. which is a full featured 3- X 5-inch PC with an 800- X 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.

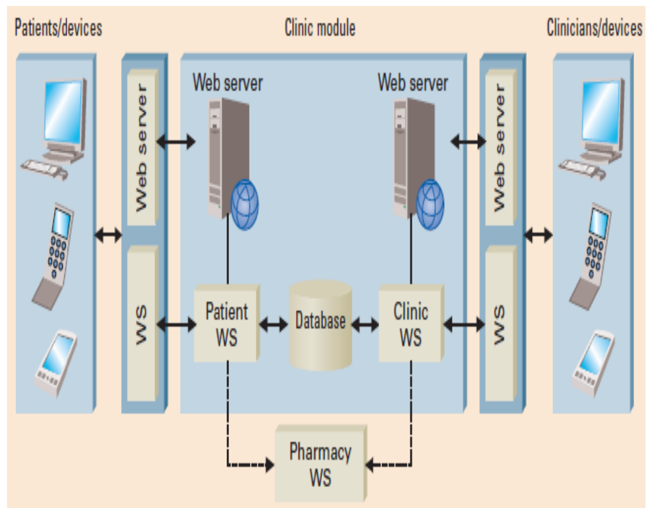

Fig.1: Clinic module with Web server and Web service (WS) interfaces.

The use of a small keyboard makes it difficult for the physician to input information, so in addition to the graphical interface, the hand held 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 the 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.

The pharmacy module, which provide 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 Fig. 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.

Fig. 2: Physician's handheld displaying a list of medications

5. PHARMACY MODULE

The Web service interface provides access for applications deployed at the pharmacy. The clinic module sends prescriptions from the physician to 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 pharmacists and maintaining information electronically reduces the possibility of human error.

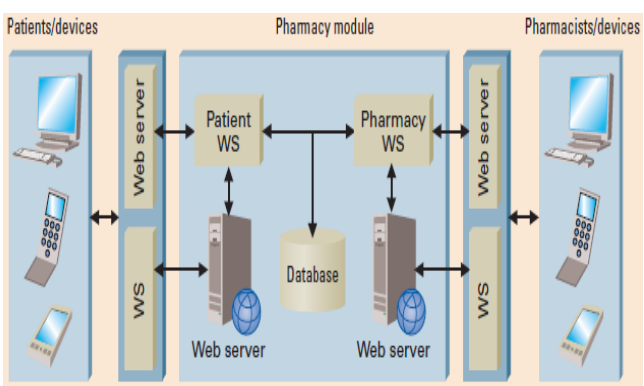

Fig. 3: Pharmacy module with Web server and Web service (WS) interfaces

The web server interface to the pharmacy module, shown in figure, lets the pharmacist monitor incoming prescriptions, update their status, and inform the physician and the patient about the status of the patient's description. The pharmacist can query the pharmacy module to obtain the status of prescriptions, the records for a particular patient, and other information, with query result shown as a list for the pharmacist to view.

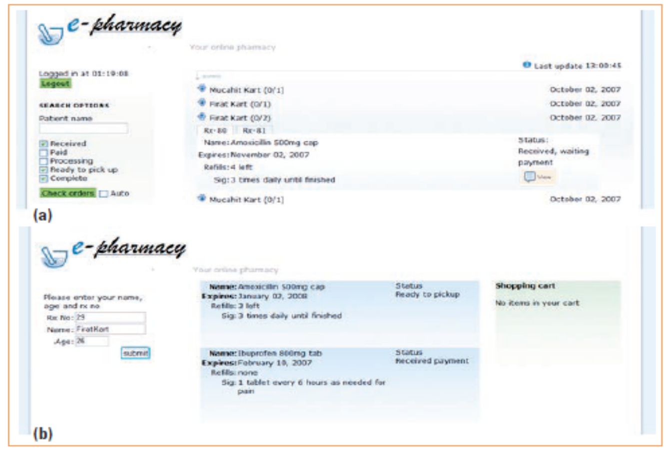

Fig. 4: The Web server interface to (a) the pharmacy module for the pharmacist and (b) the patient.

6. PATIENT INTERFACES

The web server interface to the clinic module let's 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, 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 website, 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 does not 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 has not 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. Fig. shows the output from the patient's blood pressure monitor, and Fig. shows the patient's blood pressure history.

7. UNDERLYING INFORMATION TECHNOLOGY

We implemented our prototype e-healthcare system in java because of its ability to deploy 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.

8. 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 tokens formats.

9. SPEECH SOFTWARE

Our distributed e-healthcare system uses SRI's Dyna Speak speech recognition software (www.sri.com) because it supports multiple languages, adapts to different accents and does not require training prior to use. Dyna Speak is ideal for embedded platforms because of its small footprint and its low computing requirements. Fig. given shows the prescription, grammar for the e-healthcare system and the Fig. 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.

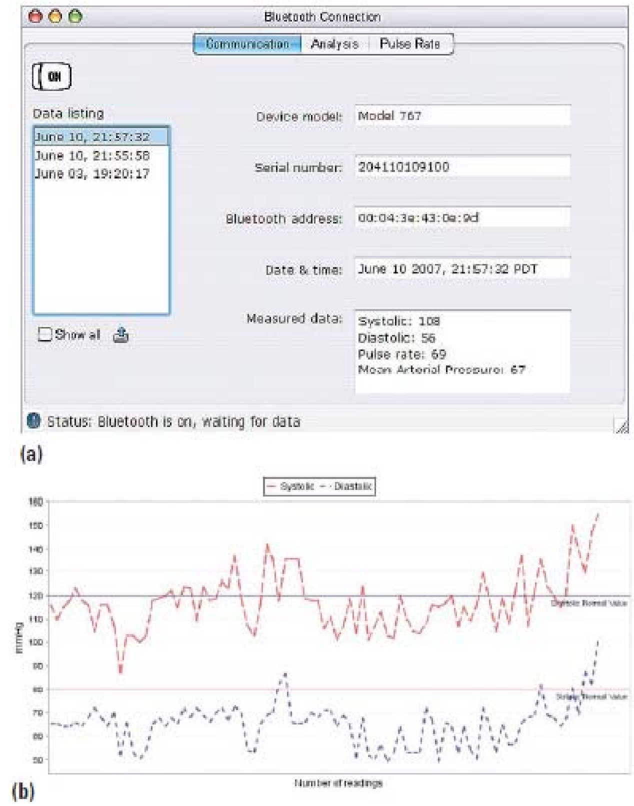

Fig. 5: (a) Output from the electronic blood pressure monitor on the patient's desktop or laptop.

(b) The patient's blood pressure history maintained using a clinic Web service.

10. ATOM AND RSS

Enabling physicians, nurses, and pharmacists to use PDAs or smart phone 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 cannot 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 health care information offline.

Atom and RSS are syndication technologies based on XML that enable the sharing and communication of information between heterogeneous platforms by making the information self-describing. Our distributed e-healthcare system uses Atom with additional infrastructure, software to synchronize information on a desktop or server with the information on a handheld. This software lets physicians, nurses, and pharmacists view and update healthcare information when it is offline. 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.

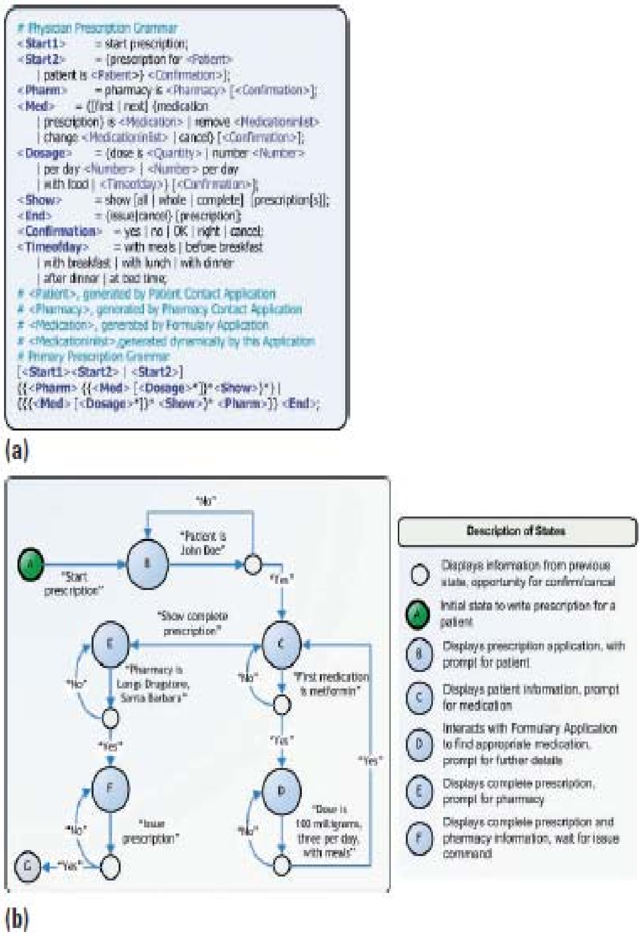

Fig. 6.(a) The e-healthcare system's prescription grammar, and (b) an example of its use on a physician's handheld device.

A distributed e-healthcare system can help to 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 to 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.

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