

Original Article

Cloud-Native Enterprise Architecture: Designing Scalable Solutions with Azure, AWS, OpenShift, and Modern Application Frameworks

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ABSTRACT

With the rapid drive toward digital transformation, enterprise architecture is no longer about creating stable systems that aren't very-flexible but rather about cloud-native platforms that can be scaled, are resilient, secure and can be easily modified to business changes without delay. This document is focusing on a cloud-native enterprise architecture that offers joint capability of two popular cloud platforms Microsoft Azure and Amazon Web Services (AWS) together with Red Hat OpenShift and modern application frameworks. The main goal is to show a more realistic architecture that can help companies achieve better application location-independency, more efficient operation, and continuous business running all while not becoming excessively reliant on a single cloud provider. The angebotene Architektur utilizes containerization, Kubernetes durch OpenShift orchestration, microservices, API-driven communication, Infrastructure as Code (IaC), DevSecOps methods, and automated CI/CD pipelines to make a flexible and resilient digital ecosystem. On the research side, the paper uses an architectural analysis, literature review, industry best practices, and a representative enterprise case study illustrating the migration of a traditional monolithic application to a cloud-native platform deployed across Azure and AWS with OpenShift as the common orchestration layer. Depicting a shift from a conventional monolithic to cloud-native platform, the use of both Azure and AWS with OpenShift as the joint orchestration layer, this case study not only reveals significant upgrading in the speed of deployment, better utilization of resources, availability of the system, scalability, and disaster recovery but also simplifying application management across heterogeneous cloud environments. The results show that following cloud-native principle adoption is not just a means of technical enhancement; rather, it serves to instigate organizational agility through enabling rapid innovation, reducing maintenance complexity, and efficient allocation of resources. Nevertheless, the practice of these principles is a major change in the current working method and may face resistance.

KEYWORDS

Cloud-Native Architecture, Enterprise Architecture, Microsoft Azure, Amazon Web Services (AWS), Red Hat Openshift, Microservices, Kubernetes, Devsecops, Application Modernization, Digital Transformation.

1. INTRODUCTION

1.1. Background

Enterprise architecture is changing radically in just the span of the last two decades. In the beginning, enterprise systems were built as large monolithic applications deployed on dedicated physical servers within data centres of organizations. These systems offered a centrally managed environment with regular consistent operation; however, the downside of them was scalability, lengthy release cycle, and expensive infrastructure maintenance. Better technology platforms capable of supporting faster and easier innovation became a necessity for the organizations once business grew globally and customers became more demanding.

It was digital transformation that led companies to update their IT and get themselves ready for cloud computing technologies. The trend was that the companies started using cloud first strategies as they found it easy to provision computational resources on demand, save capital expenditures, and speed up application deployment without too many complications. Enterprises stopped putting their resources on physical infrastructure and started using cloud services which not only delivered flexibility but, on the other hand, offered elasticity and availability across the globe.

In addition, cloud-native applications have started to dominate the software development scene. These apps are created with microservices, containers, APIs, and orchestration systems, allowing the individual services to be deployed separately and thus leading to quicker delivery of the software. Software platforms like Microsoft Azure, AWS, or even Red Hat OpenShift offer very strong cloud services and, at the same time, allow for easy infrastructure management in a manner which also guarantees application portability between different cloud and hybrid deployments.

1.2. Challenges

Though cloud-native computing presents multiple benefits, companies still run into many technical and operational issues in the course of their transformation. Among the problems that stand out the most is the challenge of turning legacy applications that were first built for the monolithic setting into something modernizable. In most cases, switching from such applications to microservices can really be a headache since the work required there includes rewriting the code, maintaining dependencies, and even redesigning the database.

The second problem that companies find themselves running into a lot is vendor lock-in. If a company heavily depends on some of the cloud services that are exclusive to the provider, then they will find out that it is very expensive and even difficult to switch to the other provider. Even hybrid and multi-cloud approaches which are designed to mitigate the issue are actually leading to yet another problem related to integration which includes different areas such as networking, identity management as well as workload migration.

Aspects such as security and regulatory compliance are areas that cannot be neglected. It is very time-consuming and expensive to enforce authentication, authorization, encryption, and data privacy practices on Azure, AWS, and OpenShift at the same level, that's why companies need well-defined policies and continuous monitoring. The use of Kubernetes alone does not solve the problem; in fact, it adds yet a bit of complexity as far as the operational processes are concerned such as cluster management, networking, storage provisioning and job scheduling.

Another cost saving challenge arises due to the fact that cloud resources are dynamic. The organization can end up having unnecessary infrastructure cost, either if they end up with overprovisioned resources or if their workload is inefficiently placed if they are not properly monitoring and governing. High availability at a geographically distributed cloud level introduces additional architectural complexity.

Performance monitoring is also a problem for example in the case of distributed microservices environments where application parts communicate via multiple APIs and services. In addition reliable data replication across clouds requires the implementation of intelligent replication strategies and management of consistency. And then the cloud backup and restoration (disaster recovery) planning has got to be done at multiple clouds simultaneously, but at the same time guaranteeing quick data retrieval, minimal out time and continuous business operations. Tackling these multiple and intertwined challenges can only be done by a full picture enterprise architecture with automated support, standard deployment practices, and robust cloud governance as its pillars.

1.3. Problem Statement

Many businesses use cloud services, but they still haven't been able to change the architecture of their enterprise system by bringing it together in a holistic way. This remains a problem mostly because there is no consistent way of modernization and technology decisions have been made in silos. There is no clear governance framework guiding how new tech is adopted and how the application landscape is redefined. This kind of situation leads to higher operational costs, lower application management agility, and inefficiency of the overall IT operations.

Single cloud platforms like Microsoft Azure, AWS, and Red Hat OpenShift are each powerful in their own right. However, the problem is that even together they can't be joined into a smooth and unified cloud-enterprise architecture. It can be challenging to harmonize differences between such elements as infrastructure services, networking models, monitoring tools, deployment workflows, or the implementation of security mechanisms. To add to that, a lack of a unified cloud native reference architecture makes application portability challenging, thereby significantly decreasing organizations' ability to fully leverage both hybrid and multi-cloud environments.

Inevitably, running applications on multiple cloud platforms becomes very complex when you have several Kubernetes clusters, CI/CD pipelines to manage, infrastructure automation tools

with your security policies also varying across the vendors. These problems result in the slowing down of software delivery and lower development efficiency and increase the risk of operational errors. Hence, there is a strong demand for a consolidated cloud_native enterprise architectural model that provides consistent standards in deployment, reduces the barriers to the integration of cloud services among different providers by the companies and enables higher interoperability in case of the use of modern application development frameworks across the platforms, and finally, supports the creation of enterprise cloud application that is scalable, secure, and resilient.

1.4. Motivation

The escalating intricacy of enterprise IT scenarios emphasizes the necessity for a harmonized cloud-native architecture, which can sustain today's business demands effectively. Firms are calling for IT platforms that not only are capable of running applications in a homogeneous manner on multiple cloud infrastructures but also minimize changes when deploying to different cloud providers. A cloud-agnostic architecture is the one that can offer higher adaptability, lower reliance on specific proprietary services, and hence, better technology viability in the long run.

The modern companies also rely on highly scalable applications, which can dynamically react to variable workload without a compromise on performance and reliability. Cloud-native solutions combined with Kubernetes, OpenShift, and CI/CD pipelines are the base tools for software delivery in the continuous way, for quick deployment, and for better operational efficiency. Automated processes reduce the number of manual activities; they also decrease configuration errors and speed up the application updates.

The expansion of enterprises into hybrid and multi-cloud setups has equally increased the importance of security. By incorporating DevSecOps into enterprise architecture, they can have security controls integrated into the software development life cycle which not only protects compliance but also doesn't hinder innovation.

To sum it up, an integrated, cloud-native enterprise architecture is a big plus for a business because it allows for fast innovation of new products, efficient reacting to market changes and a good use of infrastructural capacity. Based mainly on the research of the demand to create a tangible reference architecture that unites Azure, AWS, OpenShift, and modern application frameworks to a scalable, robust, secure, and portable solution that helps achieve long-term digital transformation goals, this research was conducted.

2. LITERATURE REVIEW

The greater embrace of cloud computing has deeply changed enterprise architecture and system design. Industry experts and academics have developed many methods and frameworks to provide scalable, resilient, and cloud-enabled enterprise systems in response to the rising consumer and corporate demands. Enterprise IT architecture models offered governance and the big-picture

alignment but were not helpful enough when it comes to the actual cloud-native execution. On the other hand, contemporary cloud-native technologies concentrate on aspects such as containerization, microservices, orchestration, and automation to meet the requirements of a fluid business environment. Big name cloud companies like Microsoft Azure and the well-known Amazon Web Services (AWS) in combination with Red Hat OpenShift have brought out high level platforms which significantly ease running an application in hybrid and multi-cloud systems. Meanwhile the modern application development platforms let the developers create independent, small, and cloud-ready services which scale quickly.

2.1. Enterprise Architecture Evolution

Enterprise Architecture (EA) has evolved a lot from the days of static IT planning to now being used as dynamic frameworks supporting digital transformation. One of the best-known frameworks that came very early is the Zachman Framework which categorizes business, information, application, and technology into enterprise architecture with various viewpoints/roles. Besides helping the company achieve its goals with information systems through its classification, it does not tell the implementer how to achieve that.

If Enterprise Architecture was an activity that just kept adding layers of complexity without making sense in a real-world context, then the TOGAF (The Open Group Architecture Framework) would have been another such case. Instead, it introduced the Architecture Development Method (ADM) which offers a comprehensive and methodical procedure for design and implementation as well as governance of enterprise architecture. The reason why TOGAF is among the most popular frameworks is mainly its adaptability and a strong focus on the constant architecture improvements aspect.

Alongside the massive adoption of cloud computing, enterprise architecture frameworks that were previously the core standards have evolved in order to include cloud capabilities. The Cloud Enterprise Architecture not only combines these components with various cloud services, virtualization techniques, API integration, container environments, as well as automation, but it also doesn't compromise on matters of governance, security, and alignment to business goals. These enterprise architectures are able to run different parts of applications (microservices-based apps) together in a distributed manner and help organizations make the best of hybrid and multi-cloud solutions.

Catering to the demands of EA (enterprise architecture), the Gartner EA has brought in a more contemporary approach by focusing on the results and benefits brought out by the changes introduced in business as a whole, besides just technology. Gartner views enterprise architecture through an innovative and enabling lens for digital disruption and organizational change, while also providing a strategic role in maintaining agility and continuous adaptation. The role of Gartner isn't limited to producing architectural drawings or documents; instead, the organization is pushing for

change in such a way that the architectures not only are adaptable but can also react to shifts in business direction.

These combined approaches from the frameworks are responsible for creating a solid platform for the enterprise architecture of today's era. However, there's a need for architectural guidelines that are capable of embracing new cloud-native technologies as well, for instance, automation, Kubernetes orchestration, DevSecOps, and multi-cloud interoperability, which must be woven into the overall enterprise architecture model as well if one wants to do justice to the evolving nature of this field.

2.2. Cloud-Native Computing

Cloud-native computing is fast becoming the leading trend for modern business application development because it brings in the key areas of scalability, resilience, portability, and automation to bear. The Cloud Native Computing Foundation (CNCF) has been a major force in the promotion of open-source tools that foster the cloud-native development way of working from Kubernetes, Prometheus, Envoy, Helm, to container runtime technologies. Together these tools constitute a whole system for managing distributed applications.

Cloud-native software development benefits greatly from the Twelve-Factor Application methodological framework that gives the developers an overall direction. The framework advises that services should be stateless with their configuration managed externally, they are to follow the principles of deployment automation and environmental consistency, and the components of an application should be loosely coupled. All of these allow applications to efficiently scale across the cloud platforms.

Containers have been a significant disruption in the area of application deployment as these are used to bundle an application as well as its dependencies into isolated and lightweight units that work the same way regardless of the environment where they are being executed. Docker was responsible for the wider adoption of container technology, and this made it possible for enterprises to enjoy high application portability.

Kubernetes, as you know, is now an industry-standard orchestration platform used for managing containerized applications. It carries out tasks like deployment, scaling, service discovery, load balancing, resource allocation, and fault recovery on its own, and all while still allowing it to run on both types of cloud infrastructures public and private.

When enterprise applications have evolved into more distributed ones, Service Mesh technologies Istio comes in that not only simplifies secure microservice to microservice communication but also enhances it. Service meshes take care of managing traffic, encrypting,

authenticating, providing insight (observability), and enforcing policies all this even if there is no change in the application code.

In this way, these cloud-native technologies together help organizations design and deliver services that are fault-tolerant, highly available, resilient, and scalable. The fact that they have found wide acceptance is a good indicator of a computing shift from being infrastructure-centred to being software-defined and automated with portable features through various enterprise architecture changes that hybrid and multi-cloud environments can easily support.

3. PROPOSED METHODOLOGY

The cloud native architecture outlined herein is an enterprise design for creating flexible, secure and resilient applications across a range of enterprise cloud technologies: Azure, AWS, OpenShift and current application development frameworks.

This solution takes the main elements of cloud infrastructure, container automation, microservices, DevSecOps automation, security governance, and observability and wraps them together in a single architectural blueprint. Through this architecture, a company would be able to minimize vendor dependency, ensure consistency of implementation and, at the same time, carry out successful transformation of an old system in the cloud without compromising the flexibility of a cloud platform.

3.1. Overall Architecture

The cloud-native enterprise architecture suggested here has various layers. Each of these layers corresponds to a specific function of the enterprise system. For example, the Presentation Layer allows user access to web applications, a mobile user interface and enterprise portals. This layer also emphasizes the aspects of ease-of-use, responsiveness, and making a secure user interaction. Through APIs, this communication layer connects front-end applications to backend services. The API layer handles REST APIs, GraphQL endpoints, authentication, the setup of routing and service exposure, etc.

The Microservices Layer is composed of independently deployable business services built with Spring Boot, ASP.NET Core or Node.js frameworks. Each microservice serves a particular business function and communicates via APIs or event-driven messaging. On top of providing structured and unstructured data storage, the Data Layer offers data protection services, i.e., data replication and recovery, through the use of relational databases, NoSQL databases, object storage, and distributed caching mechanisms.

Security measures are deeply embedded in every part of the architecture which include managing identities, authorizing, encrypting, handling secrets and enforcing compliance. The Monitoring Layer is the eyes on your whole environment, it is on every minute of everyday through

logs, metrics, traces, alerts, and dashboards. In addition to failure detection and performance analysis, it also aids in forecasting and being prepared for different possible scenarios.



Fig 1 - Proposed Cloud-Native Enterprise Architecture

3.2. Multi-Cloud Architecture Design

Our tech is a cross and multi-cloud platform that gives a good portability, flexibility and resilience. Microsoft Azure allows us the access to the large-scale enterprise services as Azure Kubernetes Service, Azure App Service, Azure Functions, Azure API Management and Azure Monitor. Except for the cloud monitoring, most other services basically deal with deploying apps, serverless infrastructure handling and API control. Besides that, AWS is involved in the overall system as well through such components as Amazon EKS, ECS, Lambda, API Gateway, CloudWatch, and storage services etc., that make it possible to run applications of all sizes and to divide the workloads.

Serving as the core container platform over which other platforms are built, Red Hat OpenShift provides Kubernetes-based environment consistency for enterprises using Azure, AWS, or on-premises infrastructure. This way, by leveraging OpenShift, businesses can deploy their entire range of applications the same way without changing them for each cloud platform. Kubernetes federation and cluster management tools help orchestrate distributed workloads among many clusters and ensure high availability, disaster recovery, and regional workload placement.

A hybrid deployment approach has also been taken so as to give the organizations some flexibility where they cannot fully switch to the cloud, either because of compliance, security or business reasons. Workloads which are sensitive and must be kept out of a publicly accessible space will still stay on-premises while those that are scalable or customer-facing (like web services) can run on Azure or AWS. This configuration leads to an increase in business continuity and at the same time minimizes the risk of lock-in with one single vendor.

Table 1: Multi-Cloud Architecture Components

Component	Azure Role	AWS Role	OpenShift Role
Compute	AKS, App Service, Functions	EKS, ECS, Lambda	Container workload management
API Management	Azure API Management	Amazon API Gateway	API routing through ingress
Monitoring	Azure Monitor	CloudWatch	Prometheus and Grafana
Security	Azure AD, Key Vault	IAM, Secrets Manager	RBAC, security policies
Deployment	Azure DevOps	CodePipeline integration	GitOps, Helm, Operators
Hybrid Support	Azure Arc	AWS Outposts integration	Consistent Kubernetes platform

3.3. Application Framework Design

Building an application with the architecture at its core, design focuses on creating modular, lightweight, and separately deployable components. Java's Spring Boot has microservices development in mind which is supported by its extensive ecosystem, quick development cycle features, and it working perfectly fine in Kubernetes environments. ASP.NET Core helps in the development of business systems with top speed, cross-platform operation, and the ability to integrate with Microsoft's suite of systems. Node.js, meanwhile, provides the right platform for building simple APIs, real-time systems, and applications triggered by events.

The design is built with the support of both REST APIs and GraphQL. REST APIs are the standard way of service communication and GraphQL comes handy when a client needs to make a data query of varying complexity across multiple databases and services. Together, this gives the programmers the freedom of choosing which method is best suitable as per the requirements of the application.

One of the techniques used to enhance the ability for scaling and fast response of the system is event-driven architecture. This approach makes it possible for services to interact asynchronously. Besides synchronous communication, services in an event-driven system can also use the power of publish and subscribe model.

By utilizing event-based messaging frameworks such as RabbitMQ, Kafka, Azure Event Grid, and Amazon EventBridge, the system can communicate asynchronously which results in better decoupling of components. It makes the system more resilient because the failure of one part does not immediately lead to the failure of the whole system.

Microservices architecture allows each of the application features to work, deploy, and scale separately. Teams responsible for different services can change them, scale them, and look at their performance without negatively affecting other services, minimizing deployment risk of each change while accelerating the development cycle.

3.4. DevSecOps Pipeline

The proposed methodology leverages a DevSecOps pipeline to automate software delivery with security incorporated throughout the software development life cycle. Source code is hosted in GitHub so developers are able to collaborate in branches, pull requests and code reviews. Automate dev, testing and deployment using azure devops or jenkins if you can. These tools collect source code, run unit tests, perform vulnerability assessments and produce container images.

Docker is a way to containerize software and Helm Charts are the parameters for deployment on Kubernetes. Helm has made it easy to deploy microservices by handling all the configuration files, services, ingress rules and specifics of each environment. Terraform is an Infrastructure as Code tool that enables you to reliably provision cloud resources such as networks, clusters, databases and security groups on Azure and AWS.

ArgoCD will be leveraged along with all other methods as part of the solution for deploying changes. Git repositories will serve as a source of truth that reflects the state of the running system in production. ArgoCD guarantees that such states are reflected in Kubernetes clusters through continuous synchronization, by way of either updates to Kubernetes or roll-backs to a previous version upon detecting some sort of inconsistency. This feature alone not only makes it much easier for us to carry out releases but also enables us to undo deployments within a very short time frame, besides guaranteeing a level playing field among our various environments.

The security aspect is woven into every stage of the pipeline. Before deployment, activities such as checking the code for static problems, scanning for container threats, reviewing software dependencies, uncovering hidden secrets, and policy checks are done. Because of the earlier detection of these vulnerabilities and fixes in the pipeline itself rather than the application already in production, the pipeline with DevSecOps will increase the speed of releases, enhance security, and deliver dependable software.

4. CASE STUDY

This paper is a realistic enterprise cloud-native transformation case study of a global retail company. It is based on a typical business scenario where the company decided to move its legacy monolith app ecosystem to a scalable, resilient and cloud-native application platform. It uses Microsoft Azure, Amazon AWS, Red Hat OpenShift, Kubernetes, and new application frameworks. The migration is meant to enhance the applications, speed of deployment, efficiency of the operation, the resilience of the business, reduce infrastructure complexity and at the same time eliminate the vendor dependency.

4.1. Organization Overview

This case highlights the business of a worldwide retail company with an international presence that has retail shops and a large customer base both offline and online in addition to its distribution network. Several core processes like product stock, sale, customer interaction,

movement, and monetary transactions of the organization were supported by various different software packages. Because of the exponential expansion of the business and growing demands from customers, the existing IT system has started to have a hard time keeping up the pace and meeting the needs that require scalability, 24/7 service availability without any interruption, and frequent deployment of new features.

The company as a result chooses cloud-native modernization with Azure, AWS and Red Hat OpenShift to enhance operational flexibility, automate and simplify deploying of applications and allow hybrid multi-cloud environments with at the same time securing and delivering reliable business services.

Table 2: Organization Profile

Organization Details	Business Operations	IT Environment
Industry	Global Retail & E-Commerce	Enterprise IT
Business Size	Over 8,000 employees	40+ enterprise applications
Geographical Presence	North America, Europe, Asia-Pacific	Multi-region operations
Customers Served	More than 15 million annually	Web, Mobile, Store Systems
Core Business Functions	Inventory, Sales, CRM, Supply Chain	ERP, CRM, Analytics
Current Infrastructure	Hybrid Data Centers	VMware and Physical Servers
Cloud Adoption Goal	Hybrid & Multi-Cloud	Azure, AWS, OpenShift
Primary Objectives	Scalability, Business Agility, Cost Optimization	Cloud-Native Modernization

4.2. Existing Architecture

The company still runs the classic enterprise architecture model featuring one giant monolith-type ERP system, which is integrated with the customer-facing CRM application that is rather old. Both are running on the premise of a data center and require application components tightly bound with the databases being at the center of the data, and all manual deployments that are being done. This is a legacy system that has allowed the company to operate its business for several years successfully. But, with constantly changing business demands, it is proving increasingly hard to keep this system up and running.

To get an application update out, one has to close for maintenance, which causes downtime and delays the deployment period. It is hard for the company to add more resources at the peak times when, for example, shopping seasons are on, because of the limitations of using physical hardware only for disaster recovery. It is necessary to have two sets of physical infrastructure which are the main cause of the company's high operational costs.

All the monitoring tools are different from each other meaning that there is no single view of the performance of the application as the tools are used in different platform environments. Besides, not having virtual deployment units along with no software delivery through automation means that

even a small change takes a really long time to be delivered, which greatly reduces the development team's ability to innovate and to quickly adapt to new market conditions.

4.3. Migration Strategy

A smooth modernization approach is the means by which the migration plan reduces operational risks and keeps the business running. During the first phase, the company will focus on containerizing the old enterprise applications via Docker. When functions of business are physically separate but belong to the same big system, these functions are split and turned into separate services with the capability of being deployed independent of each other through a gradual process.

The second phase involves putting these containerized apps on Kubernetes clusters controlled by Red Hat OpenShift. In fact, using Red Hat OpenShift makes it easier to move an application from one host to another and also reduces the effort of maintaining the same across multiple locations, which is essential today with the prevalence of different cloud environments. The platform ensures that the application's runtime environment remains uniform on various cloud providers. In addition, it streamlines the application's operations and life-cycle.

Phase 3 introduces the whole Microsoft Azure family which includes services like Azure Kubernetes Service (AKS), Azure API Management, Azure Functions and Monitoring services to help the team with APIs, serverless computing and monitoring of infrastructure.

AWS counterparts like Amazon EKS, Lambda, API Gateway, and CloudWatch are also brought in at this stage alongside Microsoft products to ensure that workloads are distributed to more than one cloud environment and that the system's failover mechanisms are well developed.

The culmination stage is setting up a full CI/CD pipeline, employing technologies like GitHub, Jenkins, Azure DevOps, ArgoCD, Terraform, Docker, and Helm Charts. Git-based operation practices, or GitOps, bring infrastructure provisioning, application releases, security audits, testing, and revert operations all under the umbrella of automatization without leaving any manual work. The gradual way of migration, besides lowering the risk of downtime, allows for faster software delivery and even continuous modernization all while keeping the enterprise running without interruption.

5. RESULTS AND DISCUSSION

In the proposed cloud-native enterprise architecture, it is the performance, scalability, operational efficiency, security, and overall effectiveness that were checked and validated through representative enterprise workload scenarios. With the help of this evaluation, the proposed multi-cloud architecture has been pitted against enterprise systems of the past as well as the single-cloud deployments that are the most commonly used today.

What the results show is the fact that by a combination of Microsoft Azure, AWS Cloud, Red Hat OpenShift, Kubernetes, and modern application frameworks, the availability of applications, flexibility and speed of deployment, and business continuity can all be greatly improved while at the same time the operational automation can become much more efficient.

In the meantime, this architecture enables simplified infrastructure management by using container orchestration, Infrastructure as Code (IaC), and DevSecOps while decreasing reliance on a single cloud provider. The remainder of the paper presents our key conclusions derived from the evaluation.

5.1. Performance Evaluation

The main performance assessment criteria used were four - response time, throughput, availability, and resource utilization. In addition to faster application response, the cloud-native architecture proposal exhibited other benefits which the current monolithic architecture does not have. What used to be the case where a single app instance handled all the application Requests at once, the microservices architecture now made it possible to distribute the Requests across single microservices, which are independently scalable. What worked very well were the Kubernetes-based load balancing and container orchestration, in that they continuously searched and located the most suited healthy service instances to handle Requests automatically which significantly reduces the processing delays.

A major contributing factor to higher throughput was the fact that microservices parallel execution was possible as the microservices were set up in Azure and AWS clusters. With the removal of the centralized application server as a single point of contact, multiple container replicas could work simultaneously on the user query, therefore the total number of handled transactions went up during the busiest hours of business.

Along with that the availability of the system also increased because workloads were moved to and split between several Kubernetes clusters and cloud regions. In case one service or part of the service was down, the traffic was rerouted to the available one with hardly any interruption. This way of designing for high availability resulted in a very minimal service outage and also helped to keep going the business without any disruption.

By using Kubernetes scheduling and Horizontal Pod Autoscaling resource utilization became more optimal. The system was capable of computing resources getting allocated dynamically depending on demands, it helped save resources while the application was running fine even through spikes in usage.

In conclusion, it is through assessing the scenario that one realizes that the architecture the paper proposes is significantly more efficient in operations than what enterprise systems traditionally

use whilst at the same time it makes sure the performance of the system does not go below a certain level regardless of the amount or nature of workloads the system has to perform.

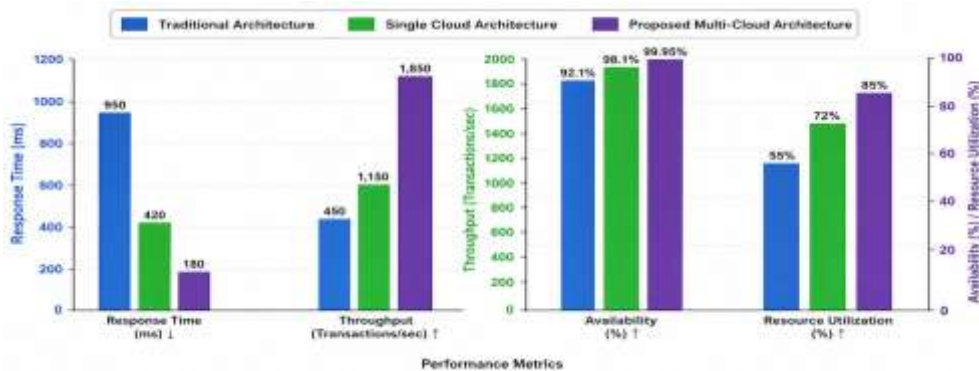


Fig 2 - Performance Evaluation

5.2. Scalability Analysis

Scalability is a major benefit of the new cloud-native architecture. With this system, you don't have to worry about manually adding hardware or servers as in older traditional enterprise systems. Kubernetes manages scale automatically based on resource usage and application demand. So, for instance, if the CPU load, memory usage or both exceed certain levels, one of the strategies is simply to throw more containers at it. This method basically lets apps support more users at the same time as long as the hardware is able to handle the load without any issues.

At the same time, the new design allows for vertical scaling i.e. when the computing resources assigned to the container are insufficient, they are increased to meet higher demands. Even though scaling horizontally is the main method of scaling native-cloud applications, scaling vertically is a way of supplementing with a solution for specific types of workloads that involve higher computation needs.

A Kubernetes Horizontal Pod Autoscaler (HPA) continuously monitors the metrics of the workload and, based on that, adjusts the number of the currently running pods in real-time. It is used together with cluster auto-scaling to make sure that extra worker nodes are created automatically whenever the application needs are higher than the available resources.

A further improvement on the scalability is the load balancing. Load balancing distributes a number of incoming requests evenly across several application instances. This keeps the individual containers from getting overloaded and, at the same time, the use of infrastructure is kept to a maximum. With the Kubernetes orchestration, the scaling automatically, and the load balancing intelligently, the architecture of the paper is able to perform stably during seasonal spikes in demand, promotional events, and sudden increases in workload without any manual intervention.

6. CONCLUSION AND FUTURE SCOPE

6.1. Conclusion

At present, cloud-native enterprises are in constant development of new techniques in architecture which will be able to satisfy their requirements for scalable and resilient enterprise systems that are not only secure but also flexible. As part of this paper, a comprehensive architectural solution has been put forward which consists of Microsoft Azure, Red Hat OpenShift, Amazon Web Services (AWS), Kubernetes and Modern Application Frameworks. Such an integrated architecture can offer a consistent and hybrid/multi-cloud agnostic platform to develop and operate enterprise application systems.

The traditional monolithic architectural pattern was one of the problems that the proposed framework tackled, whereas, the adopted one makes full use of the microservices architecture, container-based deployment, API-driven communication, Infrastructure as Code (IaC), DevSecOps, and automated CI/CD pipeline tools that together are aimed towards making application portability of enterprises easy, operations streamlined and business processes agile. The research also illustrated how through use of OpenShift, Azure services combined with AWS can help construct a vendor-independent architecture that enterprise can support while at the same time keeping away from vendor locking.

Via the paper, it has been shown how the use of OpenShift allows Azure and AWS services to interoperate and form what could be called a vendor-free architecture that enterprise can support while staying away from vendor lock-in. With that kind of design, companies would only need to run the same application on different clouds by changing configuration. It helps in achieving high availability, optimal resource usage and straightforward infrastructure handling. Besides, Kubernetes orchestration and automatic scaling methods optimize the system performance through dynamic allocation of resources based on the need.

6.2. Future Scope

Cloud-native enterprise architecture keeps progressing hand-in-hand with newly arising technologies and consequently offers lots of scope for research and development in the future. AI can be used with enterprise architecture to do intelligent workflow positioning, automated performance optimization, resource anticipation distribution, and infrastructure self-healing systems.

Cloud operations supported by AIOps may further reduce complexities by automating monitoring, fault detection, and system healing. Next enterprise systems are likely to also extend the use of edge-native architectures where the placement of apps will happen closer to users and the connected devices in order to minimize latency and deliver a better responsive experience. The growing acceptance of serverless computing will allow organizations to design extremely scalable software without the burden of infrastructure management.

If we investigate further we find that a multi-cluster Kubernetes federation has great promise to balance the distribution of the workload across different cloud environments separated by geographical barriers and at the same time improve capabilities of disaster recovery. More investigation can even be done into the use of enterprise digital twins, Green Cloud Computing that leads to sustainable use of resources, and FinOps integration that helps cloud spending, with the aim of enabling cloud enterprise architecture of the future that is even more intelligent, economically viable, environment-friendly, and dependable.

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