Position Paper: Researching and Developing Open Architectures for National Health Information Systems in Developing African Countries

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Abstract. Most African countries have limited health information systems infrastructure. Some health information system components are implemented but often on an adhoc, piecemeal basis, by foreign software developers and designed to solve specific problems. Little attention is usually paid to how these components can fit into an integrated national health information system and interoperate with other components. The Health Enterprise Architecture Laboratory was recently established in the School of Computer Science at the University of KwaZulu-Natal in South Africa to undertake research and build capacity in open health architectures for developing African countries. Based on field experiences and requirements in South Africa, Mozambique and Rwanda, the laboratory is evolving a generic Health Enterprise Architecture Framework and Repository of Tools specifically for low resource settings. In this paper we describe these three initiatives and the expected impact on implementing health information systems in developing African countries.

Keywords: health enterprise architectures; ICT for developing countries; interoperability; ontologies; postgraduate training; open architectures

1 Introduction

Health information systems (HIS) are a critical component of well-functioning health systems [27] and an important pre-requisite to improving health outcomes [1][11]. The worldwide growth in information and communication technology is opening up important opportunities to strengthen HIS and many efforts are underway to develop national health information systems (NHIS) [19][26]. Developing countries are also undergoing rapid technological transformation associated with the increased availability of mobile devices and network connectivity, among others, that are accelerating adoption of HIS [12]. While significant potential exists to leverage ICTs to improve equitable health service delivery and health outcomes in remote and underserved areas, many challenges remain.

Developing countries have unique environments in which limited availability of infrastructure, specialized technical skills and financial resources impact on the development of systems [18] [25]. In addition, the social, economic and political environments as well as the communication infrastructure are often prone to rapid change [9] [8]. Scarce resources are not optimally deployed to achieve potential cost savings and economies of scale. Limited resources are understandably directed to NHIS components with a single purpose that have a more immediate impact on health outcomes. Little attention is paid to issues such as support for open standards, interoperability and reusability across different systems. There is no well-developed notion of an open architectural framework to facilitate the design and rapid implementation of interoperable and sustainable NHIS [26]. Such a framework will be vendor-independent, based on open standards and allow various stakeholders to create add-on components or customizations and extensions that increases flexibility, functionality, interoperability and capabilities to suit individual requirements.

The application of an open architectural approach has significant potential to enable a paradigm shift in NHIS development. A systematic approach to high-level information system design at national level will assist African Ministries of Health to better utilize resources available for independent projects implemented by donors, non-governmental organizations and universities. Common paradigms or "architectural patterns" can be used as metaphors that allow the knowledge gained from one implementation to be used in others.

Several initiatives in the developed world are underway that focus on architectural approaches to building NHIS. However, given the unique environments of African countries, it cannot be assumed that technical solutions that have been successfully deployed in the developed world can be easily transferred to these environments without performing fundamental re-engineering or customization.

The Health Enterprise Architecture Laboratory (HEAL) was recently established in the School of Computer Science at the University of KwaZulu-Natal in South Africa to undertake research and build capacity in open architectures and technologies for NHIS in developing African countries. Based on field experiences and requirements in South Africa, Mozambique and Rwanda, HEAL is currently developing a Health Enterprise Architecture Framework (HEAF)[1] and Repository of Tools (HEART) specifically for low resource settings. The HEAF and the HEART will capture and distill best practices and experiences from these environments that can facilitate the development of NHIS in other low resource countries. The aim is to establish the HEAF and HEART as community-driven projects to be continually informed by user experiences and form the first tools in a generalized open architectural framework.

In this paper we describe these three initiatives and the potential impact in developing African countries. In section 2 we analyze the current landscape and research challenges and in section 3 we describe the HEAL. In section 4 the HEAF is described and in section 5, the HEART. In Section 6 we summarize the potential impact of these initiatives and draw our conclusions.

[1] `https://sites.google.com/site/heafproject/`

2 National HIS in Africa: The Current Landscape and Future Prospects

African countries differ widely in terms of their current HIS infrastructure and NHIS strategies. Typical NHIS include health, pharmacy and laboratory subsystems. Applications cover a wide variety of health services, including preventative, curative, supply chain and financial services. An ISO expert group, in partnership with the World Health Organization, is developing a technical report to help developing countries implement and harmonize NHIS[2]. The report describes the characteristics of the core subsystems and provides a maturity model for the implementation of NHIS in low resource settings. Typically, countries begin with population-based information systems, providing data on national health issues and guiding policy decisions at a national level. Once established, they develop systems that are more focused at the person level.

Our experiences are based on three African countries that differ widely in terms of their level of maturity of NHIS implementation but yet have many common characteristics.

South Africa is one of the most well developed African countries and its NHIS reflects characteristics of both high and low resource settings. The larger cities have advanced HIS technologies while most provinces in the country have deep rural settings with little or no computerized information systems. Broadband network and mobile phone penetration is well developed but focused on the urban areas.

Rwanda is one of the smallest and most densely populated African countries. The country has a progressive and expansive eHealth policy. The national eHealth coordination unit is actively driving the deployment of a number of advanced systems to strengthen the NHIS. These include patient and hospital information systems, community health information systems using mobile phones, and a health information exchange implementation project.

Mozambique is still developing much of its HIS. Working in collaboration with a local organization (MOASIS[3]) attached to the University of Eduardo Mondlane, the Ministry of Health has implemented several systems, including an aggregated data system and computerized death registration system based on a limited list of codes from the International Classification of Diseases[4]. A national health enterprise architecture project is underway that is documenting a baseline architecture and developing a target architecture in line with the national eHealth strategic plan. Other projects under development include a national data warehouse project and patient-based systems.

Based on experiences implementing HIS in these countries we have identified the following common requirements:

– *Urgent deployment.* African countries are ravaged by a high burden of disease and have an urgent requirement to rapidly deploy applications to facilitate,

[2] http://www.iso.org/iso/pressrelease.htm?refid=Ref1275
[3] http://www.moasis.org.mz
[4] http://www.who.int/classifications/icd/en/

manage and optimize health interventions that have an immediate impact on health outcomes in critical disease areas.
- *Balance between innovation and pragmatism.* It is difficult and risky to implement systems requiring substantial change to existing operations and workflows. Yet, a high level of innovation is required to introduce and leverage the latest advances in computer science and to take advantage of the rapidly improving ICT landscape in a way that makes optimal impact. Deployment of disruptive or ineffective systems can have disastrous consequences for an already overburdened health system.
- *Evidence-based and effective.* Many systems are developed from first principles with little regard to what has been done before. This may be due to limitations in documented evidence and evaluation. Wherever possible, systems should be based on evidence of the effectiveness of previous systems, while still leveraging the latest techniques and technologies.
- *Sustainable and affordable.* It is essential that systems are sustainable, affordable and harmonized with a country's strategic plans. Good design and rigor must be balanced with rapid engineering, to meet immediate needs and ensure buy-in from non technical stakeholders while also giving due consideration to long term sustainability. Special consideration must be given to developing the specialized IT skills necessary to maintain affordable and cost-effective systems.
- *Support practical modes of operation.* Systems must include both computerized and manual, paper-based solutions as well as network-connected and network-disconnected scenarios.

Development of an open architectural framework is a necessary first step to facilitate the design and rapid implementation of effective NHISs. To be effective the framework should be informed by field experiences, take into account the unique characteristics of African countries and include an open and participatory approach that encourages reuse and sharing of artifacts and experiences [10]. The framework should offer a generalized methodology and suite of tools that can be used by many countries following customization. This approach will have substantial benefits in terms of lowering the cost and risk associated with de novo implementations and "reinventing the wheel".

Desirable design features of the open architectural framework include the following:

- *Lightweight and based on highly interoperable components.* The framework must facilitate the rapid implementation of urgent, disease specific applications; integration of current components working in the field, and those developed at different times by different groups; and incorporation of carefully chosen and evolving standards [7].
- *Scalable and extensible.* The framework must allow for incremental extension into a fully integrated NHIS without substantial reengineering and must scale to national level without requiring a fundamental change in technology or design paradigm.

- *Flexible and adaptable.* In order to optimize chances of adoption and be deployable in different settings, the framework needs to be configurable and adaptable and easily customized to fulfill current requirements.
- *Reusable.* The framework should enhance the reusability of components to stop the wasteful cycle of developing the same functionality over and over and to achieve economies of scale.
- *Powerful, yet easy to use.* The framework must balance ease of use with power such that it appeals to HIS developers and genuinely facilitate the development of NHIS.

3 HEAL: The Health Enterprise Architecture Lab

The HEAL was established with seed funding from the Rockefeller Foundation and International Development Research Centre (IDRC) to undertake research in health enterprise architectures for developing African countries and to train postgraduate Computer Science students in this area.

The HEAL fills a gap in the current implementation landscape by creating a neutral space in Africa to continuously reflect on and innovate architectures and technologies for African HIS. The lab aims to develop and curate a repository of knowledge, expertise and people to develop new solutions to deal with the changing and unique circumstances and environments in African countries. Strong links and integration of the innovation process with implementing organizations ensures translation of this research into practice.

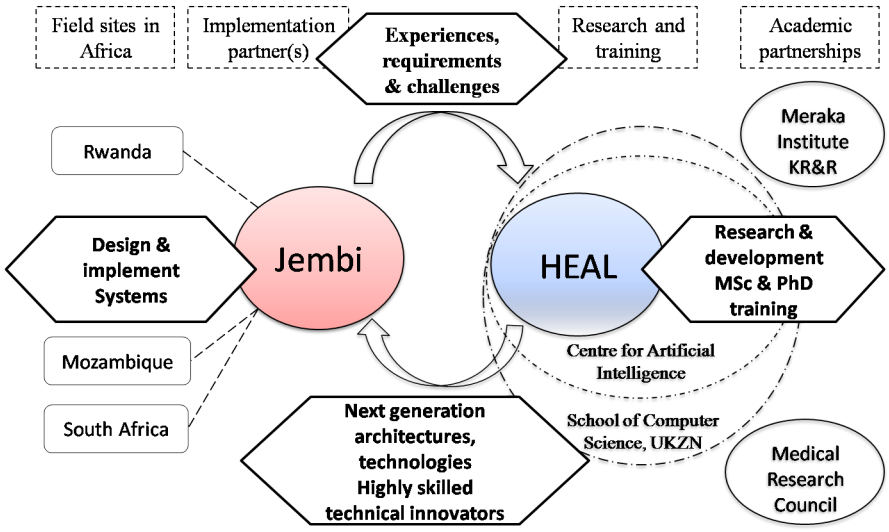

Fig. 1. The HEAL Innovation Cycle

Figure 1 depicts the lab's model for conducting its main activities of research and training. The lab is hosted within the newly formed Centre for Artificial Intelligence (CAIR)[5] within the School of Computer Science at the University of KwaZulu-Natal in Durban, South Africa. It has strong links with the Knowledge Representation and Reasoning (KR&R) group based at South Africa's national ICT research facility, the CSIR Meraka Institute and the South African Medical Research Council. This provides the lab with access to academic faculty with expertise in open systems and architectures, and knowledge representation technologies, e.g. ontologies.

The lab's research is not only informed by the state of the art in Computer Science and artificial intelligence but also actual field experiences and requirements from implementation partners such as Jembi Health Systems[6] a South African based not for profit organisation. This ensures that the technologies produced by the lab are grounded by real requirements and challenges and are relevant and usable within developing African countries. Training highly skilled technical innovators is an integral part of the lab's mandate. The lab provides an environment for students to undertake research masters and doctoral studies in Computer Science with a specialization in Health Informatics. This not only serves to develop new capacity in the area but also to strengthen existing capacity. The lab provides a mechanism for technical staff from implementing partners, e.g. Jembi, to obtain higher degrees and to become more effective HIS designers and implementers. This model is already demonstrating value in existing implementation and research projects. For example, the lead Jembi developer tasked with the design and implementation of an interoperability architecture for exchanging heterogenous health information in Rwanda is also working towards a research masters degree in the lab. The research involves the development of a generic interoperability framework for health information systems in developing countries. From a research perspective the Rwandan implementation provides a concrete case study that informs the requirements and evaluation of the framework. From the implementation perspective the developer is able to leverage the expertise of the lab's faculty to incorporate the latest developments and thinking in Computer Science into the Rwandan implementation.

The development of an health enterprise architectural framework (HEAF) and an architectural artifact repository (HEART) are two of HEAL's current activities towards creating an open architectural framework. HIS designers and implementers will use the HEAF and one or more artifacts from the HEART for in-country projects and feed implementation experiences back into an ongoing process of informing and refining HEAF. HEAL will continuously reflect and learn from field experiences and innovate new technologies and disseminate these to the community via the HEAF and the HEART.

[5] http://cair.cs.ukzn.ac.za
[6] http://www.jembi.org

4 HEAF: The Health Enterprise Architecture Framework

An Enterprise Architecture approach is increasingly being recognised as a systematic and rational approach for analysing and documenting an integrated HIS in low income countries [24].

> *Enterprise Architecture (EA) is a coherent whole of principles, methods and models that are used in the design and realization of an enterprise's organizational structure, business processes, information systems and infrastructure.* [20].

The Health Enterprise Architecture Framework (HEAF) aims to develop a set of principles and a systematic approach for modeling different aspects of a national health information systems (NHIS) specifically for low resource settings. Individual countries will use the framework to create country-specific architectures. HEAF will draw on several existing frameworks. It is a simplification of the Generic Component Model approach [3] combined with elements from the Zachman Framework [28] applied to healthcare[7], the Federal Enterprise Architecture Framework [13], the Open Group Architectural Framework [15] the development framework for interoperable health information systems (HIS-DF) [21] and the Health Metrics Network Framework [19]. HIS-DF is a consistent application of an EA approach to the healthcare domain and addresses issues relevant to developing countries, such as the integration of public health and clinical systems [4]. HEAF constrains the GCM and HIS-DF to create a more simplified form of the HIS-DF for low resource settings. HEAF also uses a domain-specific ontology to integrate the logical layers [6] of the HEAF from the enterprise viewpoint to detailed concept models [14].

HEAF is adding domain-specific specializations, artifacts and patterns based on actual implementation experiences in South Africa, Mozambique and Rwanda as well as documented experiences in a growing number of other developing countries with architecture projects, including Ghana, Kenya and the Philippines. Although the basic principles of healthcare in low and high resource settings are similar, there are many practical differences that drive the need for a dedicated framework for low resource settings, including dedicated views and viewpoints as well as unique artifacts and patterns. Lessons learned may, in turn, inform designs and practices elaborated in the developed world, through partnerships with other applied research labs, such as the Mohawk Applied Research Centre[8] in Ontario.

A key distinguishing feature of HEAF is simplicity. HEAF is attempting to distil out the best practices and artifacts that have worked or become entrenched in several developing countries and generalize these into a framework that can be applied in other countries. The intended result is a user-oriented, practical

[7] `https://apps.adcom.uci.edu/EnterpriseArch/Zachman/Resources/ExampleHealthCareZachman.Pdf`

[8] `http://www.mohawkcollege.ca/about/research/marc/healthInformatics.html`

framework that balances ease of adoption and use with completeness and theoretical rigor. HEAF is being established as a community-driven web portal[9] where users may share implementation experiences and participate in generalizing these experiences to the emergent framework. The over-arching purpose of the HEAF is to assist in developing HIS design blueprints and promoting informed decision-making by the Ministry of Health.

The expected benefits of the HEAF are to lower the cost and effort to build and extend African health information systems, to facilitate reuse, to improve interoperability and to strengthen NHIS. In this regard HEAF aims to populate a repository (HEART) with a number of well-characterized artifacts that are currently being used in African HIS. Information obtained from in-country implementations is presently being compiled and modeled. Patterns and general models are being extracted and tested against in-country implementation, consistent with our bottom-up, implementation-driven approach.

5 HEART: The Health Enterprise Architecture Repository of Tools

The HEART project aims to design a web-accessible, community driven catalogue of the various architectural artifacts that currently exist within HIS in developing countries. Examples of artifacts are: software tools and platforms; architectural designs and patterns; standards, policies and requirements.

Core to HEART is the ability to index and classify the artifacts and building blocks of a NHIS as well as a clearly defined metadata model of each of these. Formal ontologies [16] are increasingly being used for modeling and sharing domain knowledge. Ontologies have also been proposed to describe and capture the organization and characteristics of system components [17]. In such a system, termed an ontology driven information system [17], ontologies capture an online model of the system. Developers can reconfigure aspects of the system at runtime by manipulating the appropriate ontologies. We have already investigated this idea within an open geospatial architecture [22] [23] and its importance to HIS architectures has recently been highlighted [5] [6].

The first step towards building a health architecture ontology for developing countries is to conduct a survey of and model the characteristics of current architectural artifacts. The initial phase will catalogue the most widely used software artifacts deployed in African countries, such as the Open Medical Record System[10] (OpenMRS), the District Health Information System[11](DHIS) and their interoperability characteristics, including the standards they support, e.g. HL7 messaging and SDMX-HD[12] . The ontological model will be created by consultation with key role players in the community and will aim to capture unambiguous

[9] `http://heaf.jembi.org`
[10] `http://www.openmrs.org`
[11] `http://www.dhis2.org`
[12] `http://www.sdmx-hd.org/`

and consistent descriptions of current artifacts in the community, and how artifacts are combined in different HIS implementations. The increasing availability of open source software technologies such as OpenMRS and DHIS presents a great opportunity for developing countries [2]. Even though HEART will include both open and proprietary software and technologies, our initial phase will target mostly open and free technologies (software, standards, architectures, content etc.). This also promotes our core values of facilitating interoperability, reuse and innovation. Furthermore, it is difficult to justify the expense of proprietary solutions in countries with an overwhelming disease burden and the fundamental requirement for basic clinical and public health services. However, the high level of IT skills and long term costs required for maintaining free and open-source systems cannot be ignored.

The project ultimately aims to deliver a web-based searching and visualization tool and engine for a catalogue of architectural artifacts and building blocks for HIS in developing countries. Such a catalogue will form a dynamic community resource for HIS architects and developers to share, find, compare, evaluate, and reuse artifacts. Two essential aspects of the project are to establish partnerships with providers of existing artifacts, software and functionality in order to develop a community of reviewers and contributors, and designing an ontology that adequately captures and reflects the current view of the community, but that can be easily modified to accommodate changes to this view.

6 Impact and Conclusions

In terms of their national health information systems, developing African countries differ from developed countries in that: they have limited infrastructure, have limited budgets and specialized technical skills to dedicate towards a national HIS. Foreign donors fund many African HIS implementations. There is an opportunity to pool and reuse resources across multiple countries and to optimize donor funds. This requires the creation of an architectural framework that is informed by field experiences, that takes into account the unique characteristics of African countries and an open and participatory approach that encourages reuse and sharing of artifacts and experiences. Furthermore, highly specialized local skills and capacity must be developed to ensure the future sustainability of these systems. The HEAF attempts to create a generic framework and systematic approach to ease the task of creating African national HIS. While HEAF will provide an invaluable tool for modeling and designing NHIS at the macro level, its effectiveness at the micro level for modelling loosely coupled and flexible software components is not yet clear. The HEART will provide a central point where architectural artifacts can be accessed, compared and reused. The HEAL will create a neutral space to reflect on field experiences and to continuously evolve and maintain the framework and repository and where African computer science graduates can acquire specialized skills to conduct research, maintain and innovate future African national health information systems.

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