AMSE JOURNALS-AMSE IIETA publication-2017-Series: Advances B; Vol. 60; N°2; pp 450-462
Submitted Mar. 28, 2017; Revised Jun. 08, 2017; Accepted Jun. 15, 2017

Virtual Machine Scheduling Strategy for Reliable Service Resource Supply in Cloud Environment

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Abstract

Nowadays, most researchers carry out such unilateral research on virtual machine scheduling strategy, energy consumption. And there are few jobs which less concern about the impact of multiple factors. Due to heterogeneous cloud environment is made up of thousands of resource nodes. The resource utilization, virtual machine scheduling and other indicators must be related with uncertainties arising from node failure events. The paper studies the virtual machine scheduling strategy under the supply of reliable resources. And a dynamic-reliable resource supply FR strategy is proposed. In this paper, the Cloud Sim simulation cloud platform was used to simulate the experiment and compare with classical IQR/LR scheduling algorithm during simulation experiment. And experimental results show that FR strategy can effectively improve CPU utilization and is conducive to data center energy consumption reduction.

Key words

Heterogeneous environment, Service quality, Dynamic supply strategy, Resource utilization.

1. Introduction

As a brand-new type of IT resource supply model, cloud computing has been basked in the limelight in recent years. This gives birth to cloud datacentre, a high-performance computer consisting of numerous physical servers and network devices. Nowadays, countless large datacentres have been set up by governments and companies at home and abroad, namely, Amazon EC2 and S3, Google App Engine, Microsoft Azure, and Salesforce CRM. Based on modern virtual technology, the datacentre creates a shared resource pool, and converts the physical machines into virtual machines (VMs) deployed on servers, thereby realizing on-demand service, dynamic resource management and so on. Against this backdrop, VM scheduling and resource shares have become key issues in the field of cloud computing. Since the cloud environment contains thousands of resource nodes, it is rarely possible that all the nodes are operating continuously without any failure.

According to the white paper released by Microsoft on design of reliable cloud services in 2012, node failure is not a rare event, but a commonplace in the cloud environment. Owing to external network failure, Microsoft Office 365 customers were hit by email breakdown that lasts for almost nine hours in most parts of North America in 2014. One year later, a Google datacentre in Brussels was struck by lightning, leading to disruption of grid power. As a result, the disk of the datacentre was damages, the cloud storage system was broken, and some of the data were permanently lost. Also in 2015, the VENOM vulnerability of KVM/XEN VM allowed an attacker to escape from the confines of an affected VM guest, and invade or even control the VMs of other users. The attack posed major threats to the virtual hosting services from IaaS providers. These examples illustrate that node failure can cause serious economic losses to providers of cloud computing resources and application services.

The VM scheduling mechanism has evolved to cope with the failure situation. For instance, [4] from Beijing University of Posts and Telecommunications minimized the activated physical devices in the cloud datacentre and successfully reduced energy consumption. [5] from Huazhong University of Science and Technology optimized the energy-aware dynamic VM mapping mechanism in the cluster system and datacentre. The improved mechanism exerts less impact on the application performance and achieves VM migration. Overall, the recent studies mainly concentrate on VM scheduling strategy and resource allocation, and seldom discuss about the reliability of VM scheduling.

In light of the above, this paper attempts to create a proper VM scheduling strategy for reliable resource supply. The existing VM scheduling strategy was optimized to enhance the resource utilization for reliable resource supply, which, in turn, reduces the energy consumption of the cloud system. In the course of the study, the author analysed the failure law of nodes in cloud environment, and proposed the dynamic VM scheduling mechanism of VM with reliable resource supply. It is very complex to discuss cloud service reliability and VM scheduling. First, the various services provided in cloud environment have to be completed with different types of resources, and the resource requests tend to be highly dynamic and volatile.

Taking node as the basic unit, this paper probes into the following aspects of discrete task events: failure factors and pattern of cloud service system; improvement of the reliability of cloud service system; reduction in datacentre energy consumption and elevation of system resource utilization through VM placement strategy; VM acquisition strategy under reliable resource supply.

2. Overview of Cloud Platform

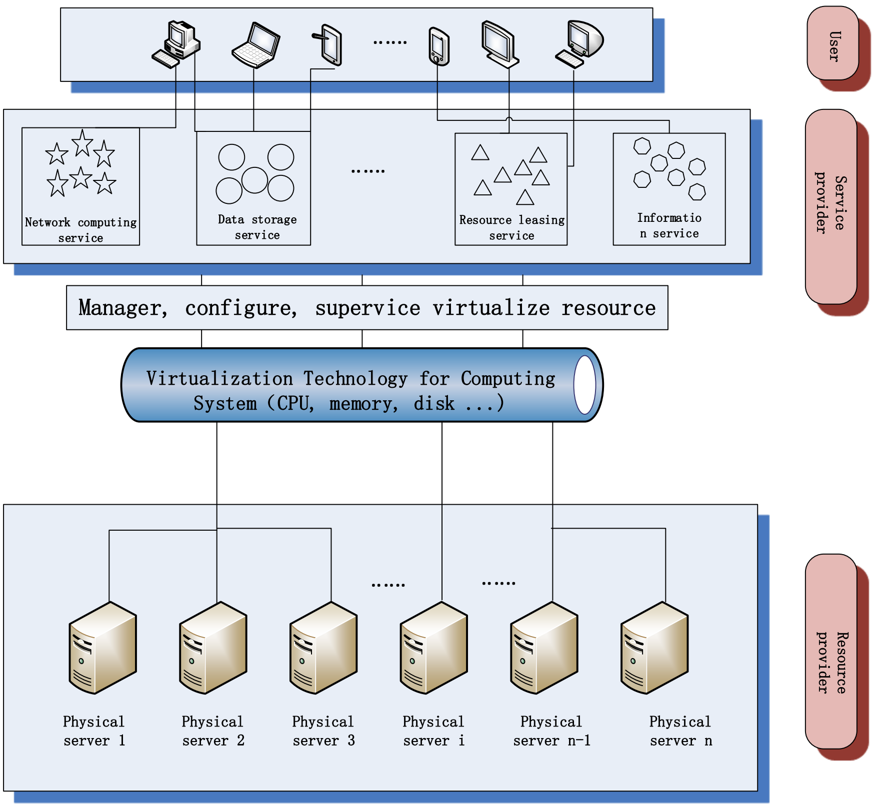

Fig.1. Cloud Computing Service Architecture

Unlike the traditional service system, cloud computing is a novel IT resource supply model based on VM technology. The resource/service provider is distanced to decouple the application from the physical device, realizing the separation of duties in the true sense. Figure 1 shows the various services and objects in the cloud service environment.

Rather than provide service to users, the resource provider virtualizes the server, the storage and the network using the virtualization technology, and deploys the application with the virtual resources in the network. The service provider needs not the specific location and implementation of the underlying physical device, but the dynamic on-demand access to virtual resources (Figure 2).

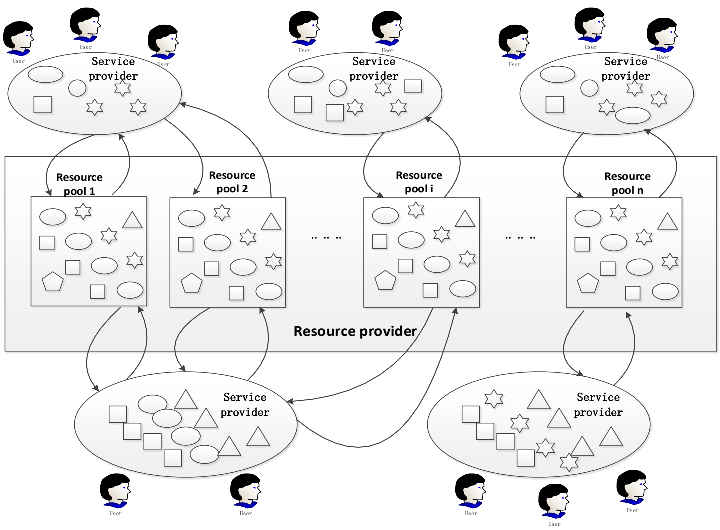

Fig.2. Resource Acquisition in Cloud Environment

3. Failure Pattern of Cloud Service System

Due to the countless software, physical servers and network devices in the complex cloud system, the cloud service system is inevitably constrained by multiple factors. The existing research has shown that the main influencing factors of node reliability include software, hardware and network communication. Hereinto, software reliability refers to the ability of software products to perform specific functions under specified conditions and time intervals. The loss of such an ability is called software failure. In the event of software failure, the system or its component is unable to fulfil the required function within the prescribed period of time, and the program operation deviates from the requirements. Similarly, hardware reliability means the ability of hardware devices to perform specific functions under specified conditions and time intervals. The loss of such an ability is called hardware failure. Both software and hardware failures may affect the reliability of cloud service system. According to the previous studies, the node failure follows a certain pattern: the failure rate is high in the early phase, and varies with time in the later phase. The software failure rate falls with the correction and elimination of errors, that is, the software performance is increasingly stable over time. By contrast, the hardware failure rate varies in the shape of the bathtub curve: it decreases in the first phase, stabilises in the second phase, and increases because of aging and other reasons.

Both software and hardware failures are featured by strong spatiotemporal locality, and accompanied by unplanned restarts. For instance, the failure rate of a random process obeys the Weibull distribution with shape parameter less than 1 [6-8]. Hence, it is highly likely for a failed node to fail again in future. In this research, the failure pattern is taken into account during VM resource scheduling, seeking to obtain a highly reliable optimized scheduling mechanism.

4. Reliability Improvement of Cloud Service System

Virtualization plays a fundamental role in the cloud service system. There are two advantages to the virtualization of a physical server. First, the application is separated from the physical device and the system is made more reliable after the physical server has been replaced by the VM as the service provider; Second, the system resource is better utilized and the overall energy consumption is reduced. The reliability of the cloud service system directly hinges on the soundness of the VM. The VM may fail in the case of a software or hardware failure, making it impossible for the user to obtain virtual resources. Furthermore, the reliable access to dynamic resources is critical to both resource and service providers. With a reliable resource supply strategy, the resource provider can make effective use of virtual resources, and the service provider can ensure the quality of services. In order to maintain a reliable supply of virtual resources, it is necessary to implement VM redundancy placement.

The VM redundancy placement is a strategy implemented at the cost of computing resources. At the failure of a VM, the monitor and scheduler will relocate the tasks of the failed VM to other VMs. To prevent cascading faults, the main VM and the backup VMs should not be placed in the same physical machine. Instead, the primary and secondary VMs should be placed on different physical machines, such that each failed master VM can be reassigned to one or more backup VMs at the failure of the primary VM.

5. VM Placement Optimization

As mentioned above, the VM redundancy placement improves the reliability of resource acquisition at the cost of node resources and energy efficiency. For lower datacentre energy consumption and cost of implementation, the strategy should be optimized without sacrificing the reliability of resource acquisition.

The common ways to improve VM placement strategy include improving resource utilization, reducing energy efficiency and so on. The previous studies have portrayed the server as the main energy consumer in the datacentre, and suggested that the energy consumption of the server is influenced by main components like the CPU, memory, hard disk, network card, etc. Since the CPU is the leading energy consumer, the CPU utilization can characterize the energy consumption of the server. According to Literature, the relationship between server energy consumption and the CPU utilization takes an approximately linear form; the no-load energy consumption must be 0.6 times of the full-load energy consumption to maintain the normal hardware operation of the system, memory, hard drive and network card. Therefore, the energy consumption of the server can be obtained through calculating the CPU utilization.

In reference to Literature, the server energy consumption model is introduced as follows:

$$P(u) = c * P_{\max} + (1-c) * P_{\max} * u \tag{1}$$

$$E = \int_{t_1}^{t_2} P(u)dt \tag{2}$$

where *P(u)* is the server power; c is a constant depicting the ratio of the no-load power to the full-load power; P_{max} is the full-load power; u is the CPU utilization; E is the server energy consumption in $[t1, t2]$.

As a multidimensional bin packing problem, the VM placement should be implemented without hindering the effect use of datacentre energy. After analysing multi-dimensional energy efficiency, the author tried to optimize multi-dimensional cloud resources and reduce datacentre energy consumption in light of the optimization of physical server resources. In other words, the purpose of this research is to find the optimal combination of multidimensional resources to minimize the server energy consumption (equation (3)). To prevent cascading faults, it should be noted that the master and backup VMs should not be placed on the same physical machine.

$$F = \min \sum_{i=1}^{n} E_i \tag{3}$$

The following constraints are added in the placement to achieve the objective function above.

$$\sum_{j=1}^{m} D_j^{cpu} P_{i,j} < C_i^{cpu} \cap \sum_{j=1}^{m} D_j^{mem} P_{i,j} < C_i^{mem} \cap \sum_{j=1}^{m} D_j^{store} P_{i,j} < C_i^{store} \quad (4)$$

$$\sum_{i=1}^{n} P_{i,j} = 1 \quad (5)$$

When $i \in [1, n]$ and $j \in [1, m]$, $P_{i,j}$ =0or1

$$P_{i,j}^{master} \neq P_{i,j}^{backup} \quad (6)$$

In the above formulas, m is number of VMs in the datacentre; n is the number of physical machines in the datacentre; E_i is energy consumption of physical machine i; D_j^{cpu}, D_j^{mem} and $D_j^{strore}$are the maximum demand of the CPU, memory and hard drive of VM j; D_j^{cpu}, D_j^{mem} and $D_j^{strore}$are the type of the CPU, memory and hard drive of VM i.

Formula (4) expresses that the CPU capacity, memory capacity, and hard drive capacity requested by VMs located on the server should not exceed such capacities of the server. Formula (5) indicates that a VM should be assigned to a server only. Formula (6) means the VMs are either placed or not placed. Formula (7) stipulates that the primary and secondary VMs should not be placed on the same physical machine.

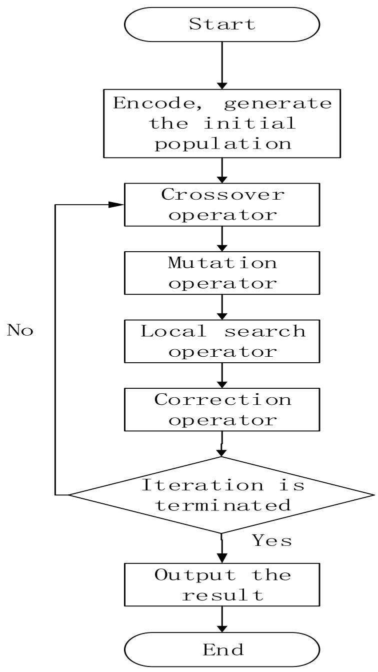

Fig.3. Flow Chart of the Optimization Algorithm

The objective function was micro-processed before finding the optimal solution via the heuristic random search. The genetic algorithm was employed to solve the problem by codec method, population initialization and crossover operator. The specific flow of the algorithm is shown in Figure 3:

6. Strategy of Reliable Resource Supply

In essence, resource supply is an on-demand process that offers dynamic access to resources. In the traditional resource supply strategy, the idle physical machines are randomly allocated at the arrival of user request to supply the required resources from the node pool. In this research, the supply strategy has to meet the resource demand with reliable resource supply and minimal energy consumption. The ultimate goal lies in the supply of resources in a reliable manner.

Assuming that the user demands a + b VM resources, where a and b are the number of master VMs and the number of backup VMs, respectively, the first step is to select the physical machine that provides at least a + b virtual resources from the resource pool, and the second step is to place the a + b VMs on the selected physical machine. The selection should follow the rules in Table 1, and the placement must abide by the optimization strategy mentioned in Chapter 5.

Tab.1. Classification of Physical Machine Selection Rules

	Specific rules	**meaning**
Category 1	NF=0, IN=1	Indicates that no failure has occurred and on the same subnet
Category 2	NF=0, IN=0	Indicates that no failure has occurred and is not on the same subnet
Category 2	NF=1, IN=1	Indicates that the failure has occurred and on the same subnet
Category 4	NF=1, IN=0	Indicates that the failure has occurred and is not on the same subnet

Note: NF depicts whether the physical machine has failed and IN reflects whether the physical machines belong to the same subnet.

As shown in Table 1, the physical machines in the resource pool are classified into four categories. The classification must be performed without hurting the resource reliability or increasing the resource consumption. During selection, the physical machine should be firstly selected from the first category. However, if no physical machine is found to meet the requirements after scanning the entire category, the second round of scanning should be conducted to select a desirable physical machine from the second category. If no satisfactory physical machine is identified in the second round, the third round of scanning should be performed to find an acceptable physical machine from the third category. If no physical machine satisfying NF = 1 and

IN = 1 is found in the third round, the invalid bit identified in that round should be modified as NF = 0. Then, the fourth round of scanning should be carried out in a similar way. Apart from meeting the purpose of design, such a method considers the failure recovery mechanism, and adjusts the resource supply in a dynamic manner.

7. Simulation Experiments

The simulation experiments were performed on the CloudSim platform. Then, the proposed strategy in this paper FR (Failure-Reliability) was compared with the classical IQR (Inter Quartile Range) strategy and LR (Locally Weighted Regression) strategy in terms of CPU utilization, process time, energy consumption, etc.

7.1 Parameter Settings

The simulation experiments were performed in a datacentre consisting of two types of servers and four kinds of VMs. The detailed configuration parameters of the servers and VMs are presented in Tables 2 and 3, respectively.

Tab.2. Server Configuration Parameter

Parameter	HOST1	HOST2
MIPS	1860	2660
PES(Number)	2	2
RAM(MB)	4096	4096
BW(Gbit/s)	1	1
STORAGE(TB)	1	1

Tab.3. Virtual Machine Configuration Parameters

Parameter	VM1	VM2	VM3	VM4
MIPS	2500	2000	1000	500
PES(Number)	1	1	1	1
RAM(MB)	870	1740	1740	613
BW(Mbit/s)	100	100	100	100
STORAGE(GB)	2.5	2.5	2.5	2.5

7.2 Experimental Comparison Results

(1) The average CPU utilization of the physical machine at different run times

Suppose the datacentre has 300 physical machines and 300 VM, and that the different types of servers exist in a heterogeneous network. During the experiment, 300 tasks were processed at different execution times and on different processing units to disclose the relationship between the average CPU utilization and the run time. The average CPU utilization gradually increased at the beginning of the experiment, and fluctuated after reaching a certain range. With the increase of the execution time, an increasing portion of the CPU was released as some of the tasks had been completed. As shown in Figure 4, the moment of 20,000 saw 150 remaining tasks and significantly fluctuations in the average CPU utilization curve. Finally, the CPU utilization was minimized at the completion of all tasks. As can be seen from Figure 1, FR and LR utilize resources more efficiently than the IQR. The proposed strategy features a stable state in the experiment, and an average CPU utilization between 40% and 70%.

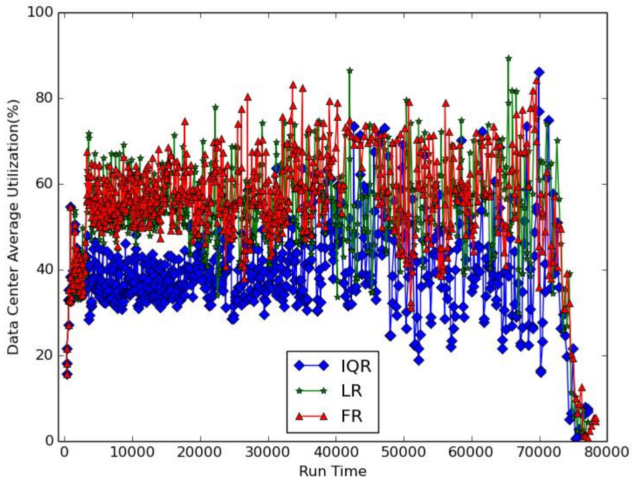

Fig.4. The Average CPU Utilization of the Physical Machine at Different Run Times

(2) The average process time of VMs at different number of tasks

To ascertain the relationship between the average process time of the VM and the number of tasks, 50~500 tasks were implemented at the step size of 50. In the initial phase, the relationship was very prominent. As the number of tasks doubled, the average process time grows by 3.75%, 3.41% and 5.18%, respectively for the three strategies: FR, IQR and LR. It is obvious that LR experienced the greatest growth, indicating that the method has the lowest processing capacity. When the number of tasks rose again, the average process time of the three strategies fluctuated due to the possible completion of the current tasks or the arrival of new tasks. According to Figure 5, the FR has a slightly longer average process time than the other strategies.

(3) The average CPU utilization at different number of tasks

To identify the relationship between the average CPU utilization and the number of tasks, 50~500 tasks were implemented at the step size of 50 in this simulation experiment. As shown in Figure 6, the average CPU utilization of IQR is much lower than FR (48.1% ~ 51.24%) and LR; FR and LR share a similar trend in average CPU utilization, but the former keeps a slight edge over the latter under the same conditions. This means the IQR has much room for improvement, and the proposed strategy boasts the best stability.

(4) The energy consumption at different number of tasks

To analyse the relationship between datacentre energy consumption and the number of tasks, the number of tasks and the step size were maintained at 50~500 and 50, respectively, in this experiment. With the increase in the number of datacentre tasks, the datacentre of FR consumed less energy than that of the other two strategies. At the end of the experiment, the energy consumption was 92.13kW, 94.16kWh and 120.33kWh, respectively, for the three strategies. The FR's energy consumption is 2.2% and 23.4% lower than the other two methods, respectively. The result shows that the proposed method can effectively improve energy efficiency.

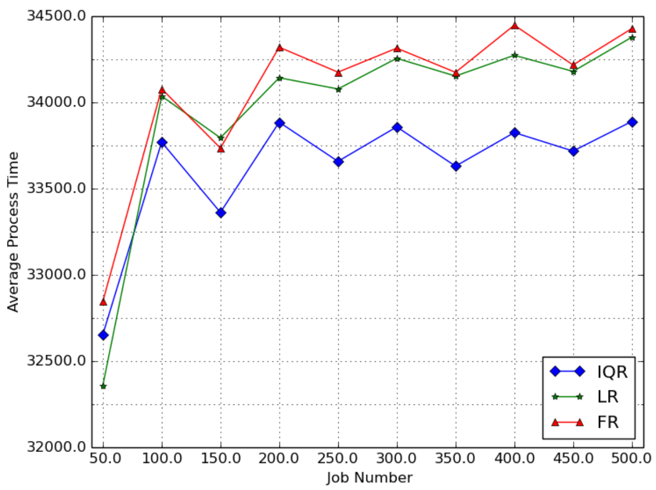

Fig.5. The Average Process Time of VMs at Different Number of Tasks

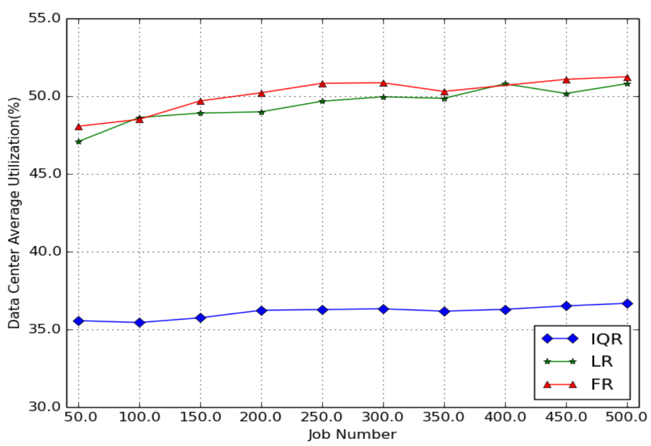

Fig.6. The Average CPU Utilization at Different Number of Tasks

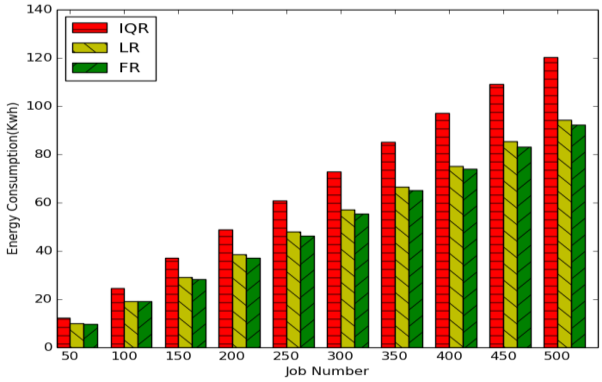

Fig.7. The Energy Consumption at Different Number of Tasks

Conclusion

This paper identifies the failure recovery pattern by analysing the datacentre failure problem, introduces the pattern into resource allocation, and proposes the FR strategy for reliable resource supply. The simulation experiments verify that the proposed strategy owns a sound running mechanism, improves resource reliability, and lowers the average CPU utilization, thereby reducing datacentre energy consumption.

Acknowledgment

This work was supported in part by the science and technology project of "13th Five-Year" planning of the Education Department of Jilin Province (JJKH20170631KJ); the key project of "13th Five-Year" planning of the Education Science of Jilin Province (ZD16024); Key Science and Technology Project of Jilin Province (20160204019GX).

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