Strategy and procedures for Migration to the Cloud Computing

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***Abstract* - The cost of enterprise IT is growing due to nonlinear expansion of IT resource's requirements. Cloud computing, a new paradigm of flexible and cost-effective computing, is being explored as the possible solution to make enterprise IT sustainable. Cloud computing also offers new cutting edge cloud native-platform to develop application composed of microservices. This paper investigates the strategies and procedures for migration to the cloud computing environment. Literature has been reviewed to illustrate upon the current state of the art strategies and procedures for cloud computing migration including tools provided by cloud service providers and application vendors. The tasks of cloud migration and procedures have been grouped into five phases and five generic strategies for migration have been identified. Future research directions have also been proposed in this area. The findings will help to stimulate the research in this direction and help cloud adopting organizations to analyze various issues and options for making informed decision for the cloud migration.**

Index Terms* - *Cloud Computing, Cloud-Native, Microservices Cloud Migration Strategies, Cloud Migration Phases, Future Research Directions for Cloud Migration

I. INTRODUCTION

ICT infrastructure management has always posed great challenge from diverse facets such as security, reliability and availability, due diligence, regulatory compliance, return on ICT assets, capital investment, support for digital innovation, and more recently for sustainability [1]. Organizations constantly seek out and explore ICT technologies to drive the best out of their ICT resources. In the recent time cloud computing [2] and internet of things [3] has come out to provide much needed ICT platform for digital transformation or innovation. Cloud computing paradigm has been demonstrated to solve all age old problems associate with ICT. This platform promises organizations to focus on their business and drive the digital transformation and innovation as and when needed in a completely flexible fashion, technologically and financially.

Adoption of cloud computing is growing at a very rapid pace. Many leading ICT companies have launched cloud computing platform and increasing their offerings day by day. ICT vendors are carefully developing the Cloud computing platforms and integrating applications and services to offer data analytics and machine learning capabilities to the client companies. Service level agreements and security has also been developed significantly. Gartner [4] predicts the public cloud services market to grow at 21.4 percent in 2018 that is USD 153.5 billion in 2017 to USD 186.4 billion in 2018. And the worldwide market is expected to reach USD 302.5 billion by the year of 2021.

More and more organization are experimenting and adopting cloud in all out approach or partial deployment on experimental basis or for non-critical business units, process and applications. Organizations want to be agile, face the challenges of huge influx of data and develop innovative culture in the Information Systems (IS) divisions. They perceive cloud computing as cheap services for real engine of digital transformation. Some of the motivational factors are API based modular platform, security, compliance, reliability, pay as you go, data and analytics, integrated artificial intelligence and machine learning.

Migration to cloud requires well defined strategy and procedures to maintain business continuity and focus on digital transformation and innovation. Organizations must plan, architect and migrate from their own datacentres to the cloud and constantly manage, optimize and secure their environments. ICT in organizations still holds the traditional view of consisting of technology, people and process, true in cloud paradigm as well. Therefore migration should start with a good business case, people and process alignment and post migration optimizations and operations. Similarly organizations must study thoroughly their complex requirements, huge datasets and security.

Gartner [5] gave five R's to summarize ways for the migration to the cloud. These R's were revised into six R's such as Re-host, Re-platform, Repurchase, Refactor, Retain and Retire [6]. Similarly all the leading cloud providers and application vendors such as Oracle, Microsoft and SAP have some support for automating the migration. There are several strategic frameworks proposed in the literature and industrial practices for migration to the cloud computing. This paper investigates these frameworks and procedures for cloud migration. Remaining of the paper is organized as cloud computing and cloud-native platform to introduce its concept, review of cloud migration strategies and procedures, future research direction in this domain, and conclusion.

II. CLOUD COMPUTING AND CLOUD-NATIVE PLATFORM

Commercially, Cloud computing has been around since the advent of 21st century with Amazon launching Amazon Web Service (AWS) in 2002 and all the leading IT vendors such as Microsoft, Oracle and SAP marking their presence on the cloud [7]. Cloud computing has been defined as "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable

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computing resources (e.g., networks, servers, storage applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" [8]. It is offered through various service models such as Software as a service (SaaS), Platform as a service (PaaS), Infrastructure as a service (IaaS) and Anything as a service (XaaS). Cloud computing is deployed through private, public, hybrid or community cloud. There are various stakeholders and technologies involved that make this platform work [5].

Cloud computing rests primarily on virtualization, achieved through hypervisors and containers, to offer hardware sharing. There are two types of hypervisor, type-1 or bare metal that directly works on the hardware and type-2 or virtual machine monitor that works on top of operating system. Some of the famous hypervisors are Xen, VMware ESX and ESXi, Microsoft Hyper-V, Citix XenServer, Redhat KVM, Oracle VM Server etc. On the other hand cloud services are offered through web services designed on Web Services Description Language (WSDL) and Simple Object Access Protocol (SOAP) and Universal Description, Discovery, and Integration (UDDI) industry standards. And inside the cloud managed and orchestrated through service oriented architectures (SOA) [5].

Container technology also provides virtualized, isolated and multi-tenant environment. Public clouds such as Google, IBM/Softlayer and Joyent, use container technology. Its history dates back to 1979 in Unix chroot command FreeBSD's jail in 1998 to Solaris 10's zone in 2004 to present containers offered in Solaris 11 and proprietary containers such as HP-UX [6]. Most common containers are based on Linux kernel containment features, LXC. Containers share a common host OS as opposed to hypervisors, so may store many more containers on single physical host and are highly portable on Linux platforms. Dockers (www.docker.com) facilitate the Linux application deployment inside the portable containers. Containers exhibit higher performance but hypervisor based Virtual machines are more secure [9]. Kubernetes, a cluster manager for docker containers, decouple the application containers from the specifics of systems they run on.

Cloud computing offers new application development and deployment approach called cloud-native. It is a methodology of building and running applications that fully exploits the power of cloud computing. Additionally, being stateless, it also ensures elasticity as the load balancers can forward users to any server irrespective of their session in-progress. Formally it may be defined as "A cloud-native application (CNA) is a distributed, elastic and horizontal scalable system composed of (micro) services which isolates state in a minimum of stateful components. The application and each self-contained deployment unit of that application is designed according to cloud-focused design patterns and operated on a self-service elastic platform" [10]. They have some common characteristics microservices architecture, packaged in container, continuous delivery (develop, build, test, deploy and release) and dynamically managed in the cloud [11]. Micorservices are independently managed and owned. Containers provide isolation to these services and are highly accessible, scalable, portable and fast to create and tear-down. They run on kubernetes and pivotal cloud foundry that offer hardware decoupling, helping in automated deployment, scaling and management of cloud native applications. Organization may take phased approach re-packaging, re-platforming, re-factoring to cloud-native. It will bring speed, agility and resilience in app development and management.

III. CLOUD MIGRATION STRATEGIES AND PROCEDURES

Cloud migration has been defined as "the process of partially or completely deploying an organization's digital assets, services, IT resources or applications to the cloud" [12]. Migration to the cloud computing platform may cause disruption to the businesses. Therefore well formulated strategy needs to be followed for making decision as well as execution of migration. This section provides the review of the existing strategic frameworks and processes for the migration to the cloud computing. First strategic model is the six R's model [6]. These R's are Re-host, Re-platform, Repurchase, Refactor, Retain and Retire. Re-host strategy takes the existing applications and host it onto the cloud platform essentially in the IaaS type service model. Re-platform migration strategy warrants changes in the platform to host application for the optimizations and utilizes the PaaS service model. Repurchase strategy allows buying new products in the SaaS model. Refactoring option will require redeveloping the services utilizing the cloud native features. In some cases it may be wise to retain some services to the on-premise infrastructure. Whereas, some services and application might not have been of any use therefore, better retire them. Amazon has given six phased strategy for execution of migration to the cloud for Amazon Web Services (AWS) such as cloud assessment, proof of concept, data migration, application migration, leverage the cloud and optimization [13].

Migration to the cloud shouldn't be purely based on financial and technological advantages. Organizational aspects must also be studied. Stakeholder impact analysis needs to be applied to identify benefits and risks associated with cloud migration by the user company [14]. In one of the case company following benefits were identified: opportunity to manage income & outgoings, opportunity to offer new products/services, improved status, removal of tedious work, improve satisfaction of work, opportunity to develop new skills, and opportunity for organizational growth. Similarly following risks were identified: deterioration of customer care & service quality, increased dependence on external 3rd party, decrease of satisfying work, departmental downsizing, uncertainty with new technology, lack of supporting resources, and lack of understanding of the cloud.

There exists a cloud migration reference model Cloud-RMM, derived through systematic literature review, for migrating legacy system to the cloud. [15]. It defines four migration processes with specific tasks such as planning, execution evaluation and crosscutting concerns. It also mentions under researched areas such as lack of tool support for migration, architectural adaptation support and self-adaptive cloud systems. It identifies four different strategies for the migration such as replace (one or more component with cloud service), partially migrate (one or more application layers or set of architectural components from one or more layers

implementing particular functionality to the cloud), migrate the whole stack (application encapsulated in VM and run on cloud) and cloudify (complete application implementation via cloud services).

Cloudstep is a step-by-step cloud migration decision process for legacy applications [16]. It utilizes the concept of template based profiles for three entities such as cloud adopting organization, application to be migrated and cloud provider. Similarly the constraints are identified in each entity and addressed. Upon successful resolution of constraints migration strategy is defined and finally the migration is performed. It also stresses upon the pilot migration project. Decision to migrate on the cloud to achieve goals of application cost and performance is based on four decision criteria and seven tasks related in networked fashion as opposed to hierarchical manner [17]. These decision criteria are application distribution, cloud service providers and offerings, Multi-tenancy requirements, and Elasticity strategy. The tasks to be carried are work-load profiling, compliance assurance, identification of security concerns, identification of acceptable QoS levels, performance prediction, cost analysis, and effort estimation.

In one study five strategies have been identified for the legacy application migration migrate to IaaS, migrate to PaaS, replace by SaaS, revise based on SaaS and reengineer to SaaS [18]. For SaaS migration legacy system needs to be restructured into SOA form first as the cloud deployment model also follows SOA. Reuse and migration of legacy applications to interoperable cloud services (REMICS) project has given detailed frameworks to migrate the legacy application to the cloud (http://www.remics.eu/). Firstly the recovery phase extracts the architecture of legacy application by knowledge discovery and reverse engineering. Next is the migration activity that involves application of SOA and cloud patterns, replacement or wrapping of legacy components and redesign of architecture by service composition. Finally the SaaS cloud implementation is done through model driven architecture (MDA).

Multi-cloud migration is becoming the norm due to several issues such as organizational, compliance or technical. V-PAM (Variability-based, Pattern-driven Architecture Migration) enables migration pattern selection and customization for the applications [19]. The pattern defines the architectural modification (refactoring) necessary in the application re-engineering and deployment parameterization. And the variability in pattern selection is introduced in three dimensions such as access, application and platform. It has identified 15 migration patterns coded as MP1 to MP15 categorized into five core patterns such as re-deployment, relocation, multi-cloud refactoring, multi-cloud rebinding, replacement and their variants.

On the same lines Enterprise IT industry leaders have setup their own cloud to offer strategies, tools and technique to migrate their clients' IT infrastructures on their cloud. Oracle provides EBS cloud automation tool for enterprise business suite applications to explore the cloud environment as well as lift and shift clients' applications to oracle cloud. Similarly they have one clip provisioning tool for JD Edwards Applications [20] and one click provisioning tool for the JD Edwards Applications. Similarly, SAP offers several options for migrating ABAP based SAP systems to SAP HANA Cloud platform. They provide SAP landscape transformation software and software provisioning tools for migration [21]. SAP also offers thousands of applications developed by SAP partners on PaaS model to develop new applications. Microsoft's Azure is a cloud computing platform and provides tools in all three stages of assess, migrate and optimize. It offers four strategies for migrating to Azure namely re-host, refactor, re-architect and rebuild [22]. Re-host refers to lift and shift strategy, refactor strategy utilizes the PaaS services, re-architect requires converting code into micro-services and rebuild strategy entails rebuilding the application on cloud native platform.

Cloud migration strategies and procedures can be grouped into five stages namely Business Assessments, Technical Assessments, Migration strategy, Migration planning and execution and Optimization Fig. 1. Important tasks of business assessments are workloads assessments, Workloads Assessment, Compliance Assurance, addressing Security Concerns, ascertaining Quality of Service Levels, Performance Predictions, Cost Analysis, Effort Estimation and Organizational readiness. In this stage workloads, a processing unit consisting of shared multiple applications, system images and users, should be assigned with business components for easy prioritization [23]. After having a sound business case organizations may go on to stage of technology assessments such as Portfolio Discovery, Map Dependencies, Cost benefit analysis, Requirement Analysis and Decision on Providers and adoption of pattern based approach as mentioned in [19].

Following on to the third stage, that warrants the adoption of migration type or strategy. There exist five strategies for migration to cloud for the existing applications re-host (lift and shift), re-platform, repurchase, refactor or rebuild. Whereas retire or retain are strategies that doesn't execute migration. Re-host or lift and shift utilizes IaaS service model and Re-platform requires re-architecting of applications in order to utilise cloud based platforms such as database so PaaS service model. For SaaS service model organization need to adopt repurchase strategy. Refactor or cloudify approach converts the application into microservices architecture to utilize the full potential of cloud computing such as isolation, scalability and elasticity and can be run in containers. Rebuild option utilizing cloud native platform, demands the complete redesign and development of applications from scratch. Organizations may choose strategies from least risky re-host, re-platform, repurchase, refactor to rebuild in the phased fashion in the optimization stage once the application is migrated to mitigate the risks.

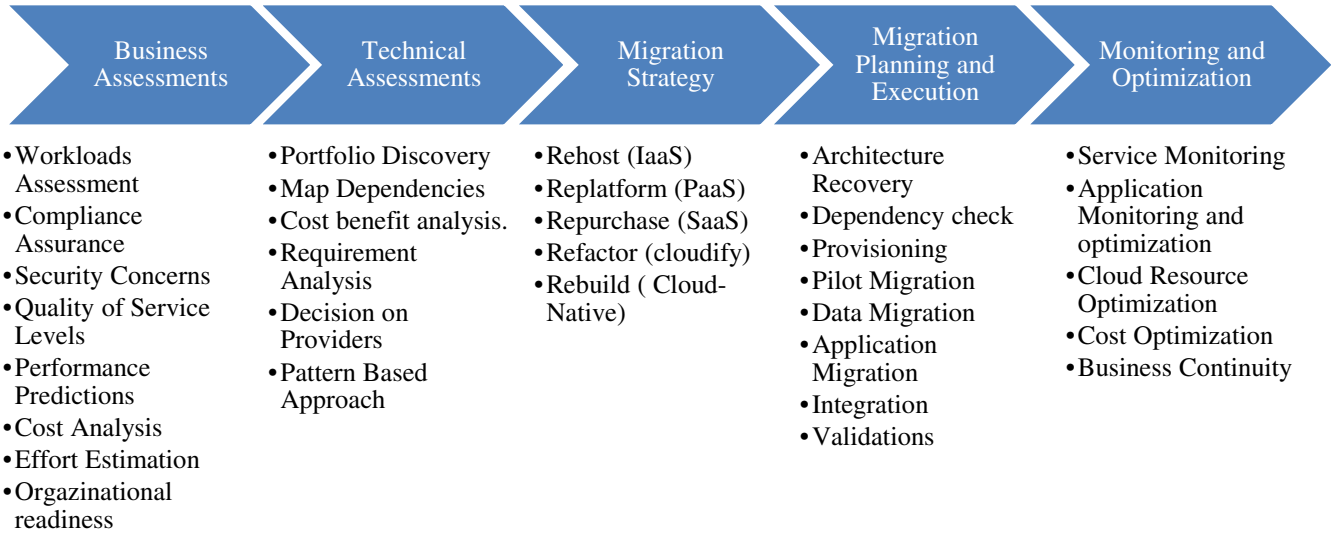

Fig. 1. Cloud Migration Strategies and Procedures

Upon successful completion of these stages migration planning and execution can commence. Important tasks of this stage are Architecture Recovery, Dependency check, Provisioning of cloud resources, Pilot Migration (if needed), Data Migration, Application Migration, Integration and Validations before final production cutover. Once the real users are switched from premise to cloud environment continuous monitoring and optimization stage begins. Important activities are Service Monitoring, Application Monitoring and optimization, Cloud Resource Optimization, Cost Optimization and Business Continuity [24]. Monitoring and management tools are normally provided by the cloud providers. Cost optimization is very essential as cloud migration is migration from CAPEX (Capital Expenditure) to OPEX (Operating Expenses) model in financial terms. Business continuity planning such as capability to operate in times of failure and recovery should also be continually assessed as the nature and magnitude of threats is dynamic.

IV. Future Research Directions

In this section agenda for the future research in this domain has been identified. There are various dimensions that needs to be studied in the context of cloud migration such as cloud-native platform, frameworks and tools for different deployment models, organizational issues, long term financial advantages and high data regulatory compliance industries.

- Decision tools to assess the need to develop cloud-native applications versus migrating cloud-enabled applications.
- Development of cloud migration frameworks and tools to provide automated migration, specific to IaaS, PaaS and SaaS cloud service delivery models.
- Establishment of Concrete models to predict organizational compatibility and risk mitigation strategies for cloud migration.
- Long term cloud migration financial modelling or cost optimization models as the data size grows so do the computing and network loads.
- Cloud computing migration strategies for Banking, Financial Services & Insurance (BSFI) sector to fulfill the compliance needs laid out in different acts such as Gramm-Leach-Bliley Act, Sarbanes-Oxley Act, Payment Card Industry Data Security Standard and European Union Data Protection Directive.
- Comparative analysis of migration tools and support provided by cloud service providers and application vendors, and their support for eco-system specially, vendor partners.

V. Conclusion

In order to adopt cloud there should be customized cloud solution and migration plan with the consideration of size of data, regulatory consideration, business applications' cloud readiness, cost of downtime and SLA requirement, and application and data migration in case of change in cloud provider. In other words organizations must have clear strategy, application architecture and governance model to migrate to the cloud. This paper has given high level brief introduction of cloud computing and cloud native platform. And, mentions the evolution cloud technology from bare-metal, hypervisors to container. Migrating to cloud from application perspective is migration to SOA hence redesigning the entire application portfolios will bring in the true value of cloud computing. Leading business application vendors have deployed cloud infrastructures and offer best in class migration options and strategies for their applications in addition to third party vendor support. Nevertheless multi-cloud scenarios, necessitated by regulatory compliance or technology constraints, pose a great challenge for all stakeholders.

The whole cloud migration strategy and procedure can be defined into five stages namely Business Assessments, Technical Assessments, Migration Strategy, Migration Planning and Execution, and Monitoring and Optimization. Mapping workloads to business components will facilitate the

prioritization easier and aligned with business strategy. Similarly the pattern based migration procedure seems most comprehensive such as V-PAM. There are majorly five options or strategy for cloud migration such as re-host, re-platform, repurchase, refactor and rebuild in the increasing order of resource requirement and risks. Thorough validations are essential before final production cloud cutover. Likewise cost optimization is mandatory as the cloud is deviation from CAPEX model to OPEX model financially. Finally the business continuity planning on failures should be continual process to ward off and recover from potential threats.

The journey to the cloud for legacy applications will most likely is to go through re-host (lift and shift) utilising IaaS delivery model to re-platform utilizing PaaS delivery models to refactor or cloudify the applications to utilize the full strength of cloud computing. Finally the rebuild or cloud native applications strategy may be adopted in the optimization stage in the phased manner to minimize the risks. Nonetheless in the endeavour of cloud migration the organisational fit and important pre-migration assessments should not be overlooked in favour of technological and financial gains. Future studies may be carried out in the following areas such as decision making tools for cloud native applications versus legacy application migration, frameworks for automated migration, organization compatibly and risk mitigation models, Cost estimation and optimization models, migration strategies for high data security domains such as BSFI and support for cloud eco-system.

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REFERENCES

[1] N. Ahmad and R. Mehmood, “Enterprise systems: are we ready for future sustainable cities,” Supply Chain Manag. An Int. J., vol. 20, no. 3, pp. 264–283, 2015.

[2] N. Ahmad, “Cloud computing: Technology, security issues and solutions,” in 2017 2nd International Conference on Anti-Cyber Crimes, ICACC 2017, 2017, pp. 30–35.

[3] M. Irfan and N. Ahmad, “Internet of medical things: Architectural model, motivational factors and impediments,” in 2018 15th Learning and Technology Conference (L&T), 2018, pp. 6–13.

[4] Gartener, “Gartner Forecasts Worldwide Public Cloud Revenue to Grow 21.4 Percent in 2018,” 2018. [Online]. Available: https://www.gartner.com/newsroom/id/3871416. [Accessed: 02-Sep-2018].

[5] Gartner, “Gartner Identifies Five Ways to Migrate Applications to the Cloud,” 2011. [Online]. Available: https://www.gartner.com/newsroom/id/1684114. [Accessed: 03-Sep-2018].

[6] S. Orban, “6 Strategies for Migrating Applications to the Cloud,” 2016. [Online]. Available: https://aws.amazon.com/blogs/enterprise-strategy/6-strategies-for-migrating-applications-to-the-cloud/. [Accessed: 03-Sep-2018].

[7] A. Mohamed, “A history of cloud computing,” Comput. Wkly., vol. 27, 2009.

[8] P. Mell and T. Grance, “The NIST Definition of Cloud Computing,” National Institute of Standards and Technology Draft (NIST) Special Publication 800-145, 2011. [Online]. Available: http://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-145.pdf.

[9] D. Bernstein, “Containers and cloud: From lxc to docker to kubernetes,” IEEE Cloud Comput., no. 3, pp. 81–84, 2014.

[10] N. Kratzke and P.-C. Quint, “Understanding cloud-native applications after 10 years of cloud computing-a systematic mapping study,” J. Syst. Softw., vol. 126, pp. 1–16, 2017.

[11] VMware Cloud-Native, “Cloud Native 101 Video,” 2018. [Online]. Available: https://www.youtube.com/watch?v=9Ik96SBaIvs. [Accessed: 06-Sep-2018].

[12] C. Pahl, H. Xiong, and R. Walshe, “A comparison of on-premise to cloud migration approaches,” in European Conference on Service-Oriented and Cloud Computing, 2013, pp. 212–226.

[13] J. Varia, “Migrating your existing applications to the aws cloud,” A Phase-driven Approach to Cloud Migr., 2010.

[14] A. Khajeh-Hosseini, D. Greenwood, and I. Sommerville, “Cloud migration: A case study of migrating an enterprise it system to iaas,” in Cloud Computing (CLOUD), 2010 IEEE 3rd International Conference on, 2010, pp. 450–457.

[15] P. Jamshidi, A. Ahmad, and C. Pahl, “Cloud migration research: a systematic review,” IEEE Trans. Cloud Comput., no. 1, p. 1, 2013.

[16] P. V Beserra, A. Camara, R. Ximenes, A. B. Albuquerque, and N. C. Mendonça, “Cloudstep: A step-by-step decision process to support legacy application migration to the cloud,” in Maintenance and Evolution of Service-Oriented and Cloud-Based Systems (MESOCA), 2012 IEEE 6th International Workshop on the, 2012, pp. 7–16.

[17] V. Andrikopoulos, S. Strauch, and F. Leymann, “Decision Support for Application Migration to the Cloud: Challenges and Vision,” in Proceedings of the 3rd International Conference on Cloud Computing and Service Science, CLOSER 2013, 8-10 May 2013, Aachen, Germany, 2013, pp. 149–155.

[18] J.-F. Zhao and J.-T. Zhou, “Strategies and methods for cloud migration,” Int. J. Autom. Comput., vol. 11, no. 2, pp. 143–152, 2014.

[19] P. Jamshidi, C. Pahl, and N. C. Mendonça, “Pattern-based multi-cloud architecture migration,” Softw. Pract. Exp., vol. 47, no. 9, pp. 1159–1184, 2017.

[20] T. Noyes, “EBS on Oracle Cloud: New and Improved Automation.” [Online]. Available: https://blogs.oracle.com/ebsandoraclecloud/ebs-on-oracle-cloud:-new-and-improved-automation. [Accessed: 12-Sep-2018].

[21] M. Missbach et al., SAP on the Cloud. Springer, 2016.

[22] Microsoft, “Migrate: Drive value faster with flexible, powerful cloud migration strategies—while minimizing business impact.” [Online]. Available: https://azure.microsoft.com/en-us/migration/migrate/. [Accessed: 16-Sep-2018].

[23] C. S. C. Council, “Migrating applications to public cloud services: roadmap for success,” 2016.

[24] AWS, “An Overview of the AWS Cloud Adoption Framework,” 2017. [Online]. Available: https://d0.awsstatic.com/whitepapers/aws_cloud_adoption_framework.pdf.