



A REVIEW OF THE IMPACT OF COVID-19 ON SERVERLESS COMPUTING TECHNOLOGY

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ABSTRACT

The Covid-19 pandemic had a profound effect on technology in general, and serverless computing is no exception. Covid-19 pandemic has shaped the field of serverless computing, and how technology has evolved in response. Serverless computing technology have been adapted to meet the need for remote working, and how the technology has changed in terms of scalability and cost-effectiveness. This pandemic has affected virtually every aspect of daily life as significant measures are being taken to limit the spread of the virus. The pandemic has changed not only the way companies operate, but also the way they have been able to survive. Studies indicate increased requests for cloud services ranging from resident users, particularly for telecommuting, entertainment, commerce, to education, and as a result, causing traffic shifts at the core of the Internet. Covid-19 had such a significant impact on cloud services that there is an unprecedented amount of demand for cloud service providers like Amazon Web Services (AWS), Google Cloud Platform (GCP), and Microsoft Azure. This study used data from a variety of sources to analyse the impact of serverless computing during the pandemic and to justify its significance for a pandemic-affected business. It also reviewed the pre-Covid, Covid and post-Covid-19 era. Two survey reports were used in this study and the effect of Covid-19 on Serverless computing. This paper emphasizes the benefits and adoption of Serverless computing during the pandemic, in contrast to other studies that concentrated on the impact of the Covid-19 epidemic on the cloud computing environment.

Keywords: Serverless computing, Cloud Computing, COVID-19

INTRODUCTION

The novel coronavirus has caused a great deal of awareness and usage of cloud computing services and solutions (Misbah et al., 2020). The coronavirus led to a high increase in mortality and morbidity all-round the globe. COVID-19 is said to be caused by the coronavirus named severe acute respiratory syndrome (SARS). The rising situations caused by this new form of virus have posed challenges and great threats to governments, countries and the population of the globe as a whole. Hence government took preventive measures to impose temporary regulations in order to mitigate the spread through interactions and communications. This seemed to be a good temporary solution but in turn, was a critical issue for the masses of some African countries where the self-employed could not provide for themselves as they could not step out, others working in the private and government agencies were not catered for, students in government and federal institutions had drawbacks, the health sector was not apt, equipped or ready to fight the rising situations and could not obtain the required necessities due to the occurring pandemic, areas affected by the ongoing crisis and insecurities became worse and the economy managing its stance on one foot crumbled (Al Ashhab et al., 2020a).

The outbreak of covid-19 has not only disrupted the economy but also education, security, health sector and other sectors. Every aspect of life has been affected by the Coronavirus Pandemic (COVID-19). This has led to several changes in science, technology, economy and other conditions. Regardless of the impacts situated around the novel Corona virus, the Cloud Computing Environment (CCE), has not only proven to be stronger but quite reliable and effective. In light with physical interaction no longer accepted as a form of communication and considering social distancing, companies, enterprises, organizations and institutions round the globe have made a sudden-massive shift to digital tech solutions in

a strife to maintain efficiency in productivity (Misbah et al., 2020).

Serverless computing among other services provided by the cloud computing providers has brought about a paradigm shift. Serverless computing takes cloud computing efficiency to the next level. The name "Serverless" does not exactly insinuate that there is no server at all available because somewhere in the world in an enormous warehouse, there are definitely actual servers powering Serverless computing. Serverless computing provides a Function as a Service (FAAS) to end users while promising reduced hosting costs, high availability, fault tolerance and dynamic elasticity for hosting individual functions known as micro services. With Serverless computing you don't have to think about the server at all. So, in effect, it's "Serverless", though not technically or literally, and that's where the term comes from. The setup, capacity planning, and server management are invisible to you because they are handled by the Virtual Cloud (vcloud) provider (Microsoft, Amazon and Google Cloud) and Serverless applications don't require you to provision, scale, and manage any servers. The server disappears from your list of concerns (Shafiei et al., 2019).

To cloud users, cloud partners and cloud vendors, this tech is quite the necessity in this pandemic era. Also, there are only a handful of companies offering Serverless computing but with the increase in awareness caused by the impact of the pandemic, it is positive to say that there will also be an increase to vendors and companies rendering Serverless computing services. This review is based on the analysis of various articles consisting of corona virus and its impact to Cloud Computing Environment's (CCE) most recent Emerging Technology, Serverless computing. We hope to understand how Serverless computing has contributed to an economy suffering from pandemic such as Covid-19, its ramifications, and biases for the future. Understanding the

impact of Serverless computing in the Covid-19 era and clearly analysing its contributions to an economy suffering from the pandemic using data from various sources (Lynn et al., 2017).

Related Literature

The section presents previous related surveys in the area of Cloud Computing research relating to Serverless Computing applications and usage. Al Ashhab *et al.*, (2020b), presented a paper that demonstrated the practical and futuristic significant of COVID-19 pandemic on cloud computing environment and other technologies due to the rapid rise to work from home. They analysed the different types of business models in and the evolution that have occurred due to the emergence of the pandemic which has shifted us to work from home. Examples of these technologies are virtual meetings, digital healthcare, online education, cybersecurity, logistics to smart cities and telecommunications. Their paper also analysed the security risks involved in working from home in which the condition might expose the users to different types of attacks due to lack of preparedness to face such sudden situation. However, their review focused broadly on the cloud Computing Environment. Kratzke (2020), released a perspective paper on how COVID 19 pandemic created the largest idle volunteer supercomputers in the world. The German proposes a way to solve the resource sharing inadequacy of cloud computing using technologies that are already in existence, of high efficiency, and adapted for various purposes by cloud-native companies like Uber, Airbnb, Google, or Facebook. Examples of these already tested technologies in large web-scale deployments include containers, Serverless architectures, image registries, distributed service registries which can solve question posed by hardware heterogeneity, sandbox, code signing and updating, result verification and most importantly project exclusiveness. (Cappellari et al., 2021) examined how a cloud native program would use Serverless computing and other cloud technology applications. They also carried out a comprehensive search and recorded the impact that the pandemic had on the development of applications in the cloud. It was observed that the capability of cloud service providers evolves at a very fast rate. However, it was noted that not all services are provided by every service provider. This serves as a limitation because some functionalities would likely change and be required which may not be provided by the cloud service provider in use.

Research Methodology

The research methodology section presents the research strategy followed to review the existing works in the area of Serverless computing and COVID 19 impact on Serverless computing environment. We also explain the selection of the existing studies which was done through a set inclusion and exclusion criteria.

For this systematic search, we developed a search strategy to identify relevant literature. This search strategy was tailored to Google Scholar and Microsoft Academic, and the search terms used were the following: "Serverless Computing" OR "Cloud Computing" OR "COVID 19" OR "Cloud Computing Usage". All databases spanned from 2018 to 2021, and included journal articles, review papers, research reports and white papers published in English language only. Appropriate literature related to Serverless Computing, the impact of COVID 19 on the technology was gathered. The research procedure adopted in this article spanned through relevant papers from Google Scholar.

The selection criteria were based on the PRISMA Statement (Page and Moher, 2017). Table 1.0 shows the literature inclusion and exclusion at every stage. The search mainly focused on the mapping existing literature on COVID 19 in the field of science and Engineering, Business and economics. The search then narrowed to the subject areas to inter-disciplinary science and Engineering. The search span was from year 2018 to 2021. All articles before 2018 were excluded from search.

There were 40 records extracted at this stage. The study is based only on original research articles, review papers and conference papers. For maintaining the quality of the review, all duplications were checked thoroughly. Abstracts of the articles were checked deeply for the analysis and purification of the articles to ensure the quality and relevance of academic literature included in review process. A careful evaluation of each research paper was carried out at a later stage. The next exclusion criterion was to limit the papers published in the English language only. We selected 15 articles after assessing each article on the aforementioned inclusion and exclusion criteria.

Impact of Covid-19 on Cloud (Serverless) Computing

The increase in death rate and downsizing of staffs over these past days can only be attributed to the deadly disease, COVID-19. The effect is vivid as it crippled every sector in an unprecedented scale. Nevertheless, there is one industry that has emerged unyielding to the effect of the virus – Cloud computing industry.

Increase in cloud usage and Serverless applications

A study by (Report, 2020) demonstrated the expanded utilization of cloud computing assets during pandemic among undertakings and little and medium-sized organizations as demonstrated in the figure 1. As associations move more responsibilities to the cloud, they can resign the specialized obligation related with keeping up and working conventional server farms. Compartment use can likewise help control costs since they permit more proficient utilization of foundation. Thusly, they offer a more practical approach to send responsibilities in the cloud.

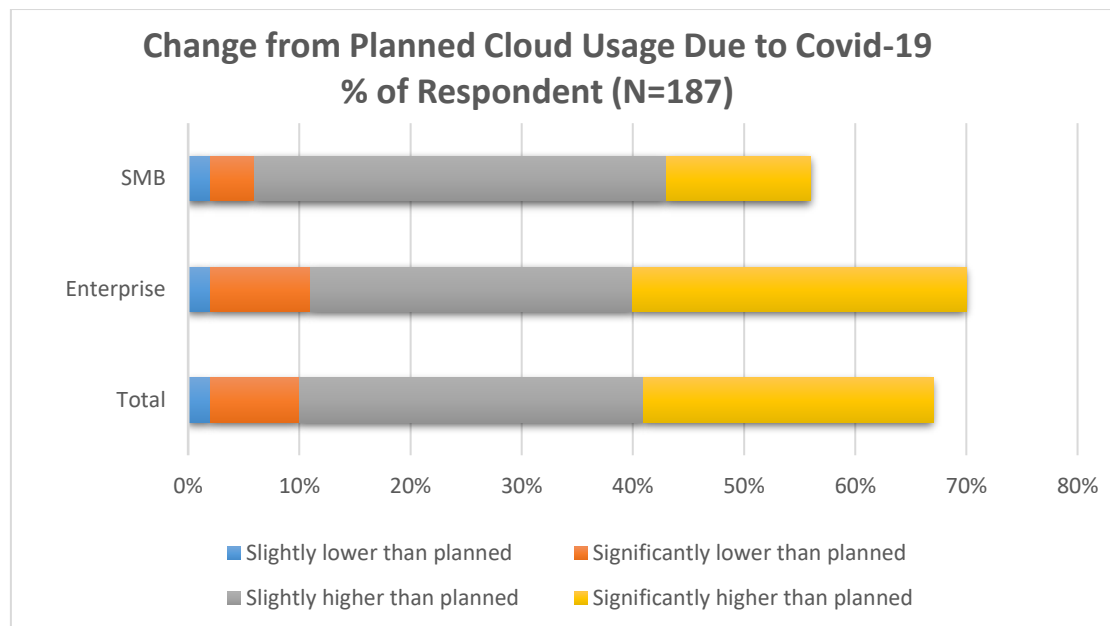


Figure 1: Change in planned cloud usage due to covid-19 (Flexera, 2020)

Our survey demonstrated the increased in usage of Serverless computing applications among individual who are mostly students as shown in the charts below.

Productiveness from desk

With the enforcement of the lockdown due to the virus, many enterprises and industries has shifted their work to digital solution in an attempt to retain productivity. Video conferencing became a solution to facilitate farness learning through live or recorded classes. Thus, Slack and Zoom reported a record-breaking rise in figures and Microsoft team collaboration product and virtual desktop offering saw a growth of 775% and 300% in Italy (The Times of India, 2020) shortly after the lockdown was imposed.

Netflix and Amazon Prime video saw a huge boost from consumers of entertainments due to the closure of movie theatres, football stadiums. Amazon Prime Video saw a high spike in app download of 60% in Italy, 30% in Spain, and 9% in the United State. Video game usage also increased by approximately 75% and digital game purchases rose by 11% year over year from March 2019. Netflix acquired the principal position, the normal time went through will surpassed 30 minutes out of each day in the US in 2020, which is up over 16% from 2019 (Feldmann et al., 2020).

In light of the current situation, the requirement for consistent joint efforts over the Internet calls for solid cloud foundation has risen. The increment in the use of Software-as-a-Service

(SaaS) answers for help the far-off labour force adds to showcase development too.

The e-commerce Booms

E-commerce is another industry scaling in these turbulent times as lot of people across the globe are considering or has actually migrated their businesses to the cloud. Thinking about the e-Commerce space, with the rising number of Covid-19 cases in the wake of opening in numerous nations, vendors have noticed an immense move in customer propensities. Shopping from physical stores while keeping up friendly removing is causing extraordinary degrees of disturbance for purchasers which has urged them to change their gears to shop on the web. Embracing distributed computing helps shippers effectively upscale or downscale their business. It not just causes dealers to diminish the expenses of merchandise and ventures yet in addition empowers new organizations to develop. At the purchaser end, the cloud gives simplicity of shopping experience, whenever and anyplace conveyance, credit only advanced instalments, and significantly more.

The speed with which e-Commerce deals is blasting during the Covid-19, it is certain that they will outflank post-Covid and, consequently, lead to an expansion in cloud market development. The chart beneath shows a quarterly distributed computing and facilitating income produced by Amazon Web Service (AWS) of roughly 12.7billion US dollars.

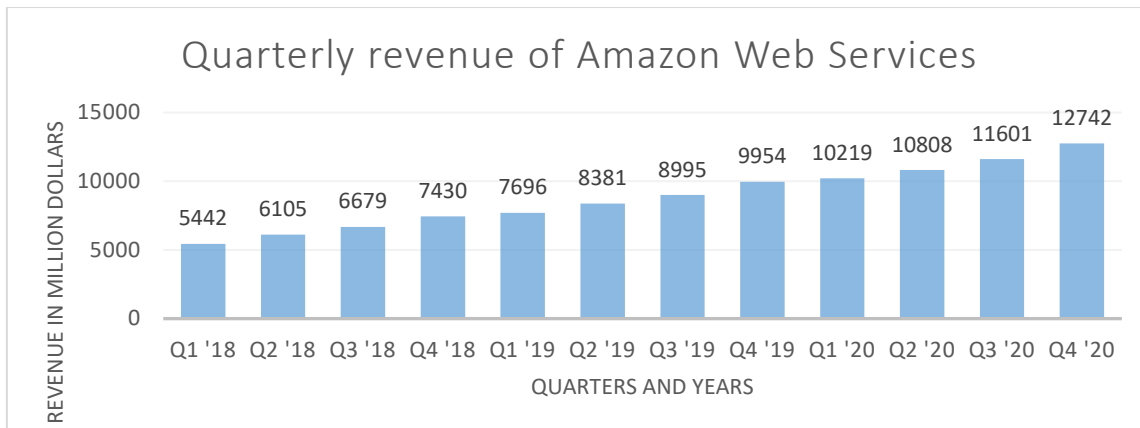


Figure 2: Quarterly revenue of AWS (Statistical.com)

Increase in Cloud adoption

There has been a significant increase in the adoption of cloud services by individual due to the emergence of the covid-19 virus. Many enterprises are choosing the lane of cloud

computing technology due to its multiple advantages. Compared to the previous year, the statistics shown in figure 3, depicts an increase over the previous and comprises of public cloud adoption (figure 3).

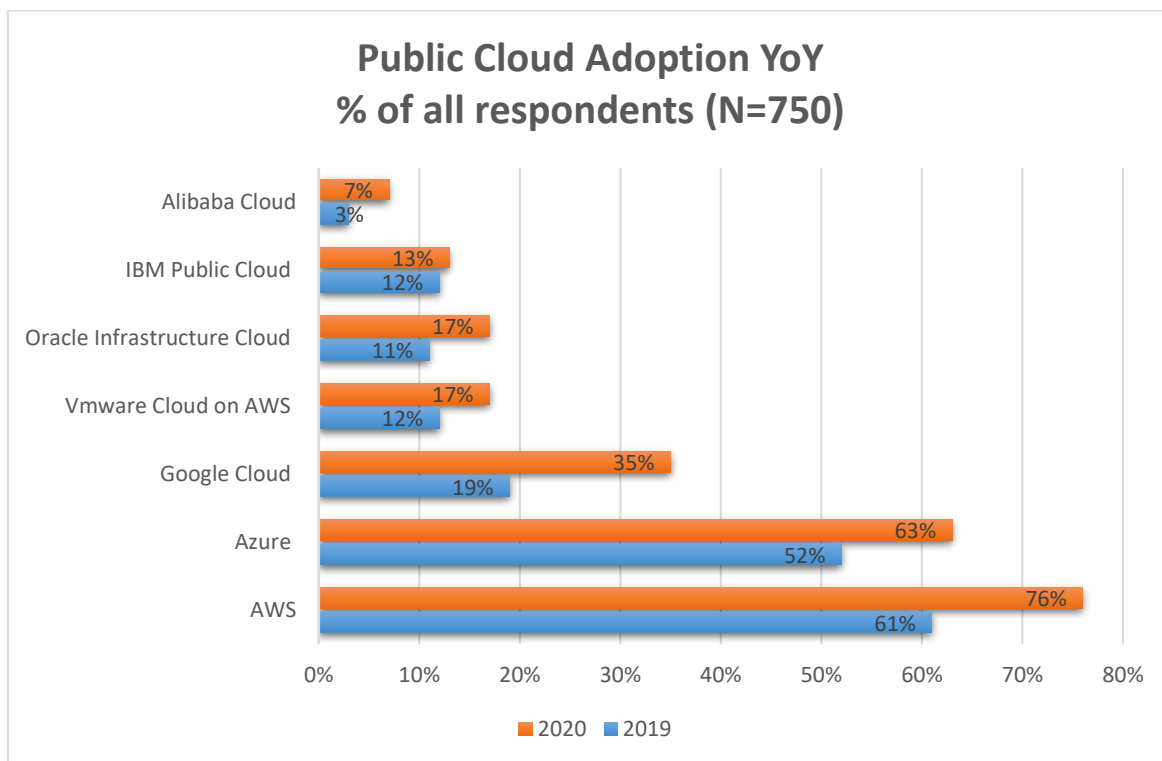


Figure 3: Public cloud Adoption YoY (Flexera, 2020)

Change in perspective of the education business

With the pandemic, the speed of appropriation appears to increase from the normal rate. With surprising lockdowns, the educational associations encountered a total closure, including schools, universities, and colleges, in numerous world segments. The schooling anyway did not stop, praise to the man-made cloud innovation. In spite of the fact that significant colleges are now running on cloud models for offering imaginative eLearning experience, the pandemic constrained many school-going understudies to go for their scholastics by means of online stages which prompted the development of the cloud market.

Numerous advanced education giving associations are putting resources into cloud computing services to satisfy their need of a brought together framework for academic cycle

management. Cloud computing has end up being a help for the instructive organizations to bring everybody onto a for all intents and purposes associated grounds, changing the learning interaction. Supporting the idea of 'learning past homerooms,' cloud computing merchants make certain to keep developing post-Covid-19 (Jangda et al., 2019)

Summary of Findings

The table 3 depicts that public cloud provider has seen immerse growth in terms of adoption due to the covid19 restrictions (Aggarwal, 2021; Gokarna, 2023). Amazon Web Services gaining the most growth of 15% from the previous year as more people tend to move their business to the cloud. The least growth recorded was recorded by IBM public cloud, 1% followed by Alibaba, 4%.

In contrast to public cloud, some private cloud providers have not seen much adoption of their services in 2020 compared to the previous year. Bare-Metal cloud saw a negative adoption rate of -3%, VMware Cloud Director and Cloud Stack recorded a reduced adoption by cloud users of -1% each while OpenStack had no increment nor decrement in the adoption rate. Though some providers might have had a rough time during the pandemic other private cloud providers like AWS

Outpost (11%), VMware vSphere (8%), and Microsoft Azure Stack (13%) had a rise in adoption rate (Haider, 2021). The fastest growing cloud Platform-as-a-Service (PaaS) services for 2019 and 2020 is shown in the table 3 (Jones, 2021). The growth rate for the various cloud services provide visibility into how enterprise usage is changing over time. All five had a significant growth in 2020, with container as a service being the fastest among the five.

Table 1: Public Cloud Providers Growth (2018 - 2020)

| S/N | Cloud public Providers | 2019 | 2020 | Growth Difference |
|-----|-----------------------------|------|------|-------------------|
| 1 | AWS | 61% | 76% | 15% |
| 2 | Azure | 52% | 63% | 11% |
| 3 | Google Cloud | 19% | 35% | 16% |
| 4 | VMware Cloud on AWS | 12% | 17% | 5% |
| 5 | Oracle Infrastructure Cloud | 11% | 17% | 6% |
| 6 | IBM Public Cloud | 12% | 13% | 1% |
| 7 | Alibaba Cloud | 3% | 7% | 4% |

Figure 4 shows a survey report by CBInsight of serverless computing application usage from 2016 to 2021. This report clearly establishes the fact that, the use of this technology has not only impacted and sustained businesses during the COVID-19 era but has become new normal. The use of serverless computing technology by organizations in the post-

COVID-19 era has witnessed an unprecedented growth. The CB Insights Market Sizing tool estimates that the serverless computing industry will grow from around \$1.88 billion in 2016 to \$7.72 billion by 2021, reflecting a compound annual growth rate of 33%.

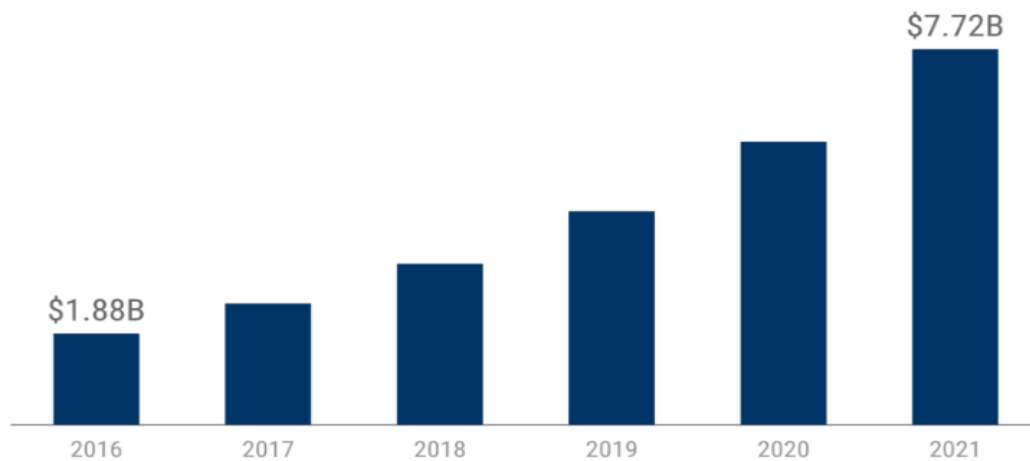


Figure 2: Survey Chart Showing Serverless Application usage statistics (2016-2021) (CBInsight, 2024 Report)

2020, as described by most respondent in the survey was the year their usage of Serverless computing applications increased due to the lockdown imposed by the government. Figure 5 demonstrated the how the usage of serverless

computing heighten up in 2020 and the projection increased by years. Figure 5 shows the aadoption of serverless status by organizations worldwide from 2019 to 2022

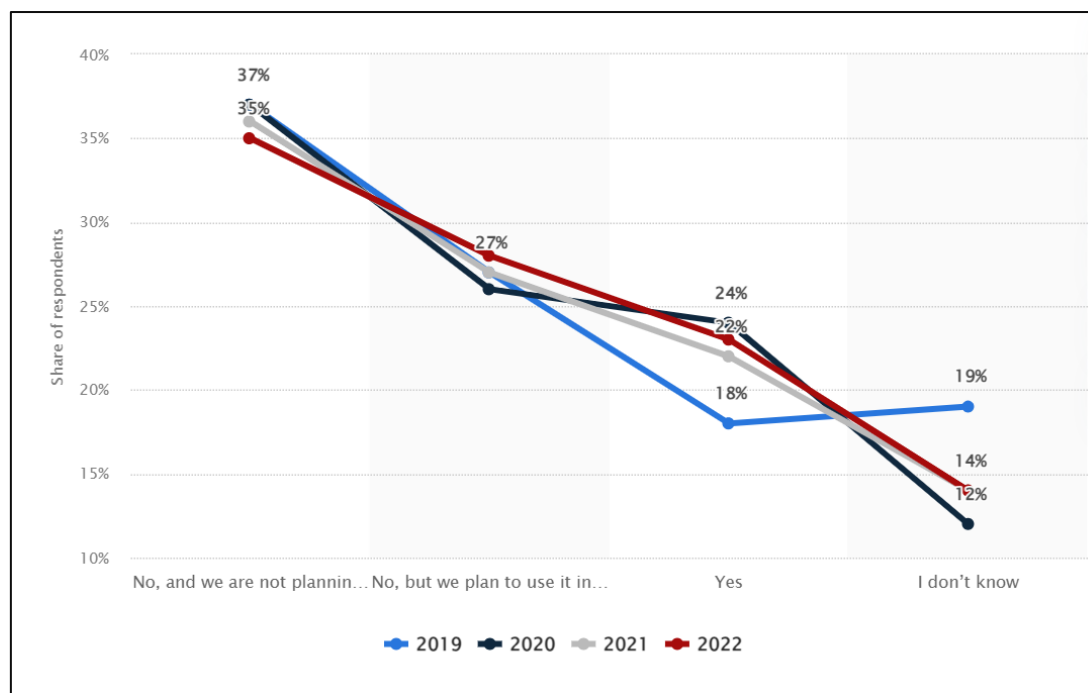


Figure 5: Adoption of serverless status by organizations worldwide from 2019 to 2022 (Statista, 2023)

This statistic illustrates how companies used serverless computing in their operations from 2019 to 2022. In 2019, 2020, 2021, and 2022, a total of 37%, 37%, 36%, and 35% of respondents stated they did not have serverless computing and had no intention of using it in the next 18 months. The adoption of serverless computing for 2019, 2020, 2021 and 2022 as depicted by respondents, 18%, 26%, 22%, and 23% consecutively, said their organization uses serverless computing. In contrast to previous years, serverless computing saw a greater rate of adoption in 2020. After that, it increased consistently to 2022 as depicted in Figure 5.

Recommendations

To introduce Serverless computing and familiarize people with it, hundreds of Serverless conferences and workshops have been held over the last couple of years. What needs to be taken into consideration is that there are still many details that need to be discussed and resolved when it comes to transitioning companies from traditional solution to Serverless.

Here are some of the weaknesses to consider:

- i. Monitoring invoked functions
- ii. The security of third-party dependencies
- iii. The cost of adding another integrated cloud solution
- iv. Vendor lock-in which makes migration to another service tough
- v. Implementation drawbacks (test and debugging, long-running processes, request to cold start a code)
- vi. Architectural complexity

However, the benefits of cloud computing are still auspicious. Considering that 69% of IT leaders identified “process automation and transformation” as the primary focus of their digital agendas (Jyothylakshmi, 2023; Shah, 2023), according to the 2018 Deloitte global survey, we can expect to see much more of Serverless computing in the years ahead.

Future Directions

Serverless computing is relatively new and evolving domain, it will require several research paths can be conducted to focus on as followings:

Quality of Service

A significant barrier to cloud providers offering ideal performance metrics is maintaining a guaranteed QoS level in the software level agreement (SLA) (HoseinyFarahabady et al., 2017) that outlines the lower service level provided by the service providers (Kim et al., 2018; Asghar et al., 2018). Customers and developers have little to no control over QoS (Shahrad et al., 2019), hence serverless frameworks should take into account the goals of both providers and consumers (Mohanty et al., 2018). Furthermore, there are no QoS assurances in the auto-scaling capability. Serverless application performance is impacted by this lack of QoS. Efficient framework can be developed to integrate developers and customers input in the quality-of-service delivery.

Function startup

Initializing the necessary libraries on the first function call will result in a cold start (Carver et al., 2019; Aditya et al., 2019). Finding scalable solutions to the cold start issue without compromising serverless's key characteristic of scaling to zero is one of the main research opportunities in serverless computing.

Pricing

Cost is important to cloud providers as well as customers. However, since serverless providers, developers, and service end users have different needs, there is a lack of pricing models (Shahrad et al., 2019). According to Wang et al. (2019) and Crespo-Cepeda et al. (2019), the majority of cloud providers base their price on the quantity of resources consumed as well as the number of function requests and execution time. At the moment, functions bound to I/O are less expensive with FaaS than those bound to CPU. Furthermore, constantly adjusting resource-consuming services cannot forecast the advancements in optical computing technology. Thus, it is imperative to implement technologies that provide affordable computing resources (Horowitz et al., 2019). Machine learning algorithms can be developed to predict and determine accurate price. Price estimation has a great impact on selecting the most optimal

provider. Therefore, there should be more researches on developing tools to predict the pricing in advance.

Testing and Debugging

Given that the testing, debugging, and deployment tools are still in their infancy, some developers are unable to work in the serverless environment. One of the main issues with FaaS is the lack of tools, especially testing tools (Leitner et al., 2019). Furthermore, the majority of FaaS settings lack adequate local emulation tools for testing. Due to this, developers mostly rely on the costly server-side. Study can be conducted to determine standardized tools for testing and debugging. Developers need to be ensured of the adequate testing tools before deploying serverless computing.

Benchmarking

A challenging aspect in benchmarking is the lack of information due to the heterogeneity of the cloud provider data center: hardware, software, and configurations (Martins et al., 2020). Additionally, benchmarking FaaS platforms should take advantage of analyzing the cloud services, which lacks limited accessible measurements and hidden modification of services over time (Kuhlenkamp et al., 2019). Thus, researches can be conducted to evaluate the operations of serverless computing and produce technical document that will ensure that operational processes are transparent, fair, and standardized benchmarking tools are available for developers.

CONCLUSION

The contribution of this study is in three folds: (i) the paper presented a review of related literature on the topic of serverless computing and address its' impact on businesses pre-COVID-19, COVID-19 and post COVID-19 era. (ii) Evaluated seven fastest growing cloud Platform-as-a-Service (PaaS) services for 2019 and 2020, the impact of the technology on their businesses and their growth differences. (iii) This review undertakes an extensive analysis of the differences, benefits, and challenges associated with serverless computing to provide a more comprehensive understanding of the topic. Given the rapid evolution and increasing interest in the domain, it focuses on identifying the most significant trends and findings in serverless computing, as reported by recent researchers.

The COVID-19 pandemic has profoundly accelerated the adoption and evolution of serverless computing technology. As businesses and organizations worldwide faced unprecedented challenges, the agility, scalability, and cost-efficiency of serverless solutions became indispensable. This study highlighted serverless computing's potential to handle unpredictable workloads and rapid scaling needs, proving its worth in ensuring business continuity and enabling digital transformation. The pandemic has not only validated the importance of serverless computing but also driven innovation and investment in this field. Moving forward, the lessons learned and the advancements made during the covid-19 and post-covid-19 time will continue to shape the future of computing, cementing serverless technology as a cornerstone of modern IT infrastructure.

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