A Service Oriented Architecture Approach to Implementing an Omnichannel Personal Health Record System.

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ABSTRACT

Interoperability of eHealth systems has been a problem that has been unresolved due to variations in platforms, protocols, data formats, patient matching criteria and lack of universal patient identification. Most of the eHealth systems are owned and controlled by individual hospitals and not exposed to other third parties by choice or fear of losing competitive advantage when they share with other institutions The popular Personal Health Record (PHR) systems, instead of patient centric, are also institution-specific, proprietary, expensive and mostly permit patients to collect and enter all their medical information manually as only few physicians or hospitals submit their medical information electronically to a PHR. Having a unique patient identifier that is consistent nationwide is the ultimate solution to patient matching across different healthcare provider's systems. There is also a need to manage and avail PHR data anytime, anywhere and to any terminal with patient consent. The data need to be kept up to date as soon as medical information is available preferably automated upload from EMR or in real-time from monitoring devices through open APIs. We thus designed an Omnichannel PHR solution based on Service Oriented Architecture to enable patients to sign up, manage profile and share medical information through cross platform mobile application, web application and monitoring devices in real time. IBM's Service Oriented Modelling and Architecture (SOMA) phases was used to model, identify, select, implement, deploy and monitor the services in the Omnichannel PHR solution. The main goal of using SOA was to provide consistent services across all channels, terminals or devices. This research therefore recommends open APIs using SOA for central identification and management of personal health records, use of open source technologies and adoption of Internet of Things to collect vital patient medical information in real-time.

KEYWORDS: Personal Health Record, Omnichannel, SOA, Service Oriented Architecture, mHealth, IoT, Internet of Things

INTRODUCTION

Interoperability of eHealth systems has been a problem that has been unresolved due to variations in platforms, protocols, data formats and patient matching criteria. Even with the availability of a multitude of message exchange standards, the systems still operate in isolation, with little or no potential to interoperate due to lack of universal patient identification. Most of the eHealth systems are owned and controlled by individual hospitals and not exposed to other third parties by choice or fear of losing competitive advantage when they share with other institutions (Ge, Ahn, Gage, & Carr). The popular Personal Health Record (PHR) systems are also institution-specific and have not been concerned with data interoperability and data protection with other PHR vendors, which explains why there is low uptake especially in Kenya (Jingquan, 2017). Existing mHealth solutions are proprietary, expensive and hence unsustainable as patients are unwilling to use and pay for multiple applications which do not share data with other systems but stand-alone 'siloed' applications. As a result, patient records are spread across different institutions that cannot easily be accessed by patient nor caregivers. According to (Arzt, 2017), a universal identification of patients within a nation would result in a safe and secure exchange of patient healthcare information since it ensures an accurate, timely and efficient matching of the patient between different EMR systems, in and out of a healthcare facility. The burden of patient matching and lack of data exchange falls on the patients who are forced to pay for duplicate consultations, tests, treatments that were not necessary at all including succumbing to negative side effects of misdiagnosis, hence the need to establish and implement a framework for patient-centric universal patient identification and sharing of data. Most of the PHR solutions permits patients to collect and enter all their medical information manually as only few physicians or hospitals submit their medical information electronically to a PHR (PharmD, 2016). Therefore, there is need to manage and avail PHR data anytime, anywhere and to any terminal with patient consent.

Objectives of the study

The main objective of this research was to implement an Omnichannel Personal Health Record System based on Service Oriented Architecture (SOA) framework to facilitate patient centered selfcare and collaboration with health care providers. The specific objectives under the study was understanding people's perception on personal health record systems, identifying the current mechanisms of identifying patients in health facilities, developing a Service Oriented Architecture (SOA) model and prototype for the proposed Omnichannel PHR System, and finally testing, evaluation and validation of Omnichannel PHR prototype system developed.

LITERATURE REVIEW

Internet of Things

We are accustomed with internet of people, now we have internet of everything. Internet of Things refers to network of objects (things) that can sense and share information, with other objects, devices, machines through specified protocols. IoT encompasses Machine-to-Human communication (M2H), Radio Frequency Identification (RFID), Location-Based Services (LBS), Lab-on-a-Chip (LOC) sensors, Augmented Reality (AR), robotics, and vehicle telematics as it exists today (Lake, Rayes, & Morrow, 2018).

IoT devices are quickly evolving and adopted due to its characteristics such as they are typically small and inexpensive devices that are designed to operate autonomously anywhere, either in the field, embedded in other devices including human body. IoT's ability of building "intelligence" into "things" differentiates them from the ordinary internet (Keyur & Sunil, 2016). Such characteristics makes them suitable for healthcare, manufacturing, finance, agriculture and many other sectors.

IoT architecture consists of interrelated layers of technologies that allows the IoT devices to communicate and exchange data. The sensors allow interconnection to physical and digital worlds to collect data in real time. Examples include temperature, pressure, speed, etc. The sensors are small in size, require low power and need to connect to sensor gateways like GSM and GPRS to transmit data to physical world.

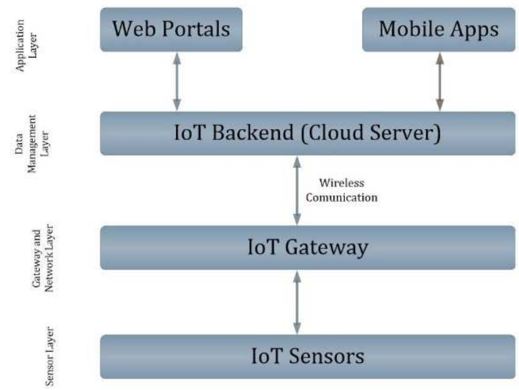

Figure 1: Internet of Things Architecture

IoT sensor devices produce lots of data and it requires a transport medium to communicate and exchange the data to the digital world (e.g. a cloud server) via a gateway. Gateway networks include GPRS, WI-FI, GSM. The network gateways and sensors are attached to a IoT (microcontroller, microprocessor). Data management service layer provides information access on need basis. This information can be accessed from other devices such as mobile apps and web applications. It also ensures that data privacy is ensured and the data is disclosed in the correct format. The application layer encompasses the end user applications such as the web, mobile and dashboard applications. The data and functionality is presented to specific consumers of the IoT data such as Agriculture, Health Care, Supply chain, Energy, etc

Service Oriented Architecture

Service-oriented architecture (SOA) is an approach to designing, implementing, and deploying information systems such that the system is created from components implementing discrete business functions called "Services"

(Sonic Software Corporation, 2005) that can be distributed across geography, across enterprises, and can be reconfigured into new business processes as needed. It is an orchestration of services that interact with each other in servicing a business process in a client/server design approach (software services versus software consumers/service requesters). It is different from traditional client/server model in that it advocates for loose coupling of services and autonomy of services. SOA has key potential desirable benefits not limited to interoperability, reusability, loose coupling and protocol independence (Pulier & Taylor, 2006). According to Rosen et al. (2008), SOA divides the complex organisational environments into smaller functions called services, that are designed to do one thing hence re-usability. The services are exposed using standard Web Services using a Web Service Description Language (WSDL) that can be consumed by any programming language in any platform thus realising interoperability and protocol/platform/technology independence.

The discovery of Web Services and Extensible Markup Language (XML) has been embraced by many as a defacto integration framework. This led to the adoption of Enterprise Service Bus (ESB) which is still dominant today despite mushrooming of Micro Services. ESB uses Hypertext Transfer Protocol (HTTP) web services to expose business services to client systems while at the same time takes advantage of various existing messaging services like Java Messaging Services (JMS) for routing requests to and from disparate systems. ESB has been accepted as a single point of integration of organisation's business services in a service-oriented architecture (Masava, 2013).

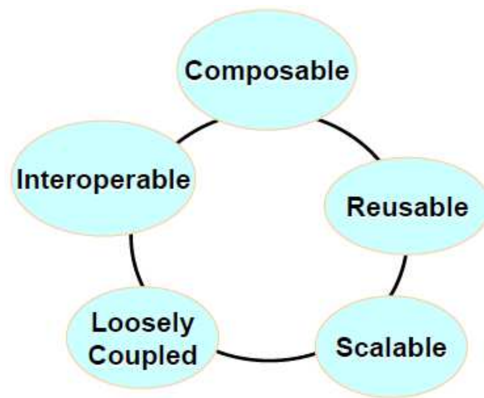

Figure 1: SOA Characteristics

In a Service Oriented Architecture, the business functions are packaged into services which are consumed by client systems as Web services. The service provider must first register the service in a service directory. The service consumer will search for the business service in a service directory, bind and then invokes the web service provider's endpoint address.

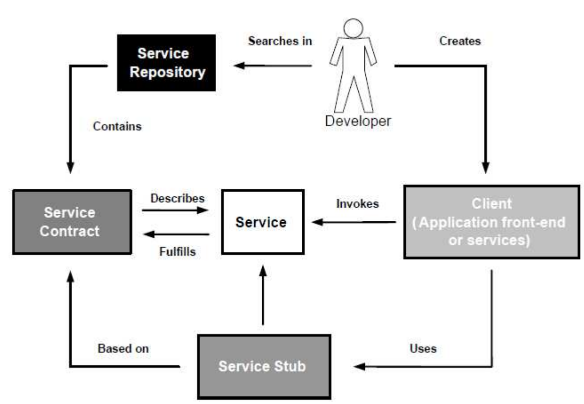

Figure 2:SOA Components

METHODOLOGY

The nature of this research was to address patient data interoperability. Purposeful sampling was used to select patients or individuals for study. This method is suitable in that participants will be chosen according to the need of the study. Questionnaires and interviews were the main data collection tools. Patients (individuals) and healthcare personnel were given questionnaires. The participants were asked to confirm if they were familiar or had used a PHR and if it was useful to them, and if so, they were also asked about the aspects of a PHR that would be most helpful in their own care. The sampling frame for the health providers included 1 health care provider in Nairobi. It also included all patients and identified caregivers from hospitals and clinics. Healthcare personnel were also interviewed about the current patient identification methods and medical data handling processes.

IBM's Service Oriented Modelling and Architecture (SOMA) phases was used to model, identify, select, implement, deploy and monitor the services in the Omnichannel PHR solution. Service-oriented modelling is a phase-oriented process for modelling, analysing, designing, and producing a SOA that aligns with business processes and goals (Arsanjani, 2004). SOMA was developed by IBM to guide the design and building of SOA-based application. It consists of seven phases as shown in figure below:

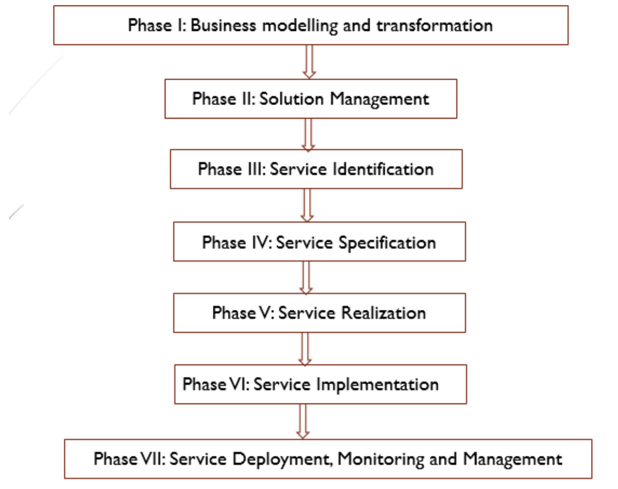

Figure 4:SOMA Phases

First, a business model was defined, along with a set of templates for each of the possible integration solutions. Thereafter, the Omnichannel PHR services were idenfied and included in the solution architecture as required. The services were refactored, rationalized and specified as part of a SOA architecture while others were deferred for later implementation (out of scope of this research project). Finally, the critical services were selected as per need and priority, implemented, deployed and monitored. As soon as the web services were designed and developed, database was designed and the channels were developed (mobile application, web portal and temperature monitoring device) and they consumed the deployed web services. At the end of study, the artefacts created included a SOA Model, Mobile App, Web Portal, Open API Webservices and a temperature monitor (IoT device).

Technology Description

The Omnichannel PHR web services was designed and implemented using the Service Oriented Architecture and Modelling Methodology phases described in the literature review and methodology section.

The prototype was designed using open source technologies such as: -

i. Java Enterprise Edition (Java EE) programming language
ii. HTML5 and JavaScript technologies for user interface design
iii. C-programming for temperature monitoring hardware device interfacing
iv. Tomcat Enterprise Edition (TomEE) application server
v. MySQL community edition database
vi. Jasper reporting tools
vii. Linux Operating System (Ubuntu)
viii. Netbeans Integrated Development Environment (IDE)
ix. Cross platform Mobile Applications
x. Arduino Mega 2560 Board, Ethernet LAN Network and LM35 Temperature Sensor

The database and third-party integrations functionalities were exposed via REST APIs to end-user applications and web interface. These services were hosted on Tomcat Enterprise application server. Representation State Transfer (REST) APIs were chosen for this project over Simple Object Access Protocol (SOAP) as they were lightweight, produce human readable results and are easy to build as no toolkits are required. The message formats were in JavaScript Object Notation (JSON). However, the backend applications were able to support the various client protocols and message standards which can be continuously added or removed overtime. Thanks to Service Oriented Architecture and Modelling (SOMA) and agile software development methodology. Figure 5 illustrates the high level representation of the Omnichannel PHR solution whereas Figure 6 shows the SOA reference model.

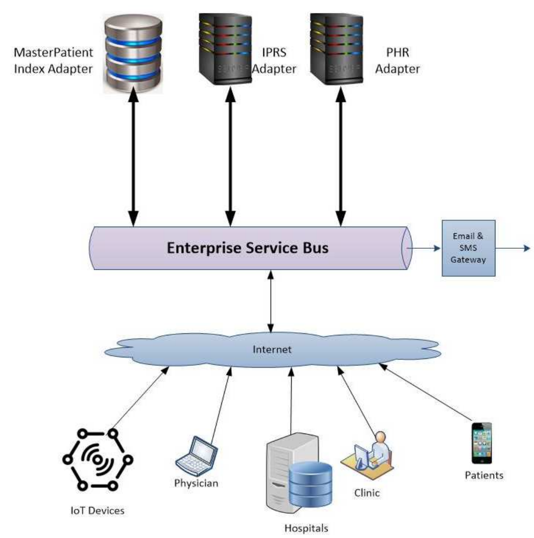

Figure 5:High-level representation of the solution

Agile testing methodology was adopted to allow the researcher fail early. The process was iterative in the sense that a specified user group (colleagues and friends of the researcher) were given the prototype to test specific services. It started with high fidelity wireframes for the mobile app. Amendments were made to the wireframes and the mobile application until the final system was implemented. System testing was inevitable as it evaluates the system's ability to fulfil the desired requirements.

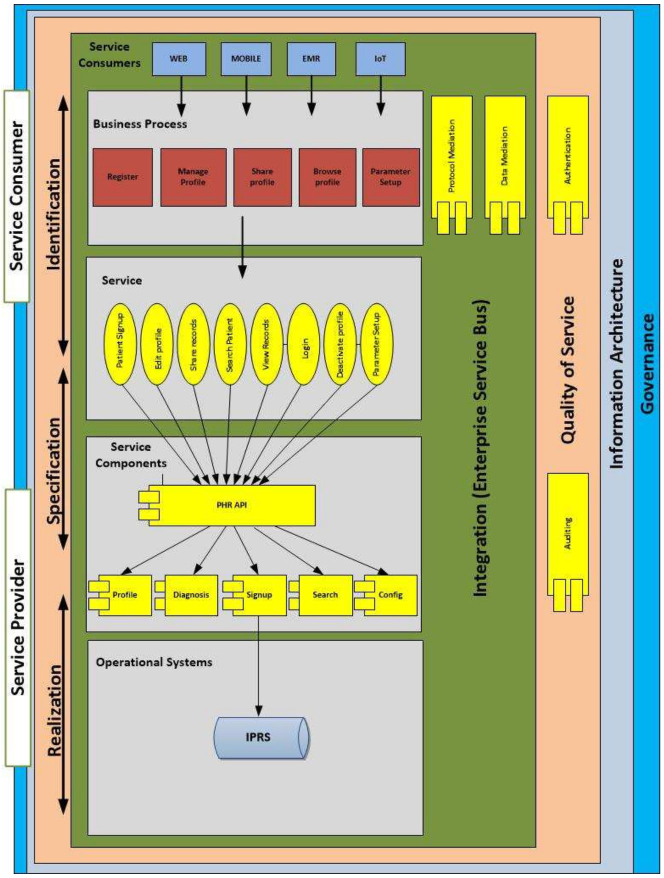

Figure 6: Instantiation of the SOA reference architecture for Omnichannel PHR Solution

RESULTS

The findings of the study revealed that most patients have never heard nor used PHR systems whereas majority were willing to use it if they are recommended by their physicians. Despite the fact that more than half the health facilities in Kenya have unique patient identification scheme, they are not interoperable between hospitals which further hamper medical data sharing among health care facilities. Post implementation results revealed that data sharing between patients and healthcare personnel significantly improved by rolling out device agnostic ways (omnichannel systems) where patients and healthcare personnel (physicians) can share and access medical history using web, mobile or other platforms. This was facilitated by adoption of Service Oriented Architecture.

In evaluating the proposed prototype's features for patient medical data recording and sharing, a 5-point Likert scale was used. On Average, more than 78% of the respondents agree that the PHR features listed have met their objectives to a large and very large extend cumulatively.

PHR features	***no extent at all***	***small extent***	***moderate extent***	***large extent***	***very large extent***
Storing illnesses and hospitalizations	0	0	12	29	59
Storing allergies and adverse drug reactions	0	0	0	24	76
Storing medical Prescription record	0	0	0	18	82
Laboratory test results and image reports	0	0	6	29	65
Transfer medical information to doctors and specialists	0	0	18	76	12

Discussions

The findings have implications on patient care improvement, lower costs of treatment and reduced cases of misdiagnosis. Having a unique patient identifier that is consistent nationwide is the ultimate solution to patient matching across different healthcare provider's systems. Having centralized storage of PHR data that is available anytime, anywhere, any terminal and to any healthcare provider with patient consent is the most effective way of ensuring medical data interoperability across medical institutions. The data needs to be kept up to date as soon as medical information is available preferably automated upload from EMR or in real-time from monitoring devices (IoT) through open APIs. The Service Oriented Architecture was useful in providing consistent services across all channels, terminals or devices.

CONCLUSIONS

The findings of this research study and evaluation of the prototype demonstrated interoperability can be easily achieved by giving the patients the ability to record their own medical information using different platforms (web and mobile) without having to carry papers whenever they seek medication. Health care professionals can assist the patients in updating their profiles whenever they seek medical treatment. Patients are very cautious about the privacy of their data and were comfortable by having control on who can read or write their records.

Finally, the Service Oriented Architecture provided integration layer that will facilitate interoperability of different channels, devices and third-party systems or applications. As such PHR will make data to be available anytime, anywhere, any terminal over cloud technologies.

As the government of Kenya is working towards rolling out the Kenya Health Enterprise Architecture, it should consider adopting Service Oriented Architecture. Lessons learnt from the universal identification of patients using a single source of truth (IPRS) which has been predominantly used by banks, should be used as well. Implementers of mHealth applications or PHR solutions are encouraged to create solutions that are able to share data with other institutions and systems (mHealth, EHR) as patients are unwilling to use and pay for multiple stand-alone 'siloed' applications.

Future Work

Since not all aspects of PHR were implemented (like reminders, medical device integrations, health insurance, wellness information) future work should focus on these aspects. Future researchers are also encouraged to implement linkage of existing patient data with PHR systems and also adopt distributed ledger technologies to improve security and usability of the PHR system. Although Blockchain technology is still in its infancy, distributed ledger technologies have great potential in solving most of the healthcare issues especially on data sharing, security and speed of transactions. Private permissioned blockchain is recommended like IBM Hyper Ledger Fabric.

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