Revisiting Cloud Migration: Strategies and Methods

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Abstract. Cloud computing attracts users with its advantage of unlimited resource supply where resources can be elastically expanded on demand and balanced-load at the same time. This means that the application in the cloud environment should run in the way of elastic expansion cluster. At present, most of the elastic expansion and load balancing technologies provided by IaaS level are oriented to virtual machines (VM), with little consideration of application level, which does not fundamentally meet the needs of users. Based on this, starting from the motivation of cloud migration, we first analyse the cloud migration technology from three aspects: migration object, migration means and migration objectives, then explore the cloud migration criteria and four cloud migration strategies at the application level in the cloud environment, and point out that cloud migration should be optimized and maintained in terms of elastic expansion, load balancing, security, etc.

1. Introduction

In recent years, cloud computing and its applications have been one of the hot spots in academic and business research and concern [7]. Cloud computing provides virtualized computing resources (such as servers, storage, network resources, development environment and even the whole software) as services on demand [10]. Cloud users can flexibly apply for or release computing resources according to their own needs, which enables them to focus more on their own applications and business needs, rather than on the underlying hardware management and maintenance of equipment and facilities. At the same time, compared with the traditional mode, the pay as you go method can avoid the excessive purchase of infrastructure in the early stage of business, so that enterprises can more flexibly manage operating expenses. The flexibility and scalability of cloud computing can help enterprises flexibly cope with the changes of business access. Multiple backup and persistent storage can improve the reliability of application. Based on these advantages, more and more enterprises, groups and organizations are considering migrating their applications to the cloud platform.

Some researchers analyzed the feasibility of cloud migration from the economic and technical aspects to help users decide whether to migrate to the cloud or choose a cloud product. P., V.B. et al. proposed the concept of cloud step, which is a step by step decision wizard process to support the migration of legacy systems to the cloud [10]. In this process, they first create a template based configuration file for the organization, target system, and candidate cloud suppliers, and through a series of cross analysis to find and eliminate the constraints that hinder the migration to the cloud as much as possible, so as to objectively and systematically help enterprises make migration decisions.
A., K. et al. described two tools to support migration decision [3]. The first is a modeling tool to assess the cost of migrating to a shared IaaS cloud. The second is a tabulation software to describe the benefits and risks of cloud migration and conduct risk assessment. The other part takes a specific migration case as the research object to analyze the problems encountered in the process of migration. A., K. et al. studied and analyzed the migration process of an information system in the oil and gas industry from an existing data center to the Amazon EC2 cloud, and analyzes the benefits and risks from the perspective of stakeholders [2]. The results show that moving the system to EC2 can reduce 37% of the original cost in five years. This adds enough persuasion for enterprises to choose cloud migration. At the same time, the author points out the huge risks associated with the huge benefits, and reminds enterprise decision makers to consider the possible changes that cloud migration will bring to the entire organizational structure. The other part starts from the migrated objects (applications or data) and studies how to use existing technologies to migrate applications or data to the cloud platform. Andrikopoulos, V. et al. discussed the possible challenges and solutions for each layer of application when migrating multi-tier applications [4]. Yousafzai, A. et al. analyzed the impact of platform dependent native applications on computing streaming in edge networks, and proposes a framework of computing streaming based on lightweight process migration [15]. The framework does not require application binaries on edge servers, so native applications can be migrated seamlessly. Experimental results show that the framework saves nearly 44% of execution time and 84% of energy consumption. Sun, G. et al. focused on online real-time migration of multiple related VMS in the virtual data center (VDC), and proposes an effective VDC migration algorithm (VDC-M) [13]. The simulation results show that the proposed algorithm has good performance in the total cost of VDC remapping, blocking rate, average migration time and average downtime. Considering the needs of real-time applications in the future, R., A.A. et al. proposed and evaluated two different mechanisms to improve the end-user experience by using container based real-time migration technology [11]. The first solution knows the user's mobile mode, while the other ignores the user path. Wu, Q. et al. studied how to pay limited migration cost through dynamic VM integration in heterogeneous cloud data center to save as much energy as possible [14]. In order to achieve the above goals, they designed a comprehensive evaluation function based on the migration cost estimation method and the maximum energy saving estimation method. Then, based on greedy heuristic algorithm and switching operation, they proposed an improved group genetic algorithm (IGGA). Rai, R. et al. systematically reviewed cloud migration technology, proposed a cloud migration conceptual model, which can provide research basis for existing cloud migration solutions [12]. Gholami, M.F. et al. reviewed the existing cloud migration methods in detail from the perspective of process model, and proposed an evaluation framework to evaluate and compare the existing methods to highlight their functions, similarities and key differences [5]. Narantuya, J. et al. proposed a perception strategy for cloud to cloud (C2C) service migration on multiple VMS. The strategy analyzed the dependency of multiple VMS, and used the network traffic intensity to determine the migration order of dependent VMS, so as to reduce service downtime [9]. They implemented the recommended migration method in the test platform environment based on Openstack. Experimental results show that the method successfully identifies the dependency between VMS for C2C migration. Midya, S. et al. proposed an adaptive resource placement policy by optimizing live VM migration process in ITS. In this scheme, the Pareto optimal mapping of migrating VMs to a physical host is carried out using a hybrid optimized algorithm, which is the combination of particle swarm optimization and genetic algorithm [8].

2. Basic Principles of Cloud Migration

Cloud migration is the whole process of migrating digital assets, services, it resources and applications of an enterprise or organization from an existing data center to a cloud environment in whole or in part. This process involves a set of analysis, design, reconstruction and other activities to support the migration from internal deployment to cloud platform. Cloud migration technology is committed to solve many business and technical problems in the migration process from the perspective of overall planning. Figure 1 is the schematic diagram of cloud migration technology. Next, we will elaborate the basic principle of cloud migration from three aspects: migration object, migration means and migration goal.
2.1. Migration Objects
As shown in Figure 1, the core implementation object of cloud migration technology is the existing software that is providing a service. These software are deployed within an enterprise or community organization, run on traditional physical servers, or run in a virtualized data center. In order to make the core business software run normally in the new environment, in addition to the business software itself, the migrated object should also include the software runtime environment that the business software depends on. Therefore, we will model the migrated objects, as shown in Figure 2. The first thing to be determined is the core business software to be migrated. The software can be any type of application, such as large-scale computing application, web access application, information management system, specific industry application software, etc.; the second layer is the data required for the normal operation of business software, which may exist in relational database, or in common file or specific file format; the third layer is the operation of business software, other application software or middleware services, which are relied on by, have the relationship of collaborative operation or service and being served. If these supporting software is missing, some functions of business software cannot run; the fourth layer is system service software. These softwares are general management software at the server level, providing the most basic underlying support services, such as database server, web server, security management software such as identity authentication service, etc.; the last layer is the operating system.

2.2. Migration Means
Migration means to solve the problem of how to transport migration objects, that is, after determining the complete and effective migration objects, we need to consider how to move the migration objects out of the current physical environment or virtualization environment. As shown in Figure 3-1, the current mainstream technology uses image as the carrier to load migration objects. In other words, cloud migration technology is committed to making a machine image of the identified migration objects, and saving and transporting the migration objects in the way of image files. Different migration objects are loaded into different machine images and stored in the image library, which can be used as the startup template for software running in the cloud environment. On the one hand, the image migration method benefits from the increasingly popular cloud service model IaaS, on the other hand, it relies on virtualization technology, especially server virtualization technology.
2.3. Migration Objectives

After the migration object is made into a machine image, you can use the image as a template at any time, start the virtual machine with the virtualized hardware resources provided by IaaS cloud service provider, and start related services, so that the business software can run in the cloud environment. Compared with the traditional physical environment software running mode, this image instance cloud environment running mode improves the portability of applications. Image, as the original template of software, can be used in different environments and locations at any time, without being limited to the environment at the time of initial deployment. But this only benefits from the pure virtualization technology, and does not take advantage of the characteristics and advantages of cloud computing services in a real sense. The ultimate goal of cloud migration is to properly adjust the application programs, reasonably allocate the dynamic resources in the cloud environment, so as to ensure the security and high availability of business within the minimum cost range.

Figure 3. Cloud Migration Strategies and Methods [6]

3. Cloud Migration Strategies and Methods

Migration strategy refers to the method mode and technical means of migration. Compared with the traditional physical environment, cloud environment has its own unique features. First of all, the core technology of cloud computing is virtualization, IaaS Level service abstracts hardware (computing, network, storage) resources into virtual resource pool, and provides services in the way of virtual machine. This means that all applications moving into the cloud must run in a virtualized way. Secondly, cloud computing advocates that resources should be controlled on demand, and can be flexibly and elastically expanded and contracted according to the change of demand. This means that the business of the programs running on the cloud will work in a parallel and cluster mode. However, not all the existing application architectures are designed in a parallel or cluster mode. The inherent deficiencies in this software architecture design make the application not adapt to the local conditions in the cloud environment. Of course, cloud computing can not flexibly exert its own advantages and charm. Therefore, it is particularly important to study the method pattern of application migration to the cloud. Generally speaking, the cloud migration strategy adheres to two basic principles. On the one hand, cloud computing provides three types of services: IaaS, PaaS and SaaS. IaaS level services provide hardware resources such as virtual machines, network services and storage services, which provide solid hardware resources for applications running in the cloud. Of course, virtual machines also become the most direct entry for applications running in the cloud. PaaS level services provide platform level services, such as development, deployment, monitoring and other tools in the cloud environment and platform level software in other clouds, to help applications more easily, quickly and effectively migrate to the cloud. On the other hand, most of the existing applications cannot run directly in the cloud environment due to their own architecture differences or other reasons.

3.1. Whole Migration

Whole migration or Overall migration refers to the migration of the entire software stack of the application to the cloud environment. This is a classic way of cloud migration, and also a popular way at present. The overall migration is based on the relatively mature IaaS service model, and the core technology is virtualization technology. Specifically, the whole software part of the application is
encapsulated in the image and runs in the cloud as a single virtual machine. Under the overall migration strategy, the whole software stack and its data of the application program are imagined as a black box. No matter what the internal architecture of the software is, it is packaged as an image offline, and finally runs in the cloud in the way of remote virtual machine. In this way, the original application can run in the cloud environment without any modification, which ensures the minimum intrusion to the application. It is the simplest migration method, which is suitable for small applications. However, this kind of migration only uses the virtualization characteristics of cloud computing, and does not play the elasticity, scalability and other characteristics of cloud applications.

3.2. Mixed Migration
The mixed migration strategy refers to the migration of some applications or components, and the other part remains in the original deployment environment. Most of the existing applications are multi-layer software architecture, as shown in Figure 3-3, common three-layer architecture (presentation layer, business layer, data layer) applications. There are different service objects and business processes in different layers of multi-layer applications, so the demand for cloud resources is different. The black box migration of the overall migration strategy ignores the characteristics of multi-level application architecture. Compared with the black box overall migration, hybrid migration pays more attention to the internal architecture of the software. It is considered to migrate one architecture layer of the application rather than the entire software stack to the cloud platform, while the components of the other layers remain in the original physical environment. Furthermore, we can migrate multiple architecture components of one or more layers to the cloud platform, and make different deployment strategies according to the characteristics of each layer. For example, we can migrate the business layer with flexible load to the cloud platform to provide flexible resource supply for it, and leave the data with high security level inside the enterprise.

3.3. Component Replacement
Component replacement strategy refers to using cloud service components to replace multiple components of software. The overall migration is based on IaaS service model and adopts the migration method based on virtualization technology. Hybrid migration focuses on the internal structure of the software, but its use of cloud services is also limited to the IaaS layer. However, with the development of more and more PaaS level or SaaS level service products by cloud service providers, there are more options for the migration of applications to the cloud. We can use cloud service components provided by cloud service providers to directly replace one or more parts of our software. These cloud components are designed and developed based on the cloud environment and directly deployed on the IaaS cloud. They can automate elastic expansion, load balancing, fault detection and processing, and provide multiple levels of security, so users only need to use them on demand.

3.4. Cloud-enable Migration
Cloud-enable is the highest level of cloud migration, which is more suitable for cloud environment. Of course, the degree of application reconstruction and composition is also the highest, such as cloudify. Compared with hybrid migration, cloud enabled extends the migration scope of applications to every layer. Compared with the overall migration, it can implement different migration and deployment methods for different application layers or different functional modules. At the same time, the application is also adjusted to support elastic expansion and load balancing, so as to fully adapt to the cloud environment.

4. Conclusion
Compared with the traditional environment, the cloud environment has great flexibility in the deployment of infrastructure resources. Only by supporting this flexibility and scalability from the architecture design and code implementation, can the application fully adapt to the cloud environment and give full play to the huge advantages of cloud computing. At present, the legacy systems that support core business processes do not have the characteristics of cloud applications, but it is not easy
to develop new applications that can adapt to the cloud environment in a short time. Therefore, how to adjust the existing applications to better adapt to the cloud environment is the key problem to be solved in cloud migration. Starting from the motivation of cloud migration, this paper first analyzes the cloud migration technology from three aspects: migration object, migration means and migration objectives, then explores the cloud migration criteria and four cloud migration strategies at the application level in the cloud environment, and points out that cloud migration should be optimized and maintained in terms of elastic expansion, load balancing, security, etc.

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6. References
[1] AWS re:Invent 2016: Large-scale AWS Migrations (ENT204).
[2] A. K, D. G and I. S 2010 Cloud Migration: A Case Study of Migrating an Enterprise IT System to IaaS. In: 2010 IEEE 3rd International Conference on Cloud Computing, pp 450-7
[3] A. K, I. S, J. B and P. T 2011 Decision Support Tools for Cloud Migration in the Enterprise. In: 2011 IEEE 4th International Conference on Cloud Computing, pp 541-8
[4] Andrikopoulos V, Binz T, Leymann F and Strauch S 2013 How to adapt applications for the Cloud environment COMPUTING 95 493-535
[5] Gholami M F, Daneshgar F, Low G and Beydoun G 2016 Cloud migration process-A survey, evaluation framework, and open challenges J SYST SOFTWARE 120 31-69
[6] Jamshidi P, Ahmad A and Pahl C 2013 Cloud Migration Research: A Systematic Review IEEE T CLOUD COMPUT 1 142-57
[7] Khajeh-Hosseini A, Greenwood D, Smith J W and Sommerville I 2012 The Cloud Adoption Toolkit: Supporting cloud adoption decisions in the enterprise Software - Practice and Experience 42 447-65
[8] Midya S, Roy A, Majumder K and Phadikar S 2020 An adaptive resource placement policy by optimizing live VM migration for ITS applications in vehicular cloud network T EMERG TELECOMMUN T 31
[9] Narantuya J, Zang H and Lim H 2018 Service-Aware Cloud-to-Cloud Migration of Multiple Virtual Machines IEEE ACCESS 6 76663-72
[10] P. V B, A. C, R. X, A. B A and N. C M 2012 Cloudstep: A step-by-step decision process to support legacy application migration to the cloud. In: 2012 IEEE 6th International Workshop on the Maintenance and Evolution of Service-Oriented and Cloud-Based Systems (MESOCA), pp 7-16
[11] R. A A, D. L C D, M. B, T. T and H. F 2020 Fast Service Migration in 5G Trends and Scenarios IEEE NETWORK 34 92-8
[12] Rai R, Sahoo G and Mehfuz S 2015 Exploring the factors influencing the cloud computing adoption: a systematic study on cloud migration SpringerPlus 4
[13] Sun G, Liao D, Zhao D, Xu Z and Yu H 2018 Live Migration for Multiple Correlated Virtual Machines in Cloud-Based Data Centers IEEE T SERV COMPUT 11 279-91
[14] Wu Q, Ishikawa F, Zhu Q and Xia Y 2019 Energy and Migration Cost-Aware Dynamic Virtual Machine Consolidation in Heterogeneous Cloud Datacenters IEEE T SERV COMPUT 12 550-63
[15] Yousafzai A, Yaqoob I, Imran M, Gani A and Noor R M 2019 Process migration-based computational offloading framework for IoT-supported mobile edge/cloud computing IEEE INTERNET THINGS 7 4171-82