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Microservices and It's Applications : An Overview

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***Abstract*—** The shift from monolithic to micro services architecture has been remarkable. Micro services have emerged to be an effective and efficient architecture pattern for various applications and have become a preferred choice for efficient and rapid development of distributed applications. Micro services follow a decentralized approach where each service has an individual outcome and communicates with other services. This communication is carried out with the help of a well-designed set of protocols which are known as Application Programming Interfaces (API). It is seen that micro service architecture is used popularly for cloud applications. But apart from cloud applications, micro services along with block chain, internet of things (IoT), machine learning, and other domains have varied use cases. This paper tries to emphasize the importance of the micro services architecture in these domains. We also provide an overview of the research carried out in these fields along with some of the real time use cases of micro services.

***Keywords*—**Micro services, application domains

I. INTRODUCTION

Micro services, as explained in [1], is a set of small services which revolve around business capabilities and are characterized as being independent, decentralized and capable of being written in various programming languages. The traditional monolithic architecture was built as a single unit which was difficult to scale and was not suitable for the development of complex processes. The need for a robust, flexible and reliable pattern, led to the growth and popularity of micro services.

As micro services are built as a group of services, they require an explicit communication mechanism. This communication is carried out with the help of application programming interfaces (API) which form the backbone of this architectural pattern. The main basis for the popularity of micro services is the numerous benefits it provides which include modular structure, independent deployment, ease of integration and modification, fault isolation and continuous delivery. But due to its distributed nature, it is important to focus on efficient communication mechanisms and design the services to minimize the operational complexities.

Most of the organizations nowadays are moving towards micro services to fulfill their application specific requirements. Some of the big firms which adopted this architectural style are as follows:

- Netflix: It can be considered as one of the pioneers of this architectural style. Netflix initially used the monolithic architectural pattern for its video streaming service. But the monolithic application as well as the data centers could not handle the increasing number of users and the ever-increasing data and services. Hence, they migrated to the cloud and adopted the micro services architecture. It proved to be very beneficial in terms of scalability, elasticity and even faster development and deployment of its application. The migration to cloud also helped them in optimizing and reducing their costs and at the same time increasing its service availability to its users [2].
- Uber: This transport company also adopted the micro services architecture when the monolithic architecture could not cater to its demand of rapid expansion. But the migration to micro services also led to some of the challenges. They sought solutions to most of these challenges and are using micro services to make their application fault tolerant and scalable [3].
- Amazon: Amazon also made changes in its development lifecycle by adopting micro services. They also changed their organizational structure by assigning small teams which could function independently. This enabled them to deploy their applications faster, coordinate effectively and even add new and improved features.

Apart from these, many other companies have adopted the micro services architectural style to achieve scalability and availability. The requirements of the development and deployment of applications differ from one organization to

another. Hence, the style of architecture adopted by them depends on their respective demands and necessities.

The rest of the paper is organized as follows. Section II reviews the literature and the survey carried out by researchers considering various micro service characteristics. Section III explains the micro service architecture in detail. Section IV provides an overview of the domains where micro services can be utilized for their various advantages. Section V provides a comparison based on factors such as the technological aspect as well as the use case of the studies carried out by the researchers. Section VI concludes the research work and also suggests some future directions.

II. RELATED WORK

Various researchers have tried to identify micro services from different perspectives. The study carried out by the researchers can be grouped into the following categories:

A. A systematic mapping study and survey of micro services

A systematic mapping study is proposed by in [4], which takes into consideration 21 studies in this field. Moreover, characterization framework is used for their classification. The comparison of these studies based on their technical contribution is evaluated by the authors. The contribution of authors in this case is important because it tries to compare the studies based on six different attributes and is useful for researchers and practitioners trying to identify relevant literature related to the application of micro services particularly in the context of cloud.

A survey on micro services is also carried out [5], in which the authors try to identify the practical applications of micro services in the industry. Initially, existing literature related to micro services is identified by the authors. The focus here is the practical use case of micro services which is evaluated using a survey carried out with the professionals working in this area. Useful insights regarding the use of main programming languages used for development, the advantages and challenges faced by the developers are obtained with the help of this study.

A survey on the history of software architecture and the current state of micro services is described in [6]. Some important future issues related to the dependability as well as trust and security of micro services are also discussed by the authors.

B. Study of architectural patterns of micro services

The process of architecting micro services from the point of view of its adoption in the industry is studied in [7]. The research questions provided in this work try to identify various techniques used in the micro services architecture.

A mapping study in micro service architecture is also presented in [8] and [9]. The research approach used in [8] helps to identify the various architectural views as well as the quality attributes of micro services. On the other hand, the authors in [9] evaluate different architectural patterns and the deployment strategies.

The work carried out in [10] tries to compare the service-oriented architecture to the micro service architecture and describes their respective strengths and weaknesses. A systematic mapping study is also performed by the authors which emphasizes the research challenges related to micro services and the relative work in that domain. The use of micro services with respect to its application in cloud computing is also studied in [11] and [12]. Its security and privacy in the cloud environment is also explained in [12].

When migrating towards micro service architectures, various challenges are faced by the developers and practitioners and it is described in [13]. An in-depth survey of practitioners pertaining to the adoption of micro services in the industry is performed and the relevant challenges are explained which can be beneficial for people who want to adopt this architectural style.

C. Challenges in the deployment of micro services

The challenges in architecting micro services are identified by the in [14] with the help of a survey. The main attributes which lead to the difficulties in architecting micro services are analyzed from its practical viewpoint.

Various challenges related to the performance engineering of micro services are also explained in [15]. The assessment of parameters is essential as it affects the working and quality of micro services and hence, various attributes listed by the authors provide a way to strategize the monitoring as well as the testing for performance improvement.

This work is different from the previous work in this field, as we try to provide the overview of micro services along with their use in different domains such as IoT, machine learning and block chain and so on to enhance their features. We also provide a comparative analysis of the work carried out by different researchers proposing the real time use cases leveraging the micro services architectural scenario.

III. MICRO SERVICES ARCHITECTURE

The most significant aspect between various services in micro services architecture is loose coupling. The individual services may have different technology requirements and may share or have their own database and servers. The design and development of micro services may therefore differ according to the scaling requirements of the application. Reliable micro services architecture should also have suitable communication techniques as well as deployment methods. Some of the most common

architectural patterns, deployment schemes, communication and monitoring mechanisms are as follows.

A. Architectural Patterns

To adopt the micro services architecture, the choice of an appropriate pattern is an essential aspect.

Some of the patterns for implementing micro services are as follows [16]:

- Backend for frontend
- Key value store
- Document store
- Log aggregator
- Service registry
- Database is the service

The coordination between different components of the micro services is integral for its effective development and working. Apart from the above-mentioned patterns, micro services can be designed using multiple techniques depending upon the complexity of the desired application. Multiple architectural patterns can also be grouped together based on similar characteristics such as orchestration, migration, communication, design and so on which can help developers in identifying a suitable alternative.

B. Deployment Strategies

Apart from building and developing micro services, the management and maintenance is also a key aspect. The requirements of every micro service are different due to variability in its resources and technology stack. Based on this, there are various possible alternatives for deploying micro services [9].

- Multiple Service per Host Pattern: There are various physical or virtual hosts for provisioning of micro services. In this pattern, multiple service instances will share the same server and operating system. Efficient resource usage is one of the main benefits of this pattern. Also, scalability and performance can be improved by using this pattern. It can also present some difficulties for monitoring the resource usage of individual service instances.
- Single Service per Host Pattern: In this deployment pattern, the service instances do not share any resources or hosts. Every service instance is deployed on a specific host. This host may be in the form of virtual machine or even container. The service instances may be deployed using container technologies such as docker. The separation of service instances allows better resource monitoring. But the resource utilization along with performance and scalability are affected in this pattern.

One more approach for deploying micro services is the server less deployment which can be used by some applications.

C. Communication Mechanisms

As micro services consist of a collection of small services, they require a proper and sophisticated channel for inter service or inter process communication. This can be divided into two categories namely synchronous and asynchronous communication mechanism.

- Synchronous: This type of interaction works on the request and response technique. The client after making a request waits and sometimes even blocks other clients for a specific time until it gets a response. A prompt and well-timed response is essential for smooth communication between the processes. HTTP (Hypertext Transfer Protocol) or REST (Representational State Transfer) protocols may be used for this purpose.
- Asynchronous: In this type, the client does not wait for a response from the service. The service may send a response but in an asynchronous manner.

For external communication, the clients can interact with the application with the help of an API (Application Programming Interface) Gateway. This API Gateway acts as an interface which routes the client requests to appropriate services.

D. Monitoring

Since micro services are distributed in nature, it is very essential to track their resource utilization as well as the performance. It is particularly important to supervise the availability of the system and take preventive measures to avoid further issues. Monitoring of micro services is not just limited to its performance. Monitoring also takes into consideration the health of the system, tracking and authenticating users for security monitoring, supervising unusual events and behaviours in the system and proper availability for meeting the SLA (Service Level Agreements).

As various micro services are independent of each other and sometimes make use of different technologies, the performance monitoring of these services poses a big challenge. Moreover, there is a need of runtime monitoring of services for better fault detection. Also, the change in the behaviour of the system needs to be tracked appropriately to avoid false anomaly detection. Monitoring of data is therefore crucial to design performance models with different environments, can help to diagnose problems and can help plan some effective deployment strategies [15].

IV. MICRO SERVICES APPLICATION DOMAINS

The use of micro services architecture spans multiple domains and industrial applications due to its flexible and agile nature. We describe some of the technological aspects where the use of micro services can be beneficial.

A. Internet of Things (IoT)

Internet is omnipresent nowadays, and the advancement in networking and computing capabilities has led to the rapid adoption of internet of things (IoT). Everything today right from buildings, phones, cities and even wearable objects has become "smart". In the Internet of Things, applications are deployed in a distributed environment and the devices communicate through lightweight communication mechanisms. The micro services architecture has identical characteristics for development and deployment. Hence, it can not only act as an agent but can also become an apt alternative for the management of the internet of things (IoT) applications. A multi-agent system based on micro services can deliver the required functionality as a single agent can act independently and coordinate with other agents. Such a system is explained in [18]. Moreover, micro services also provide various benefits for internet of things (IoT) as compared to monolithic architectures.

B. Block chain

Block chain, which is based on the cryptographic mechanism, consists of a list of records which are linked together and contain unique transactional information. The transactions carried out on block chain are very secure as the data in the blocks once recorded, cannot be modified easily. Like IoT, block chain and micro services also share some characteristics. The block chain network is decentralized and distributed in nature. The use of block chain for secure data handling and management is proposed by some researchers. One of the use cases is nothing but a smart public safety scheme with the help of IoT. A micro services-based system is proposed for surveillance and security purpose. As micro services and the IoT devices are distributed in nature, they exchange data with some communication mechanisms. The Block chain technology is useful as it helps in secure data transmission among the various independent services and devices. Access control technique is also introduced to allow access to authenticated users only.

C. Machine Learning

Machine learning gives systems the ability to learn automatically to make predictions or decisions. Different phases of machine learning process can be developed in different scenarios and with different programming languages. For them to work together, the use of micro service architecture wherein, each part of the application is devised as an individual micro service can be instrumental. These micro services can then collaborate with the help of API calls and other related communication mechanisms. Apart from this, machine learning as a service is also proposed in [36]. The proposed approach is significant as it facilitates the use of three different machine learning algorithms as a reusable micro service to illustrate the use of these algorithms for various machine learning applications.

D. Cloud Robotics

The use of cloud computing is manifold and one such use of cloud resources is for robotics. Cloud robotics is a field where the computationally intensive tasks are carried out by the remote computing resources. Moreover, it also provides opportunities for collective learning, shared tasks among robots, interconnectivity, greater memory and even reduced costs. While developing robotic applications, flexibility and scalability are important. Micro services architecture seems to be a favourable choice for the development and deployment of cloud robotic applications. One such use of micro service architecture is proposed in [32]. Every individual function can be developed and deployed as a service for use in intelligent space. It provides a promising approach and advantage over traditional architecture design.

TABLE I: Microservices in various domains and it's use cases

Sr. No.	Paper Title	Technological approach	Use case	Contribution
1.	BlendMAS: A Block chain Enabled Decentralized Micro services Architecture for Smart Public Safety	Block chain	Smart Public Safety	Use of micro services to handle the challenges of large data generated by the video streams
2.	A Micro service-enabled Architecture for Smart Surveillance using Block chain Technology	Block chain	Smart Surveillance	Secure data handling due to block chain framework and decomposition of video feeds into individual micro services
3.	Cloud-based Disaster Management as a Service: A Micro service Approach for Hurricane Twitter Data Analysis	Data analysis	Disaster management	Cloud based analytics framework for handling twitter data for disaster management
4.	IoT and Micro services Based Testbed for Connected Car Services	Internet of Things (IoT)	Connected car services	Integration of vehicular resources with cloud-based framework to provide advanced functionalities through open APIs

5.	An Atmospheric Dispersion Modeling Micro service for HazMat Transportation	ALOHA simulation-based system	Hazardous material transportation	Use of micro service framework to simulate the evolution of hazardous material and assess its impact for real-time disaster response
6.	Exploring Web Objects enabled Data-Driven Micro services for E-Health Service Provision in IoT Environment	Internet of Things (IoT)	Health provision	A model for depressive disorder (DD) assistance with data driven micro services
7.	InterSCity: A Scalable Micro service-based Open Source Platform for Smart Cities	Internet of Things (IoT)	Smart Cities	A micro service based platform for smart city research
8.	Revenue Oriented Air Quality Prediction Micro Services for Smart Cities	Internet of Things (IoT)	Air quality prediction	Air quality prediction framework with the help of machine learning and cloud micro services
9.	Enabling Community Health Care with Micro services	Internet of Things (IoT)	Health Care	A micro service framework to model complex healthcare scenario
10.	Micro service Architectures for Advanced Driver Assistance Systems: A Case-Study	Internet of Things (IoT)	Driver Assistance Systems	Reducing the complexity of complex software with the help of micro service framework for automotive use case
11.	A rule-based eCommerce methodology for the IoT using trustworthy Intelligent Agents and Micro services	Internet of Things (IoT)	E-commerce	An integrated framework for e-commerce using IoT, multi agent system and micro services with a rule-based mechanism also providing innovative approach for safe trading on the internet
12.	Micro service-based IoT for Smart Buildings	Internet of Things (IoT)	Smart Buildings	A small prototype for smart buildings executed in a real-world environment using Jolie programming language for micro services implementation is presented
13.	Research on Designing an Integrated Electric Power Marketing Information System Based on Micro applications and Micro services Architecture	Data analysis and processing	Electric power marketing system	Information System composed of multiple micro applications and services for charging and accounting scenarios of the purpose of electric power marketing
14.	Micro service-based Cloud Robotics System for Intelligent Space	Cloud robotics	Intelligent Space	Cloud robotics system prototype which can be utilized in an intelligent environment. Also, the use of micro services for SLAM (Simulation localization and mapping) process implementation is demonstrated
15.	Micro services Architecture: Case on the Migration of Reservation-based Parking System	-	Parking System	A reservation-based parking system divided into multiple service instances capable of functionalities such as membership, parking, payment and so on collaborating with the help of API Gateway is proposed
16.	A micro service-based middleware for the digital factory	IoT and Big Data	Automation mechanism for production environments	A simulation-based mechanism making use of IoT along with micro services architecture for enhancing the distributed nature of components in the manufacturing environment. The security and privacy are also taken care of for this smart factory infrastructure
17.	Research on the Construction of Regional Credit Bank Platform Based on Micro services	Container	Regional credit bank platform	The use and feasibility of micro services architecture for the development of bank platform is studied and the experimental results suggest that it is suitable to use this

				architectural style
18.	Machine Learning as a Reusable Micro service	Machine learning	Machine learning service	The provision of machine learning capabilities in the form of micro services is presented which provides easy integration and configuration of machine learning algorithms in diverse and complex applications
19.	Micro service-based Architecture for the NRDC	Cyber infrastructure component	Information Storage in the data center	Use of micro services architecture for its various benefits such as maintainability and scalability to design the data center for the Nexus Project. The software design along with the components as well as the prototype information for the system are also provided
20.	Smart ITS Sensor for the Transportation Planning Based on IoT Approaches Using Serverless and Micro services Architecture	Internet of Things (IoT)	Intelligent Transportation System	An efficient approach to design the O/D(origin/destiny) matrix for effective planning in BRT (Bus Rapid Transit) systems. The use of IoT and Bluetooth technology provides a cheap and reliable alternative

V. COMPARATIVE ANALYSIS

The micro services architecture along with block chain, internet of things (IoT), and machine learning and so on is applied and used in various domains by the researchers. A comparative study of the technological aspect and the possible use case is described in Table I.

VI. CONCLUSION

The use of micro services as a preferred architecture pattern is not just limited to cloud applications. As the amount of data goes on increasing, the maintenance and processing of this data becomes a complex task. The use of micro services therefore comes into picture wherein a loosely coupled, autonomous service can handle an individual functionality. This advantage together with its flexibility and scalability is the reason due to which micro services have applications in varied domains. A lot of researchers have explored this architectural framework for enabling rapid development of software applications. We have studied some of the work carried out in this field which gives an insight about the applicable domains as well as its varied use cases. The comparative analysis provided can help the readers in the identification of the contribution and an overall view of the utilization of this pattern for further studies. This work can be further enhanced by implementing the micro services for their real time use cases and analyzing their performance.

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