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Designing an Efficient Cloud Architecture for Online Lifelong Education

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Abstract

As online learning and e-learning are prevalent and widely used in education, it is important to design an efficient and reliable information system for storing learning data and providing on-demand learning services. In this paper, we design a cloud-based information system architecture for online lifelong education. Since a cloud system is based on the virtualization technology, we propose a virtual resource management scheme, that is, virtual machine allocation and monitoring nodes assignment. With the proposed cloud-based architecture, we can build and operate an e-learning information system for online lifelong education, which requires efficiency, reliability, and persistence.

Key words: Online learning, e-learning, lifelong education, information system

Introduction

Education is commonly equated to an experience for children and young adults, but the reality is that lifelong learning can benefit in many ways [1, 2]. The world is constantly changing, and this means that you must be open to absorbing and actively seeking new information to stay up-to-date. This, of course, expands far beyond education in your area of professional expertise.

According to Eurostat [3], over 45 % of adults aged 25–64 participated in some form of education or training in 2016. Among adults of working age (25–64), 45.1 % across the EU-28 took part in formal or non-formal education or training in 2016. This marked an increase of 4.8 percentage points compared with the previous survey when 40.3 % of the working-age population had participated in formal or non-formal education or training. In 2007, this share was 35.2 %.

Among education methods, there are several advantages of online learning since it provides convenient and portable learning options [4]. More importantly, users can learn by online education at their own pace [5, 6]. Therefore, users are able to develop skills and explore knowledge whenever and wherever there are.

Cloud computing is an Internet-based computing paradigm that provides an illusion of infinite computing resources in the form of pay-as-you-go and on-demand [7-9]. Cloud computing is an attractive solution to offer fundamental computing resources to online learning systems because of its flexibility [10, 11]. More specifically, cloud computing offers an automation process for resource provisioning [12-14]. When a user requests a virtual machine, the cloud infrastructure selects a template or image from which to create a new virtual machine. The request includes ownership information, tags, virtual hardware requirements, the operating system, and any customization of the request. Then, the request goes through an approval phase and executed. Educational institutions, as well as teachers and learners can benefit from the cloud computing model for cost reduction, elasticity, easy and wide accessibility, and high availability [15, 16].

In this paper, we present an efficient cloud architecture for online lifelong education. Since there are a lot of computing and storage nodes in the cloud computing system, efficient resource management is essential especially for resource allocation and node monitoring. For resource allocation and node monitoring, we propose a complexity-efficient algorithm based on classic balls-and-bins and n-queen problems, respectively.

The aim of the resource allocation is load balancing. The load balancing is an important metric for cloud computing since it is related to service level agreement (SLA). When a virtual machine is allocated in a heavily loaded physical machine, the allocated virtual machine does not perform well and this leads to SLA violations. On the other hand, when a virtual machine is allocated in a lightly loaded physical machine, the energy consumption will rise due to the physical machine. Therefore, balancing the load of physical machines is important to achieve both SLA satisfaction and energy reduction.

As for node monitoring in cloud computing environments, the monitoring node may result in a single point of failure. In other words, when the monitoring node fails, the whole cloud computing system will stop from working. If the monitoring node does not fail, it can be a bottleneck for monitoring a large number of nodes in the cloud computing system. This motivates us to develop an efficient monitoring scheme that does not exhibit a single point of failure or bottleneck problem. The proposed monitoring scheme is able to monitor nodes in the cloud computing system efficiently by designating a fixed number of monitoring nodes.

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Algorithm 1. The proposed cloud architecture management algorithm.

```
begin virtual machine allocation
    vm_info ← get_vminfo(user_request);
    do
        host_candidate1 ← get_randomhost(seed);
        host_candidate2 ← get_randomhost(seed);
    while check_requirement(vm_info, host_candidate1) && check_requirement(vm_info,
host_candidate2)
    if check_utilization(host_candidate1) < check_utilization(host_candidate2) then
        target_host ← host_candidate1;
        nil_host ← host_candidate2;
    else
    target_host ← host_candidate2;
    nil_host ← host_candidate1;
    end if
    if check_migration_suitability(nil_host, target_host) then
        while retrieve_vm(nil_host) do
            source_vm ← retrieve_vm(nil_host);
            schedule_migration(source_vm, target_host);
        end while
        schedule_shutdown(nil_host);
    end if
end
begin queen nodes assignment
    num_host ← count_running_host();
    num_queen ← round(sqrt(num_host));
    num_chessman ← num_host;
    while num_chessman < num_queen * num_queen do
        tmp_chessman ← get_randomhost(seed);
        assign_chessman(tmp_chessman, num_chessman + 1);
    end while
    solution ← calculate_nqueen(num_queen);
    num ← 0;
    while num < num_queen * num_queen do
        node ← get_chessman(num);
        assign_queen(node, solution);
        num ← num + 1;
    end while
end
begin resource monitoring
    for all queen_node do
        monitor vertical, horizontal, diagonal nodes in the system;
```

The Algorithm

Algorithm 1 shows the proposed cloud architecture management algorithm. There are three parts of the algorithms: (1) virtual machine allocation, (2) queen nodes assignment, and (3) resource monitoring. For the virtual machine allocation, it first checks and gets virtual machine information for a user's request. Then, our virtual machine allocation algorithm selects two host candidates at random. After selecting the two host candidates, it checks the requirement of a user's request. If a host candidate does not qualify a user's request, the procedure listed in lines 3–6 is repeated. Note that if one of the two host candidates does not qualify a user's request, it selects another random host in the system for the host candidate.

Afterward, it checks the utilization of the two host candidates. Of the two host candidates, our virtual machine allocation algorithm selects the one whose utilization is lower. The other one is selected as a nil host (lines 8–14). For optimizing cloud consolidation, it further checks the migration suitability for virtual machines of the nil host. If virtual machines on the nil host can be migrated to the target host, it performs the migration process. For each virtual machine on the nil host is scheduled for migration from the nil host to the target host (lines 16–19). Then, the nil host is scheduled to power off to reduce energy consumption.

The queen nodes assignment algorithm is for optimizing monitoring overheads induced by the master–slave architecture of cloud computing environments. The basic idea of the queen nodes assignment algorithm is to assign $\sqrt{number\ of\ nodes\ in\ the\ system}$ monitoring nodes in the n by n board. The monitoring nodes are equivalent as queens in the traditional n-queen problem. The queen nodes are designated as the monitoring nodes in the cloud computing system. The designated monitoring nodes monitor at most $3 \times (n - 1)$ nodes (vertical, horizontal, and diagonal nodes) of $n \times n$ nodes in the system. Thus, it mitigates the problems of the single point of failure and bottleneck.

The procedure of the queen nodes assignment algorithm is listed in Algorithm 1 (lines 23–41). To calculate the board size, it first retrieves the number of hosts in the cloud computing system. Then, it calculates the number of queens (monitoring nodes) by computing square root and round functions. The number of chess pieces is set to the number of hosts in the system at this stage. Note that the logical numbers are also assigned to the hosts for encoding the n–queen problem.

However, if the number of chess pieces and (the number of queens)^2 are not equal, the solution of the n–queen problem cannot be applied (e.g., assigning a queen to the (n, n) location.). Therefore, we resolve this problem by assigning duplicated signatures to existing chess pieces. The procedure for this problem is listed in lines 27–29. After assigning the logical chess pieces in the $n \times n$ board, it solves the n-queen problem and assigns chess pieces according to the calculated solution.

The resource monitoring procedure is based on the assigned chess pieces. The queen nodes monitor vertical, horizontal, and diagonal nodes in the cloud computing system. The other nodes (except queens) provide their local information to the queen node when requested from the queen node. Since the queens cannot attack each other in the $n \times n$ board, system information of a node is forwarded to only one queen in the system.

Conclusions

As online lifelong education becomes popular, cloud computing systems have received a lot of attention since it can provide computing resources and persistent storage with easy. To offer more reliable and efficient cloud services for online lifelong education, we proposed an efficient cloud architecture management algorithm. The proposed virtual machine allocation reduces the complexity of the resource allocation process in virtualized cloud computing environments and the monitoring nodes assignment algorithm based on the traditional n–queen problem resolves the potential problems in existing cloud computing systems (i.e., single point of failure and bottleneck). As future work, we will perform a number of experiments based on our scheme and offer the proof of the proposed algorithm.

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