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E-HEALTH CLOUD FOR NIGERIAN TEACHING HOSPITALS

DESMENNU SENA, IKHU-OMOREGBE NICHOLAS AND AYO CHARLES

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ABSTRACT

A major challenge to the adaptation of e-Health solution in developing countries is the lack of infrastructure for massive data storage and availability of resources on demand. With well over 150 million people to care for, the health sector in Nigeria lacks an organized and interoperable data storage facility to hold large volumes of data that results from unprecedented visits of patients to hospitals on a daily basis. This has further worsened the ineffective and cumbersomeness of treatment processes due to inconsistence in data representations. This paper tends to address this issue by proposing a Cloud computing infrastructure for e-Health solutions in Nigeria. This will help to effectively and efficiently manage healthcare resources and data and also make healthcare services available across the existing teaching hospitals in the country.

KEYWORDS: Cloud, e-Health, grid, multitenant, teaching hospital, utility

1.0 INTRODUCTION

Computing nowadays is being designed to consist of services that are delivered in a manner similar to basic services such as water, electricity and gas. In such situations, users access services based on their requirements without regard to where the services are hosted or how they are delivered. This can also be called Utility computing. Presently, contents can be accessed over a network such as the Internet without reference to the infrastructure hosting such contents, an act also referred to as Distributed Computing. These contents are managed by content providers. They reside in well managed, monitored and maintained data centers across the globe. Several Distributed computing paradigms have evolved over time and they include Cluster computing, Grid computing, and more recently, Cloud computing [1].

Cluster Computing consists of a collection of locally inter-connected stand-alone computers working together as a single integrated computing resource [4]. Clusters have tightly-coupled and homogenous nodes. Health clusters are resident locally in hospitals. Hospitals have made use of inter-connected computers to help facilitate interaction among health personnel. Computing in clusters did not provide efficient use of idle resources, and are highly susceptible to failure as a result of homogenous nodes (single point of failure). An improvement on Computer Clusters brought about the Grid.

Grid computing is a kind of distributed computing over a network (public or private). It is based on the principle of virtualization of computing and data resources. Server virtualization is the act of using a software access point (hypervisor), so as to allow a physical computing server provision multiple applications resident on multiple virtual machines. These resources include processing, network bandwidth, and storage capacity. They are used to provide seamless access to vast IT capabilities [2]. It's set of standards and protocols are open and as such enable communication across heterogeneous and geographically dispersed environments. Three aspects of Grid functionality in healthcare are: Computing Grids, Data Grids and Knowledge Grids [15]. HealthGrids offers many advantages to the health community, one of the biggest being its ability to combine data from various sources quickly and securely. However, grids are not efficient when running applications that can't take advantage of Message Passing Interfaces (MPIs), when large computing speed is required and when applications require licenses to run across servers. Cloud computing is an extension of Grid computing that builds on these limitations with its own special attributes.

A definition of Cloud computing as proposed in [1] denotes a Cloud as a type of parallel and distributed system. It consists of a collection of inter-connected and virtualized computers. It also applies the principle of server virtualization. These computers are dynamically positioned and presented as one or more unified computing resource(s) based on service-level agreements. These service level agreements are established through negotiation between the service provider and consumers. The super-computing power of a cloud is made available by a network of data centers in which several servers are installed. Cloud computing represents the infrastructure as a "Cloud". Users (tenants and clients) are able to access cloud applications from anywhere in the world on demand (On- demand computing). This is gradually and rapidly transforming the computing world towards developing software to be consumed as a service (Software-as-a Service: SaaS), rather than to run on their individual computers. There are sets of parameters and features that clearly distinguish Cloud computing [1]. They include:

Desmennu Sena, Department of Computer and Information Sciences, College of Science and Technology, Covenant University, Ogun State.
Ikhu-Omoregbe Nicholas, Department of Computer and Information Sciences, College of Science and Technology, Covenant University, Ogun State.
Ayo Charles, Department of Computer and Information Sciences, College of Science and Technology, Covenant University, Ogun State.

- Single ownership,
- It is populated by commodity computers and high-end severs whose network speed is high-end with low latency and high bandwidth.
- The resources in a Cloud are either centralized or distributed with their capacities provisioned on demand.
- Clouds have strong support for virtualization with high potential for dynamically creating value-added services with web-service interface and for fail over and content replication.
- Clouds guarantee high-level security and privacy as each application has its own virtual machine and support access control list.

Some emerging cloud platforms and technologies include [1]: Amazon Elastic Compute Cloud EC2, Google App Engine, Microsoft Azure, Sun Grid, Aneka, Virtual Workspaces, OpenNebula, CloudSim and Reservoir. Areas of application of cloud computing include social networking, web hosting, gaming portals, business applications, scientific workflows, healthcare, content delivery and data processing and storage.

1.1 Nigeria's Health System

Primary healthcare delivery is the mode of operation of the healthcare system in Nigeria. This also forms an integral part of the National Health Policy. This policy entails the delivery of a full-packaged health care system. This package includes health education, maternal, newborn and child healthcare, nutrition and immunization. Effective management of healthcare at the grassroots requires record keeping and data storage. Massive Data storage and availability of such data on-demand have been sources of concern to health institutions. Lack of storage facilities and media have brought about a slow rate in hospital-to-hospital collaboration. Also, secure information exchange between and across institutions poses as a great challenge to medical practitioners. This does not enhance collaboration (also referrals) among such institutions. These challenges have brought about a lack of proper accountability in the health sector. A health sector reform was introduced in 2004 to address this issue. As a result, there is an appreciable increase in the resources committed to the health sector. This is to ensure the attainment of the Millennium Development Goals (MDGs) on healthcare.

With the advent and significant advances of Information Technology over time, there have been increasing areas of application. The healthcare sector has had its own share. The emerging field is E-Health. E-Health is an intersection of medical informatics, public health and business. It refers to health services and information delivered or enhanced through the Internet and related technologies. One of the attendant benefits of E-Health is Electronic Health Records (EHR).

2.0 Comparative Analysis of Existing EHR systems

An application area of e-Health is Electronic Health Records (EHRs). EHRs imply medical records in digital format [16]. Clinicians and health service providers are beginning to realize the value of confidentiality and accessibility of patients' information. As electronic patient records and hospital information become more accessible regardless of location, a reliable horizontal and vertical communication between healthcare facilities is established. This further drives quality and improved healthcare delivery to all. Unlimited access also strengthens collaboration efforts among hospitals and providers. Such collaborative efforts facilitate information exchange and experience sharing. An Electronic Health Records system facilitates the following:

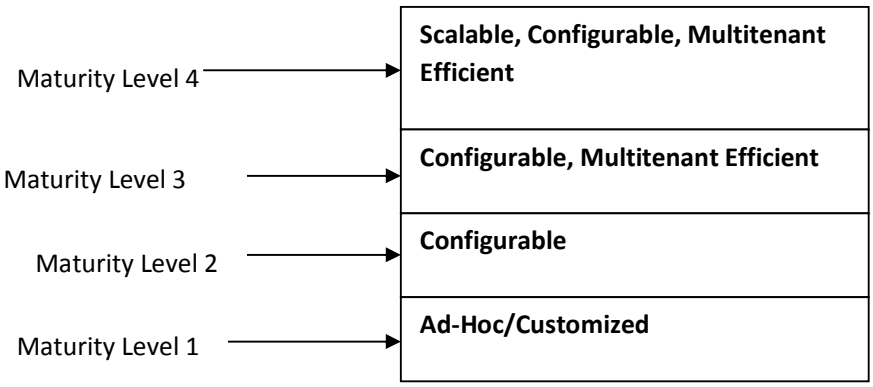
- Unrestricted access to patient data by clinical staff at any given location,
- Accurate and complete claims processing by insurance companies,
- Building automated checks for drugs and allergy interactions,
- E-Prescriptions,
- E-Scheduling,
- Sending and viewing laboratory reports.

Many frameworks and architectures have been proposed, developed and deployed in literature. A part of these architectures made use of the web-based technology, have three-tiered client-server architecture. The client-server architecture is made up of front-end (client), middleware (web server), and back-end (database server). These architectures have thin client-side (this implies that all custom application codes are resident on the server). Frameworks built on this type of technology infrastructure include Basic Telemedicine Service (BTS) in [11], Web-based multichannel telemedicine architecture in [12], and MediaStation 5000 in [13]. Another technology infrastructure proposed was the Grid approach which provides large-capacity computational power. Healthcare applications on the grid (HealthGrids) include MediGRID [cited in 15] and GridSphere portal [cited in 15]. NeuGrid which aims to supply neuroscientists with the most advanced ICT tools to help overcome neuro-degenerative diseases such as Alzheimer's, gLite which optimizes the use of heterogeneous computing resources to process medical imaging and RadioTherapyGrid which has been used to optimize the process of cancer treatment are also instances of grid applications in healthcare.

In Nigeria, One of such that has been developed and deployed across hospitals is MINPHIS. MINPHIS is an acronym for Made-In-Nigeria Primary healthcare and Hospital Information System [7][8][9]. It was developed in 1989 as a product of collaboration between Nigeria (Obafemi Awolowo Uiversity, Ile-Ife [10]) and Finland research and development project on health informatics. Its second version is currently available. It has been deployed across eight (8) Nigerian teaching hospitals as of July 2005, and it's suitable for the different types of health facilities as a result of its scalability.

Cloud Computing Approach

In this paper we propose an architecture premised on Software-as-Service (SaaS). This delivers a single application through the browser to thousands of customers (users) using a scalable multitenant architecture. SaaS architectures are generally classified to one of four "maturity levels", where each level differs from the previous by unique attributes as represented below.



This works adopts SaaS' maturity level 4. Multitenant architecture allows several customers to share infrastructure, without the customers being aware of it. Scalability allows increase or reduction in the system's capacity to match demand per time, without the need for any further alteration of applications. This can be done without compromising the privacy and security of each customer's data. SaaS is a higher level abstraction of the cloud, where there are now services in the place of data pipes, routers and servers. The underlying hardware and software of networking is still available but there are now higher level service capabilities available to build applications. Service users are only particular about its accessibility and a high level of reliability. They are not concerned about the service implementation, the technologies adapted and the service management.

3.0 Proposed Health-Cloud Architecture

The proposed Health Cloud runs on a multitenant architecture. Multitenancy refers to a principle in software architecture where a single instance of the software runs on a SaaS vendor's server, serving multiple client organizations (tenants) [5]. The multitenant data will be managed using a single database. The teaching hospitals in Nigeria are the tenants of the cloud. Encryption and permission are the security patterns that will be applied to Health-Cloud. A database access account will be created for each health institution, and Access-Control Lists (ACL) will be used to grant each of these institution accounts access to the database objects they are allowed to use. Within the health application itself, role-based access is put in place to prevent unauthorized access to data. Health Institutions can connect from any geographic location to the cloud and utilize needed resources.

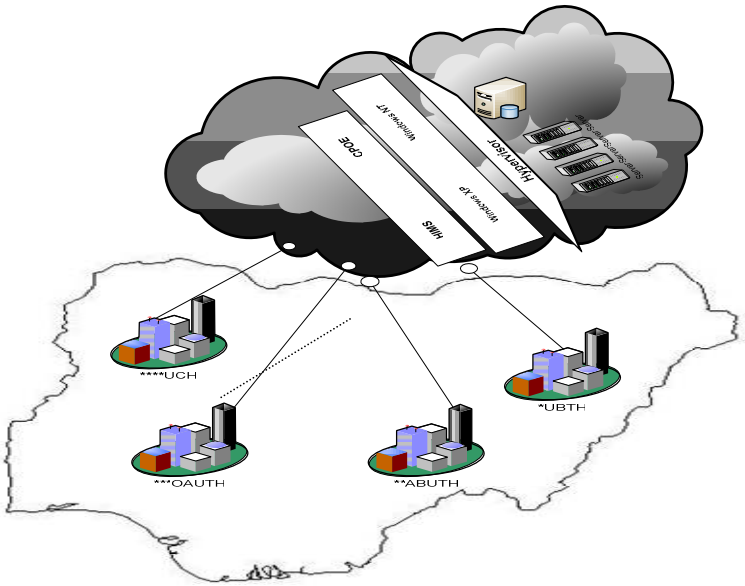


Figure 1: Proposed Health Cloud for Nigerian Teaching Hospital

Health-Cloud in Nigeria

The adoption of Health-Cloud will make patient records available on demand. It will minimize cost expended on infrastructures especially storage infrastructures (hardware and software) by healthcare institutions as applications are consolidated on the same physical server. This server will be located somewhere in the cloud where it will be managed by some service providers. This will help overcome the lack of such infrastructures across health institutions. The cost of

manpower managing the infrastructures is also reduced as each health institution is billed per utility consumed. Health-Cloud will also foster collaboration among various health institutions and medical personnel and finally help create a national hospital chain. This methodology ensures no upfront investment in servers or software licensing for clients or users; while with just one application to maintain, providers enjoy minimum costs compared to conventional hosting. The proposed architecture has a high possibility of making healthcare services available universally irrespective of location in Nigeria especially at the grassroots through the efficient and effective management of the available resources.

CONCLUSION

The introduction and adoption of the Health-Cloud will ensure all individuals have equal rights to primary healthcare so no one is underinsured or over insured. In the long run, it will help to meet the Millennium Development Goals (MDGs) on healthcare delivery for all.

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