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Case Report

Vision Paper for Enabling Applications of Digital Health with EHR in OHP2030

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Abstract

Internets of Things (IoT) and Big Data applications and services have spread and are rapidly being deployed in the information services of the healthcare and financial industries, etc. However, the previous paper suggested that the current IoT services were individually developed, therefore, the open platform and architecture for the above IoT services of the healthcare industries should be deemed necessary, while the Big Data applications prevail in healthcare industry gradually. On the other hand, an electronic health record (EHR) is a repository of information regarding health status and a longitudinal electronic record of patient information. During past a decade, EHR has grown in Australia significantly, while adoption rates of EHR across the United States reaching more than 90%. An open healthcare platform is expected to promote and implement the digital IT applications for healthcare communities in an alignment with EHRs efficiently. In this paper, we suggest that various IoT and Big Data applications will be designed and verified while the open platform for healthcare related IoT services should be proposed and verified by the research initiative named "Open Healthcare Platform 2030 - OHP2030". In addition, the vision paper for enabling applications of Digital Healthcare with EHRs in the above OHP2030 research initiative is explained.

Keywords: Digital Healthcare; Enterprise Architecture; Internet of Things; Big Data; Digital Platform; Electronic Health Record; Digital IT

Abbreviations

OHP: Open Healthcare Platform; AIDAF: Adaptive Integrated Digital Architecture Framework

Introduction

Many global corporations have encountered a variety of changes, such as progress of new technologies, globalization, shifts in customer needs, and new business models. Significant changes in cutting-edge IT technology due to recent developments in Cloud computing and Mobile IT (such as progress in big data technology) have emerged as new trends in in-formation technology. Furthermore, major advances in the abovementioned technologies and processes have created a "Digital IT economy," bringing about both business opportunities and business risks and forcing enterprises to innovate or face the consequences [3]. Enterprise Architecture (EA) should be effective because it contributes to the design of large integrated systems, which represents a major technical challenge toward the era of Cloud/Mobile IT/Big Data/Digital IT in Digital Transformation. From a comprehensive perspective, EA encompasses all enterprise artifacts, such as business, organization, applications, data, and infrastructure, to establish the current architecture visibility and future architecture/roadmap. On the other hand, EA frameworks need to embrace change in ways that consider the emerging new paradigms and requirements affecting EA, such as Mobile IT/Cloud [1,4].

Furthermore, considering the above background, the previous study proposed the "Adaptive Integrated EA framework", which should align with IT strategy promoting Cloud/Mobile IT/Digital IT, and verified this in the case study [23]. The author of this paper has named the EA framework suitable for the era of Digital IT as

"Adaptive Integrated Digital Architecture Framework - AIDAF" [32].

Many electronic health records (EHRs) exist worldwide with variety, that are operated by the public and private sectors. EHRs can cover a range of data, such as medical history and laboratory test results, medication and allergies, immunisation status, demographics, etc. These days, Australia's centralized electronic health record-keeping system was implemented, known as 'My Health Record' (MHR) - previously named the 'Personally Controlled Electronic Health Record' (PCEHR). The PCEHR/MHR system was designed by the National Electronic Health Transition Authority (NEHTA) with the Australian Government [45]. Despite increasing health care costs and investments, there are faults affecting the quality and efficiency of EHRs related systems [62]. There is a continuous lack of management alignment of information systems and knowledge management technologies [57]. EA should have an important role in governing and managing the EHRs in each IS/IT project in related organizations in alignment with IT strategy.

This paper is organized as follows: the next section presents the background of this study, followed by the description of the research methodology and an overview of the AIDAF application for the cross-functional healthcare community, and healthcare community case. Finally, the challenges and final thoughts for this OHP2030 are outlined.

The direction of EA and digital healthcare, EHR

Related work and direction of digital healthcare, cloud/mobile IT/big data/ internet of things

In the past decade, EA has become an important method for modeling the correlation for overall images of corporate and individual systems. In ISO/IEC/IEEE42010:2011, architecture framework is defined as "principles, and practices for the architecture descriptions established within a specific domain of application and/or community." Furthermore, EA visualizes the current corporate IT/business landscape to promote a desirable future IT model [4]. It is not a simple support activity [1], and it offers many benefits to companies, such as coordination, communication and planning between business and IT, and reduction in the complexity of IT [20]. For the delivery of these benefits, EA frameworks need to cope with the emerging new paradigms such as Cloud computing or enterprise mobility [1].

Mobile IT computing is an emerging concept using Cloud services provided over mobile devices [16]. In addition, Mobile IT applications are composed of Web services. Many studies discuss the integration of EA with Service Oriented Architecture (SOA), except for Mobile IT. The SOA architecture pattern defines the four basic forms of business service, enterprise service, application service, and infrastructure service [19]. The OASIS, which is a public standards group [14], introduces an SOA reference model. Many organizations have invested in SOA as an approach to manage rapid change [5]. Meanwhile, attention has been focused on Microservices architecture, which allows rapid adoption of new technologies, such as Mobile IT applications and Cloud computing [17]. SOA and Microservice vary greatly from service characteristics perspective [19]. Microservice is an approach for dispersed systems that is defined by the two basic forms of functional services through an API layer and infrastructure services. Multiple Microservices cooperating to work together enable the implementation as a Mobile IT application [7].

For Cloud Computing, the NIST defined three cloud service models such as SaaS, PaaS, and IaaS [12]. PaaS is an IaaS platform that includes both system software and an integrated development environment. SaaS is a software application developed, implemented, and operated on a PaaS foundation. IaaS accommodates PaaS and SaaS by offering infrastructure resources, such as computing network storage memory through specific centers [12]. The enormous adoption of cloud computing technologies in the health domain has been confirmed in several works [53]. The state of research concerning the adoption of cloud technologies in the health field were identified [52]. Furthermore, the main cloud-based healthcare and biomedicine applications were reviewed [48] and the state-of-art privacy-preserving approaches were employed in the e-health clouds [46]. Many Mobile IT applications also operate with SaaS Cloud-based software [16]. The integration and relationship between EA and Cloud computing is discussed rarely in literature. Considering the recent dynamic moves in Cloud computing, it is necessary for companies to link the service characteristics of EA and Cloud computing [13]. The traditional approach takes months to develop an EA realizing a Cloud adoption strategy, and organizations will demand adaptive enterprise architecture to iteratively develop and manage an EA adaptive to the Cloud technology [11].

Moreover, according to previous research [15], when promoting Cloud/Mobile IT in a strategic manner, it is proposed as a good option that a company that applies TOGAF or FEAF can adopt the integrated framework with the Adaptive EA framework supporting elements of Cloud computing.

Furthermore, in terms of Big Data, new computing trends require data with far greater volume, velocity, and variety than ever before. Big data is utilized in ingenious methods to predict customer buying behaviors, detect fraud and waste, analyze product opinion, and react quickly to changes in business conditions (a driving force behind new business opportunities) [24]. The term "big data" refers to data that is so large, it is difficult to process using currently-available IT systems. There is a growing opportunity for analysis, visualization, and distributed processing software to enable users to extract useful information from such data [3]. Sources of big data include the following:

- Corporate data in SQL databases.
- Data in cloud-based SQL or NoSQL databases.
- Data provided by social networks.
- Data provided by sensors or object identifiers in the internet-of-things (IoT).

Big data applications may include visualization functionality for effective user presentation of analytical results. Furthermore, big data applications should leverage web services that make the results of their analyses available to other applications through APIs; objects in the IoT can be data generators [3].

Existing big data reference architectures have been shepherded by NIST, which helped create the big data interoperability framework, including a reference architecture volume [25].

LinkedIn, for example, collects data from users and offers services, such as skill endorsements or newsfeed updates to users based on data analysis. Additionally, Twitter uses collected data for real-time query suggestion [30]. Therefore, most solutions exist in the Big Data Application Provider component and should be categorized as Specific Application Layers on Cloud and Mobile IT platforms. Technology vendors such as Oracle [27], IBM [28], and Microsoft [29] have also developed Big Data Reference Architectures [26]. These vendors publish practical Reference Architectures for Big Data toward EA practitioners in corporations and other groups. The implementation of big-data analytics in the healthcare field is the process of examining the large data sets involving EHRs to reveal hidden patterns, unknown correlations and other useful information [47,50]. Advances in big-data analytics may transform research statuses from being descriptive to predictive and prescriptive [49]. Big-data analytics in healthcare contribute to evidence-based medicine, genomic analysis, device remote monitoring, and patient profile analyses. Big-data analytics can reduce healthcare concerns effectively, like selections of appropriate treatment paths and the improvement of healthcare systems [54], and inefficiency in clinical operations, public health, research and development [56,58].

The term of "Internet of Things (IoT)" is used to mean "the collection of uniquely identifiable objects embedded in or accessible by Internet hosts" [3]. A "uniquely identifiable object" can be described as follows: these objects are connected with real world interaction devices, smart homes and cars, and other SmartLife scenarios. The IoT fundamentally revolutionizes digital strategies with innovative business operating models [42] and holistic governance models for business and IT [43], under fast changing markets [41].

- A sensor, such as a temperature sensor (thermometer).
- A control; for example, to control a valve in a heating system.
- A combination of sensor and control (for example, a thermostat).
- An object identifier, such as an RFID tag or a barcode.

The current state of research for the Internet of Things architecture [36] lacks an integral understanding of EA and Management [37-40] and shows a number of physical standards, methods, tools and a large number of heterogeneous IoT devices [41]. A first reference architecture (RA) for the IoT is proposed by [44] and can be mapped to a set of open source products. This RA covers aspects like "cloud server-side architecture," "monitoring/management of IoT devices, services," "specific lightweight RESTful communications," and "agent, code on small low power devices." Layers can be instantiated by suitable technologies for the IoT [41].

Background of EHR

Over the 50 years that followed the first implementation of computerized patient medical records in 1960s, technology advances in computer innovations opened the way for advancements in EHRs and health care [60]. The utilization of software applications and stand-alone computer systems migrated from paper documentation of patient data to digital forms of record keeping [55]. The ISO standard defined an electronic health/healthcare record

(EHR) as a repository of information regarding the health status of each care in computer processable form [63]. EHR can include past medical history and medications, immunizations, laboratory data, radiology reports, vital signs as well as patient demographics [61]. The importance of organizational strategy alignment with information systems strategy was emphasized. Functional structuring of business operations in an alignment with information systems strategies can contributes to successful EHR implementation [51,59]. Developing the strategy integrating the IT systems/platforms with the hospital organization is essential to successful EHR implementation [59].

Adaptive integrated digital architecture framework - aligned with digital IT strategy

Our previous research promoted the strategic use of cloud and mobile IT, suggesting that corporate entities defining Cloud/Mobile IT/Big Data/Digital IT strategies implementing EA by applying frameworks, such as TOGAF and FEAF, could adopt a framework integrating an Adaptive EA framework to provide further support for cloud elements [15]. Accordingly, the preliminary research of this paper proposes an Adaptive Integrated EA framework depicted in figure 1 of the preliminary research paper, based on this suggestion, which should meet with IT strategy promoting Cloud/Mobile IT/Big Data/Digital IT, and verified this in the case study [23]. The proposed model is an EA framework integrating an adaptive EA cycle with TOGAF or a simple EA framework 1 for different business units in the upper part of the diagram [23]. The author of the previous paper mentioned above named this EA framework as "Adaptive Integrated Digital Architecture Framework (AIDAF) [32]".

The adaptive EA cycle makes provisions for project plan documents (including architecture designs) for new Digital IT related projects drawn up on a short-term basis. This begins with the Context Phase, which is conducted to prepare the Defining Phase (e.g. architectural design guidelines related to necessary types of Security/Digital IT aligned with IT strategy) per business needs. During the Assessment/Architecture Review Phase, the Architecture Board reviews the architecture in the initiation documents for the IT project. In the Rationalization Phase, the stakeholders and Architecture Board decide upon information systems to be replaced or decommissioned by the proposed new information system. In the Realization Phase, the project team begins to implement the new IT project agreed upon after deliberating issues and action items [23,32].

AIDAF application for cross-functional healthcare community

The author of this paper proposed an adaptive integrated EA framework to align with IT strategy, promoting Cloud/Mobile IT/Big Data/Digital IT, and verified by our case study [23]. Furthermore, the author of this paper has named the EA framework suitable for the era of Digital IT as an "Adaptive Integrated Digital Architecture Framework - AIDAF" [32]. Figure 1 illustrates this AIDAF proposed model in the Open Healthcare Platform 2030 (OHP2030) community. The OHP2030 community is comprised of healthcare companies such as pharmaceutical, medical development and aged healthcare companies, hospitals as well as the OHP2030 initiative and government as depicted in figure 1. AIDAF will be applied to the above-mentioned cross-functional healthcare community in the OHP2030. AIDAF begins with the context phase, while referencing the defining phase (i.e. architecture design guidelines related to digital IT aligned with IT strategy in the above healthcare community in the OHP2030). During the assessment and architecture review, the architecture board reviews the initiation documents and related architectures for the IT project in the above healthcare community in the OHP2030.

Figure 1: AIDAF proposed model in the Healthcare community in the OHP2030 (ex: TOGAF and Adaptive EA framework).

Healthcare community case

In OHP2030, a particular Architecture Board will be formulated in the aforementioned cross-functional healthcare community. In the case study of EA rollout in the healthcare community, they will handle IoT/Big Data/Cloud strategic projects and systems well by structuring and implementing EA with the above-mentioned AIDAF to be consistent with the IT strategy focusing on IoT/Big Data/Digital IT in the above cross-functional Healthcare community.

Figure 2: Healthcare Delivery Value Chain for Practice areas (Source: Michael Porter and Elizabeth, 2005).

Furthermore, in the case study of the cross-functional healthcare community, the author of this paper assumes that use cases of "IDC's Worldwide Digital Transformation Use Case Taxonomy, 2017: Healthcare," which were defined by IDC, should be applied in the context phase and assessment/architecture review phase as well as the defining phase of the AIDAF for new IoT projects in the healthcare community [33,34]. According to L Dunbrack., *et al*. and S Ellis., *et al.* [33,34], the above use cases and digital missions in healthcare are based on the creation of value-based healthcare systems from sick care to healthcare management as shown in figure 2 above [35].

Cases of enabling digital healthcare applications

Preventive analysis related case

According to L Dunbrack., *et al*. [33], as the digital healthcare, a value-based health system is created, which is focused on preventive care/analysis and population health management. In this section, the scenario of preventive care and analysis is described with the related challenges.

Use Case: The use case scenario of preventive care and analysis in a value-based healthcare system is shown in the following table 1, according to L Dunbrack., *et al.* [33].

Use Case	Current Situation	Goals and Objectives	Technology Deployment	Use Case Summary
Preventive Analysis, At-risk patient identification	Traditional methods of predicting at-risk patients do not take into account clinical conditions, social determinants, or impact ability.	Identify patients at risk of the onset of a chronic illness. Identify patients who would most benefit from a care/execute personalized plans.	AI-driven advanced analytics for predictive modeling, machine learning, and prebuilt algorithms/models.	Today's analytics are limited in the data on reporting. The use of AI-based predictive models can generate the data to create personalized care plans.
Social determinants	Clinical care determines about 20% of health/disease, based on living situation, and environment.	Address the full impact of health and disease to solve underlying problems.	-Access to unstructured data and external sources of data	Additions of social determinants will provide the drivers of health to mitigate barriers to health.

Table 1: Use Case Scenario for preventive care and analysis.

Challenge: There should be some issues of system performance in the operational aspect, and the issue regarding analytical methods will exist as the functional aspect in this kind of digital healthcare applications with IoT, Big Data.

Summary: The preventive analysis of digital healthcare applications can be performed with appropriate analytical methods, while determining with collecting external source of data such as medical authority's opinions from social tools, EHR and EMR (electronic medical record).

Healthcare management related case

According to L Dunbrack., *et al.* [33], as the digital healthcare, healthcare management is also emphasized in a value-based health system. In this section, the scenario of the healthcare management is described with the related challenges.

Use Case: The use case scenario of healthcare management in a value-based healthcare system is shown in the following table 2, according to L Dunbrack., *et al.* [33].

Use Case	Current Situation	Goals and Objectives	Technology Deployment	Use Case Summary
Chronic conditions management	- One-third of adults live with one or more chronic conditions. - The increasing prevalence of chronic conditions is a worldwide problem.	Encourage consumers to be more active participants in managing their own health and chronic conditions (e.g. blood pressure).	- Remote health monitoring devices (weight scales, and blood pressure cuffs) - Consumer-facing mobile applications and portals	Providing consumers with medical monitoring devices and clinical support when empowering consumers to better manage their chronic conditions.

Table 2: Use Case Scenario for the Healthcare Management.

Challenge: There should be the consideration points of patient's data structure in the viability aspect, and the issue regarding patients' data privacy should exist as the operational aspect in this kind of digital healthcare applications with mobile IT and Big Data, IoT.

Summary: The preventive analysis of digital healthcare applications can be performed with appropriate analytical methods, while determining with collecting external source of data such as medical authority's opinions from social tools, EHR and EMR.

Pharma manufacturing related case with predictive analysis

In this section, the scenario of the healthcare management is described with the related challenges. The example of solution architecture for this pharmaceutical manufacturing related system with predictive analysis is shown as the following figure 3, at this time.

Figure 3: The solution architecture for pharmaceutical manufacturing systems in digital healthcare.

Use Case: The use case scenario of pharmaceutical manufacturing with predictive analysis in a value-based healthcare system is shown in the following table 3, according to S Ellis., *et al.* [34].

Challenge: There should be some issues in terms of security for the IoT through MQTT in the operational aspect, and the issue regarding compliance and validation for communications between social tools and analytical services will exist as the viability related aspect in this kind of digital healthcare applications with IoT, Big Data.

Use Case	Current Situation	Goals and Objectives	Technology Deployment	Use Case Summary
Cognitive inventory	Inventory is inflexible. Even though companies generally have a good handle on the overall inventory number, the specific remains elusive.	Reduce the overall dollar value of the inventory while improving its ability to meet demand and buffer needs.	IoT, Big Data Analysis,	There is real-time assessment of inventory across all locations, connecting to demand and capacity. Cognitively enabled inventory means that the system learns how to best meet business variables.
Smart capacity allocation	Most Pharmaceutical companies have a general sense of available capacity at any one point in time. The ability to adjust capacity utilization in real time is a guess at best.	Better utilize capacity, leading to the ability to reduce out of stock issues or lower overall capacity costs.	IoT, mobile and Big Data Analysis	The instrumentation of assets includes real- time capacity monitoring at the machine level that provides consumption models that allow for optimization calculations across facilities.

Table 3: Use Case Scenario for the Pharma Manufacturing case.

Summary: This kind of pharmaceutical manufacturing system can monitor the data of manufacturing site regarding temperature, humidity and quality, while collecting data related to flu, pandemic from open data, social tools such as Facebook, Twitter of medical experts, which can lead to the decision making for the urgent manufacturing of enormous amount of medicines to cope with the above flu, pandemic, etc. for several months.

Discussions and Challenges

Future Issues

To address architectural issues, we need to consider the functional, the relationship with patients' data structure, EHR/EMR and analytical methods for a digital healthcare systems of IoT, Big Data, while considering the alignment with the Value based Healthcare Delivery model in each digital IT systems.

At the same time, for the purpose of coping with architectural issues, we need to design with coping with the operational aspects such as security and privacy of patients' data, security of IoT systems through MQTT protocol, compliance and validation regarding social analytics, system performance, etc. Furthermore, we will proceed with the international systematization of a digital healthcare application systems such as IoT, Big Data, while proceeding and analyzing each digital healthcare related systems/projects in an alignment with EHRs in OHP2030.

Final thoughts for enabling applications of digital health with EHR in OHP2030

In this paper, we have described the vision for enabling applications of digital healthcare with EHRs in OHP2030 with several examples. This research initiative named OHP2030 aims at an exploration and definition of a digital healthcare platform such as IoT, Big Data in the middleware layer and above. Furthermore, we would like to systematize the digital healthcare application systems in healthcare industry, while ensuring information security, privacy and compliance, validation in an alignment with EHRs.

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