MICRO SERVICE BASED ARCHITECTURE MODEL FOR EHR SYSTEMS OF MOH HOSPITALS –SULTANATE OF OMAN

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Abstract: Oman's Ministry of Health (MOH) has adopted the National Electronic Health Record 'NEHR' system called Al-Shifa. The purpose of this paper is to review and condense the architecture paradigm and drawbacks of the Al-Shifa system and to suggest an alternative architecture to overcome its limitations. This study employs a focus group based qualitative approach and the Al-Shifa project team stationed in the Directorate General of Health Services (DGHS), Sur was part of this group and they provided valuable insight into the current Al-Shifa system. The study reveals that the existing Al-Shifa system is based on the client-server model and the module deployed on the server-side is monolithic and tightly coupled in nature. The important disadvantages that were identified are lack of interoperability, lack of support for new technology stack, difficult and time-consuming modifiability, and redundant health records across different health care units, and lack of data exchange. These limitations mitigate the various benefits of adopting EHR systems. Hence in this paper, an innovative architecture model based on the Microservice paradigm is proposed that could be adopted in the MOH healthcare units across Oman to resolve the limitations of the currently existing Al-Shifa.

Key Words: EHR, Monolithic, Tightly coupled, MOH, IoT, Microservice

I. INTRODUCTION

The evolution of ICT is providing abundant opportunities for the adaptation of Electronic Health Records as an alternative to the traditional paper-based approach and has provided the opportunity for the development of diverse e-health applications. Electronic Health Record (EHR) is a system that stores the longitudinal records of patients and contains information about patient's demographics, progress notes, health issues, medications, vital signs, past medical history, immunizations, laboratory data, and radiology reports [1]. These applications improve health care and provide solutions that benefit the stakeholders such as patients and the health care professionals.

The benefits of the EHR comprises of : (1) better and evidence-based care; (2) increasingly accurate and faster diagnosis that translates into better treatment at lower costs of care; (3) avoids repeating unnecessary investigations; (4) robust analytics ; (5) improved health decisions [1]. Ministry of Health (MOH), Oman launched a wide-ranging electronic health record system called Al-Shifa in the year 2008 and its current version is Al-Shifa 3 plus has been deployed at many healthcare facilities across Oman. The focus of this study is to: review the Al-Shifa architecture style and its suitability and adaptability for the present technological development and its complete usefulness. Remaining of this paper is organized as follows: Literature review, Overview of the existing Al-Shifa architecture, Limitations of the Al-Shifa architecture, Review of Microservice architecture, Proposed Al-Shifa Architecture using Microservice, and Conclusion.

II. LITERATURE REVIEW

Al-Hamadani et al., claims that Oman needs to develop the required legislation governing access and use of patient data where legal and ethical obligations should be applied in case of violation. The lack of unique identifications for patients across the healthcare institutions with the MOH represents the administrative difficulty toward an efficient integration of the healthcare system in the Sultanate of Oman [9].

G.D.Mogali and Fahima performed a survey to understand the theme "Challenges of implementing Electronic Health Records in Gulf Cooperation Council (GCC) Countries" including the potential problems encountered before, during and after developing EHRs [10].

Jeremiah Scholl et al. conducted an ethnographically inspired interpretive case study at SankaraNethralaya (SN) eye hospital in the Indian metropolitan city, Chennai, in the state of Tamil Nadu. The study was conducted to investigate a hospital in a developing country where an EMR system had been adopted [11].

A cloud-based EHR system was implemented by Yu-Chuan Li et al., in a rural region of China. In particular, it offers two key perspectives: 1. The cloud-computing model holds great potential for supporting rural health workers in developing countries. 2.HIT (Health Information Technology) computing architectures supporting offline work with easy data back-up and synchronization through the use of DTN(Delay Tolerant

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Networking) data delivery make possible for overcoming challenges related to limited Internet connectivity [12].

Ben-Assuli.et al., investigated the implementation of EHR and electronic prescribing systems has lagged in most European nations as well as in the USA [13]

Mandirola et al. indicated the problems that need to be addressed to implement e-Health in developing countries are first, cultural and educational, secondly, economic resources and thirdly policies for long periods by a survey [14].

NeethuMathai et al., proposed research focused on expectations, issues, and challenges faced by the consumers and physicians in the implementation of EHR. The work identified the main issues concerning consumers as data breaches, privacy issues and medical identity theft [15].

OuraniaKoutzampasopoulouXanthidou et al. identified the EMR (Electronic Medical Record) system should follow an open architecture both in Greece and Oman. The EMR should be implemented gradually bearing in mind both medical and financial concerns [16].

Marco Remondino designed a novel set of metrics and KPIs, the HHC-MOTES framework, which is intended for the qualitative and possibly quantitative measurement of the various aspects related to sustainability, in the broader sense, of IT applications in healthcare [17].

MOH Oman introduced a healthcare service management system called Al-Shifa 3plus in 2008. For data transfer, the client-Server technology is used between the units by the system. However, full integration is not encouraged due to many reasons. Though Al-Shifa 3plus has a good number of beneficiaries across the Sultanate of Oman, the system has its limitations as well [18].

III. OVERVIEW OF THE EXISTING AL-SHIFA ARCHITECTURE

We have obtained insight into the Al-Shifa architecture from the team responsible for the Al-Shifa in the Directorate General of Health Services (DGHS), Sur and also from various academic works. MOH has established many health care units across Oman such as Hospitals, polyclinics, and Health centers [19] and the health centers and polyclinics together called as primary health centers.DGIT department in the Ministry of Health has developed the health record management system (Al Shifa), and implemented in various health care units of Oman. The MOHsupports in digitalization of the hospitals in Oman.

Al-Shifa software architecture is client-server based, and the software instance deployed in the server is monolithic and tightly coupled in nature. Figure -1 depicts the overall ICT architecture of the Al-Shifa where a central repository of health records at the head office of the Ministry of Health connected to different health care units such as Polyclinics, Health Centers and Hospitals via Multi-Protocol Label Switching (MPLS). The repository aggregates the data from all MOH health care units in a standard generalized schema and an application named Nabdh Al-Shifa is deployed over this to generate statistical reports based on KPI factors.

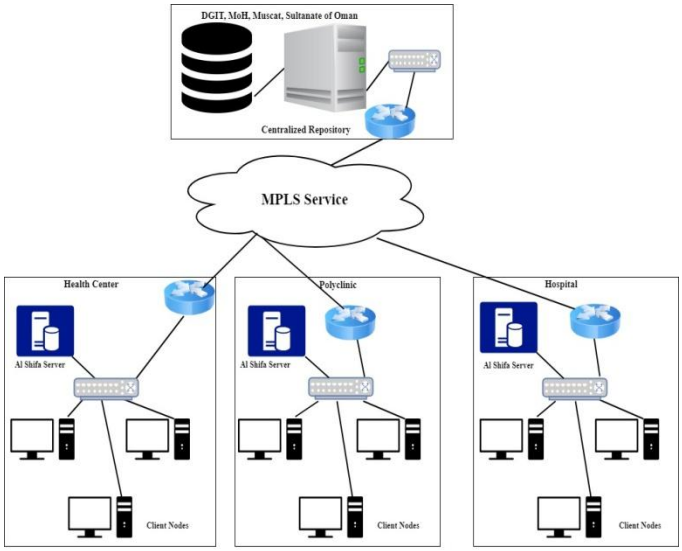

Figure 1: Existing architecture of Al-Shifa

The individual health care unit maintains an independent server, which in turn connected to several client nodes under its domain, and Table 1 shows the hardware and software configuration of the servers.

Component	Specification
Processor	2 X Intel® Xeon® Silver 4110 or higher
Processor Performance	3.1 GHz/ Core:4 / TDP:80W or better
Cache	8 MB Smart Cache
Memory Specification	32GB /PC3L-10600R /DDR4-2400 MHZ/ Registered DIMMS / Expandable to 128 GB
RAID Controller	Raid Controller with 1G FBWC Controller
Hard Disk Internal	6 X 300GB 6G SAS 10K 2.5 In DP ENT HDD (RAID 5 Config +HS)
Operating System	Red Hat Enterprise Linux Server, Standard(1-2 Sockets) (Up to 1 Guests) with 5 Year Subscription
Data Base Engine	Oracle 12 C

Table 1: Server, hardware and software specification [19]

Each server node runs an instance of server-side modules in the Oracle application server, and client nodes run a client-side module, with reports, developed using Oracle D2K. Table 2 shows the different modules and subsystems of Al-Shifa.

Module / Subsystems	Description
Computerized Physician Order Entry(CPOE)	The module that facilitates the computerized order entry for the clinicians.
MIS	An application that provides

	clinical activities and events for the day- to- day management.
Nabd Al Shifa	Data Warehousing and Business Intelligence systems. It is used to perform various KPI measurements with data captured from different health centers.
E Referral and E-Notification	The application which is used to refer patients between different MOH health care units.
Blood Bank Management system	The modules in the application are Donor Recruitment, Blood collection services, Blood Inventory, Donor Lab Testing, Reference Laboratory, Mobile Drives, and Transfusion Services.
e-Notification system	The system implements all the workflows related to public health surveillance in Oman and the exchange of the related documents between institutions.

Table 2: Al-Shifa subsystems and modules [19]

Since health care units are independent and isolated from other health care units in terms of storage and retrieval, a user would have different user accounts with different health care units. All the health care units use Internet-based communication to transfer the data to the centralized repository or to pull the data from it.

IV.LIMITATIONS OF THE AL SHIFA ARCHITECTURE

Since the Al Shifa system is based on the client-server architecture [4] and in this architecture, a client requests some service from a server and the server handles the request, executes logic, and responds. The server process exists as a single executable, and it performs all the server-side functions, and also client and server exist in independent machines. The study reveals that the application in the server tier of the Al-Shifa is monolithic, a single indivisible unit, and it evolves in size and functionality. The study has identified the modifiability and deployability as the architecturally significant requirements of any application, and the monolithic architecture does not satisfy these requirements [5][6]. The disadvantages of monolithic architecture are as follows[5][6]: (1) coordination between the different software development teams is difficult during production, implementation, and update phases; (2) Software evolution becomes more complicated in the project ;(3) Lacks agility, and the requirements of the end-users are not responded promptly; (4) Adopting new technology stack is costly, and time-consuming work-intensive endeavor, and sometimes the entire application has to rewritten; (5) Deployment takes more time since all the components of an application has to be deployed at a stretch and it has complex database schema; (6) deployment needs more downtime; (7) longer communication path to reach the production team; (8) language and library upgrade is complex since entire monolithic uses single version of the application programming interface.

The other major drawback of the existing system is that each health care unit has its independent server with a local database. A patient would have different records in different health care units, and this result in redundant records of a patient across different health care units. Lack of unique identifications for patients across the healthcare institutions with the MOH represents the administrative difficulty toward an efficient integration of the healthcare system in the Sultanate of Oman [9].

The current system has not been designed to integrate with IoT technology, and they have been designed to be more patient-centric. The Internet of Things (IoT) is a network of devices that comprises of the software, sensors, and electronic components and also these devices collect and deliver data to a variety of applications and services [7]. IoT technology facilitates the capture of patient's data from the wearable and other sensor-based monitoring devices, and hence, it needs to integrate with the EHR systems. Configuring IoT in EHR can improve patient's healthcare and facilitating the health providers to monitor the patients outside the clinical care centres. Lack of IoT support in the current Al-Shifa architecture throws the following disadvantages: (1) failing to capture the remote patient's real-time data such as blood glucose, ECG; (2) not able to monitor the remote patients, especially geriatric patients, and (3) no preventive health care mechanism.However IoTincorporation with the EHR system would result in some interoperability issues such as: Semantic interoperability, Syntactic interoperability, Device interoperability, Network interoperability and Platform interoperability.

V.REVIEW OF MICROSERVICE ARCHITECTURE

In line with the various limitations that exist in the existing architecture of the Al-Shifa, it is essential to choose the right architecture for any application development and hence we considered the Micro service architecture for the Al-Shifa. Microservices has revolutionized the way the software applications developed at an enterprise level, and it is an architectural style where an extensive application is modularized into distinct, well-defined services as depicted in Figure 2. Each service exposed as an HTTP-REST APIs fulfils a specific goal and uses a well-defined infrastructure framework to communicate with each other. A service can be characterized as a Microservice when it can be independently deployable and can be shut down without impacting other services. The main advantages of the Microservices oriented application development are: Easily maintainable and testable; loosely coupled; service mapped to the specific business module; modularity; parallelized development and continuous delivery. Microservice with minimal centralized management, can be implemented using different programming languages with the interoperabilityas avital aspect [2][3].

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Based on their [6] experience of moving towards Microservice from the legacy architecture, following advantages were discovered: (1) When updating a specific module of an application no need to face the merge conflicts with different software productions teams; (2) reduced deployment time since the size of the Microservice module is smaller than a monolithic one; (3) more straightforward deployment procedure; (4) reduced downtime during the release of application module; (5) shorter cycle time for the small incremental functional changes; (6) improved decision-making process since Microservice is associated with a smaller and autonomous team; (7) simplified communication channel and shorter path between the end-users and the software developing teams; (8) Easy to add or enhance the nonfunctional requirements; (9) more natural technology changes or adoption since the services are loosely coupled and run on independent environments; (10) more accessible API updates; (11) boundaries between the services are well-defined; (12) de-centralized data management as each Microservice can store its data in a manner that suits it.

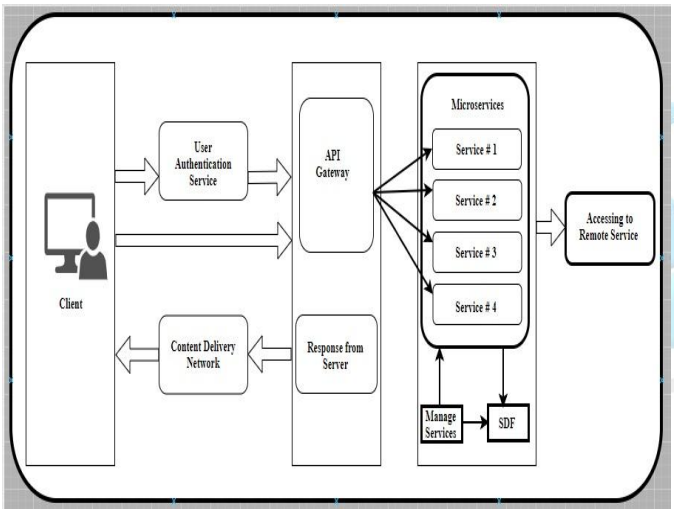

Figure 2: Microservice architecture model

In the cloud containerization technology evolution, the Microservices can be realized as a container which would facilitate quick startup, easy deployment, easy release and sharing via common repositories.Microservice has the dynamism to scale up horizontally and vertically and provide ample opportunities for the IoT deploymentand become an important part of the overall IoT Strategy. Microservices in vertically layered architecture improves service modularity, extensibility, availability, and scalability of IoT services by reusing the existing objects [8].Microservice architecture style when compared with tightly coupled monolithic architecture can harvest various benefits as aforesaid and hence it should be prioritized for the future enhancement of the Al-Shifa system.

VI.PROPOSED AL-SHIFA ARCHITECTURE USING MICROSERVICE

Figure 3 depicts the proposed Microservice based architecture for the Al-Shifa system wherein the Microservices-based architecture represents a collection of small, autonomous, and self-contained services that are built to serve a single business functionality/capability. In our proposed architecture, cluster of Microservices is configured in the head office of the Ministry of Health and each of these services hosts an independent module that is loosely coupled with the other services. Each of these services would have their own ICT resources in which modules and subsystems of the AL-Shifa as mentioned in table 2 can be deployed. These services are highly maintainable, testable, independently deployable and organized around business capabilities. Services can be consumed by external sources as well as within Microservices through the APIs and often, Microservices communicate via the Representational State Transfer (REST), architecture style. An API Gateway is implemented between the clients and the MicroService cluster and this act as a single entry point into the services provided by the different Microservice.

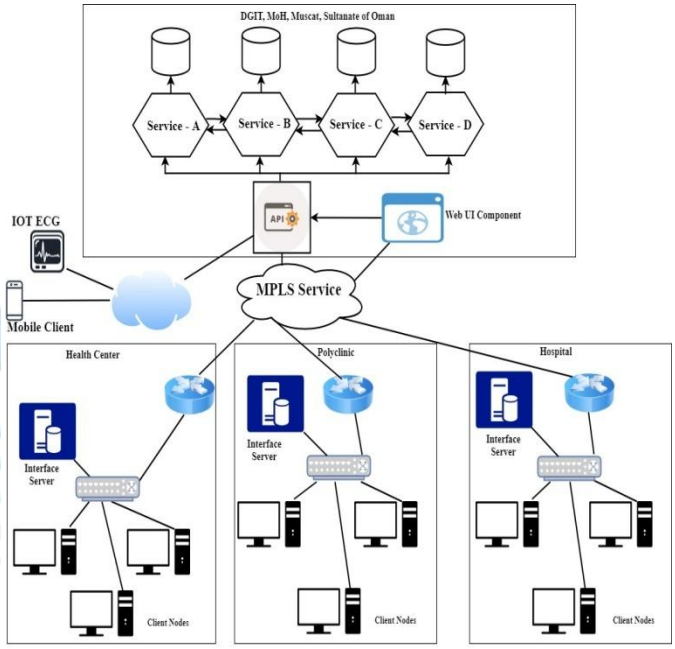

Figure 3: Microservice based Al-Shifa architecture

A major benefit of using API gateways is that they allow developers to encapsulate the internal structure of an application in multiple ways, depending upon the use case and also gateways can be used to invoke multiple back-end services and aggregate the results. In addition to exposing Microservices, API gateway features include functions such as authentication, authorization, load balancing, cache management, service level agreement (SLA) management. Each health care unit would have a local interface server wherein Microservice based application runs over that and it is supported by an independent and local database engine. Perhaps this server is connected and provides the services to the client nodes under its domain. The application running over the local interface server would consume the services provided by the central Microservice cluster through the API gateway and this application in-turn would provide the necessary Al-Shifa modules access to the client nodes. The interface server would not have any business logic of the Al-Shifa build on to it however it just consumes the services from the central cluster and maintains a local cache of data pertained to the specific health care unit. If the local data cache is not required then it can be allowed to the client nodes to consume the services from the Microservice cluster,

directly. Also, the central cluster can provide some services through the WEB UI component and this can be accessed by the client systems directly through a browser. This architecture would facilitate the mobile application and IoT devices to consume the services through the API gateway. An important aspect of this framework is that a patient record created in a health care unit is unique and visible across all the health care units and this prevents the redundant health records.

VII.CONCLUSION

We have studied theexisting architecture of the Al-Shifa system from the Ministry of Health and proposed Microservice based architecture as an alternative for future improvement. The study was accomplished by literature review and then with the focus group with the MOH IT specialists in the DGHS, Sur. The main aspectthat was reviewed with the existing architecture was the monolithic pattern and in that the main disadvantages highlighted were that it does not satisfy the architecturally significant requirements such as the modifiability and deployability and also various other disadvantages were highlighted. Also, our study has highlighted the various benefits of Microservice architecture with strong literature evidence and Microservices can be a great solution if a monolithic has gotten too big or complicated, but they can also be a good starting point. Though Microservices are often viewed as a fix for a monolithic gone wrong, a poorly-implemented Microservice architecture can suffer all of the shortcomings of a monolithic. Designing a Microservices architecture should be handled with care by experienced hands, and shouldn't be employed just because it's a new, hot trend. Hence the Microservice architecture style when compared with tightly coupled monolithic architecture can harvest various benefits as discussed above thus, distributed architecture models such as Microservice should be prioritized for the future enhancement of the Al-Shifa system. In the future we like to implement a Microservice based EHR and compare the working prototype with the existing architecture in terms of performance and security aspects. Also we like to explore the interoperability issues when IoT devices are integrated with the main EHR module.

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