

Role of Serverless Computing in Healthcare Systems: Case Studies

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Abstract. Recently, serverless architecture has gained popularity due to its cost-effective policies, independent stateless functions, auto-scaling, and simplified code deployment. It allows the developer to deploy and run their applications without worrying about the underlying architecture. The healthcare services can be made available as a serverless application that consists of distributed cloud services achieving the various requirements in the healthcare industry. The services offered may be available on-premise on a cloud infrastructure to users and health service providers. This paper presents four case studies that have been successfully adapted serverless architecture for health care systems, where the health services are provided as functional units to various stakeholders. We have also discussed various components of healthcare systems that may require serverless services over the cloud infrastructure.

Keywords: Serverless computing · Function as a service · Healthcare systems · HIPAA · Amazon lambda · Orchestration · OpenWhisk

1 Introduction

In the recent past decade, cloud computing has been emerging as one of the most successful technology in the era of digital service over the Internet. Some of the emerging public cloud computing providers includes Google cloud [8], Azure platform of Microsoft [21], Amazon web Service [20], IBM cloud [19] etc. offer a wide number of services over the Internet. OpenNebula [15], OpenStack [18], Server-space, etc. are cloud management platforms allows the system administrators to create on-premises cloud infrastructures. Although it has number of applications in various domain, it is associated with number of issues and challenges, especially when operational responsibility is handled by the developer. Serverless computing is one of the recently developed cloud technology, which migrate all configuration, provisioning and management responsibilities toward the server side. Serverless framework has been categorized into container-based

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and virtual machine based architecture [22]. In case of virtual machine, hardware is virtualized over an host operating system, whereas in container based serverless multiple separate environment is created so that multiple workload can be handled simultaneously on an host operating system. Container based serverless are found to be more popular in recent years [26]. Serverless computing has several advantages over the traditional cloud computing models by abstracting the management of underlying infrastructure [13]. However, the complexity associated with this infrastructure make more challenging to practically implemented by the normal user [1,21]. AWS Lambda is one of the most popular serverless tool that allow the users to build, deploy and run the application in serverless platform [11]. Developers are requited to upload the set of events corresponding to each stateless functions which can be used to trigger. Some of the example of event might be uploading a file to a bucket in Amazon S3 (Simple Storage Service) or HTTP calls made to a predefined endpoint created with the AWS API Gateway service. In serverless computing, FaaS platforms take over entire operational and computational responsibilities for resource management, scaling, function deployment, and monitoring. Developers can focus only on the business logic of functions, rather than expediting the application development. The serverless computing model focuses on revolutionizing the archetype and advancement of modern scalable applications, where developers can run event-driven code without managing or provisioning servers.

The technology and the service provided by healthcare sector has been growing at an exponential rate in the past few decades. Cloud computing and IoT has changed the way an healthcare operates [23]. It not only associated with health care management system or the keeping the medical records but also it deals with remote treatment of patient along with the constant monitoring. In the era of digital world, healthcare sector has been growing towards more patient-centric, data driven and more connectedness with each other. One of the major goal is to access and control the medical information and records any where anytime in the world. This is only possible, if the quick response can be provided over the cloud technology, which is the most popular trending platform in digital world. Cloud technology can be utilized to get the medical facilities over the Internet [4]. However, each of these services are required to be availed at greater response time with minimum cost. Serverless technology comes into the picture when the cost, auto-scaling services and faster response time are the major point of concern [11]. Serverless computing plays a major role in providing various service at an advanced level [7]. It can reduce electronic healthcare cost which includes, networking, hardware, software, proprietary licenses etc. It has been observed from many literature that bio-informatics sector is getting number of benefits in adopting serverless computing model [2,5,16]. Serverless has been emerging as a promising solution for maintaining digitized environment in healthcare sector where several healthcare services can be provided in low cost and faster response time.

Serverless provider may have various types of services based on the client requirement such as on-demand, on-reserve or the instance services. Healthcare sector popularly use on-demand service model of serverless which can handle

the peak load at any point of time. It may be noted that different application in healthcare system like ECG, EEG, E-blood analysis etc. requires different pricing model. 'In this paper, we have presented four case studies in healthcare domain which are getting number benefits in adopting serverless frameworks. The first case study is related to Fast Healthcare Interoperability Resources (FHIR), which leverage various serverless services for managing and storing the health records and make them accessible faster in any corner of the world. The second case study is related to IoT based remote monitoring healthcare system, which allow the healthcare workers to diagnosis and monitor the patient remotely over the Internet. The third case study is RWE and data lakes, which allows the healthcare system to store and manage structured, un-structured, semi-structured data on a single repository. The fourth case studies is related to the how serverless architecture can be leveraged in healthcare startup solutions.

The case studies related to healthcare management system utilizing serverless framework as presented in this paper are motivated by the following points:

- Healthcare management systems has been transformed to the digitized sector in last few years, which essentially need a reliable, cost effective, and faster response solution for several health services. Serverless framework could be best choice for healthcare domain due to its pricing model, auto-scaling, enhanced agility features.
- Serverless technologies in healthcare can be a magic wand for applications that need to scale fast, be readily available and perform high-latency tasks in seconds.
- Serverless has been already applied in several real-time applications. However, compatibility of this novel technology with healthcare system needs to be examined more deeply.
- The case studies provided in this paper will definitely gives potential insight to the researchers as well as stake holders of healthcare regarding applicability of serverless in healthcare management system.

The rest of this paper is organized as follows: Sect. 1 describes the motivation toward this study. In Sect. 2, some of the background details of serverless computing have been discussed. Section 3 describes serverless computing for healthcare and its various components. Section 4 discusses various case studies of serverless application for healthcare system. Section 5 summarizes the conclusion and future work of the study.

2 Background Details

2.1 Serverless Computing

Serverless computing framework is one of the popular technology where the user can deploy and execute their application with a cost effective environment along with the faster response time. The term serverless does not mean that server is absent. Server is still there at the back-end. However, the user need not be

worry about on which server the application is running. One of the major reason of its popularity is the migration of management and configuration responsibilities from the client side to the provider side. Clients are required to just upload their application in the cloud without bothering about the execution environment and the resource provisioning. Some of the notable features of serverless computing are the auto-scaling, billing per actual usages, quick deployment, very little involvement, support for diverse set of runtime, etc. Cloud providers are also responsible for constant monitoring, logging and security provision. The response time is way faster then other technology as the application is not associated with any specific server thereby it can run nearest server to the client. Serverless framework can be more suitable in healthcare sector due to its more effective pricing model. The billing is charge for the actual time the resources are utilized rather than for the resources that are provisioned.

2.2 FaaS

In serverless environment, every specific task is represented through the stateless function which are the unit of processing. Each of the functions are executed in an isolated environment may be in the form of container. The service provider are usually allocate and provision the resources to individual function rather than the environment. Therefore, an serverless application can be considered as the orchestration of functions which are independent and stateless. The user can get the service by triggering some events through the web API. User need not to be worry about resource configuration or the execution environment. The function in serverless platform is similar to the object in object oriented programming language or the functions in Functional programming concept.

FaaS service model of cloud plays an important role in providing health related service over the Internet. Each of the medical services can be bundled as a stateless function and can be executed anywhere in an isolated container. The function as a service are usually executed when an event is triggered. Developer needs to bundled the event details along with the business logic and upload into the server. Rest of the management, configuration and execution environment are taken care by the service provider.

2.3 Role of Cloud Technology in Healthcare

The use of cloud technology in the healthcare sector has been increased at an rapid pace in the past few years [24]. Some of the key features of cloud computing that helps in healthcare sector is High data availability, On-demand resource provisioned, Collaboration, Flexibility and scalability [14]. The cost effective and efficient IT services make the healthcare domain as healthTech. Many researchers, as well as experts, expect that cloud computing can change the face of information technology (IT), enhance health care offerings, and benefit fitness care studies. In particular, many researchers consider that cloud computing can reduce electronic health records (EHR) entire expenses, including hardware, software program, networking, personnel, and licensing prices, and therefore will

inspire its adoption. Various informatics improvements have proven that cloud computing has the potential to triumph over these problems. Despite the various benefits associated with cloud computing programs for fitness care, there also are management, generation, safety, and felony issues to be pointed out.

One of the biggest challenge in healthcare sector is to provide security and storage to large volume of data which has been generated at an exponential rate over the past decade. The generated data should not only be stored but also be archived for several years based on the country's medical laws. Another challenge the healthcare industry faces is the sharing of medical information and its availability anywhere and anytime. Legal measures such as the Health Information Technology for Economic and Clinical Health Act (HITECH) [17] as part of the American Recovery and Reinvestment Act promote the emergence of health information exchange (HIE) to facilitate collaboration between health care organizations. As traditional IT systems in hospitals are so diverse with data sharing across hospital systems, it is even more challenging due to the lack of a quick and secure way to access data from external organization firewalls.

3 Serverless Computing for Healthcare and its Various Components

The serverless technology is based on contemporary services used to provide automation, scalability, flexibility, and availability. The computation in the serverless platform relies on set of stateless functions which are deployed and executed on the physical machines or servers at the backend. The provisioning and maintaining of the infrastructure is abstracted from the application development and execution process. The abstraction of infrastructure management from clients is the key point for using the serverless paradigm by many fast-growing and agile health sector solutions. Depending on the serverless paradigm, large enterprises may develop, deploy and execute their business logic without bothering about configuration of infrastructure and the security. Serverless vendors like Microsoft azure, AWS Lambda, Google functions provides lot of services which can be leveraged for diverse requirement in healthcare management service. Some of the serverless components used in healthcare management system are shown in Fig. 1. Serverless infrastructure is one of the most suitable what to make web-based application which can be used to make user interface for patient portal at both front end and backend. AWS EC2 and S3 Buckets are the two storage services can be used to store huge amount of medical records in a secure manner. The authentication can be leveraged by using managed authentication services, such as AWS Cognito, while for the database, AWS Aurora Serverless can be utilized. The statistical result can be shown in a presentable form by using cloudwatch or the Datadog performance monitoring service. This leads to lower operational costs for building the portal, easier maintenance, and on demand scalability etc.

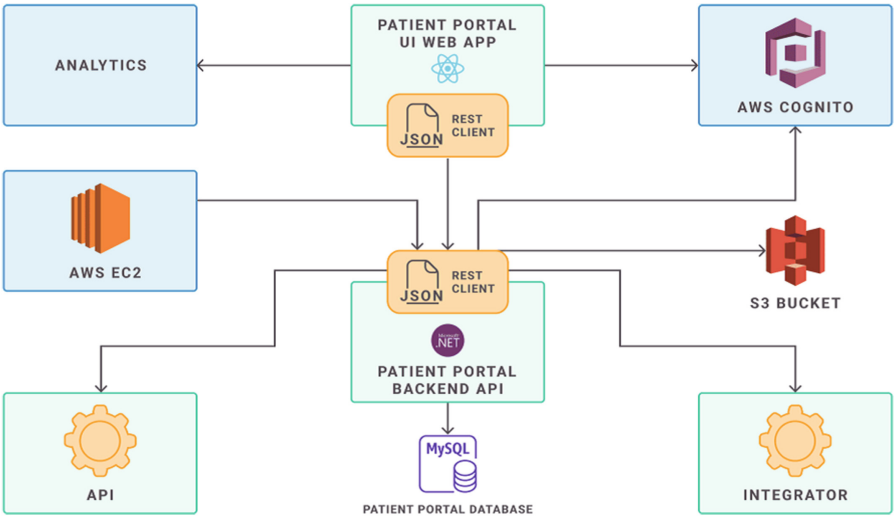

Fig. 1. Serverless architecture for healthcare management system

4 Case Studies

In this section, we have presented four case studies of healthcare management systems, which are heavily utilizing serverless framework. Some of the serverless components are used commonly in all the case studies and some of them are specifically meant for a particular use case. Each of the components are briefly discussed in this section.

4.1 Case Study I: Fast Healthcare Interoperability Resources (FHIR)

Amazon serverless cloud platform provides an efficient open source toolkit to provides various healthcare services popularly known as First Healthcare Interoperability Resources [6]. FHIR system is primarily use various serverless functions to provide APIs which can be used to access remote healthcare resources and facilities [12]. Various serverless services used in FHIR system is shown in Fig. 2. These services can be use in any mobile devices through which the stakeholder of healthcare sectors can avail the services. It also allows to integrate with existing digital services through a well-defined architectural design pattern. The serverless pattern deployed by Amazon's CloudFormation [25] tools can be used to provide services for FHIR request through APIS. The following components are provided to serve different kind of services as follows:

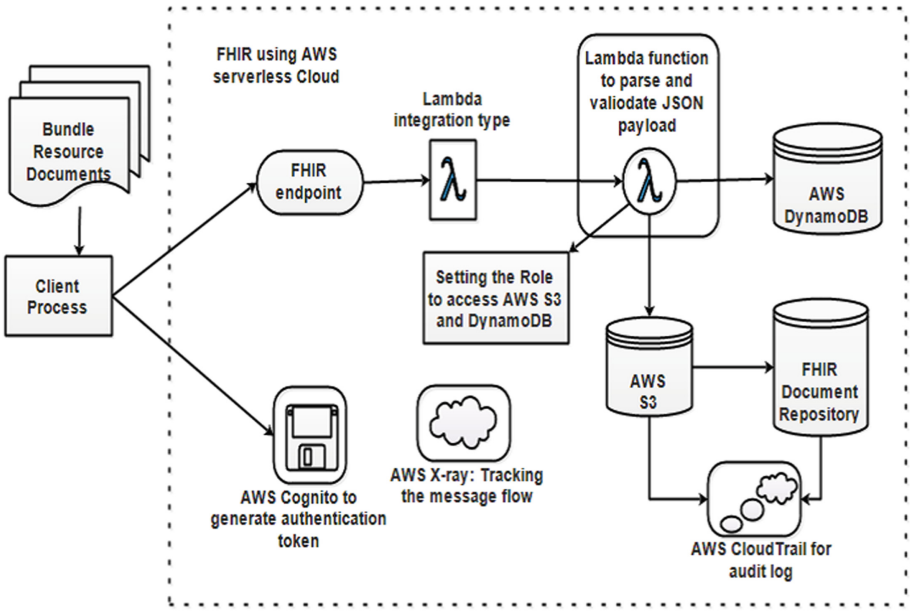

Fig. 2. Serverless configuration for FHIR system

- Amazon Cognito pools are used to provide authentication by verifying the user's identity and the group it belongs to.
- Amazon APIs are provided to routing the request towards the Lambda function which can be invoked by the event an trigger.
- Two very specified AWS Lambda functions are used in the serverless solution for FHIR. One of them is used to process the FHIR request by routing the path towards the storage services like Amazon S3 to store unstructured data, DynamoDB services to create, delete, update operation on healthcare data or to OpenSearch Service to indexing the search process for faster access by the stack holders. The other Lambda function is used to read the updates and make changes in the indexing component.
- The DynamoDB storage unit is used to store all the unstructured healthcare data. Whenever any updates are carried out the DynamoDB, the same is reflected back to the OpenSearch service. Sometimes Amazon's S3 is used to store binary data from healthcare resource such as X-ray or any ECG graphs etc. (Sivasubramanian, 2012).
- The indexing and the search process for the incoming request from FHIR APIs are provided by Amazon OpenSearch service.
- Various Key management services are used to encrypt all the storage components like S3, DynamoDB or the OpenSearch service.
- The CloudWatch service from the Amazon is used to log all API requests from the stakeholders of Healthcare system.

4.2 Case Study II: IoT Based Remote Monitoring System Using Serverless Architecture

Digital wearable devices such as smartwatches, digital blood pressure and weight scales have made it possible for patients to self-diagnose problems long before they become urgent cases that require emergency care [27]. However, self-diagnosis can be dangerous, and it is always preferable to have doctors view remote sensor data and perform diagnosis prior to clinic or hospital admittance. The challenge is to make such data available to doctors in real-time. The architecture for Integration of serverless framework with IoT based remote monitoring system is presented in Fig. 3.

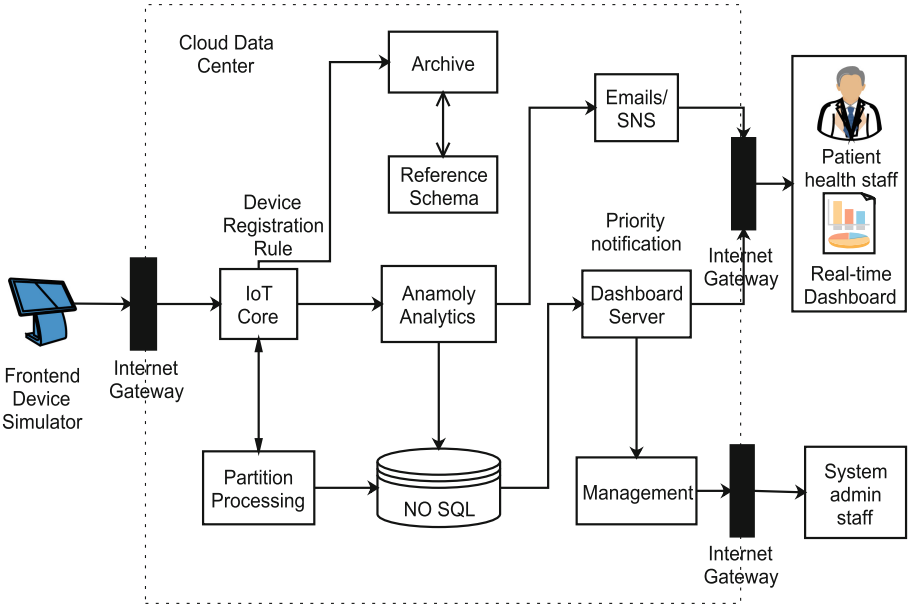

Fig. 3. Integration of IoT and serverless in remote health monitoring system

4.3 Case Study III: RWE and Data Lakes

We have all heard the phrase Real World Evidence in healthcare. This means evidence obtained from data gathered outside of randomized control trials - instead this is from data generated during regular clinical practice or real world practice [9]. In healthcare today, there is no shortage of this data, but it can be hard to glean meaningful insights from it. Think about the petabyte size data sets being generated by wearables, then factor in mobile apps, genomics, imaging and claims data to just name a few sources and you can see that the sky bound mountain of data is growing exponentially. It is also made up of data from various sources and in various formats. For example, you have the streaming data coming

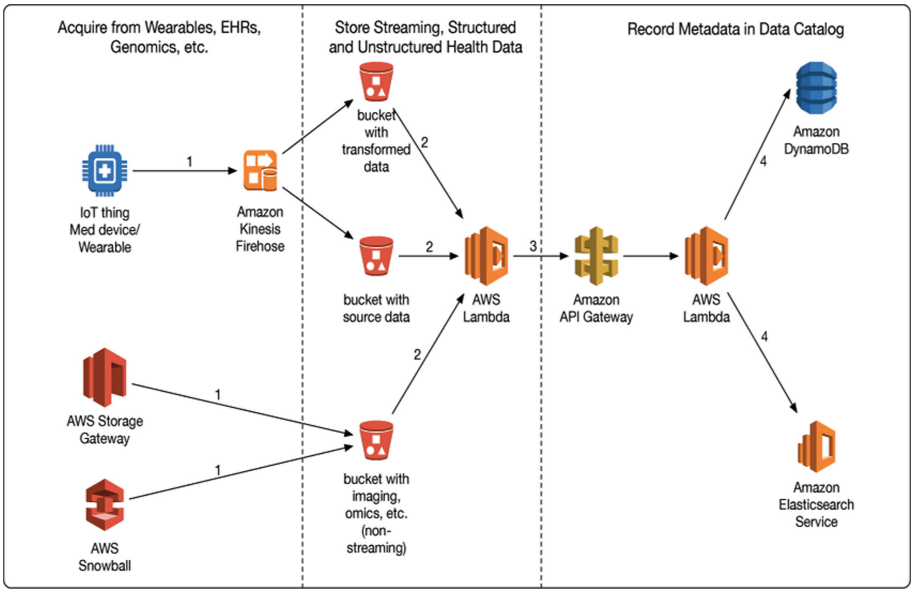

Fig. 4. An architecture of the features within a data lake

in from IoT including FitBits, Apple watches, and medical devices such glucose or heart monitors. Then, you have the structured data being generated from claims data and the unstructured data found in EMRs. The connectivity with various components in DataLake architecture for healthcare system is shown in Fig. 4.

On the public cloud, all of this data can be brought into a Real World Evidence platform with a data lake at the core. The platform stores metadata to identify where each piece of data came from and subsequent information about it. The architecture for your data lake can be built completely on serverless. If you are using AWS, for example, you can store it on S3 and invoke Lambda for your serverless to run your queries. Lambda can also write to a data catalog with metadata about the objects in your data lake. This kind of architecture lets you scale to any size, and when you're working with the kind of data healthcare stores, you'll need capacity. IAM (Identity Access Management) and other security protocols can be put in place to keep your data safe.

4.4 Case Study IV: Healthcare Startup Solution Using Serverless

A healthcare technology startup needs to create a highly scalable data gathering mechanism, which could leverage the power of data science and machine learning to create predictive insights [3,10]. Serverless architecture is found to be much more flexible for startup solution, which not only reduced the resources required to develop and maintain the product, but also it provides ample of opportunities to clients of having a highly modular and flexible product. It will always

conformed to regional regulatory and data protection mechanisms with minimal effort. A sample healthcare system utilizing startup solution is shown in Fig. 5. GS Lab decided to use AWS serverless components, microservices and SAM (serverless application architecture), for the product. Although this architecture had been developed around for a couple of years, it has not been seriously implemented in real-time startup healthcare solution. The following AWS components can be leveraged to make the startup solution for healthcare system:

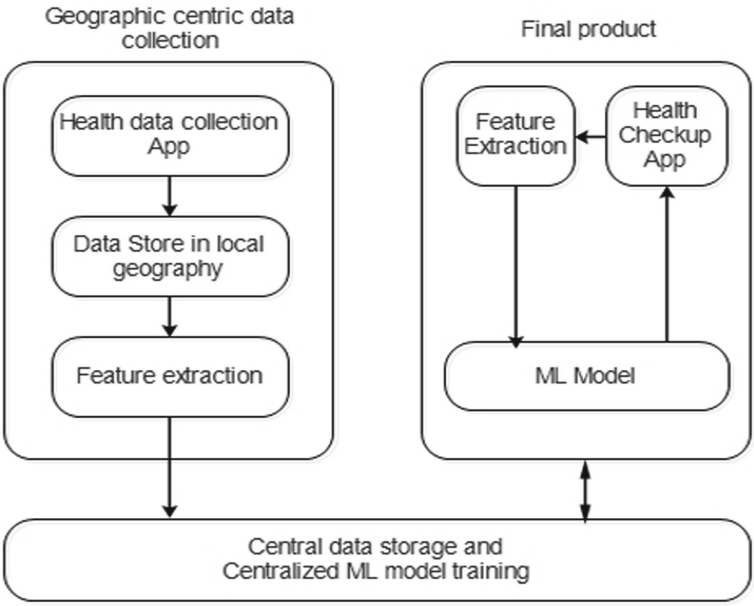

Fig. 5. A healthcare technology startup solution using serverless architecture

- The lambda function for almost all components (Lambda versioning is powerful when we have ML models as lambda).
- Kinesis service for feature extraction of the health data.
- AWS cloud formation templates.
- S3 for secure storage.
- RDS PostgreSQL for database needs.

5 Conclusion

Serverless is has been emerging as a promising solution for maintaining the digitized environment in the healthcare sector where several healthcare services can be provided at low cost and faster response time. In this paper, a survey on the serverless architecture for the healthcare system is presented along with the four case studies related to healthcare systems. In the present day, serverless

architecture is found to be an efficient framework to provide various healthcare services. However, it poses a number of challenges in integrating IoT with the serverless healthcare system. As the serverless framework relies on a number of independent stateless functions, they failed to communicate with each other by exchanging data which is one of the major concerns in a healthcare management system. Another challenge in a serverless healthcare management system lies in maintaining the tradeoff between cost and deadline of various healthcare applications. Although it poses various challenges, it has been emerging as a potential tool for handling various services in the healthcare system. The identified research challenges may be considered as the scope of research in the era of the serverless computing in the healthcare system.

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