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A Data Exchange Interoperability Framework for eHealth Applications in Ethiopia

Wondwosen Shiferaw¹, Mengistu Kifle^{1,3}, Senanu Okuboyejo^{2,3,*} and Victor Mbarika³

¹ Ethiopian Federal Ministry of Health
Addis Ababa, Ethiopia

² Covenant University
Ogun State, Nigeria

³ICITD, Southern University and A&M
Baton Rouge, Louisiana

*Corresponding author's email: Sena.okuboyejo [AT] covenantuniversity.edu.ng

ABSTRACT— *Interoperability between applications is important and creates a bridge between and facilitates data exchange between eHealth applications. In this study, we assess the existing Laboratory Information Systems (LIS) and Electronic Medical Record (EMR) for data exchange interoperability in Ethiopia with the view to proposing and developing a data exchange interoperability framework. We applied a qualitative research method to explore the status of e-Health applications (LIS and EMR) based on functional test done. Using a constructive method, a data exchange interoperability framework on eHealth applications was designed. NVivo-10 software was used for coding the interview and data analysis. The framework is tested by the developers and decision makers. The proposed and designed framework is encouraging for future change.*

Keywords— Interoperability, eHealth, Ethiopia, framework

1. INTRODUCTION

E-Health is a cross cutting area which supports all functions and operations areas by facilitating the automation of various Health processes. The World Health Organization (WHO) defined e-Health as “the combination of electronic communication and information technology in the health sector” [1]. It is a key area for improving health service delivery, promoting health, and easier information exchange on the health care organizations, assisting in decision making processes, and improving the effectiveness of operations [2]. In this regard, organizations need to invest a lot of resources to use e-health systems as a supportive tool for the effective and efficient delivery of health services. According to William and Harsh [3], the Electronic Health Record is a computerized patient tracking, patient caring system that is an essential technology for health care and a necessary tool for improving patient safety and the quality of care. One of the challenges faced nowadays by health care and e-Health industry is interoperability between heterogeneous applications such as Electronic Medical Record (EMR) and Laboratory Information System (LIS). Interoperability is defined as the ability of different information technology systems and software applications to communicate, exchange data accurately, effectively and consistently to use the information that has been changed [4]. There are three parts of interoperability: business process interoperability that deals with integrating business process by considering alignment and harmonization; syntactic interoperability deals with only the structural alignment and integration; while semantic interoperability focuses on data exchange [4].

Semantic interoperability is the ability of e-Health system to share information and have that information properly interpreted by the receiving system in the same sense as intended by the transmitting systems that deal with concepts, meanings and data exchange issues [4, 5]. There are technologies as solutions on semantic interoperability such as semantic web (Web 3.0). Semantic technologies are emerging and several applications ranging from business process management to information security have demonstrated encouraging prospects of its benefits. Semantics also play very vital roles in achieving interoperability when sharing health records. For example: the role of health level 7(HL7) for clinical data exchange; Digital Imaging and Communication in Medicine (DICOM) for imaging exchange; and other standards on semantic interoperability. The Ethiopian Federal Ministry of Health (FMoH) has recognized the benefits of e-health as a tool to support the health sector and are involved in several e-Health applications and services. These have been classified into the following major areas: data warehouse, electronic health records (EMR), laboratory information system (LIS), logistic management information systems (LMIS), geographical information systems (GIS), tele-education,

telemedicine, human resource information system (HRIS), health integrated financial information system (HIFIS), electronic health management information system (e-HMIS) [6]. According to the Ethiopian National e-Health Strategic Road Map, LIS and EMR are two major prioritized e-Health applications that enhanced data exchange, information use and reporting system at a national and hospital level [7].

Availing quality and timely health information at various levels of decision points throughout the hospitals systems is very essential for the improvement of health care and overall health system in Ethiopia. Ethiopia has implemented a Smartcare EMR and EMRComp Pro Med's –Polytechnic LIS application [8]. The E-Health Strategy Road Map [9] clearly states that redundancy and lack of interoperability exist between e-health applications [10]. This research focuses on this challenge by examining two e-Health applications (LIS and EMR) implemented at St. Paul Specialized Millennium Medical College and Zewditu Memorial Hospital to identify interoperability options. Both applications were tested for data exchange and software functionality. The research questions are as follows:

1. What are the challenges in implementing eHealth applications in terms of interoperability at national level?
2. How can we develop a framework to address interoperability on different e-Health applications?

2. METHODS

This study was done at the organizational level and qualitative research methods were used. An exploratory research approach and a constructive method were applied to address the data exchange interoperability issues and to propose a data exchange framework between the LIS and EMR. The study was conducted in Addis Ababa the capital city of Ethiopia which has 10 sub-cities. There are twelve public hospitals and thirty-seven health centers in Addis Ababa [11]. EMR has been implemented in ten hospitals and twenty-six health centers. Also, the LIS has been implemented in two hospitals (Zewditu Memorial and St.Paul Specialized hospitals) [12]. This research was conducted in the two hospitals. Access to the experts in the area was a challenge; hence, the investigator used purposive sampling technique in selecting the study population. Initially, the study was divided into three categories: 1) system user, 2) project owner and 3) eHealth application developer.

Primary data was collected through qualitative methods using structured and pre-tested interview questions adopted from various prior researches. The data was collected by interviewing eHealth application users, decision makers from the hospitals and FMOH. The questionnaires were prepared in English. Moreover, one eHealth expert was assigned to test interoperability issues on the LIS and EMR software system. He used the domain-level interoperability standard software functionality testing checklist developed by the investigator. Secondary data was collected through a review of relevant documents and literature.

3. RESULTS

The result was organized from twelve key respondents' perspectives of data exchange interoperability. The issues raised in these interviews are summarized into thematic areas. Those thematic areas were organized based on frequent words used in the responses given. These words were identified using Nvivo- 10 application software.

- **National eHealth Applications Status:** Six out of the twelve participants were interviewed: four from FMOH and two from EHNRI. The respondents clearly stressed that, ten eHealth applications exist at national level. The eHealth applications at the hospital level are characterized by duplication and redundancy. Some of the responses include:

Respondent 1, a lab-technologist in St.Paul Specialized Millennium Medical College hospital says *“there are both EMR and LIS which are almost doing the same function in our laboratory. This creates duplication of effort and heavy work load”*.

Respondent 2 from Zewditu Memorial Hospital says *“lack of interoperability and integration between LIS and EMR is the main challenge. This results in fragmentations and data redundancy as well as different report generation”*.

All respondents were aware and participated in the development of a draft e-Health Strategy document at the national level. The document has addressed most of issues related to standards and interoperability to make effective and efficient data exchange at all levels. The respondents also mentioned that the eHealth strategy document is recognized by FMOH and aligns with its five-year health sector strategic plan document. Finally, respondents stated the need for the strategy documents to be considered in the implementation of the e-health software, since the software was developed before the ratification of the e-Health strategy document.

- **Design of EMR and LIS Applications:** Respondents from FMOH agreed that no single expert in the ministry was involved in the design and development of both LIS and EMR applications; nevertheless, some experts

were trained and participated in the implementation process such as software and network installation. The experts also agreed that both applications are technically sound and well designed; but limitations still exist. They also noted that the EMR was designed based on the clinical work flow of hospitals and consists of five integrated modules. Two respondents opined that health system is very complex and multidisciplinary in nature, thus, requiring detailed analysis before the design and development of eHealth applications with the involvement of clinical personnel. The applications were developed using C# and backend SQL database. Most of the designed attributes and data type are the same but exist in different naming styles.

- **Data exchange and Interoperability in the Hospitals:** Both application users indicated that data exchange is considered as one of the major problems in the hospitals. EMR and LIS applications were implemented and operational in St. Paul Specialized Millennium Medical College and Zewditu Memorial Hospital. However, these applications create duplication of effort and burden for the laboratory technologist due to poor communication/interface between the two applications. Data transfer between both applications is being done manually because of compatibility issues. The resulting delay creates problem in service delivery, increases health care cost and proposed interfacing. Integration and interoperability are proposed as the best solution. To identify the major issues on data exchange, it is important to discuss this from the perspective of users and ICT support in the hospitals.
- **Challenges and Recommendations on the Usage of LIS and EMR:** Experts at the ministry agreed that there are data exchange challenges and gave recommendations on LIS and EMR in relation to planners and decision makers. Table 1 below describes the main challenges and recommendations raised by the e-Health experts.

Table 1: Challenges and Recommendations

Main Challenges (LIS and EMR)	Recommendations (LIS and EMR)
<ul style="list-style-type: none"> • Lack of interoperability between LIS and EMR resulting in data fragmentation and redundancy. 	<ul style="list-style-type: none"> • Implement National eHealth strategy with clear understanding of existing eHealth applications implemented in the Hospitals
<ul style="list-style-type: none"> • Dual application ownership and management. 	<ul style="list-style-type: none"> • Create individual ownership (customization) at different hospitals and by creating institutional and local content.
<ul style="list-style-type: none"> • Lack of technical support, lack of ICT professionals and poor management system in the Hospitals. 	<ul style="list-style-type: none"> • Propose a virtual team for strong support, application management, and for monitoring and evaluation of applications. • Increase user-involvement during the design and implementation of the application.
<ul style="list-style-type: none"> • Lack of awareness. 	<ul style="list-style-type: none"> • Increase user-involvement during the design and implementation of the application.
<ul style="list-style-type: none"> • Frequent power supply interruptions in hospitals leading to backlogs and return to paper-based approach. 	<ul style="list-style-type: none"> • Provide alternative power source for hospitals

The basic LIS and EMR functionalities were tested to identify the data exchange interoperability options between them. All laboratory order attributes were well designed and present in both applications, both systems enable easy access to the list of laboratory tests and had potentials for expansion and interoperability. However, the EMR application lacked laboratory standards, slow in data retrieval, had many laboratory orders, low error detecting capability such as prescription overdose, and different naming conventions.

3.1. Data Exchange Interoperability Framework between LIS and EMR

There are two considerations to design data exchange interoperability framework between LIS and EMR applications. First, data exchange interoperability framework becomes a best solution as already stated in the literature [13]. The authors clarified the method of developing a framework based on alarming barriers pertaining to eHealth application development and implementation in particular to structure, contents and communications. The study was conducted to

identify the challenges of physicians on eHealth application and interoperability between hospitals. The research used a qualitative and phased approach to develop a framework. The first phase describes and explains the meanings and functionalities of eHealth applications as well as the barriers. The second phase explains the structure and design of eHealth applications, and how to overcome interoperability issues by considering standards. Second is the adoption of existing eHealth strategic direction document. The national eHealth strategic road map document also considers data exchange interoperability between LIS and EMR applications. The applications and presentation layers in the strategic road map are directly linked with the proposed framework in this study. Finally, this research is more similar with the literature [13] and the eHealth strategic road map was considered in the design of data exchange interoperability framework [14].

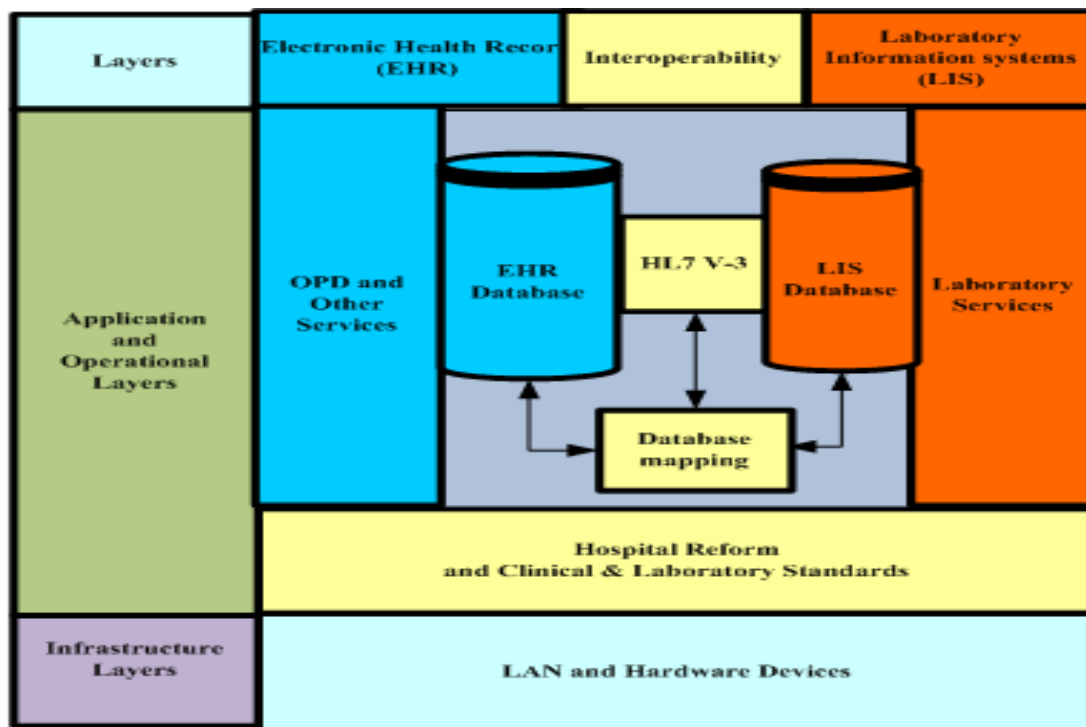


Figure 1: Data Exchange Interoperability Framework (DEIF) for LIS and EMR.

The DEIF is designed based on two pillars: operational and applications layers, and infrastructure layers. To make data available real-time to all points of service within the hospitals, EMR and LIS applications are installed in a centralized mode (client/server) then accessed with shared computers, printers and ICT accessories. This mode operates on an online communication infrastructure within the hospitals' local area network (LAN) including Wireless Local Area Network (WLAN) and demonstrated as the appropriate technology for building the communications infrastructure. LAN and WLAN make data exchange more effective and efficient, providing easy, fast, and affordable networking solution for hospitals. The EMR and LIS applications are installed at the medical records and triage rooms where the bulk of data encoding takes place and other departments using one shared infrastructure in the hospital. In the centralized mode, EMR hosts the database on a central server and using online communications infrastructures (LAN/WLAN), enables all points of services to obtain real time access to patients' information. EMR is incorporated using an industrial standard modular architecture important for data exchange like HL-7. This provides the added advantage for data exchange interoperability among LIS and other eHealth applications, without affecting the stability and integrity of the application. Other features of EMR include role-based security, data merging, import/export, and backup/restore and address user friendly interface for ease of use.

The LIS is organized and implemented using its full features, which includes and supports work and information flow in all steps of the laboratory testing process. Finally, physicians and technicians use laboratory information systems to supervise many varieties of inpatient and outpatient medical testing, including hematology, chemistry, immunology and microbiology. Basic laboratory information systems commonly have features that manage patient check in, order entry, specimen processing, result entry and patient demographics. The LIS tracks and stores every detail about a patient from the minute they arrive until they leave and keeps the information stored in its database for future reference. In addition, we should enforce the use standards in developing both applications so that the HL7 v3 can be used for data exchange between them.

4. DISCUSSION

This study tried to investigate on eHealth applications (LIS and EMR) in Addis Ababa two hospitals. No previous study has been conducted, which deals with data exchange interoperability between LIS and EMR in Health institutions. As shown in the results section, this study focuses on results of both applications functionalities testing and compiled challenges and recommendations on data exchange interoperability from the users, decision makers and eHealth experts. Finally, we proposed the data exchange interoperability framework between LIS and EMR. EMR and LIS application functionality testing aligns with previous studies. As clearly stated in the result and supported by previous literature on EMR; interoperability is expected to reduce patient waiting time by decreasing the time spent on record search, documentation, results' transfer and to communicate between sections through external applications. Both applications play important roles in the hospitals and most of the respondents agreed that creating interoperability between LIS and EMR is very crucial. The study also shows that interoperability has a potential power to solve challenges on data exchange among LIS and EMR by improving data exchange and managing hospital data with cost-effective, easily accessible accurate and manageable data processing solutions [15]. Prior studies also propose standards like HL-7 and interoperability as best solutions. Finally, making healthcare information systems interoperable will reduce cost of health care and will contribute to more effective and efficient patient care [15-17].

5. RECOMMENDATIONS

The study showed that several solutions and recommendations have been proposed to overcome main challenges on data exchange interoperability between LIS and EMR in Hospitals. The National eHealth Strategy roadmap provides the national level guideline for future interoperability. Moreover, this study provided a data exchange interoperability framework between LIS and EMR that will be helpful for developers and eHealth experts at FMOH. The framework provides a better understanding of data exchange interoperability between LIS and EMR to aid planning and decision making on eHealth application sustainability. Major recommendations are discussed below:

- **Recommendation for Decision makers**
 - Involve all health professionals and management team on the pre-implementation of any eHealth application
 - Provide on job training and continuous follow up for users on both basic computer and system related knowledge
 - Establish a strong mechanism on monitoring and evaluation of data exchange
 - Enforce the implementation of EMR and eHealth hospital management guidelines
- **Recommendation for Software developers**
 - Consider the applications interoperable and interfacing that also clearly indicated in the draft eHealth strategy.
 - Develop and make available a software development document and implementation guideline
 - Consider the present and future system sustainability
 - Increase the user involvements in the development and implementation of eHealth applications

These recommendations directly and indirectly affect data exchange interoperability between LIS and EMR framework.

6. CONCLUSION

In recent times, public hospitals have common solutions to improve patient safety, increase access and quality and decrease health care cost. However, these are standalone applications which do not interface and exchange data among themselves. Hospitals should consider how to make these applications communicate to address major challenges such as data fragmentations and data redundancy on eHealth applications, laboratory test result loss and transcription errors. Lack of interoperability also creates heavy workload because hospital personnel work on both paper-based and electronic records through EMR and LIS. Based on the findings of this research work, data exchange interoperability framework between LIS and EMR applications is developed as a solution. The framework takes in to consideration the new hospitals reform guidelines, that indicate how standardized hospital workflow looks like, data exchange standards and interoperability options that fit to software applications. This framework solves data exchange challenges between LIS and EMR applications in which large amounts of funds are invested and used in public hospitals across Ethiopia.

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