Association for Information Systems
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Issue Nr 7 (2016) Scandinavian (IRIS)

2016

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Cloud Computing as a Catalyst for Integrated Health Information Systems in Developing Countries

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Abstract. Cloud Computing is increasingly becoming important in the generation, storage and transmission of information worldwide. In this paper, we discuss the potential of Cloud Computing in terms of how it can strengthen health information systems in developing countries. Like any new technology, Cloud Computing is no silver bullet; it solves certain challenges while bringing new ones to the table. Based on a case study of the innovative use of Cloud Computing for the national health information system in Kenya, we discuss how Cloud Computing can enable the integration and harmonization of fragmented systems and provide real-time information to health managers for evidence based decision making. The key contribution of the paper is to provide an understanding of how Cloud Computing can enhance health management by acting as a catalyst for the integration of health information systems.

Keywords: Cloud Computing, Health Information Systems, Developing Countries, Integrated Health Information System

1. Introduction

The emergence of Cloud Computing has made a tremendous impact on the Information Technology (IT) industry over the past few years. Cloud Computing broadly refers to applications delivered as services over the Internet based on large data centres that provide them as services [1, 2]. The National Institute of Standards and Technology (NIST) defines Cloud Computing as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [3] p.2. The Cloud Computing architecture consists of three components: a) infrastructure as a service (delivering server storage and network technologies), b) platform as a service (an online environment for quick development of web application) and c) software as a service (for example, email in web browsers) [3]. It is usually up to the user to choose how many of these components to use. Cloud Computing can be classified as public (company selling cloud services to public), private (owned by single organization for their own work), community (owned by several organizations) or a hybrid (composition of two or more of the above) [3]. Since health care requires confidentiality and integrity of information stored,

enforcement of security and privacy is required, meaning that a private cloud is most suited.

Compared to investing and maintaining servers locally, Cloud Computing is attractive for organizations both in the private and the public sector. Running national online information systems calls for highly specialized Information Communication Technology (ICT) services that guarantee 99.9% access and availability to all the users. Robust redundancy and failover protocols must be in place to guarantee business continuity in times of system failure. Up-time is one of the most critical requirements for servers. This is to ensure that whatever hour of the day, if something goes down there will be someone to address it. Staffs need to be available 24/7 to ensure maximum amount of uptime. This level of specialized ICT services is not the domain of ministries of health [4] and so the adoption of commercial Cloud Computing becomes very attractive. Since resources in commercial Clouds are centralized, pooled and shared among many users, it is cost effective in terms of economies of scale[5]. Users only pay for their usage and they do not need to make risky investments in hardware when their future needs for capacity is uncertain. This approach is highly relevant in the public health sector in developing countries where financial resources for investments in hardware are scarce and the human capacity to maintain local servers is often lacking.

From the literature, the use of Cloud Computing in healthcare is identified to offer many benefits: storage of large amounts of data (it is scalable and elastic for increasing or decreasing), offering remote access (the data can be accessed from internet from anywhere) and allowing sharing between authorized units [6]. Other benefits include the ability to share information within the community that includes patients, regulators, providers and even insurance firms. Chang (2009) posits that the emerging Cloud Computing appears well-suited to meet the demands of a sustainable healthcare through the concept of shared infrastructure ecosystems [7].

Like any new technology, Cloud Computing is no silver bullet; it presents entirely new challenges and obstacles, particularly regarding coping with limited technical expertise, bandwidth, and IT resources [8]. At the same time, Cloud Computing also suffers from lack of institutional support and legitimacy due to lack of proper policies and regulations. In general, governmental agencies are uncomfortable with storing data on public clouds [9]. A similar finding was found in South Africa where a lack of well-coordinated regulatory framework for proper governance of eHealth standards implementation was found to be a key concern [10].

In this paper, we focus on a different, yet an important underappreciated problem facing health information systems in developing countries; fragmentation. The increasing international funding towards public health diseases like malaria, tuberculosis, immunization preventable diseases, Human Immunodeficiency Virus infection and Acquired Immune Deficiency Syndrome (HIV/AIDS), has given rise to multiple and parallel disease specific reporting systems. This happens because donors are only concerned with their disease specific reports, without adequately appreciating their relation to the larger health information system. The result is a fragmented health information system supported by different donor interests [11-13]. Fragmentation, though primarily well-intentioned, has the potential to give rise to unintended consequences like having different public health statistics for the same indicator (but from different parallel systems), leading to mistrust of national reports.

This paper explores the interaction between Cloud Computing and the implementation of reliable information systems that reduce fragmentation and foster integration of different parts of independent diseases programmes. It attempts to answer the following research question: How can innovative ICT applications like Cloud Computing support the implementation of integrated health information systems in the context of developing countries? To answer this question, we use a case study from Kenya, which is utilizing Cloud Computing for its national online health information system. The information system under the study carries aggregate service delivery data, mostly numbers and percentages, without personalized patient information. Based on the experiences from Kenya, we argue that Cloud Computing can be used as a catalyst to establish integrated national data warehouses, reducing fragmentation and availing data to Government officials, implementing partners and international health agencies "wherever they are." The key contribution of the paper is to provide an understanding of how Cloud Computing can enhance health management by acting as a catalyst for integration of health information systems.

2. Adoption of Cloud Computing in Implementation of the Kenyan Health Information System

The first organized health information system in Kenya was established back in 1972. The system has gradually grown, having started with pure paper and progressed to a hybrid paper-digital system. While computers were introduced in the 80s, the first networked computer system was introduced in the year 2008, with the introduction of File Transfer Protocol (FTP); a system that is used to transfer files over the Internet [14]. During the time of FTP, numerous data quality issues were exposed. For example, in one of the annual data review meetings, a senior district medical officer did not agree with data being presented at the national level. These discrepancies prompted heavily donor funded programs like Expanded Program of Immunization (EPI), Tuberculosis (TB) and Malaria to establish their parallel reporting systems. An evaluation carried out to improve health information system [15] suggested a better and more robust software, leading to the adoption of the District Health Information System (DHIS2)[16].

In 2010, the DHIS2 was adopted and implemented in Kenya [17, 18]. At the onset a decision was reached to install the new system in the FTP server at the data Centre at the Ministry of Health (MoH) headquarters. On evaluating the suitability of the government data centre, it was observed that the data centre was a just room that housed several racks of equipment for the ministry's Health Information System (HIS) together with the Integrated Finance Information system (IFMIS) of the Ministry of Finance. The room was dark, dusty, musty, and generally not a conducive environment for sensitive and delicate electronic equipment meant to host information of immense importance. At the same time, the Internet connection barely worked because of outdated network equipment. There were also no power backup systems.

Based on consultation with senior ministry officials, outsourcing of the server was considered a better option and therefore adopted. Still, this was meant as a temporary arrangement and the long term strategy was to build local servers and necessary

infrastructure at the MoH headquarters. The server and the system were hosted by the Cloud Computing provider Linode in London, with support from the University of Oslo. Initially, all the management of the server was done from Oslo. In this concrete setting, the greatest benefit of Cloud Computing was the immediate availability of data. Due to excellent network connections, the speed with which data were uploaded and downloaded was remarkable. Previously getting data from the central server hosting health information delivered at the MoH headquarters was difficult. The DHIS2, with excellent access through the cloud, was rapidly rolled out countrywide within one year. Another key benefit was that the cloud service provider adjusted quickly to the growth in the database and the data traffic. This elasticity of resources proved very useful, since the Kenyan database was growing at a rapid rate. By 2011, all health facilities were reporting their routine health indicators using the software hosted in the cloud [18].

Since adopting DHIS2, data management in the country's health information system is both paper and electronic based. Health workers at health facilities (Hospitals, Health Centres, and Dispensaries) record data in paper registers as they deliver their services. Data from these registers are then summarised and entered into pre-defined summary forms on a regular basis (weekly, monthly and quarterly). These are then transported by road to the sub-county health records offices (formally districts), where they are transformed into the electronic formats through entry into the DHIS2. Designated officers at the sub-county level are charged with the responsibility of scrutinising the data received from health facilities for completeness and correctness before entering them in the system. Once in the system, any person with access rights can view the outputs (charts, tables and maps). Figure 1 below shows the data flow of health information system in Kenya using DHIS2 and Cloud Computing. Figure 1: Flow of Data in Kenyan Health information using of DHIS2 and cloud computing

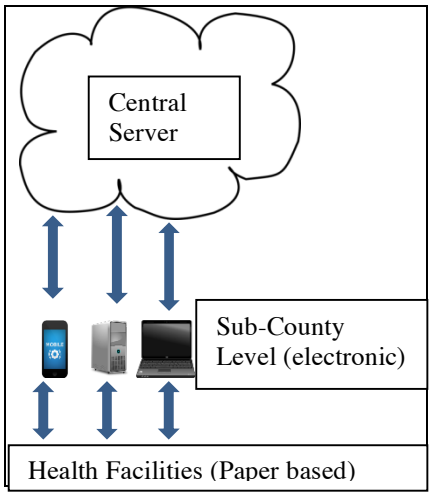

Figure 2: Data flow From Health facilities to Central server using cloud computing facilities

Since hosting of DHIS2 was initially thought to be a temporary fix, the government constructed a modern data Centre at the Ministry of Health headquarters in 2012. During the opening ceremony of the data Centre, the Permanent Secretary for the Ministry of Health said, "*This data center is unprecedented in the history of the Health Ministry and represents the biggest investment in IT to date; as technology improves, so does the quality of life, therefore the ministry is willing to embrace technological advancements that will help improve the health sector*" [19]. However, due to staff shortages and lack of a dedicated internet connectivity to the data Centre, Kenya continued to host the DHIS2 in the commercial public cloud, raising many issues with the government. For example, one senior MoH official was concerned with the lack of legal framework supporting hosting of health data out of the country. The official hinted to the possibility of confidentiality breaches with sensitive health data in the cloud. Even though it was only aggregated data without any personal identifiers, some senior ministry officials continued asking: "where is our data?" Based on these concerns, the ministry again tried hosting the software on the newly refurbished data center. But again, this was not possible due to the fact that in country facilities were slow. Eventually the ministry organized for the migration of the system to an in-country server at the Safaricom (mobile company) cloud in 2012. However, due to growth constraints and limitations of the ICT resources at the Safaricom cloud, the system was once again migrated to an offshore managed server - Digital Ocean in 2013. Digital Ocean is an American cloud infrastructure provider that provides virtual servers for software developers. The company is headquartered in New York City and possesses data centres worldwide [20].

All costs for hosting the database in the cloud are currently supported by the United States Agency for International Development (USAID) through a Kenyan Non-Governmental Organization (NGO). Besides hosting costs, four ICT officers at the NGO were trained in the administration and support of the DHIS2 database and software through the cloud computing technology. The hired ICT specialists work closely with selected government workers from the Ministry of Health, providing on-job training. The same NGO also collaborates with a local University on issues of software development, management and sustainability.

3. Methodology and Data Analysis

This paper is part of a larger study on the implementation of an online health information system in Kenya. The larger research utilizes Acton Research methodology, a qualitative research method in which the researcher is actively involved in solving a real-world problem by bringing about change in an organization, while at the same time contributing to development of knowledge and theory [21, 22]. It involves integrating theory with practice through an interactive process of problem diagnosis, action intervention, and reflective learning [23]. The action research in Kenya is part of the global Health Information System Program (HISP) research on

health information systems in developing countries and the development of the District Health Information Software (DHIS2). HISP is a global network of people, entities and organizations, who design, implement and sustain Health Information Systems. As a network, HISP was established by the Department of Informatics at the University of Oslo and supports local management of health information systems [24]. The principal researcher is part of this HISP team and some of the empirical data used in this paper are derived from his participant notes on lessons learnt in the Action Research.

The main study methodology for this paper is case study, because it is well suited to answer the research question[25]. The unit of analysis was the health information systems. Data were obtained by interviewing key stakeholders in the health sector. The stakeholders interviewed included health information officers, health facility managers, senior ministry of health managers at the national level, and the chief executive officer of a Non-Government Organization (NGO) project with the mandate for managing the country's health information system. Table 1 shows the number of key informants interviewed.

Table 1: Summary of Interviews

Type of informants	Number interviewed
Senior government officers	4
Health records and information officers	10
IT officers	2
Bilateral donor agencies	3

Analysis of the qualitative data was done by summarising the interviews, participant notes and proposing explanations. The principle researcher was part of the stakeholders working for the ministry of health and his opinions were also considered taking, an interpretivist position.

4. Findings

Cost Effectiveness: Hosting a national and robust system such as DHIS2 requires a secure environment with specialized ICT experts. In Kenya, the ICT staffs do not form part of the skill mix at the Ministry of Health; making it very hard to implement some of the complex ICT procedures such as server management. Kenya built a state of the art server but was not able to operationalize it partly due to staff shortages and other technical issues. This is a classic example where funds are invested in the information infrastructure, but does not translate into use. On a monthly basis, the cost of the rented services for the country are less than 500 US dollars, far less than what was used to construct and what would be required to hire specialized staff to operate and maintain local infrastructure. In Kenya, the cost of maintaining the cloud servers was provided by donors.

Support from the policy makers: Hosting of the software out of the country was discussed with the senior ministry of health official. Despite agreeing on a lack of an appropriate legal framework, they accepted the cloud option on the condition of maintaining high data security (in view of the confidentiality nature of health data). This was interpreted by other stakeholders as an assurance of security, ultimately allowing their data in the system. This further reinforced the integration of data from the disease based systems.

Improved internet connectivity in the country: Improved access to online systems through the availability of fibre optic cables and mobile internet makes it easy to get data from the cloud. With excellent connectivity, clients are able to download data for use wherever they are. However, the internet connectively is not uniformly good across the country, making it hard to access the data on the cloud. This overdependence on internet has once delayed important meetings due to lack of data since the internet was not sufficient to download data from the central server. However, the users of the system have been advised on the need to make data backups, in order to avoid delays due to connectivity. DHIS2 has been designed to allow data entry while offline, allowing those with low internet to work offline without interruption.

Due to accessibility afforded by the country's good internet connectivity and the efficiency of international clouds, it was very difficult to adopt local clouds which were slower, thereby reinforcing the continuous use of high efficiency international commercial clouds.

The use central server as a centralizing factor in a decentralized health sector: During the study period, Kenya adopted devolution as a form of government, effectively decentralizing the health sector. With most activities being decentralized, hosting the DHIS2 on a central server was a key factor to keep a national and centralized health information system. This has made it possible for stakeholders at all levels of the government to access the data online, avoiding the bureaucracy of seeking permission from the decentralized government units. This meant that the running of the health information system was not drastically affected by the political change of governance.

Addressing Security Concerns: Literature has identified privacy and security issues as the top concerns for Cloud Computing [26]. Negative institutional influences are related to the perceived lack of security of Cloud Computing. This is particularly so for patient based information which is highly sensitive and requires appropriate security. Of great concern is the possibility of unauthorized access to sensitive data and confidentiality breaches with the use of public clouds. The commercial cloud providers take care of physical security in terms of controlled access, surveillance systems and onsite security. Cloud providers also offer solutions using anti-virus, fire-walls and data encryption software to assure data security and privacy. The fact that Cloud Computing offers great security features, organizations felt comfortable hosting aggregated non personalized health data on the commercial cloud.

Integration of Previously Fragmented Systems: At the time of implementation, DHIS2 was a customization of seven datasets that were previously being used during the FTP days. Due to the scalability of the Cloud Computing arrangement, more data sets (such as those on HIV, malaria commodities, nutrition and many others) were added to accommodate other stakeholders (National AIDS control program, Malaria program, department of vaccines). This reduced the fragmentation of the previous poorly performing information system. As a reinforcing side-effect, this also prompted several donors in Kenya to start integrating their previously parallel systems with DHIS2. As a result, the number of datasets increased from the original seven in 2010 to 90 in June, 2016 [24]. The elasticity nature of the cloud afforded this integration of parallel systems since storage space was not an issue anymore. Further, accessibility, a key characteristics of Cloud Computing [27] made it very easy for many stakeholders to have confidence in the system. Managers were able to view their data wherever they had Internet access. This is a big step towards integration of parallels systems using DHIS2 as data warehouse. Beyond health information, this Cloud Computing arrangement also offered the opportunity for certain information systems to share information through established standards. Such systems included: Human Resources Information System (HRIS); which aims at bringing Human Resource Information for the tens of thousands of health workers and Electronic Medical Records (EMRs) that facilitate effective patient management especially in large hospitals. Additional information systems involved in data sharing include: disease outbreak monitoring through Integrated Disease Surveillance & Response (IDSR) and a number of projects using mobile technology for reporting.

5 Discussion

Over the past couple of years, we have witnessed diffusion and adoption of Cloud Computing in the health sector of developing countries. However, health and IT managers need to have clear ideas of what they wish to achieve by moving to the cloud. Whether it is reducing overhead costs, increasing internal IT efficiencies, or ensuring that data are kept secure and compliant, it is important to document the reason for the move.

A well-documented problem affecting health information systems in developing countries is fragmentation, which is typically brought about by independent health programs and donor dependencies [11, 28]. The emergence of Cloud Computing offers an opportunity to solve this problem by reducing the hurdles of integrate data from different and parallel health programs and systems. This case study shows that with cloud computing the number of data sets in the health information system in Kenya soared from seven to 90. This was due to the fact that Cloud Computing facilities are scalable according to the needs of the client and have excellent Internet connectivity. The development of a strong Internet backbone and utilization of fibre optics in developing countries like Kenya is reinforcing this.

Another factor driving cloud adoption is costs; the cloud has been proven time and again as a more cost-effective model than running an on-premises data centre [29]. This is further shown by the fact that countries can utilize the benefits of web based

systems with minimal initial infrastructural costs. Countries can simply pay for services before constructing their own private servers. It is also an assumption that countries can save money when they do not need to pay staff to manage local servers. In Kenya and other developing countries, the argument of staff must also be seen in relation to the availability of human capacity to operate and maintain servers locally and inside the ministries.

This study shows that Cloud Computing is promising, but not a silver bullet. Challenges included the failure of countries to come up with timely legal frameworks to support its uptake. Also as medical data is shrouded with secrecy and confidentiality, many health managers are concerned, particularly pertaining to the breach of patient confidentiality. While most companies have addressed this issue by careful encryption, and continuous monitoring of security compliance, it is always difficult to assure the customers 100% security. Despite the security concerns, some authors argue that most enterprise-centric cloud architectures have a stronger security than in-house servers [30]. The issue of costs for maintaining the Cloud Computing servers is an issue in developing countries, which most often than not depend on donors for such installations. External support is not always sustainable and so hosting costs are seen as one of the challenges of Cloud Computing. Further, addressing the lack of local capacity to run and maintain local servers is a short term solution that removes any incentive for buildings such capacity.

5.1 **Conclusion**

Following the interpretation of the findings and supported by arguments from existing literature review, we find that this study has several contributions to make to literature. The following are key contributions highlighted from the paper.

Cloud computing as a catalyst for integration of health information systems: we have seen that a strong "side effect" of Cloud Computing is facilitating integration. This aspect of Cloud Computing has not been addressed before in literature.

Donor Dependency: This paper shows that the success of Cloud Computing in developing countries is highly dependent on donors and the IT infrastructure especially the emergence of fibre optic internet connectivity. The dependency on donor may be a short term fix but risks related to dependency can be devastating due to unreliability of some donors.

Human Resource: Most developing countries lack human resource capacity for handling local servers. Even when local servers are present, they are situated in murky server rooms, not properly maintained.

Recommendation: In order to leverage on Cloud Computing, it is recommended that adequate and long-term planning should be done to avoid situations that might lead to

disruption of services, confidentiality breaches and support the development of human capacity to deal with servers also in developing countries.

Acknowledgement: We acknowledge the contributions made by the peer reviewers who gave valuable contributions to this paper during the 2016 IRIS conference in Sweden. We cannot forget to thank the Kenyan Ministry of Health and the Afyainfo project in Kenya for participating in the study.

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