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National Interoperability Middleware Operation Implementation for E-Healthcare Services in Developing Countries

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ABSTRACT

One of the major challenges confronting healthcare institutions in developing countries is the problem of interoperability of both the processes of care and data that are used within those processes. Failure of interoperability would result in repeated diagnostic testing, redundant record keeping, high travel cost associated with seeking and receiving healthcare in centres located far from patients as well as costly and substandard healthcare services. Healthcare organizations run different applications that are of heterogeneous standard which has made it difficult for them to collaborate and interact together. This has resulted in a number of specialized health service departments and specialties, each with its own practices, rules and organization. Thus it is necessary to look at healthcare interoperability from an overall system perspective. This lack of integration in the healthcare domain has affected the provision of quality healthcare services especially in the rural areas. Various e-Health technologies provide the tools to facilitate integration, but those tools must be used within a framework that integrates all users of the system across the various levels. This work presents an enterprise view to e-Healthcare service interoperability among individuals and organizations who are stakeholders in healthcare domain in Nigeria. The national interoperability middleware requirements were presented and the work integrates existing applications also known as legacy applications rather than replacing them with new applications.

Keywords:- Healthcare, Interoperability, Data, Heterogeneous, e-Health, Middleware Requirements

1. INTRODUCTION

One of the main challenges confronting healthcare in many communities is accessibility to important healthcare information. Most rural communities, especially those in developing countries are generally characterized by prevailing issues such as low health level, limited resources, low literacy level and medical isolation. Information and Communication Technology (ICT) is generally believed to have tendency to provide solution through the use of electronic healthcare technologies (e-healthcare). ICT can undoubtedly improve the use of information by healthcare professionals in day-to-day patient care [1]. The overwhelming acceptance of ICT has culminated into a number of fields such as e-Healthcare [2]. However, ICT projects in many developing countries are generally associated with failure, mainly due to operational, contextual and strategy constraints. E-Healthcare represents a substantial ICT investment and as such, its failure can result in huge losses in time, money and effort [3]. The role of ICT can no longer be ignored within the healthcare industry. In fact, for the healthcare industry to maintain and improve both clinical and business operations, it has to depend on Information Technology (IT) [4]. This is as a result of the capability of e-health initiatives ability to tackle challenges that exist within the healthcare industry [5]. Electronic health (e-health) describes the application of ICT across a whole range of functions that affect the healthcare industry when it comes to matters relating to health through the various solutions that exist [6]. E-health can also be described as any electronic exchange of health related data through an electronic connectivity for improving efficiency and effectiveness of healthcare delivery. The solutions that are provided through e-health initiatives within hospitals include: Hospital Information Systems (HIS), Telemedicine Services, Electronic Health Records and Internet Services [7]. Interoperability means the ability to communicate and exchange data accurately, effectively, securely, and consistently with different information technology systems, software applications, and networks in various settings, and exchange data such that clinical or operational purpose and meaning of the data are preserved and unaltered [8]. In most cases, people change their locations and do not move with the paper based medical records [9]. This wastes time

and increases costs since the same tests have to be repeated. Moreover, in case of emergencies patients do not usually have medical records at hand. A system that can serve patients without regarding the changes in patient's location and additionally, act as a backup during emergencies is beneficial [10]. Moreover, by using such systems, physicians are allowed to focus more on their patients instead of worrying about medical records [11]. Therefore physicians should take advantage of the upcoming technologies and make use of them. This is because IT can dramatically revolutionize the delivery of healthcare making it safer, efficient and effective [12]. Electronic Health Record (EHR) enables patient information to be stored safely and retrieved when necessary thereby improving efficiency, reducing medical errors and improving access to patient's information [9], [12], [13]. There were days when patients relied on physicians for all the information concerning their health. Those days are gone. Nowadays patients are constantly on the lookout for information regarding their health on the Internet hence by the time they arrive at the physician's offices; they already have an idea concerning the disease that is bothering them [14], [15]. This transformation has not only affected the patients but also other e-health stakeholders. Physicians are constantly on the lookout for online information in regard to research and education [16]. Pharmaceuticals are selling their products online, hospitals are purchasing their products online and billing insurance companies use the Internet, hence the need for a drastic shift from the traditional way of conducting health affairs [17]. Therefore the use of the internet cannot be ignored within hospitals. Middleware is software that is used in the context of distributed systems. A distributed system is composed of different applications that are running on possibly different heterogeneous computers and that form one system by communicating to each other. Middleware can be seen as the glue between separate applications as it is used to realize the communication between the separate applications [18].When you submit your paper print it in one-column format, including figures and tables. In addition, designate one author as the "corresponding author". This is the author to whom proofs of the paper will be sent. Proofs are sent to the corresponding author only.

2.INTERACTION TYPES OF INTEROPERABILITY

The three interaction types of interoperability that can exist across different organization in healthcare domain are presented below:

i. Across different healthcare organizations - Inter-organization e.g. hospital in location A connecting with a primary healthcare centre in location B. This is depicted in Figure 1.
ii. Evolutionary e.g. change from an old EHR to a new EHR. This could be within the same organization or across organizations. This is depicted in Figure 2.
iii. Within a single healthcare organization - Intra-organization e.g. interoperability between the pharmacy, laboratory and the billing department. This is depicted in Figure 3.

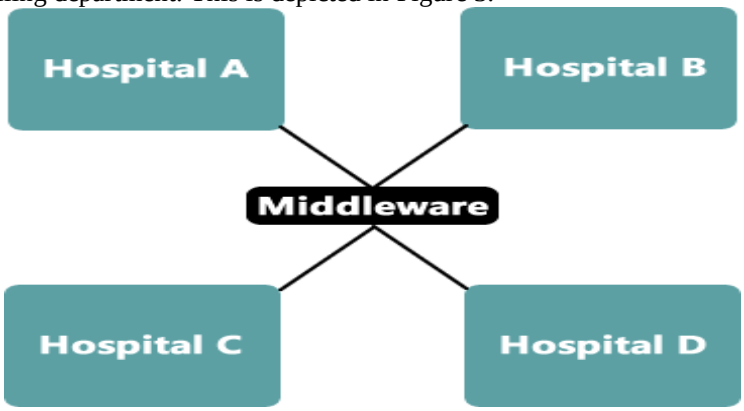

Figure 1: Interoperability Inter-organization interaction

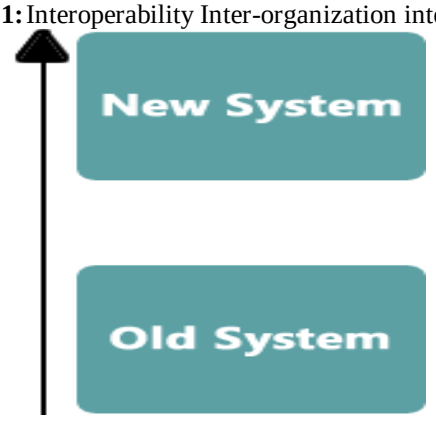

Figure 2: Interoperability Evolutionary Interaction

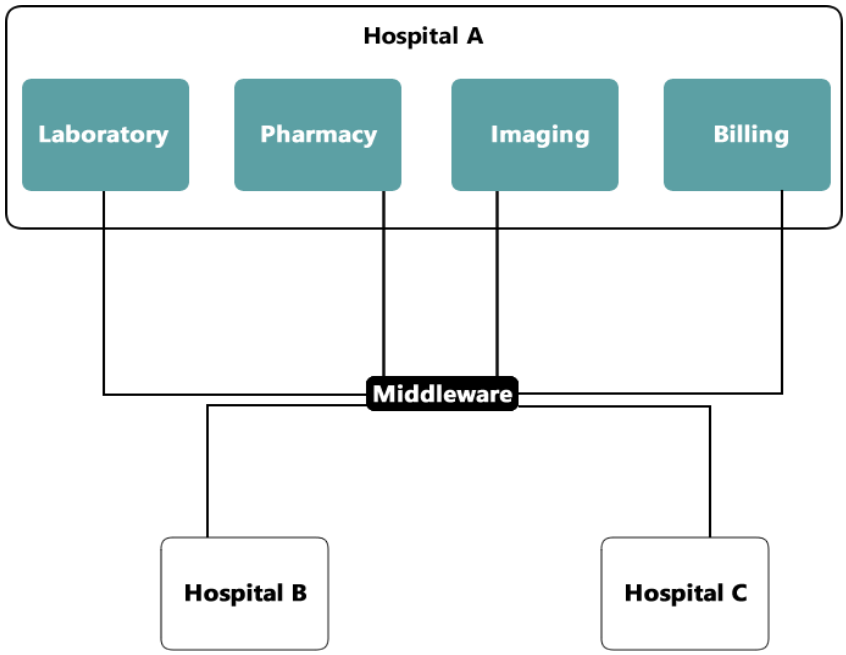

Figure 3: Interoperability Intra-organization Interaction

3.STAKEHOLDERS OF E-HEALTHCARE ECOSYSTEM

Some of the stakeholders of e-healthcare ecosystem are presented below and this is shown in Figure 4:

i. Patients: who require medical treatment
ii. Providers: e.g. doctors, nurses, hospitals and nursing homes, which provide medical assistance and treatments.
iii. Governmental agencies: ensure the quality of the national health systems.
iv. Cost bearers: e.g. insurance companies, which compensate the medical treatment costs.
v. Other recognized stakeholders are independent regulatory bodies, application developers who develop e-Health applications and middleware, and original equipment manufacturers (OEMs) who manufacture e-Health devices.

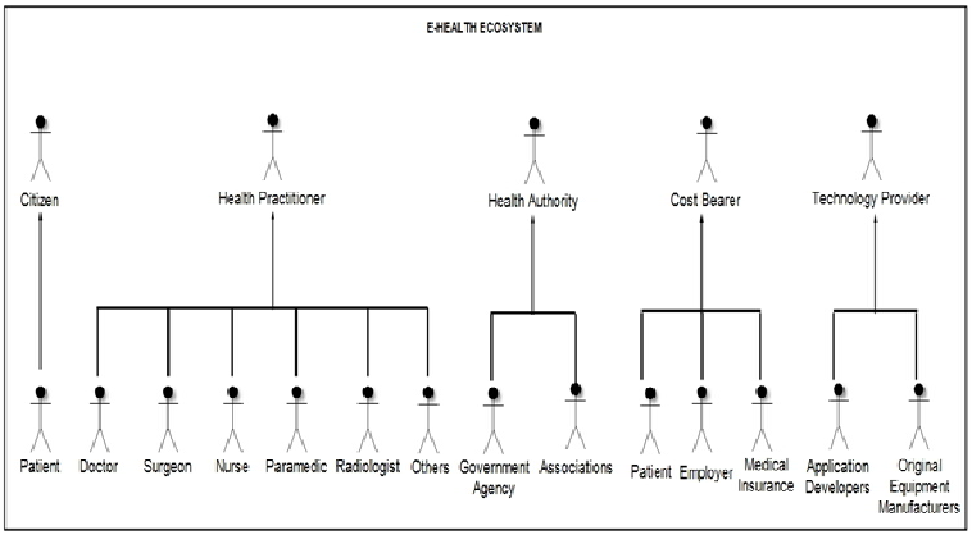

Figure 4: Use Case of E-health Ecosystem

4.STAKEHOLDERS' INTEROPERABILITY MIDDLEWARE REQUIREMENTS

The stakeholders' interoperability middleware requirements have the following procedure in common:

i. Connection of applications (both old and new) to the middleware.
ii. Access to applications by authorized stakeholders(s).
iii. Update/Modifications to applications by authorized stakeholder(s).
iv. Request and Retrieval of information from application by authorized stakeholder(s).

5.FUNCTIONAL REQUIREMENTS OF THE INTEROPERABILITY MIDDLEWARE

The functional requirements concern the necessary functionalities that the middleware applications must have for stakeholders to perform their task in a secured and authorized manner. These are an overview of the functional requirements needed for all the applications connected to the middleware to perform their basic functions. These requirements include the following:

i. **Application/Middleware Interaction:** New or Legacy applications connected to the system and exchanging data.
ii. **Data Structure and Representation:** means to represent, store, query and process data in the middleware and service of other applications.
iii. **Signing and Encryption:** security mechanisms to avoid unauthorized access and modification to data.
iv. **Authentication and Authorization:** means to aid identification of users with respective access rights.
v. **Registration and Discovery:** management of applications, devices and users using the middleware.
vi. **Servicing and Conversion:** means of accepting requests, processing, converting formats and feeding requests.
vii. **Reporting:** Generating summaries and reports for stakeholders.

6.NON-FUNCTIONAL REQUIREMENTS OF THE INTEROPERABILITY MIDDLEWARE

Non-functional requirements may affect the overall architecture of a system rather than the individual components. A single non-functional requirement, such as a security requirement, may generate a number of related functional requirements that define system services that are required. The non-functional and quality requirements derived are: i. Interoperability ii. Performance: Availability and Reliability iii. Usability and User-friendliness iv. Maintainability and Modifiability v. Privacy, Security and Integrity vi. Testability vii. Development Time. This is depicted in Figure 5.

i. Interoperability: The most crucial requirements of the national interoperability middleware implementation developed is interoperability, i.e., applications and devices from different vendors must be integrated seamlessly to guarantee an easy access to the whole functionality for the respective stakeholders.
ii. Availability and Reliability: This is how dependable the developed system would be, in terms of availability and reliability. The capability of the middleware to remain available and maintain the level of performance of the system when used under specified conditions. The capability of the middleware to avoid failure as a result of faults in the software. The fault tolerance is the capability of the software to maintain a specified level of performance in cases of software faults or of infringement of its specified interface.
iii. Usability and User-friendliness: A basic quality requirements of the middleware is to provide an easily accessible means by which stakeholders interface new and old applications together with the middleware. The ease of doing this will reduce the learning curve of integrating the middleware, thus increasing the rate of solution adoption. The applications provided by the middleware must also be easy to operate for non-technical stakeholders to use.

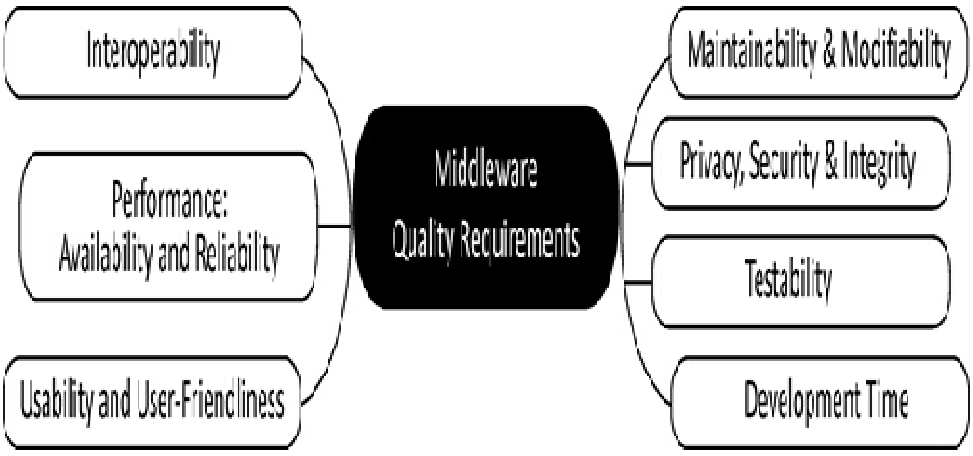

Figure 5: Non-Functional Requirements of the Interoperability Middleware

iv. **Ease of Deployment and Maintainability:** This is the ease of which the middleware can be developed, set up and configured for use. This is aided by the minimal complexity of the solution. On deployment, maintenance commences. This is the capability of the software or hardware configuration to be modified to suit different needs. Most importantly, the integration of new applications or device should have minimal or no hitch at all.
v. **Privacy, Security and Integrity:** These three are core requirements in the healthcare domain. The use of systems accessible via internet to enhance user-friendliness has some drawbacks concerning privacy and security. As it is not possible anymore to build closed ecosystems, which are per definition not accessible to potential fraud, and face unexpected and unauthorized use of system resources, up to the possibility of attacks, e.g., denial of service attacks damaging safety functions, or intrusions to get access to private data. This requires the need for a complete authentication, authorization, and accounting mechanism in connection with a suitable encryption technology is

necessary to enable authorized access only. Furthermore, countermeasures against potential attackers and methods of ensuring the privacy of data (e.g., data aggregation) have to be considered. The physical locations of devices that can be compromised also have to be put into consideration. Integrity of data ensures that only authorized stakeholders can access and modify data.

vi. **Testability:** The extent in which error messages are communicated to the component causing the error. The ease of constructing test software. The extent in which component interactions of the system as a whole can be visualized and logged. The extent in which errors are reproducible by partially fixing the order of interactions between various components.

vii. **Development Time:** The amount of time and effort required to build a system. The ease at which components can be reused in other systems. The extent in which support on the middleware product is available in the form of a helpdesk, support forum or active user community.

7.NATIONAL INTEROPERABILITY MIDDLEWARE OPERATION FOR E-HEALTHCARE SERVICES IN DEVELOPING COUNTRIES

The e-Health infrastructure providers include the government, private and public organizations, original equipment manufacturers, application developers, service providers and individuals. These providers together provide policies, connectivity, applications, systems, devices, insurance and skilled manpower required to have a functional e-Health infrastructure in the nation. These provisions serve direct and support infrastructure required by users in the e-Health community. The e-Health infrastructure users include: Patients, Medical Practitioners, Mobile Clinics, Hospitals, Pharmacies, Diagnostic Centers, and other Healthcare Providers. Each of these users has their local applications, systems and devices which are different from one another, though sometimes compatible with one another. The core interoperability infrastructure is a server infrastructure which can be provided by a private organization or governmental organization such as NHIS (National Health Insurance Scheme). The e-Health users are connected to the server via an internet network. The server consists of the middleware service which is interoperability service provider that interacts directly with generic system applications. The Apache web server is used to connect with portal or web based applications to provide web services, which is also connected to the middleware for interoperability. The database provides the storage of data and information required to support the interoperability process. The server serves as an enterprise bus to which users with different systems from different locations are connected to access the interoperability service. E-Health infrastructure users connected to the server infrastructure provide and retrieve information during the interoperability process. This is illustrated in Figure 6. The interoperability infrastructure provides services such as data sharing, storage, authorization and authentication, portal and other e-Health services which are made accessible to e-Health infrastructure users via the server.

8.NATIONAL INTEROPERABILITY MIDDLEWARE REQUIREMENTS

For a national implementation of the interoperability middleware to be successful, the following requirements have to be met:

i. The e-Health infrastructure users need to be identified, engaged, registered and connected to the interoperability infrastructure. Agreements must be made among stakeholders regarding the authentication of the sending and the receiving party, the accountability of the data transmitted and received the appropriate security levels and the procedures and mechanisms to be used in this respect.

ii. A standard security policy should be established to enable the reliable exchange of information which takes place in conformity with an established security policy. From the user perspective, functions associated with security (identification, authentication, non-repudiation, confidentiality) should have a maximum level of transparency, involve minimum effort and provide the agreed level of security.

iii. E-Heath services need to ensure uniform levels of personal data protection, including measures in which individuals have the right to choose whether their data may be used for purposes other than those for which they originally supplied the data in question.

iv. Each e-health user be it individual or stakeholder are independent in their operations and do not suffer from interference.

v. The interoperability middleware operations should be updated with developments in the healthcare sector. Developments could include change in privacy legislations, evolution of a healthcare standard etc.

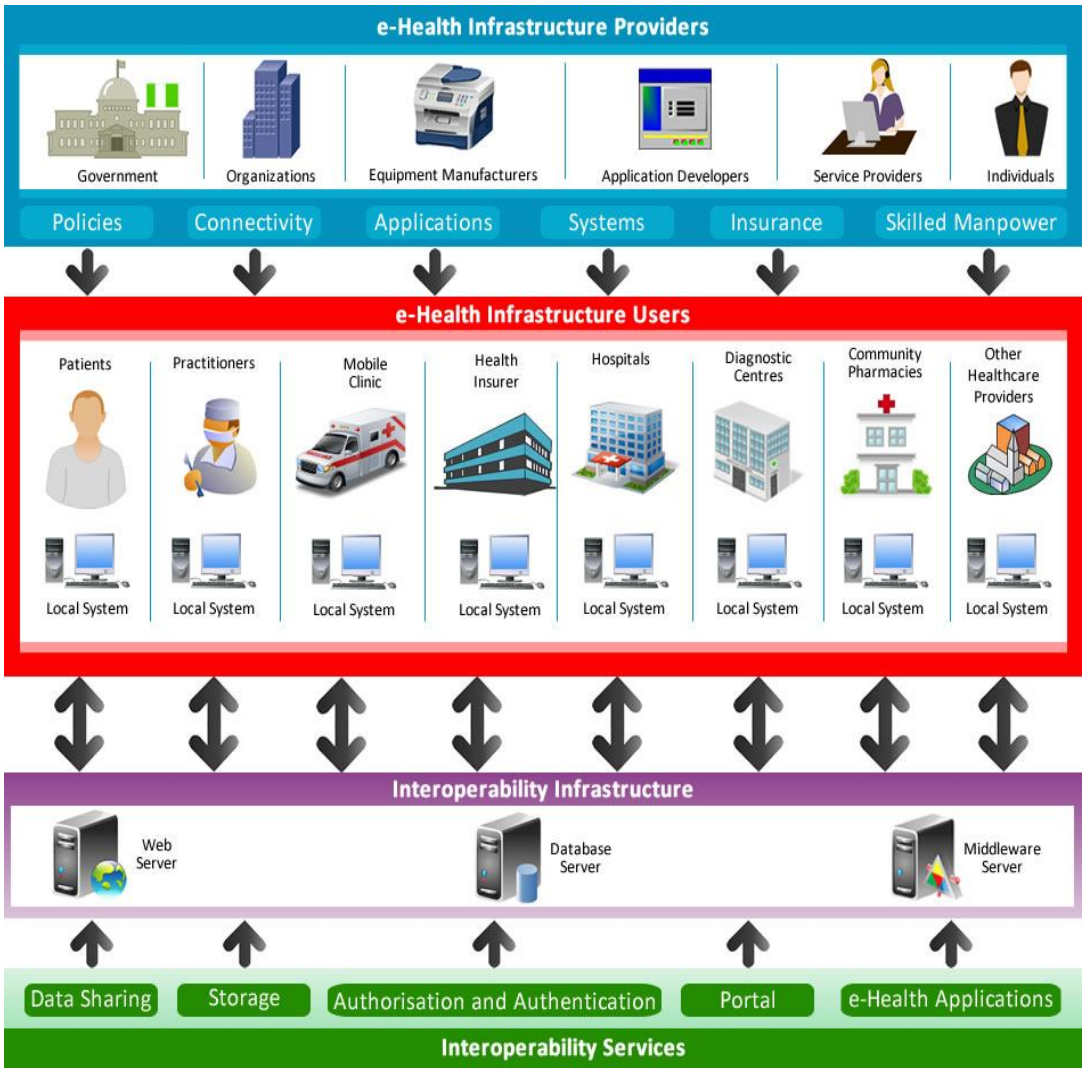

Figure 6.0: National Interoperability Implementation Middleware Operation for e-healthcare services

9.CONCLUSION

The national interoperability middleware operation for e-Healthcare service interoperability provides an enterprise view to e-Healthcare service interoperability among individuals and organizations who are stakeholders in healthcare domain in Nigeria. The interoperability middleware operation focuses on integrating existing applications (also known as legacy applications) rather than replacing them with new applications. New applications can then be easily accommodated by following standard specifications or standards issued by the design. In order to enhance integration, the rural e-health service provider must have an existing e-Health infrastructure on ground whose standard though heterogeneous with others can be accommodated into the interoperability middleware.

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