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SLA-Based Flexibility Cost Strategy for Cloud Computing System Architecture in Chemical Industry

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Under multiple pressures of environmental protection and increasing in the cost of raw materials, the production and operation costs of chemical companies remain on the rise. It is of great sig-nificance to investigate how to reduce the production and operation costs of chemical companies, provided that the flexible demands of the basic systems in chemical companies are met. The application of the flexible cost strategy of cloud computing system offers an opportunity for improving the cost management efficiency of chemical companies. This paper adopts the Operational Research, aiming at the flexible cost of the cloud computing system architecture, to consider the SLA flexibility requirements and machine-enhanced learning feedback of the cloud computing system architecture in the flexible strategy decision model, discusses and compares what kind of strategies the chemical companies adopt in various situations, in an attempt to pro-vide reference for chemical companies to make appropriate strategies when developing cloud computing systems.

1. Introduction

Aiming at the SLA in cloud computing, many scholars have conducted studies on different di-mensions. Some proposed relevant models for cloud users and cloud providers to maintain the availability of SLA through negotiation process, e. g. Alhammed et al. put forward the credi-bility model for evaluating cloud services that could provide a new set of criteria for cloud pro-vider to select these; some focused on maximizing the benefits of cloud service providers or cloud providers by the service quality in SLAs, e. g. Alhammed et al. provided a SLA framework outlined to maintain the credibility and reliability of cloud users and providers; some scholars proposed an architecture that could improve cloud service SLA supervision capacity, e.g. Mario et al. introduced a method to maximi ize the benefits of cloud provider with an intermediate entity, i.e. the economic expansion resource management. When the cloud provider cannot satisfy the demands of the SLA, this intermediate entity will provide some SLA references in light of possible losses in the next step, regardless of reputation losses as these methods may lead to.

The cloud computing system architecture is the software that provides cloud services. It connects up cloud components with a coupling mechanism. Because of the complexity of cloud computing system architecture itself, it is immature to analyze it based on technologies and models, given such elements as performance, safety and reliability. For this purpose, scholars and cloud providers have proposed a variety of different could computing system architectures for different purpose and from different angles. Some scholars regard the cloud computing system as a tool, and think that the cloud computing system architecture should describe its internal technical characteristics. Some believe that the architecture should far less restrict specific technologies, but concern commonality and focus on the integrated model. The cloud computing system architecture refers to a kind of model that can access shared resources well allocated on demand via the Internet whenever and wherever possible. Some scholars also focus on the presentation mode of cloud computing systems. It, as a cloud computing service, runs on cloud computing networks. Its architecture is designed based on demands for various cloud services, as a keystone this study focuses on.

CCS flexibility is described as a new computing model that extends the flexibility of IT with IT services available everywhere. Chebrolu believed that CC-based deployment itself is a mode of IT flexibility. Virtualization is considered to be one of the major implementation technologies for cloud computing system architecture flexibility. By the virtualization flexibility, the original fixed CPU, memory, and broadband are

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configured into multiple virtual machines to facilitate the horizontal expansion of underlying resources in the cloud computing system. while the modularity of the platform and application layers achieves the overall flexibility of the entire cloud computing system architecture.
Based on the review of the above literature, the flexible cost of the CCS architecture is defined here as the sum of overall cost paid by company for appropriate flexibility in the entire life cycle of CCS architecture to meet the demand of user SLA in the cloud.

2. Literature review

With the rapid change of the social economy and the convenience of entering the Internet era, the business model and environment have changed greatly. On the one hand, enterprises need to respond quickly to demand, absorb, form and reconstruct the business process according to the fast changing environment, and continue to adopt innovative actions to cope with the fierce market competition. On the other hand, the generation of large amounts of data requires a corresponding technology and timely processing to form competitiveness. Cloud computing appeared in this background in the business field in 2006. It is the representative of the third IT technology after the personal computer and the Internet, and also the development trend of the next generation of IT technology architecture. It has become the most influential model in IT industry because of its advantages such as resource virtualization, and it is gradually applied to many fields, including business, medical and health, financial services, information technology, and even known as the fifth basic element except for water, air, electricity and telephone. At the same time, the development of the adaptive system, the monitoring module as the necessary module of the cloud computing system, has a small impact on the flexible cost of the architecture of original cloud computing system. The wide application of DevOps tools makes the cost of the cloud computing system has a great change compared to the original cost of the traditional information system architecture during the operation of the traditional information system architecture. It has become a hot topic how to effectively meet the SLA needs of cloud users and effectively control the flexibility cost of cloud computing system. Flexibility is an indicator of competition between enterprises and supply chains, which are equal to cost, quality and delivery time. It is the ability to respond quickly and follow changes when the environment, conditions, or process states change.
Cloud computing system architecture is a software system architecture that provides cloud services, and the cloud components are connected by coupling mechanism. Because the architecture of the cloud computing system itself is very complex, it needs to consider such elements as performance, security, and reliability. It is not mature to analyze enterprise cloud computing system architecture by technology and model. Therefore, according to different needs and perspectives, scholars and cloud providers have proposed many different cloud computing system architectures. Some scholars regard the cloud computing system as a tool, and think that the architecture of cloud computing system should explain its internal technical characteristics. Some scholars believe that the architecture should be less limited to specific technology, but needs to care for generality and overall model. The cloud computing system architecture refers to a pattern that can be accessed by the network at anytime and anywhere. Some scholars also focus on the expression of cloud computing systems. Cloud computing systems are cloud computing services running on cloud computing networks. The cloud computing system architecture is designed according to various cloud service requirements.
The flexibility of cloud computing system is described as a new computing mode, which expands the flexibility of IT through the available IT services. Vilalta and other scholars believe that deploying cloud computing is a way of IT flexibility. Virtualization is considered to be one of the main technologies of cloud computing system architecture flexibility. Through virtualization flexibility, the original fixed CPU, memory and broadband are configured into multiple virtual machines to facilitate the horizontal expansion of the underlying resources of the cloud computing system. At the same time, the overall flexibility of whole cloud computing system architecture is realized through the modularity of the platform layer and the application layer (Vilalta et al., 2017). Hashem and Ibrahim believe that cloud computing is not only the application of services through the Internet, but also system resources and hardware resources that provide data centers for these application services (Hashem and Ibrahim, 2015). Cavalcante and Everton believe that cloud computing is a combination of high level platform resources and low level infrastructure resources, and users' access to cloud services is achieved on demand and paid in the way (Cavalcante and Everton, 2016). Cuenca-Alba and Jesús have a more comprehensive definition of cloud computing: cloud computing is a large-scale distributed computing paradigm driven by economies of scale, a large number of abstract, virtualized, dynamic, and manageable computing resources, storage capabilities, platforms and services across the Internet for external users to be distributed (Cuenca-Alba and Jesús, 2017). Ren and Lei believe that cloud computing is provided to consumers in the form of a variety of computing resources, storage resources, platforms and applications through services, and the consumers of the service need not know how the resources they use are provided.

In the cloud environment, the cloud should not only meet the needs of the users, but also reduce the cost of the cloud computing, and improve the resource utilization ratio (Ren and Lei, 2017). Bobek and other researchers believe that flexibility refers to the ability of the system to deal with changing environment or environmental uncertainty (Bobek et al., 2017). Bai and other researchers believe that flexibility is the ability of the system to handle changes. This capability needs to be analyzed from the perspective of the third nature and stability. And they also identified a number of ways to test flexibility, such as, to assess flexibility by detecting the economic consequences of a system adapting to changes (Bai et al., 2017). Wang and Fei define flexibility as a system's ability to respond effectively to changing environments. Two types of flexibility are described: behavioral flexibility and state flexibility. The former refers to the ability to adapt to change through the interference from the outside of the system, that is, to increase the ability of the system to adapt to change through the structural changes in the organization and process. In contrast, the latter refers to the ability of the system to operate well in a different environment, that is, the system is not affected by the changes in the environment, but it ensures the relatively stable and effective operation of the production system (Wang and Fei, 2017).

To sum up, in the above research work, the cloud computing system is compared with the original system, and one of the most important features is flexibility. While meeting the SLA requirements of the cloud users, the flexible cost of the cloud computing system needs to be effectively controlled. At the same time, the instability of the social and economic environment, the increasing uncertainty of the market, and the enormous pressure of the enterprises, all require enterprises to reduce the cost and improve the efficiency by adopting new technology. If the cost and output of the cloud computing system cannot be well controlled, the enterprises may not be able to benefit from them. Because of the constraints of resources, few related research guides them to control the cost and achieve sustainable development in the case of meeting the flexible needs of the cloud users. Therefore, based on the above research status, the method of operational research is adopted to subsection the flexible cost calculation formula of each stage, which provides the basis for enterprise decision making, and enables the enterprise make the appropriate flexible cost strategy to achieve the optimization of efficiency.

3. Decision model for flexible cost

This model is proposed by Schober and Gebauer based on the basic investment cost model for information systems, given the impact of the SLA flexibility requirements and machine-enhanced learning feedback of CCS architecture. The flexible cost decision process is shown in Figure 1 below.

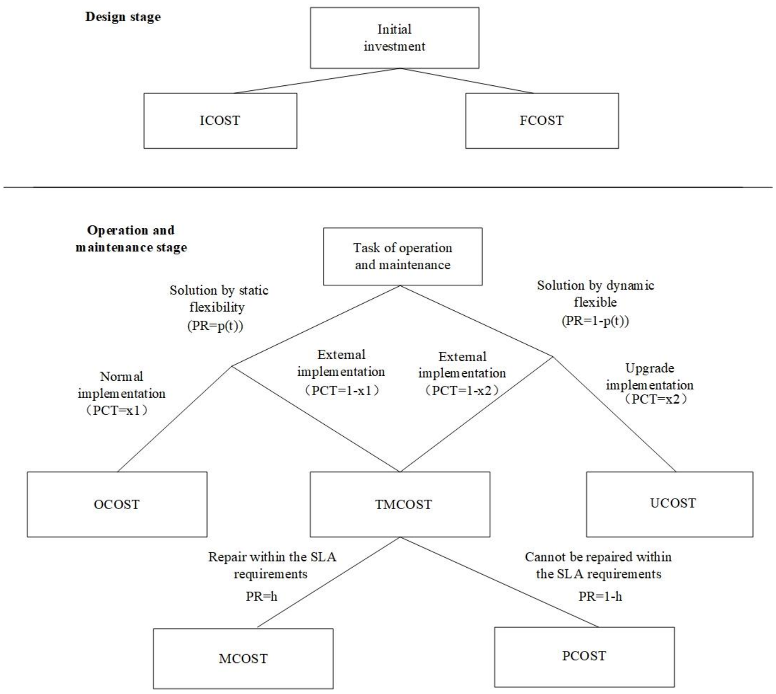

Figure 1: Schematic diagram of flexible cost strategy process

The flexible cost decision process consists of three phases. Phase 1 is the design phase. The decision is made based on whether a static flexible strategy or a dynamic flexible strategy is adopted. This flexible cost in this period mainly includes basic components and adaptive costs for supporting static flexibility, as well as dynamic costs for supporting dynamic evolution. Phase 2 is the operation and maintenance (O&M) phase, including three types of flexible strategies, i.e. static, dynamic, manual flexible strategies, which correspond to the O&M, upgrade, and manual costs, respectively. The third stage includes manual and external flexible strategies, which correspond to manual and external costs, respectively.
The total cost, TCOST, for the cloud computing system architecture in Figure 1 includes the following several parts: ICOST is the cost when the company adopts the static flexible strategy at the design time; FCOST is the cost when the dynamic flexible strategy at the design time; UCOST is the cost when company upgrades the dynamic flexible part originally designed for CCS at the time of the operation and maintenance; OCOS is the cost when company upgrades the static flexible part originally designed for CCS at the time of the O&M; MCOST is the cost when company manually repairs external flexible strategy adopted within the time as SLA requires at the time of the O&M; PCOST is the cost when company can not repair the external flexible strategy manually within the time as SLA requires, but by other method at the time of O&M. At this time, the enterprise adopts an external flexible strategy and can manually repair the costs within the required time of the SLA. When the PCOST is operated and maintained, the enterprise adopts an external flexible strategy, which cannot be manually repaired within the required time of the SLA, but through other methods.

$$\mathrm{TCOST} = \mathrm{ICOST} + \mathrm{FCOST} + \mathrm{OCOST} + \mathrm{TMCOST} + \mathrm{UCOST} \tag{1}$$

The following formulae are explained:

3.1 ICOST is the cost of the static flexibility strategy that the company adopts at the design time:

$$\mathrm{ICOST} = \{\mathrm{a} + \mathrm{bL}(x_1)[\mathrm{q} + (1-\mathrm{q})\mathrm{DC}]\}\mathrm{z} \tag{2}$$

a is the fixed cost;
b is the variable cost;
q is the ratio of completed development until now;
$\mathrm{L}(x_1) = {x_1}^v[1-(1-x_1)^{1-v}]$ Lorenz coefficient curve, used to represent the ratio of tasks that have been processed. The greater *v* is, the more the concentration of tasks is, that is, the greater the difference is;
$\mathrm{DC} = ((1+\mathrm{i})^T - 1) / (i(1+i)^T T)$ represents the average discount rate; *i* is the annual average interest rate; *T* is the life cycle of the CCS; *z* is a binary number, used to ensure the availability of the calculation formula, then the following conditions are true: [1] $\mathrm{z} \in (0, 1)$; [2] $x_1 + x_2 > 0$, then $\mathrm{z} = 1$; otherwise $\mathrm{z} = 0$; [3] $\mathrm{z} \geq 0.5(x_1 + x_2)$;

3.2 FCOST is the cost when company adopts the dynamic flexible strategy at the design time:

$$\mathrm{FCOST} = \mathrm{cy} \tag{3}$$

c is the cost of dynamic flexible strategy;
y is a binary number, used to ensure the availability of the calculation formula, then the following conditions are true [1] $\mathrm{y} \in (0, 1)$; [2] in the design phase, when company adopts dynamic flexible strategy, $\mathrm{y} = 1$ and $\mathrm{y} \geq x_2$;

3.3 UCOST is the cost when company upgrades the dynamic flexible part originally designed for CCS at the time of O&M:

$$\mathrm{UCOST} = \mathrm{eL}(x_2)\mathrm{DC} \tag{4}$$

e is the cost that company performs this operation;
$\mathrm{L}(x_1) = {x_1}^v[1-(1-x_1)^{1-v}]$ Lorenz coefficient curve, used to represent the ratio of tasks that have been processed. The greater *v* is, the more the concentration of tasks is, that is, the greater the difference is;
$\mathrm{DC} = ((1+\mathrm{i})^T - 1) / (i(1+i)^T T)$ represents the average discount rate; *i* is the annual mean interest rate; *T* is the life cycle of the CCS;
There is a relationship between static, dynamic, external flexibilities and uncertainty. Due to the adoption of monitoring components, adaptive will continuously improve the uncertainty over time training, so that the uncertainty here refers to a function of time *t*, the specific strategies are as follows:

$$w_1 = p(t)x_1; \tag{5}$$

Dynamic flexible strategy:

$$w_2 = \big(1 - p(t)\big)x_2; \tag{6}$$

External flexible strategy:

$$w_3 = 1 - w_1 - w_2 \tag{7}$$

3.4 OCOST is the cost when company operates and maintains the upgraded parts based on the static flexible and dynamic flexible strategies originally designed for CCS

$$\mathrm{OCOST} = \mathrm{Sd}\{\big(\mathrm{q} + (1-\mathrm{q})L^{-1}(0.6)\big)\mathrm{w1} + 0.4\mathrm{w}_2\}\mathrm{TDC} \tag{8}$$

d is the O&M cost of parts based on the static and dynamic flexible strategies originally designed for CCS;
S is the scalability of business loads during O&M;
T, DC, w1, w2, q, and L(x) are given as above. Since the CCS is also an information system, 60% tasks proposed by Mutschler [31] are finished by the static flexible strategy, while 40% done by a dynamic flexible strategy

3.5 TMCOST is the cost when the chemical company adopts the external flexible strategy during O&M. It includes the costs that company can manually repair it within the time as specified by SLA and exceeds the SLA time limits, only the compensation costs need to be met in other ways:

$$\mathrm{TCOST} = \mathrm{MCOST} + \mathrm{PCOST}; \tag{9}$$

When MCOST is the cost when the chemical company adopts an external flexible strategy that can be manually repaired within the time required by the SLA:

$$\mathrm{MCOST} = \big(\mathrm{hSf}(1+\mathrm{rg})\{\big((1-\mathrm{q})(1-L^{-1}(0.6))\big)\mathrm{w1} + 0.4\mathrm{w}_2 + \mathrm{w}_3\}\big)\mathrm{TDC}; \tag{10}$$

h is a binary number, which takes 0 when the SLA request time is exceeded, otherwise it takes 1;
f is the cost of manual repair for the cloud computing system within the time required by the SLA;
r is the urgency of the repair time;
g is the cost-plus rate of time urgency;
T, DC, w1, w2, w3, q, L(x), S are the same as above;
When PCOST is the cost when the company will be unable to repair the parts of external flexible strategy within the time as required by SLA but by other method at the time of O&M;

$$\mathrm{PCOST} = \big((1-\mathrm{h})\mathrm{Sf}(1+\mathrm{rg})\{\big((1-\mathrm{q})(1-L^{-1}(0.6))\}\big)\mathrm{w1} + 0.4\mathrm{w}_2 + \mathrm{w}_3\}\big)\mathrm{T}_{SLA}\mathrm{DC} + (1-\mathrm{h})\mathrm{K} \tag{11}$$

TSLA is the time requirement for how long time the cloud user in the SLA takes to respond to the cloud provider;
K is the cost that the cloud provider cannot repair the system within the time SLA requires.

4. Discussion of strategies

The flexible cost model of the cloud computing system architecture proposed in this paper involves three phases. In the design phases, it mainly involves the static and dynamic flexible strategy costs. The flexible cost of the static flexible strategy will also impact the cost in later O&M stage; dynamic flexible strategies can affect later upgrade and manual costs. Therefore, chemical companies should make decisions based on the flexible requirements of the SLA and the later O&M costs in the design phase, and a hybrid strategy has achieved the optimal effect. In the O&M phase, the major flexible costs include the O&M, upgrade, and manual costs. The chemical companies should make adjustments as required by the SLAs in time to avoid the external costs incurred in third phase. In the third phase, the chemical company should determine whether they continuously meet the requirements of SLA manually by negotiation or by external means such as compensation.

5. Conclusion

In relation to the original system, the cloud computing system features most the flexibility. How to effectively control the flexible cost of the cloud computing system on the premise that cloud user SLA in the chemical industries is satisfied becomes a hot topic. Simultaneously, the instability of the social and economic environment, the increasing uncertainty of the market, the high pressure of environmental protection, the fluctuation of the costs of raw materials, and the huge pressure that chemical companies suffer from, all of these requires chemical companies to adopt new technologies to save costs and improve efficiency while satisfying the basic demands. Chemical companies may have not benefited from cloud computing system if they failed to well control its costs and output. Due to the constraints of resources, there are few studies that can provide the clues to the challenge on how to control costs and achieve sustainable development while satisfying the flexible demands of cloud users. the OR method adopted herein gives the flexible cost formulas at each stage to provide a basis for chemical companies to develop the future strategies, so that they can correctly make flexible cost strategies to maximize the efficiency. But badly, actual data inspection can not be performed, it needs to be supplemented in the later period.

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