

SEMANTIC INTEROPERABILITY IN THE CONTEXT OF e-HEALTH IN NIGERIA: THE GOAL, THE VISION AND THE CHALLENGES

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Abstract

Within the context of Nigeria's e-Health strategy, interoperability is the only sustainable way to help partners acting in various locations, with different expertise, perspectives, agendas and status, even cultures and languages, and using distinct information systems from different vendors, to collaborate harmoniously to deliver quality healthcare. Furthermore, to meet the technical demands for the successful support of complex healthcare processes, modern healthcare enterprise architectures must achieve and implement interoperability in all the healthcare domains. Interoperability, which may be expressed using functional, syntactic, or semantic methods, it is necessary to provide information dissemination for all areas in healthcare. Semantic interoperability, which defines the ability for information shared by systems to be understood at the level of formally defined domain concepts, so that the information is computer processable by the receiving systems, it is essential for the development of automatic computer processing healthcare applications and decision support systems. This paper provides an overview of the terminology and definitions needed to understand the implications of interoperability in the context e-Health as well as the influence that semantic interoperability could have for achieving seamless interoperability between several healthcare domains.

Keywords: e-health, interoperability, healthcare applications, architectures, system integration

Introduction

With advances in information technology, the need to cut health care delivery costs, and consumer demands for more effective and better-

quality care have hastened the exploration of alternative methods for storing and retrieving health care information. But the implementation of new and improved electronic health records

(EHR) systems faces several formidable challenges. First, the acceptance of information technology in the health care industry has been slow compared to other industries, such as banking and financial services (Powner, 2006a; Powner, 2006b). Compounding this is the limited knowledge available in deploying applications, thereby leading to a steeper learning curve. Second, the health care delivery process is inherently complex due to the presence of multiple players and providers. These participants may be unwilling to share health-related information, but even when they agree to share information, individual entities may have their own ad hoc, customized or vendor-driven software that is incompatible with other systems (Chaudhry et al., 2006).

Additional surveys reported in Powner (2005) and Powner & Koontz (2005) found that majority of the systems described were internal to the organizations and had no ability to connect with external or other internal systems. A significant barrier, therefore, to the introduction of EHRs is the lack of interoperability. Most EHRs do not interact well with other applications (Himmelstein and Woolhandler, 2005). The result is that physicians who eventually use an EHR provide poor quality of healthcare services because current EHR applications in Nigeria are not designed to “speak” to other external entities related to the systems within the healthcare domain. The technology in most doctors' offices

cannot send or receive clinical information, such as the laboratory and radiology results and medication lists critical to patient care (Bates, 2005). In a nutshell, nearly all of the EHR systems in use today are little more than database management programs that help generate patient data entry (forms) and produce reports; and none of these applications have the capacity to scale up to fully, multi-functional prototypes or to be commercially viable in terms of complete interoperability in a large-scale distributed environment (Chaudhry et al., 2006; Koontz, 2005; Powner, 2005; Powner, 2006a; Powner and Koontz, 2005).

Newer socio-technical approaches to design, for example, a distributed systems approach such as a service-oriented architecture (SOA) combined with Web services are needed to produce viable EHRs. Standardized interfaces and use of middleware enable loosely coupled interoperability amongst the various participants and components, thereby eliminating the constraints of disparate vendor-driven systems. Given the SOA is an overarching architecture (Papazoglou and Georgakopoulos, 2003); it embraces open standards with which vendors of components comply.

In this exploratory research, we discuss applying the SOA approach to developing distributed,

interoperable EHR systems. The rest of the paper is organized as follows. First, we identify the design issues in EHRs, focusing primarily on interoperability. Second, we examine the potential of the SOA framework in modeling and implementing interoperable EHRs. Thirdly, we describe a prototype model for a health clinic setting based on the SOA framework. Fourth, we discuss the challenges in implementing SOA-based EHRs. Finally, we offer our conclusions.

Main Problems in Health Information Systems

There has been a tremendous progress in Health Information Systems during the last two decades, especially during the last 10 years, yet there are many problems which limit the further progress. The main problems are as follows:

a. Degree of Hospital Standardization is Poor

Hospital information relate to medical treatment, education, medical research, personnel, money, and substance. Unification of the title, the concept, the classification and the codes are the basic precondition for information interchange. But the most difficulty is that the standards are not unified. For example, the titles and codes of the case reports, drugs, personnel, equipments, inspection and examination differ in different hospitals. The definition, description and practice

operation for the same thing are different. Without unified and authoritative hospital standardization data dictionaries, it will be difficult for software systems within the healthcare domain to interoperate.

b. Software Systems Developments Lack Unified Layout

HIS developments began to boost up since the early 1990. All levels of health administrations, hospitals and some information development companies invested huge personnel and money into HIS development. In developed regions, the HIS achieved success and have larger scale, yet without standards to comply with and without surveillance by some related administrations thereby leading to a non-normative HIS development process. Furthermore, HIS development companies were in different levels, and many of them didn't specialize in HIS development, they were not familiar with the style of hospital management and workflows, or they only knew some specific hospitals. Again, some companies have the idea of eager for quick success and instant benefit, and only considered the current benefits without long term investment. Some companies even thought that HIS market had potential, so they made some simple system packages together, and took some measures to deceive the users. All above brought severe bad

influence to HIS development (Wang and Hu, 2005).

c. Models of Hospitals Management Are Non-Normative

It seems that models of hospitals management have nothing to do with the HIS. In fact, they have many influences on HIS construction. HIS implementation requires technical, structural and behavioral sense, and development of HIS should be carried out within the context of the development itself (Ball, 2003). Application with HIS without studying and absorbing has become one bottleneck for HIS development. To meet the need of the hospitals management, the developers had to act according to actual circumstance. Good HIS should optimum hospital processes and decision making.

Interoperability in Healthcare: Definitions and Terminology

The main purpose of standardizing healthcare information systems is to make interoperability and integration possible. Therefore, the distinction between interfacing, integration and interoperability is extremely important to understand.

a. **Interface:** A boundary at which interaction

occurs between two systems or processes. In computer science terminology, there are three types of interfaces: user, hardware, and software interfaces. For instance, a software interface according to Webopedia, defines “the languages and codes that the applications use to communicate with each other”.

b. **Integration:** A combination of diverse application entities into a relationship which functions as a whole i.e. the joint collaboration of several system components to form a single system.

c. **Interoperability:** A state which exists between two application entities when, with regard to a specific task, one application entity can accept and understand data from the other and perform that task in an appropriate and satisfactory manner without the need for extra operator intervention.

The Impact of Interoperability

It is critical to recognize the complexity of the processes that surround healthcare when aiming towards interoperability of healthcare information, in which various categories of players are directly or indirectly involved as enumerated below:

a. **Healthcare Companies:** This includes vendors of clinical systems, administrative IT systems, and medical devices e.g. imaging, ultrasound, laboratory, etc. This category usually involves large multinational companies with global objectives, to companies of small and medium size, focusing on a market in a small geographic area, or narrow scope.

b. **Healthcare Providers:** This category includes health professionals, belonging to a variety of professions e.g. physicians, nurses, technicians, etc. Unfortunately, very few have all the necessary and appropriate skills in computer science and technology; or the necessary time to dedicate resources to tackle interoperability problems or participate actively in standardization of health informatics and standards.

c. **IT and Administrative Staff:** They both play key roles in large healthcare providing institutions, but are often absent in small healthcare facilities. In addition, very few are active in standards development organizations or technology integration.

d. **Health Authorities and Governments:** This is the related bodies that supervise or manage the health system at the national level. With

evolving technologies and standards, usually, governments and authorities enforce interoperability through national standards, and in most cases this has proven to be effective.

Design Issues in Interoperable EHRS

The EHR, as defined by the Medical Records Institute, is electronically maintained information about an individual's lifetime health condition and health care. The EHR is expected to replace paper medical record(s) as the primary source of information for health care, and still comply with all clinical, legal and administrative requirements (<http://www.medrecinst.com>). The Healthcare Information and Management Systems Society (HIMSS) define the EHR more comprehensively as a “longitudinal electronic record of patient health information generated by one or more encounters in any healthcare delivery setting.

Included in this information are patient demographics, progress notes, problems, medications, vital signs, past medical history, immunizations, laboratory data and radiology reports. The EHR automates and streamlines the clinician's workflow. The EHR has the ability to generate a complete record of a clinical patient encounter, as well as supporting other care-related activities directly or indirectly via interface - including evidence-based decision

support, quality management, and outcomes reporting”

(http://www.himss.org/ASP/topics_ehr.asp). This definition reflects the interoperable and scalable nature of the EHR. It is not merely limited to the internal organizational use but expands out to include data and processes of all the participants in the health care delivery process.

However, to date, EHR application design appears to have been technology/vendor driven (Himmelstein and Woolhandler, 2005). It also does not adhere to generalized standards for portability. This limitation implies several things: One, as we've mentioned, systems are mostly internal with the primary purpose of tracking patients. Two, there is no multi-function capability, such as inclusion of clinical decision support (Chaudhry et al., 2006). Three, the current generation of EHRs lacks compliance with open standards (Himmelstein and Woolhandler, 2005; Koontz, 2005; Powner, 2005; Powner, 2006b; Powner and Koontz, 2005). Therefore, the next generation of EHRs must include properties of federation, flexibility, interoperability and openness (Halamka et al., 2005; Himmelstein and Woolhandler, 2005; Rollins, 2005), as health care delivery participants (e.g. physician clinics, HMOs, hospitals, diagnostic labs and pharmacies) strive to share health information within the context of ethics, privacy and security.

The essential but missing piece is an overarching architectural framework that pulls all the elements together. In this regard, other industries, such as banking and financial services, have begun conceptualizing and developing the SOA framework for their organizational information processing. Considering that characteristics of the health care delivery process, such as multiple providers and systems, are similar to those of these other industries, the SOA has great potential to address some of the design challenges. A comprehensive EHR at the point of care could be created by aggregating and sharing data among all sites at which patient receives care, as well as with data supplied by the patient. To share and use data from multiple institutions, data must be built upon common words (data elements and terminology), structures, and organizations. In the health information technology (HIT) environment, this requirement is called interoperability. Functional interoperability means that the participating groups support common functions and procedures, much as the parts of an automobile must fit and work together. Semantic interoperability means that the language of communication must be understandable by the computer at the receiving end of any communication (Hammond, 2005).

The newer SOA and Web services models hold considerable promise for assimilating the variety

of inputs in a decentralized fashion. The need for the SOA-based interoperable EHR has emerged in health organizations because of increased organizational complexity and environmental uncertainty (e.g. the multi-payer system). The

SOA, then, provides the conceptual framework for the implementation of distributed interoperable HIT applications such as EHRs on this network. Figure 2 represents framework for basic SOA architecture.

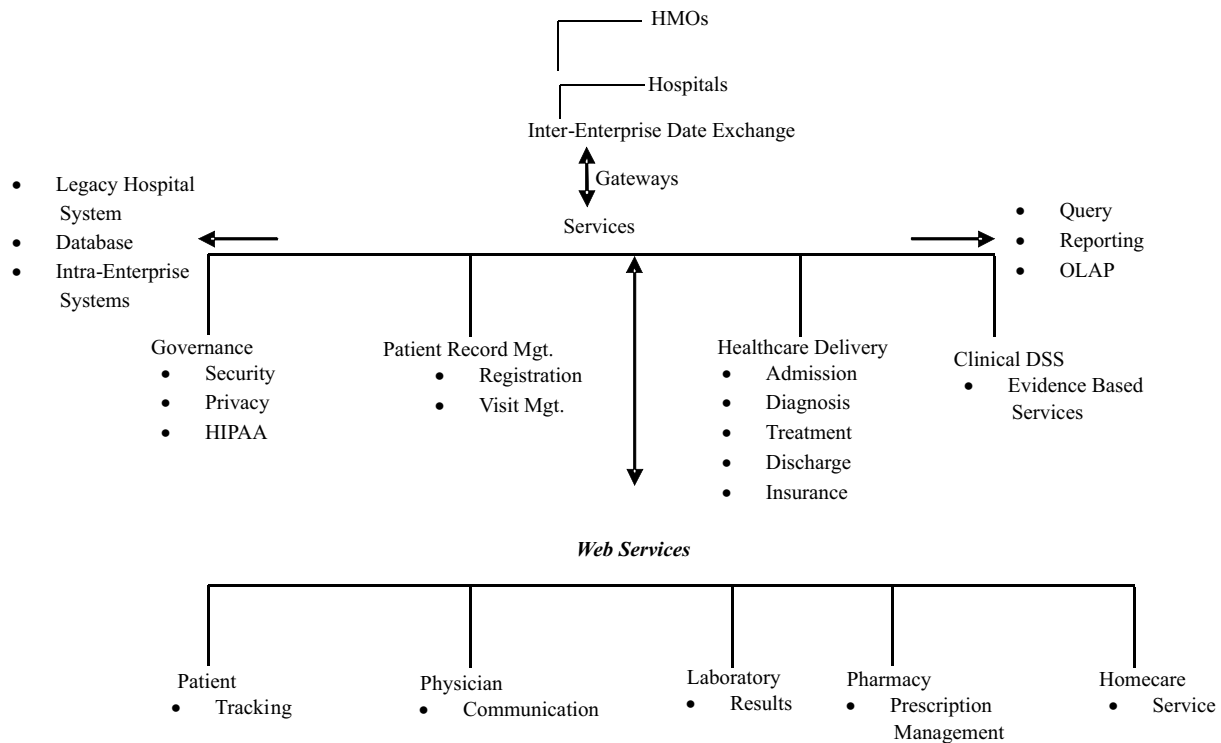


Figure 1: A Conceptual SOA-based integrated health care delivery framework

Challenges in SOA Implementation

There are enormous challenges in implementing SOA for a health care. These range from organizational to technical challenges. Analogous to the paradigm shift to enterprise systems (e.g. ERP), the notion of a “service” forces health care delivery organizations to redesign their health care processes. This shift entails organizational, cultural, political and technical changes that a new architecture brings with it (Marks and Bell, 2006). The health care industry particularly faces the

challenges of incomplete standards (e.g. of medical terminology) and lack of robust development and modeling tools. Additionally, security issues are compounded by the inherent complexity in health care delivery wherein multiple providers must work together to deliver quality care. Furthermore, SOA governance has been addressed only recently. Measurement of cost and effectiveness of SOA in the health care industry is critical for rightful allocation of resources. Yet another challenge lies in finding

“SOA architects” with experience in implementing complex distributed health care applications (Marks and Bell, 2006).

On the technical side, several issues need to be resolved. Arriving at the right level of service granularity is important. Too much granularity leads to compartmentalization while too little granularity limits reuse.

At the vendor level, vendors must offer service-oriented health process and workflow, as well as service orchestrations, tools and services. Modeling tools must be available that can adequately reflect health care services in an agile, platform-independent way. Technologies must have the tools to generate code from models and to update these models when the code changes (MDA tools, for example). Finally, vendors must offer SOA-enablement software that allows service-oriented architects to build and maintain the level of abstraction between services and underlying technology in a reliable and scalable way. Testing an SOA environment is a challenge. Typically, the testing environment is simulated because the SOA applications are built across multiple health care provider organizations. But simulated data may not reflect the real health care services' processing. Performance limitations due to the distributed nature of the SOA constrain the use of the SOA to logically separate applications.

Additionally, loose coupling comes at a price. While tightly coupled interfaces (fine-grained services) have the potential to reduce flexibility and reuse, loose coupling (course-grained services) may limit efficiency. An important challenge is the development of a health care “service ontology.” While progress has been made in the area of medical terminology ontology, the application of SOA in health care is relatively new, and there is much more to be done with regard to commonly agreed upon services in health care delivery. For example, hospitals may assign different meanings to the services, “pre-certification” and “pre-authorization” of procedures. Various researchers and standards organizations are addressing these and other challenges. **Conclusions**

We have discussed the problems and challenges of interoperability in software systems as well as the potentials of the SOA in the design of interoperable EHRs and the development of an SOA framework in a health clinic setting. The framework may be implemented in multiple platforms. Vendors are rapidly accepting SOA and developing platform suites to support SOA in the health care area. Gradually, we are also seeing among developers coalescence towards open standards. While new services can be constructed across the health care delivery spectrum leading to reusability, existing systems (including legacy

applications such as the ones in hospitals) are not abandoned but rather integrated via middleware. Web services within the SOA provide a platform-neutral approach by uniform access to the health care services and better interoperability as more vendors and health care delivery organizations buy into it. The representation of each health care application, process or resource as a service with a standardized interface allows one to rapidly combine new and existing systems to address changing health care delivery needs and improve the operational effectiveness. Individual organizational systems, such as the EHR in the health clinic setting, can be scaled up to participate in integrated health systems. The SOA framework can enable this by the inclusion of additional components, services, and interfaces and by allowing the participating organizations to join the service bus. Note the larger trend among regional health care providers to use integrated and single-patient-view technology to create unified pictures of service availability and patient care across their geographic areas. Information coordination between and across regional organizations, therefore, is essential for ensuring that care providers work together effectively to support integrated care initiatives, such as multidisciplinary care pathways.

Another paradigm of potential to the interoperable EHR is grid computing which enables one to divide resources into multiple

execution environments by applying one or more concepts, such as hardware or software partitioning or time-sharing, machine simulation, emulation and quality of service. The interoperable EHR and related systems would reside on this grid. This virtualization, or on-demand deployment of all the distributed computing resources, lets one use them wherever and however they are needed within the grid. Virtualization is simply a form of resource management for devices, storage, applications, services or data objects. Hence, applying SOA allows one to maximize resource utilization in a grid environment. The user can deploy and migrate services in the health care ecosystem onto appropriate nodes in a grid environment to respond to changes in the internal and external environment. Another potential is on-demand computing, that is, health services on demand where application level services can be discovered, reconfigured, assembled and delivered on demand, with just-in-time integration capabilities. In time, we will also see the augmentation of open source architectures and tools to support the SOA-based interoperable EHR. In this regard, the goals of the Open Healthcare Framework (OHF) “to extend the Eclipse Platform to develop an open-source framework for implementing interoperable, extensible health care systems” are significant (<http://www.eclipse.org>). Future research can focus on the operational and

validation issues in the implementation of SOA in health care as well as developing solutions to meet the challenges of SOA.

References

- Ball, M.J. (2002). Hospital Information Systems: Perspectives on Problems and Prospect, *Int J Med Info*, 2003, 69(2-3):83-89.
- Bates, D. W. (2005). "Physicians and Ambulatory Electronic Health Records," *Health Affairs* (24:5), pp.1180-1189.
- Brown, A. W., Delbaere, M., Eeles, P., Johnston, S., and Weaver, R (2005). "Realizing Service-Oriented Solutions with the IBM Rational Software Development Platform," *IBM Systems Journal* (44:4), pp. 727-752.
- Chaudhuri, B., Wang, J., Wu, S., Maglione, M., Mojica, W., Roth, E., Morton, S. C., and Shekelle, P. G (2006). "Systematic Review: Impact of Health Information Technology on Quality, Efficiency, and Costs of Medical Care," *Annals of Internal Medicine* (144), pp. 742-752.
- Himmelstein, D. U., and Woolhandler, S (2005). "Hope and Hype: Predicting the Impact of Electronic Medical Records," *Health Affairs* (24: 5), pp. 1121-1123.
- Koontz, L. D (2005). "Computer-based Patient Records: VA and DOD Made Progress, but Much Work Remains to Fully Share Medical Information," *GAO-05-1051T*.
- Kreger, H. (2003). "Fulfilling the Web Services Promise," *Communications of the ACM* (46:6), pp. 29-34.
- Marks, E. A., and Bell, M (2006). *Service-Oriented Architecture: a Planning and Implementation Guide for Business and Technology*, John Wiley & Sons, Hoboken, NJ, 2006.
- Powner, D. A (2005). "Health and Human Services Estimate of Health Care Cost Savings Resulting From the Use of Information Technology," *GAO-05-309R*.
- Powner, D. A (2006)(a). "Health Information Technology: HHS is Continuing Efforts to Define a National Strategy," *GAO-06-346T*, March 15, 2006.
- Powner, D. A (2006)(b). "Health Information Technology: HHS is Continuing Efforts to Define Its National Strategy," *GAO-06-1071T*.
- Powner, D. A., and Koontz, L. D. (2005). "HHS is Taking Steps to Develop a National Strategy (Information Technology)," *GAO-05-628*.

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