ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ

ИНФОРМАЦИОННЫЕ ТЕХНОЛОГИИ

INFORMATION TECHNOLOGY

UDC 681.518:658.519 **DOI: 10.20998/2079-0023.2020.02.06**

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USING CLOUD PLATFORMS TO BUILD DISTRIBUTED LEARNING MANAGEMENT SYSTEMS

Distributed systems have problems with downtime, data loss during malfunctions, scalability and efficient use of computing resources. At the same time in the learning and training process, the use of a distributed system has the advantage of data processing: storage of information about students, construction of training courses, verification of passed material, etc. The problems of scaling and efficient use of resources in distributed learning management systems are investigated in this research. Cloud platforms for hosting the system, such as Amazon Web Services, Microsoft Azure, Google Cloud Platform and DigitalOcean are reviewed. Problems and features of a scalability in cloud computing are discussed. Methods, scaling and load balancing algorithms for the efficient use of computing resources are proposed. According to the list of advantages, the DigitalOcean platform was selected for the investigation. DigitalOcean provides cloud servers that can be used for quick creation of the new virtual machines for the projects. These servers allow to fully control the web hosting environment at the same time that the user pays only for the resources used. The main goal of DigitalOcean is to use a solid-state drive (SSD) to create a user-friendly platform that will allow clients to migrate projects to and from the cloud, increasing productivity with high speed and efficiency. As a result of analyzing information on existing technologies, approaches and methods for using cloud platforms in distributed systems, they have been applied to develop a solution to reduce downtime for a distributed adaptive Learning Management System (LMS). It is concluded that the use of cloud platforms for the construction of distributed LMS a practice that allows to use only the required amount of computing capacity. It is proven, that the implementation of the proposed solution into the work of adaptive LMS will improve its efficiency by reducing the time of the content delivering.

Keywords: cloud platforms, distributed systems, cloud computing, scaling, load balancing, virtualization, containerization.

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ВИКОРИСТАННЯ ХМАРНИХ ПЛАТФОРМ ДЛЯ ПОБУДОВИ РОЗПОДІЛЕНИХ СИСТЕМ УПРАВЛІННЯ НАВЧАННЯМ

Розподілені системи мають проблеми з простоєм, втратою даних під час несправностей, масштабованістю та ефективним використанням обчислювальних ресурсів. Водночас у процесі навчання та тренінгу використання розподіленої системи має перевагу обробки даних: зберігання інформації про студентів, побудова навчальних курсів, перевірка зданого матеріалу тощо. У даній роботі досліджено проблеми масштабування та ефективного використання ресурсів в розподілених системах управління навчанням. Розглянуто хмарні платформи для розміщення системи, такі як Amazon Web Services, Microsoft Azure, Google Cloud Platform та DigitalOcean. Розглянуто проблеми та особливості масштабованості хмарних обчислень. Запропоновано методи, алгоритми масштабування та балансування навантаження для ефективного використання обчислювальних ресурсів. Відповідно до переліку переваг, для дослідження було обрано платформу DigitalOcean. DigitalOcean надає хмарні сервери, які можна використовувати для швидкого створення нових віртуальних машин для проектів. Ці сервери дозволяють повністю контролювати середовище веб-хостингу, при цьому користувач платить лише за використані ресурси. Основною метою DigitalOcean є використання твердотільного накопичувача (SSD) для створення зручної платформи, яка дозволить клієнтам перемішувати проекти в хмару та з неї, підвищуючи продуктивність з високою швидкістю та ефективністю. В результаті аналізу інформації про існуючі технології, підходи та методи використання хмарних платформ у розподілених системах було розроблено рішення щодо скорочення простоїв розподіленої адаптивної системи управління навчанням (LMS). Зроблено висновок про те, що використання хмарних платформ для побудови розподілених LMS – це практика, яка дозволяє використовувати лише необхідну кількість обчислювальних потужностей. Доведено, що впровадження запропонованого рішення в роботу адаптивної LMS підвищить її ефективність за рахунок скорочення часу доставки контенту.

Ключові слова: хмарні платформи, розподілені системи, хмарні обчислення, масштабування, балансування навантаження, віртуалізація, контейнеризація.

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ИСПОЛЬЗОВАНИЕ ОБЛАЧНЫХ ПЛАТФОРМ ДЛЯ ПОСТРОЕНИЯ СИСТЕМ УПРАВЛЕНИЯ РАСПРЕДЕЛЕННЫМ ОБУЧЕНИЕМ

Распределенные системы имеют проблемы с простоем, потерей данных при неисправностях, масштабируемостью и эффективным использованием вычислительных ресурсов. В то же время в процессе обучения и тренинга использование распределенной системы имеет преимущества обработки данных: хранение информации о студентах, построение учебных курсов, проверка сданного материала и тому подобное. В данной работе исследованы проблемы масштабирования и использования ресурсов в распределенных системах управления обучением. Рассмотрены облачные платформы для размещения системы, такие как Amazon Web Services, Microsoft Azure, Google Cloud Platform и DigitalOcean. Рассмотрены проблемы и особенности масштабируемости облачных вычислений. Предложены методы, алгоритмы масштабирования и балансировки нагрузки для эффективного использования вычислительных ресурсов. В соответствии с перечнем преимуществ, для исследования была выбрана платформа DigitalOcean. DigitalOcean предоставляет облачные серверы, которые можно

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использовать для быстрого создания новых виртуальных машин для проектов. Эти сервера позволяют полностью контролировать среду веб-хостинга, при этом пользователь платит только за использованные ресурсы. Основной целью DigitalOcean является использование твердотельного накопителя (SSD) для создания удобной платформы, которая позволит клиентам перемещать проекты в облако и из него, повышая производительность с высокой скоростью и эффективностью. В результате анализа информации о существующих технологиях, подходах и методах использования облачных платформ в распределенных системах было разработано решение по сокращению простоев распределенной адаптивной системы управления обучением (LMS). Сделан вывод о том, что использование облачных платформ для построения распределенных LMS – это практика, которая позволяет использовать только необходимое количество вычислительных мощностей. Доказано, что внедрение предложенного решения в работу адаптивной LMS повысит ее эффективность за счет сокращения времени доставки контента.

Ключевые слова: облачные платформы, распределенные системы, облачные вычисления, масштабирование, балансировка нагрузки, виртуализация, контейнеризация.

Introduction. The emergence of distributed systems in the field of IT technology was because one computer could not process all the information that comes every day with the development of technology.

However, distributed systems still have problems with downtime, loss of important data during malfunctions, scalability and the most efficient use of computing resources. Over time, platforms have emerged to help solve this problem by providing cloud computing services. Cloud technologies (or cloud computing) are distributed digital data processing technologies that provide computer resources to the Internet user as an online service.

For the training system, the use of a distributed system has the advantage of data processing: storage of information about students, construction of training courses, verification of passed material, etc. When using cloud computing in such systems, mobility is an advantage. Therefore, a person can access training materials, courses, or test their knowledge from anywhere on the planet with Internet access and the device they need.

Learning management systems have become an integral part of the e-learning content development process, especially if there are many trainers and few trainers in the school or not, so one of these systems needs to be used to facilitate the tasks and refine the learning process.

Taking into account integrated knowledge-based methodological framework for staff-training in IT-companies [1; 2], the purpose of this work is to explore the technologies, approaches, and methods used in cloud platforms. Develop a solution to reduce downtime, scalability, and use only the required computing resources at any given time that can be deployed in distributed adaptive Learning Management System (LMS) [3].

Existing platform and technologies overview. *Overview of cloud platforms.* The hardware and operating environment of a server in an Internet-based datacenter. The system software components (OS, virtual machine monitor, etc.) are called the “cloud stack” [2].

When using cloud platforms by clients, only the organization of the workplace (computer/laptop/tablet) is required, regardless of the location. The only condition is the availability of Internet access. The client (user of the cloud platform) is only responsible for the administration of its applications and software.

Amazon Web Services is a subsidiary of Amazon.com, which provides a cloud-based leasing platform to individuals, companies, and governments on a paid subscription basis. The technology allows subscribers to have a complete virtual cluster of computers, which is always accessible via the Internet.

Microsoft Azure is a cloud platform and infrastructure of Microsoft Corporation designed for cloud computing developers and designed to streamline the process of creating online applications. A close competitor to AWS with an extremely capable cloud infrastructure. The Azure platform is also working with data centers.

Google Cloud Platform is Google's suite of cloud services that run on the same infrastructure that Google uses for its end-user products, such as Google Search and YouTube. Google later entered the cloud market and has no enterprise focus to help attract corporate clients. But his technical knowledge is deep, and his leading capabilities in deep learning and artificial intelligence, machine learning, and data analytics are significant strengths.

DigitalOcean is a US-based hosting company focused on helping developers launch more applications faster and easier. DigitalOcean provides cloud servers that developers can use to quickly create new virtual machines for their projects. They allow you to fully control the web hosting environment at the same time that the user pays only for the resources used. DigitalOcean's ultimate goal is to use a solid-state drive (SSD) to create a user-friendly platform that will allow their clients to migrate projects to and from the cloud, increasing productivity with high speed and efficiency [3].

Scalability in cloud computing. Scalability is the unique feature of cloud computing where dynamic provisioning of the resources is being done by the clients themselves with in the real time slice. Vertical scalability is the ability to increase the capacity of existing single hardware or software by adding more resources to the same server or hardware. Horizontal cloud scalability is the ability of the system or resources to connect multiple hardware or software entities, such as servers or networks so that they work as a one logical unit [4].

Load balancing. Load balancing is a method that has helped networks and resources, to provide maximum throughput with minimal response time [5].

In the static load balancing method, the performance of nodes is determined at the beginning of execution. Then, depending on their performance, the workload is distributed at the outset by the master node. The slave process calculates its distributed work and transmits its result to the master. The task is always performed on the node to which it is assigned.

Dynamic load balancing differs from static algorithms in that the workload is distributed between nodes at runtime. The wizard assigns new processes to subordinates based on the newly collected information. Unlike static algorithms, dynamic algorithms distribute processes dynamically when one of the processors becomes under load.

Virtualization. The creation of isolated environments within a single physical device. Each environment looks

like a separate computer with its characteristics, such as memory, processor and so on. This environment is called a set of logical resources [8].

Containerization. An alternative to full machine virtualization, which involves encapsulating the program into a container with its operating environment. This provides many benefits of downloading the application to a virtual machine since the application can be run on any physical machine without having to worry about dependencies.

Proposed approach. *Choosing a cloud platform.* Among all cloud platforms considered for use in a distributed system, DigitalOcean was selected. This platform has several significant advantages over other platforms:

- uptime 99.99 %;
- convenient tariff plan for the use of resources – payment only for what they used;
- IaaS is a provider of computing resources, so it is possible to adjust the distribution of resources according to needs [9];
- the ability to get computing resources quickly by deploying the required number of virtual machines or "drops»;
- the use of solid-state SSDs, which raises the speed of cloud computing on the platform;
- use of KVM (Kernel-based Virtual Machine) hypervisor [10, 11].

Scaling the system. When reviewing scaling methods for a distributed system, two main ones were selected – horizontal and automatic, and manual as a secondary.

The horizontal method is best suited for running LMS in the cloud since it is easier to create new virtual machines on the platform during high load and transfer to them the load that arises from systems upon request. If you take the vertical method, you need to create a new virtual machine of larger size and transfer all the data to it and deploy it in the cloud. This means that the system may not be available for some time, so users will not be able to work with it [12].

The second main method is automatic. It will allow you to create new computing units to distribute the increased system load in the cloud.

We will also use the manual method as an auxiliary. After all, if the system administrator knows that the load will increase, then he can add new virtual machines himself or remove if some of them are no longer in use.

Load balancing in the system. Throttled load balancing method was chosen for system load balancing (fig. 1).

The load balancer (LB) maintains a table of virtual machine indexes, as well as their states (Available or Busy). The client/server first requests the data center to find a suitable virtual machine (VM) to perform the recommended task. The data center requests a LB to distribute the virtual machine. The LB scans the index table from above until the first available virtual machine is found or the index table is completely scanned.

If a virtual machine is found, the data center passes the request to the virtual machine identified by the identifier. Also, the data center confirms the load balancing of the new distribution, and the data center appropriately revises the index table. When processing a client request, if the corresponding VM is not found, the LB returns "–1" to the data center. The center request is processed by the data center.

This choice is due to the following factors use only the required computing resources, simple implementation and speed of execution.

At the moment, this algorithm is optimal for our system. But it should be noted that in the future, with

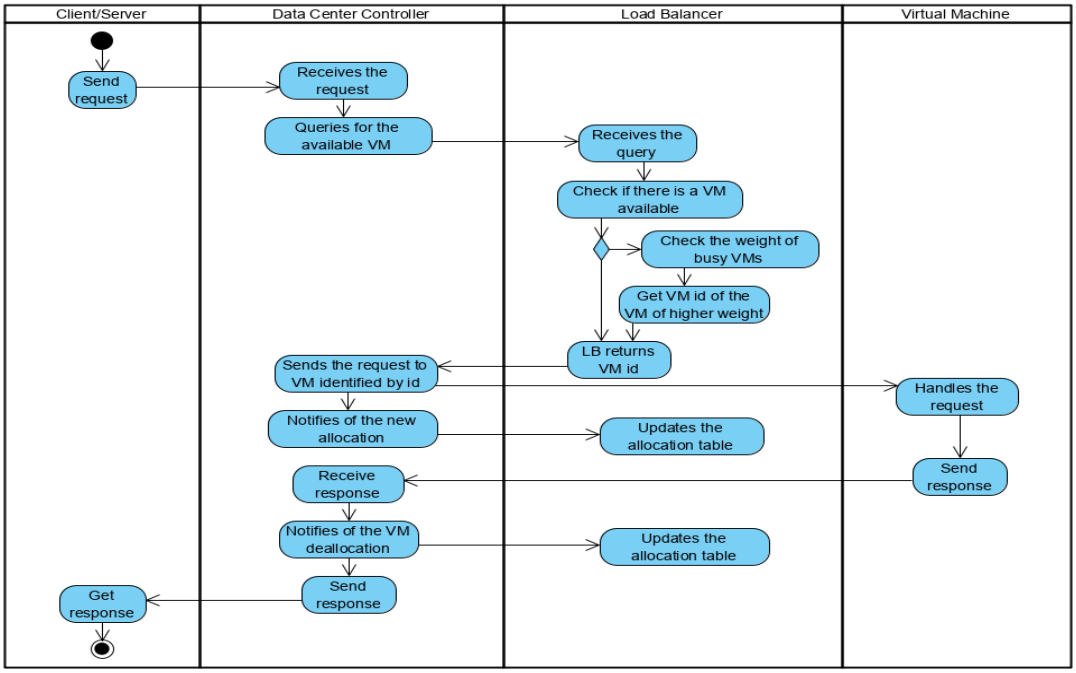

Fig. 1. Activity diagram for throttled load balancing

system scaling, a more sophisticated algorithm will have to be used to efficiently use all computing resources.

Deployment in the cloud. The chosen cloud platform is DigitalOcean, which provides computing units called drops (fig. 2). To ensure maximum data security and the fastest data processing in the cloud, we will use containerization in a virtual machine. Containerization will be provided by Docker Compose, as the system consists of several components (fig. 3). Also, to create containers, we will create virtual machines that have a specially designed OC for the best Docker support [13].

Comprasion of solutions. Let's compare the proposed solution with the solution where vertical scaling will be present. When using this scaling method, we need to move all the data from one virtual machine to another with higher characteristics (CPU, RAM, hard disk). In this case, LMS will be in downtime for a certain time:

$$t_{\text{downtime}} = t_{\text{allocation}} + t_{\text{transfer}}, \quad (1)$$

where t_{downtime} – downtime for LMS;

$t_{\text{allocation}}$ – time for hypervisor to allocate resources for VM;

t_{transfer} – time for transferring data from one VM to another.

Moreover, time for transferring data from one VM to another growing as more size of data is.

At table 1 we can find a simple comparison between the data size of VM and time for copying its data to another VM.

Here you can clearly see that the time to copy data is growing along with the volume of this data. Accordingly,

In the proposed solution, the downtime time formula remains the same (1), but the data transfer time will be constant, because it is limited by a certain template size of our virtual machine. Now we can get the efficiency and availability of the proposed solution (2):

$$Ef = \left(\frac{t_{\text{vert}}}{t_{\text{hor}}} - 1\right) \cdot 100\ \%, \quad (2)$$

where Ef – efficiency of the proposed solution;

t_{vert} – time for transferring data with vertical method;

t_{hor} – time for transferring data with vertical method, we set it to 86, if we use 1024MB template of VM for deploy.

with each change of VM, the downtime will increase.

Table 1 – Dependency between time and data size

Size(MB)	Time(secs)
32	10
64	14
128	24
256	40
512	60
1024	86
2048	115
4096	148

Table 2 presents the efficiency calculations for two cases in which it is necessary to change a virtual machine that has a larger volume. You can see how the efficiency of solutions using horizontal scaling is growing in comparison with vertical.

Table 2 – Calculation of efficiency

t_{vert}	t_{hor}	Ef
115	86	43,75 %
148	86	85,00 %

These data are illustrated in more detail in Fig. 4.

Where y-axis is Efficiency and x-axis is the size of data in VM growth in the vertical method.

The implementation of this solution into the work of adaptive LMS will improve its efficiency. Now users will not need to wait more and more times each time before they can again access their training courses. Of course, increase their effectiveness during training [1].

Conclusions. The use of cloud platforms for the construction of distributed systems is a practice that allows to use only the required amount of computing capacity. This way you can focus on other aspects of the system.

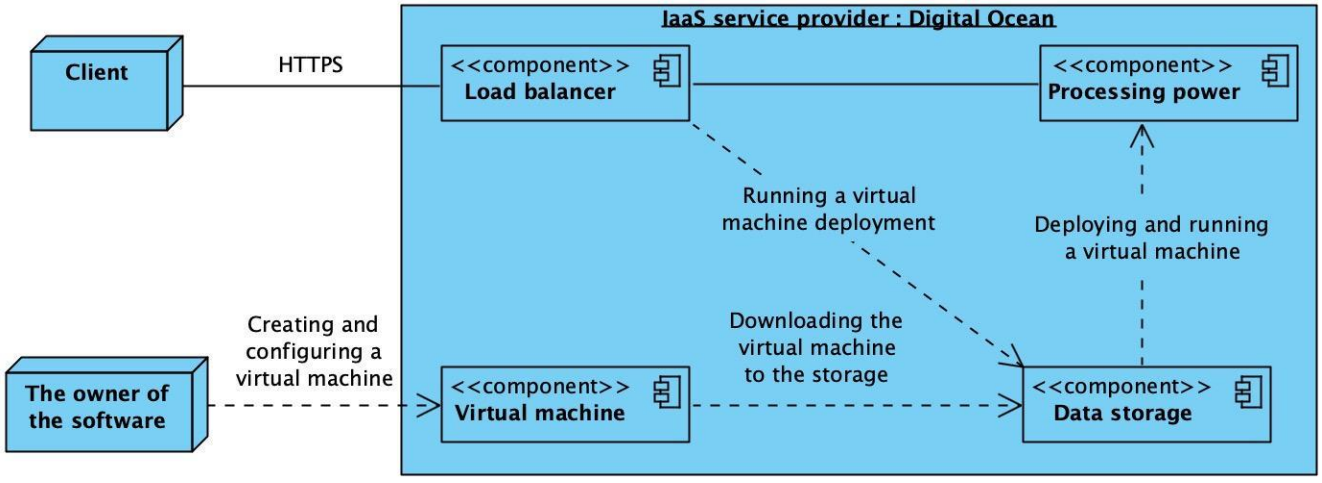

Fig. 2. Model of system operation using Digital Ocean cloud platform

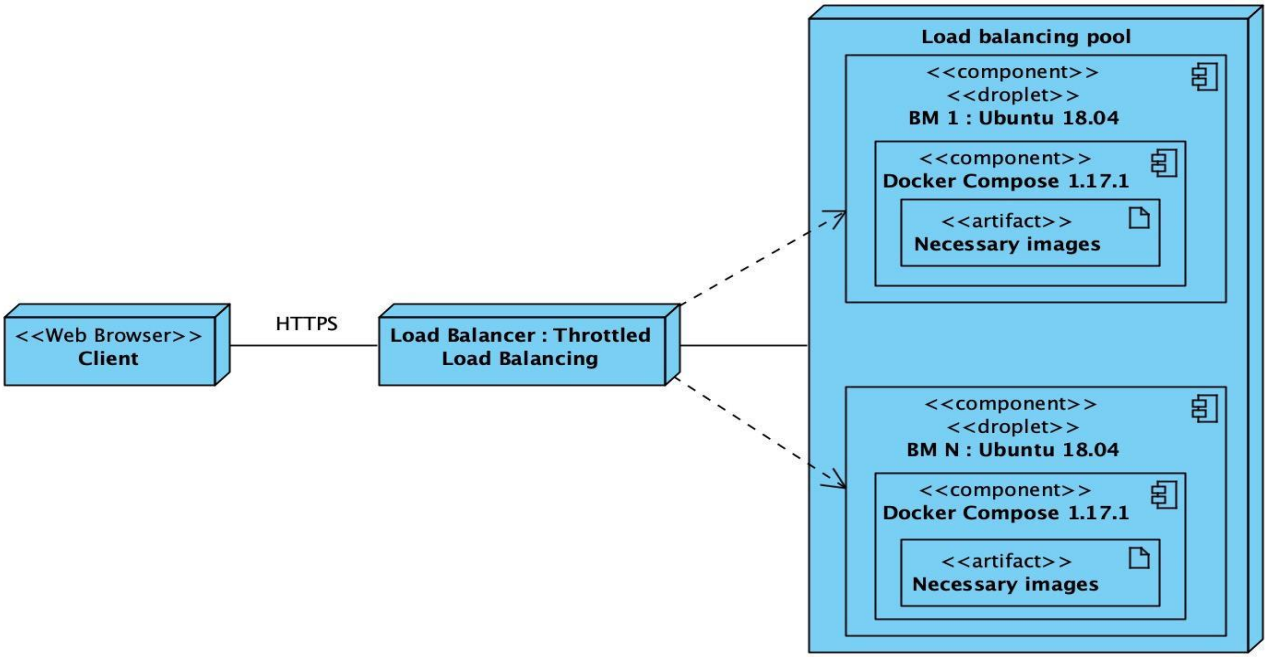

Fig. 3. Web application deployment diagram

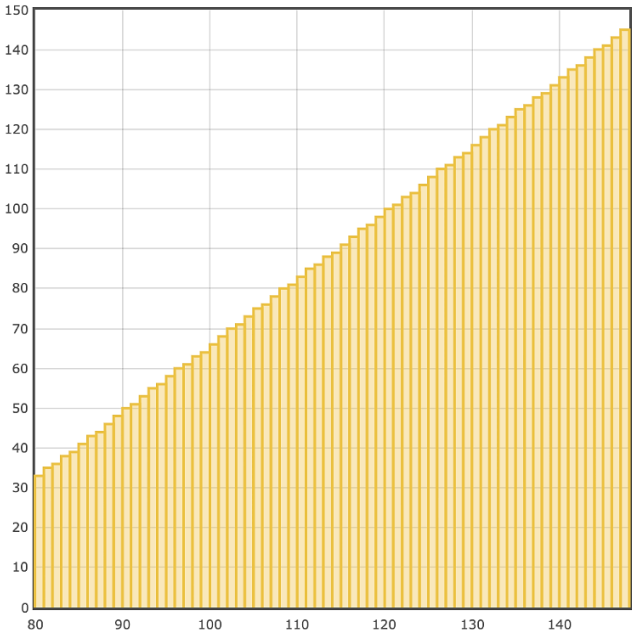

Fig. 4. Efficiency growth

Cloud computing and platforms, scalability, load balancing, virtualization, and deployment through containerization were reviewed during the work. The DigitalOcean platform was investigated their way of providing computing resources with Drop-lets.

As a result of analyzing information on existing technologies, approaches and methods for using cloud platforms in distributed systems, they have been applied to develop a solution to reduce downtime for a distributed adaptive LMS.

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Received 12.11.2020

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