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Comparison of the offer of selected cloud service providers from the point of view of implementing IT projects based on open code

Porównanie ofert wybranych dostawców usług chmurowych z punktu widzenia realizacji projektów informatycznych opartych o otwarty kod

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Abstract

The article presents a comparison of the offers of selected cloud computing providers in terms of their use in the process of developing and implementing IT services based on the idea of open-source code. The research concerns two groups of cloud services. The first one is provided according to the IaaS model and has the form of a virtual machine lease. The second service based on the PaaS model and is represented by database instances. The analysis is both qualitative (subjective assessment) and quantitative. In the latter case, it consists in a series of measurements of the parameters of virtual instances. Based on this analysis, the best public cloud service provider for users starting to use cloud computing resources was selected.

Keywords: cloud computing; IaaS service model; PaaS service model

Streszczenie

Artykuł przedstawia porównanie oferty wybranych dostawców chmury obliczeniowych pod kątem ich wykorzystania w procesie przygotowywania i wdrażania usług opartych o idee otwartego kodu źródłowego. Przeprowadzone badania dotyczą usług dostarczanych według modelu IaaS w postaci dzierżawy maszyny wirtualnej oraz usług dostarczanych według modelu PaaS w postaci usług baz danych. Zaprezentowana analiza ma charakter tak jakościowy (ocena subiektywna) jak i ilościowy, który polega na szeregu pomiarów parametrów instancji wirtualnych. Na podstawie tej analizy, wybrany został najlepszy dostawca usług w chmurze publicznej dla użytkowników rozpoczynających wykorzystywanie zasobów chmur obliczeniowych.

Słowa kluczowe: chmury obliczeniowe; model usług IaaS; model usług PaaS

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1. Introduction

Observation of trends in the IT (Information Technology) market shows the increasing importance of services, which are implemented on a cloud computing infrastructure. The availability of this infrastructure and the related offer of IT service providers are expanding practically overnight [15]. Consequently, among individual software developers as well as small and medium-sized IT companies, there is a growing interest in using cloud resources on daily basis. In this area, services offered on public cloud computing infrastructure play by far the most important role [8],[15]. Thanks to these services, the technological and economic barrier of entering the IT market has significantly decreased. Simultaneously, the competitiveness on the market has also increased rapidly and the development of innovative IT solutions has accelerated [13],[18].

Considering the above observations, this article is devoted to a multi-criteria comparative analysis of the offer of cloud service providers who are leaders in this market [19]. The analysis is focused on the offers addressed to individuals and companies wishing to join the on-going IT revolution, and thus want to use the possibilities and advantages of cloud computing.

The purpose of the research is a multi-criteria evaluation of cloud services that are most often used by novice users and developers od open-source applications [17]. Therefore, the tests based on cloud computing resources that are offered under free tiers. The research method used for this study is comparative method. The chosen features of the selected cloud computing services are tested and compared. The cloud computing offers are selected and analyzed based on their published documentation and provider web pages.

1.1. Literature Review

Research and analysis of cloud computing services are the subject of many publications presented both in scientific journals and online resources [14]. However, few of them refer to the issue of comparing the characteristics and parameters of services used by all those who can be described as beginner users of cloud services. In our opinion, this is a point of view that deserves a deeper analysis.

A similar approach to the one presented in this article can be found in the article [1], in which the authors set themselves the goal of comparing the offer of the two most popular cloud service providers. Based on the comparisons' results, it was indicated that the Microsoft

Azure cloud offers the best interface for managing and monitoring services (the friendliest, especially for novice users). However, by analyzing all the results describing a wide range of service features, the authors indicated the Amazon AWS cloud as the one with the most positive sub-assessments. On the other hand, publication [2] contains a description of a comparative analysis of three selected cloud service providers. The research covered 12 services that are particularly useful for programmers implementing their projects in an organizational structure typical of small and medium-sized companies. The conclusions that have been defined based on the conducted analysis indicate that the Amazon AWS cloud is the best offer when the implemented IT project enters the implementation phase. In this phase, the ability to scale and monitor the project based on a global infrastructure begins to play a key role efficiently and flexibly. On the other hand, Microsoft Azure was indicated as a very good solution for small companies whose service projects are based on Microsoft solutions and when migration to the cloud from its own IT infrastructure (from a private cloud) is considered. Another service provider included in the discussed comparison, Google, and its flagship service Google App Engine confirmed advantage in terms of configuration flexibility and a wide set of solutions dedicated to developers, while at the same time competitive conditions for using the resources offered by Google infrastructure. The last of the companies compared, IBM and its IBM Cloud Platform proved their high competitiveness thanks to the unique implementation of virtualization and based on it a wide and (in many cases) unique offer of services.

A completely different approach was presented in [3]. The author of the research presented in it conducted a comparison of the costs of using several of the most popular services offered by selected cloud computing providers. The article compares the following services: data warehouse and virtual machines. In the first of the above-mentioned categories (data warehouse services), the highest marks were awarded to services offered in Microsoft Azure. In the group of virtual machine lease services, the comparison of costs in various payment models, ranging from the PAYG (pay-as-you-go) model, through annual subscriptions to the lease in the spot scheme, did not indicate a clear winner. The results cited in the article preferred, alternately, Amazon AWS or Microsoft Azure as the most advantageous service offer with specific lease parameters.

1.2. Service delivery models in cloud environments

Each public cloud provider has the choice of providing services according to three models.[4] From the point of view of novice users, the most important are those that provide the ability to quickly configure the necessary virtualized infrastructure and, on its basis, configure the development environment for their own service [9], [10], [11]. Based on this assumption, services provided according to the IaaS and PaaS models play a key role. All three models are characterized below.

- IaaS model (Infrastructure as a Services). This is the basic model that is offered as part of services available in public clouds. This service offers on-demand network resources, data warehouses and computing resources that can be easily scaled to individual needs. An example of this type of service model is the lease of virtual machines and network switches. They create a foundation for defining routes and access rules for individual infrastructure components.
- PaaS model (Platform as a Services). The second model covers all the services available under the IaaS model, but additionally also provides services related to the possibility of using specific supporting software. In practice, this means that in this model, immediate availability of selected software components is offered, the delivery of a virtual machine with the appropriate operating system installed (along with the necessary licenses), or the delivery of a ready-made database platform managed by the provider. Usually, the implementation of this model is additionally associated with the service provider's guarantees that the condition for the provision of individual services will remain unchanged. These conditions are defined in SLA (Service Level Agreement) contracts.
- Saas Model (Software as a Service). The last of the discussed models of providing services based on public clouds is the SaaS model. This model allows for the provision of infrastructure dedicated to the customer's own service, which is to be provided by a given service provider. For the end user, this means that he can implement a developed application or service that can be used immediately, and the costs of its operation are related to the real time of its operation.

Table 1 presents a summary of the features of the above-discussed service delivery models which based on public clouds.

Table 1: Characteristics of service delivery models

Model	Typical services	Use cases
SaaS	e-mail, task automation, service acquisition, social media	platform for service providers
PaaS	development team collaboration, application design and testing, database integration	supplemental or alternative to locally managed tool sets configured per project/service
IaaS	virtual machines, clustering, load balancing, storage resiliency, log access, monitoring	high-performance computing (HPC), web application, data storage

According to the information in the previous parts of this chapter, the presented comparative analysis concerns services provided according to the IaaS and PaaS models.

2. Benchmarking of free virtual machine instance lease services.

During the comparative analysis, the most popular cloud service providers were considered, respectively: Amazon AWS, Microsoft Azure, Google GCP. As part of all the above-mentioned clouds, new users are offered a set of services that can be used for one year at no cost. This creates an easy and cheap way to test and implement IT solutions for a wide range of small businesses or newly launched projects. In addition, thanks to this offer, thousands of users can create applications and services based on open-source licenses [16].

This chapter presents a comparative analysis of the lease offers of free virtual machines provided according to the IaaS model. All the presented measurements were carried out based on virtual machines running under the Linux operating system, Ubuntu 20.04 LTS distribution. Each of the VMs (Virtual Machines) had the same or similar parameters. The list of these parameters is presented in Table 2.

Table 2: Parameters of the virtual machines used during the tests

Cloud provider	Service name	vCPU	RAM
AWS	AMAZON EC2 t2.mikro	1	1GB
AZURE	Virtual Machine - B1s	1	1 GB
GCP	Compute Engine E2-micro	2	1 GB

The bench.sh script [5] will be used to carry out the first group of performance tests on virtual machines. The role of this script is to collect information about the software available on the VM, to test the speed of writing and reading data on the VM disk, and to test the network connection parameters to the server based on the speedtest.net service. The Phoronix-Test-Suite Benchmark program will be used for the implementation of another group of tests, which will enable the performance of RAM memory performance tests [6].

2.1. Test results

Table 3 shows the virtual machine parameters collected with the bench.sh script. These data include information about the processor model, the number of processor cores and their clock frequency. Additionally, data on disk capacity and operating memory capacity as well as system architecture and operating system version were collected. The last data set contains information about the location of the VM and the type of the virtualization system.

When analyzing the data from Table 3, it can be noticed that individual machines use different hypervisors. A virtual machine running in the Amazon AWS cloud uses the XEN manager, the machine running in the Microsoft Azure cloud uses Hyper-V (Microsoft Virtual Machine), and the machine working in the Google cloud is based on the KVM (Kernel-based Virtual Machine) hypervisor.

Table 3: Specification of the tested virtual machines

Parameter	AWS EC2	Azure Virtual Machine Linux – B1s	GCP Compute Engine E2-micro
Processor	Intel® Xeon® CPU E5-2686 v4@2.30GHz	Intel® Xeon® Platinum 8272CL	Intel® Xeon® CPU@2.20GHz
No. of cores	1	1	2
CPU cache	46080 KB	36608 KB	56320 KB
Encryption standard AES-NI	on	on	on
HD size	29 GB (użyte 1,9GB)	32,9 GB (użyte 1,6 GB)	29 GB (użyte 2,6 GB)
RAM	967,9 MB	908,5 MB	968,1 MB
Operating system	Ubuntu 20.04.4 LTS	Ubuntu 20.04.4 LTS	Ubuntu 20.04.4 LTS
CPU architecture	x86_64 (64 bit)	x86_64 (64 bit)	x86_64 (64 bit)
Linux kernel	5.13.0-1022-aws	5.13.0-1023-azure	5.13.0-1024-gcp
Networking - TCP	TCP CC: cubic	TCP CC: cubic	TCP CC: cubic
VM standard	Xen-DomU	Microsoft Virtual Machine	KVM
Location	Frankfurt am Main Region: Hesse	Frankfurt am Main Region: Hesse	Frankfurt am Main Region: Hesse

The processors are of a similar class, but the machine provided by Microsoft Azure has the highest processor clock speed. However, in the case of GCP Compute Engine, the e2-micro machine can be launched for which Google offers 2 virtual processors and it should be emphasized that this is the lowest option. It should also be noted that each tested machine has the same operating system installed, but the load on the machine at the start of each cloud service provider differs, e.g., the disk usage in Amazon AWS is 1.9 GB, in the case of Google GCP it is already 2.6 GB, while in Microsoft Azure it is only 1.6 GB of the occupied space on the hard disk.

Figure 1 summarizes the results of I/O operation performance measurements for the hard disk for selected virtual machines,

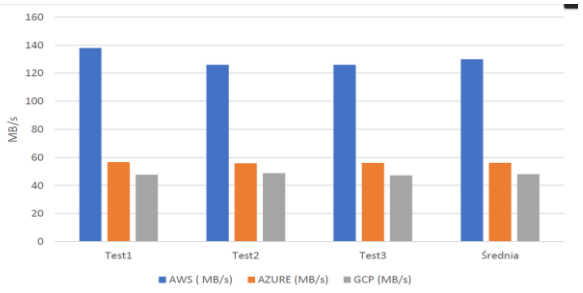

Figure 1: List of I/O operation parameters for disks on the three types of virtual machines.

Based on the obtained results, it can be concluded that the best parameters for reading data from the disk were obtained for a virtual machine running in the Amazon AWS cloud. The average of the obtained measurements was 130 MB/s. This means that it is 56.7% higher than the disk performance of a virtual machine running in the Microsoft Azure cloud and 63% higher than in the case of Google GCP. Disk performance is one of the key elements in a virtual machine, which affects the level of acceptance and comfort of work for each user, including beginners.

Figure 2 contains a summary of the speed measurement of the data download and upload along with the recorded delay values. The speedtest.net service was used in these tests.

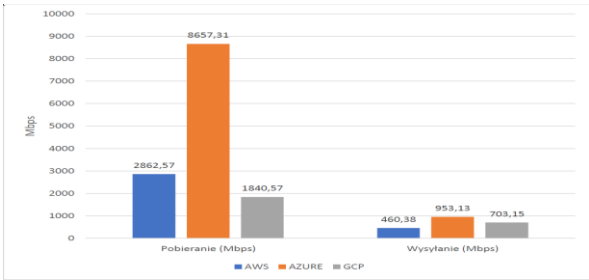

Figure 2: The results of network connection performance measurements.

The obtained results show that the virtual machine running in the Microsoft Azure cloud turned out to be the clear leader in terms of network connection parameters. The second place was taken by a virtual machine based on the Amazon AWS public cloud infrastructure, and the worst results were obtained for the Google cloud.

Another test concerned the measurements of the performance of individual virtual machines from the point of view of operations at the operating memory level. This test has been divided into 5 steps: add, copy, scale, triad and average, which provide a quantitative description of the performance of the process of reading and writing data blocks. Table 4 shows the results of the measurements obtained in this test.

Table 4: Results of operational memory performance measurements for selected virtual machines

Test	AWS (MB/s)	AZURE (MB/s)	GCP (MB/s)
Integers			
Add	9644,03	13141,87	1852,49
Copy	4221,35	12587,29	1610,35
Scale	1124,93	10198,95	1518,61
Triad	1072,1	12876,24	1570,3
Average	1128,44	12214,11	1565,42
Floating point			
Add	9430,72	11222,99	1834,53
Copy	8226,21	12742,88	1572,45
Scale	4238,46	9766,61	1534,29
Triad	992,47	12942,24	1598,51
Average	1038,32	11681,72	1582,43

In this test, the grade is better when the measured value is higher. The results of the operational memory performance measurements show that the best parameters are offered by a virtual machine running in the Microsoft Azure public cloud. At the same time, the virtual machine running in the Amazon AWS cloud showed much better parameters than the virtual machine running in the Google cloud.

3. Benchmarking of free database services

Analysis of the performance of database services is based on VM instances offered as part of free annual subscriptions, the so-called free tiers [12]. In addition, it was assumed that performance tests of subsequent database services are carried out based on a VM located in the same subnet as the database service. The database performance measurement was based on the Sysbench [7] program installed on Ubuntu 20.04 LTS amd64. This program measured the parameters of reading and writing to the database, using for this purpose data previously prepared especially for the needs of the presented comparative analysis. The use of Sysbench is illustrated by the following commands:

```
sysbench --db-driver=mysql --mysql-db=test \
--range_size=100 --table_size=10000 \
--tables=2 --threads=1 --events=0 \
--time=60 --rand-type=uniform \
/usr/share/sysbench/oltp_read_only.lua prepare
```

In turn, the command used to test the database is as follows:

```
sysbench /usr/share/sybench/oltp_read_write.lua
--mysql-db=test --threads=60 \
--db-driver=mysql -report-interval=1
```

3.1. Comparison of parameters of database services

The list of parameters of free database services offered by the analyzed cloud service providers is presented in Table 5.

Table 5: List of parameters of tested database services

Service provider	Service name	vCPU	RAM	HDD size
AWS	AMAZON RDS db.t3.micro	2	1 GB	20 GB
AZURE	Microsoft Azure for MySQL - B1s	1	2 GB	20 GB
GCP	Cloud SQL db-g1-small	1	1,7 GB	20 GB

When performing tests on database services, limitations in the number of possible simultaneous database connections were observed. Therefore, the test was limited to 60 simultaneous database connections. Table 6 summarizes the test results for the three analyzed cloud service providers. The test is divided into 4 parts (read, write, number of transactions per second and delay) and in each part 3 tests were performed, and the average value was calculated on their basis.

Regarding the average values for the process of reading data from a specific database, the best parameter values were obtained for the database service running on the Amazon AWS cloud. At the same time, the worst results were obtained for the case of tests for the database service working in the Microsoft Azure cloud.

Table 6: Test results of selected parameters of database services

	AWS	AZURE	GCP
READ [no. of queries]			
test1	62748	25984	56924
test2	63098	25200	58002
test3	59136	28392	55944
average	61660,67	26525,33	56956,67
WRITE [no. of queries]			
test1	17835	7345	16104
test2	17946	7115	16447
test3	16843	8005	15846
average	17541,33	7488,33	16132,33
TRANSACTIONS [no. of transactions/s]			
test 1	440,66	177,41	393,19
test 2	443,04	171,27	403,77
test 3	415,3	190,98	385,66
average	433	179,89	394,21
DELAY [ms]			
test 1	135,51	332,85	151
test 2	134,65	343,79	147,34
test 3	143,6	307,43	153,7
average	137,92	328,02	150,68

The analysis of the measured average values of writes to the database leads to similar conclusions as in the case of data reading tests. Based on the tests, it can be indicated that the best one was the database running in the Amazon AWS cloud, while the worst results were obtained for the database operating in the Microsoft Azure cloud infrastructure. On the other hand, the database operating as part of the Google GCP service was characterized by the results relatively not much worse than in the case of the Amazon AWS cloud, but at the same time the results indicate that data reading was 53.58% faster than in the case of the Microsoft Azure cloud.

In the next measurement, the number of transactions per second was examined, and similarly to the previous tests, the more transactions, the better the result. Based on the results, the Amazon AWS cloud service was found to be 8.96% more efficient than the GCP cloud service and 58.46% more efficient than the Microsoft Azure cloud.

4. Conclusion

The article presents the comparative analysis of selected services offered by the key cloud service providers.

The performance tests of the virtual machine lease services can be concluded that the most efficient offer was the machine running on the IaaS service implemented in the Microsoft Azure cloud. For this machine, better values of parameters were obtained than for a virtual machine running in the Amazon AWS cloud and Google GCP. Virtual machines based on the Google cloud infrastructure offered the worst parameters among all three tested solutions.

The performed tests of the database service showed the superiority of the Amazon AWS infrastructure, which offered the highest performance. At the same time, the results obtained in this group of tests allow pointing to the Microsoft Azure cloud as the one that offered the worst parameters. In addition, it should be added that the Google cloud database service ranked among the above-mentioned clouds, but in terms of prices it is comparable to the analogous AWS cloud service.

To summarize all the tests performed, a final evaluation scheme was adopted. This scheme is based on the award of points for individual scheme: 10 - the best, 5 - average, 0 - worst. Following the above procedure, the best service can be indicated. Table 7 presents the collected and subjectively assessed results of the analysis of the tested offers of cloud providers. They base on the results presented in previous chapters.

Table 7: The results of subjective analysis of selected services

	AWS	AZURE	GCP
Registration	10	5	0
Documentation of VMs	5	10	0
Database service documentation	5	10	0
Running a Virtual Machine	5	0	10
Use of a database service	10	0	5
Sum	**35**	**25**	**15**

As a result of the subjective assessment and after summing up the points awarded, the Amazon AWS cloud came out best, with a total of 35 points. The Microsoft Azure cloud was in second place.

Table 8 contains a summary list of points awarded based on the results of the performed performance tests of selected virtual machine instances.

Table 8: Virtual machine lease service evaluation results

	AWS	AZURE	GCP
Virtual machines: free tier offers	5	5	10
Costs without free tier	10	0	5
HDD I/O tests	10	5	0
Networking	5	10	0
RAM tests	5	10	0
Sum	**35**	**30**	**15**

In virtual machine performance tests, a virtual machine running in the Amazon AWS public cloud wins with a slight advantage. It received 35 points. The Microsoft Azure cloud received a total of 30 points and the lowest score was received by a virtual machine based on the Google cloud.

In the last statement, Table 9 presents the scores resulting from the performance tests of database services.

Table 9: Database services evaluation results

	AWS	AZURE	GCP
Specification	10	5	0
Costs	5	10	5
Tests of simultaneous connections	0	5	10
Read tests	10	0	5
Write tests	10	0	5
Transactions tests	10	0	5
Delay tests	10	0	5
Sum	**55**	**20**	**35**

After summing up the points for the performance tests of the selected database service, the database service in

Amazon AWS was the best. The lowest points were scored for a database service based on Microsoft's Azure cloud solutions.

Summarizing all the scores presented above, Amazon and its Amazon Web Services cloud services turned out to be the clear leader, followed by the Microsoft Azure public cloud and Google Cloud Platform. Both scored the same number of points

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