SYSTEM APPROACH TO THE DEVELOPMENT OF CLOUD SERVICES AND ITS IMPLEMENTATION PROPOSAL IN AN ACADEMIC ENVIRONMENT

[a]IVANA BRIDOVA, [b]PAVEL SEGEC, [c]MAREK MORAVCIK, [d]MARTIN KONTSEK

University of Žilina, Faculty of Management Science and Informatics, Univerzitná 8215/1, 010 26 Žilina
email: [a]ivana.bridova@fri.uniza.sk, [b]pavel.segec@fri.uniza.sk, [c]marek.moravcik@fri.uniza.sk, [d]martin.kontsek@fri.uniza.sk

The research was supported by the project KEGA No. 004ŽU-4/2024 “Improving the quality of education in the field of cyber security” and by the project VEGA No. 1/0588/22 "Location-Aware System for Achievement of QoE in 5G and B5G Networks". We also thank Maria Brandoburova, who helped create this paper.

Abstract: The article provides a comprehensive overview and practical contribution to the development, implementation, and deployment of cloud services in an academic environment. A systematic approach is applied throughout the paper. The result of the solution is a cloud service design methodology and an example of cloud service deployment in an academic environment.

Keywords: Cloud Computing, System Approach, Service, SDLC

1 Introduction

In today's digital age, there are countless services all around us that help users simplify and optimize their work. With the rapid and dynamic development of Information and Communication Technologies (ICT), these technologies and related services have become an integral part of our daily life in all areas. With the increase in the volume of data that we need to process, store and share, together with the availability of computing resources and diverse supporting applications, the use of cloud services becomes an increasingly interesting and effective means. One of the main benefits of cloud services is the possibility of storing and processing data from any location without the need to invest large funds in own hardware and software. Of course, it is important for the user to know what options such a cloud service provides and what advantages it brings. But the user often does not see what technical processes and infrastructure are behind these cloud services, and how it is solved so that the services meet their needs. Before a service can become available, it must be properly designed, developed, and deployed. On the contrary, in the case of its inefficient use or technical problems, the service may be taken out of operation, and our article is devoted to this area and issue.

2 Materials and Methods

The aim of our work and of this article is to review the existing works devoted to the issue of Cloud Computing (CC) and the development of CC services. Based on the knowledge, we develop and apply a systematic approach to the design of a new cloud service. As part of the solution, we developed a methodology for the design of CC services. We will present the methodology in the example of an effective design and deployment of a CC service for the needs of a small academic organization such as the Department of Information Networks at the Faculty of Management and Informatics of the University of Žilina, Slovakia. As the last part of the solution, we propose evaluation forms that will allow you to verify the quality of the provided cloud service and its actuality.

In the next parts of the paper, we will deal with specific steps and approaches to the design and deployment of cloud services. We analyze the existing procedures and studies and based on them we will develop a methodology that will enable the systematic and effective development and management of CC services. We will thus combine theoretical knowledge with practical examples and experiences from the real world to provide relevant and up-to-date information on the development and management of cloud services.

Ultimately, we believe that our article will provide valuable insights for cloud computing professionals, researchers, and developers. Our work is aimed at improving the current state and providing concrete recommendations for the design, development and deployment of cloud services that will be used by our department and its students.

3 Related works

The topic of cloud computing and the use of cloud services are becoming more and more popular, as they provide easier and more efficient operation of IT services. Using remote storage or software stored on remote hardware is very attractive, convenient, and beneficial for current users and companies. Thanks to this, many researchers are working on CC issues in various fields, as evidenced by the number of published scientific works in globally recognized databases. In our paper, we focus on a partial area of CC service development, which is related to the following analyzed areas.

The problem of the service development process was addressed by the authors in [1], the result of which is the finding that the design and development of cloud services is a complex task. This includes specification of requirements, secure deployment of services, maintenance, and assurance that the right measures have been taken to support security while also considering legal aspects. The study [2] investigates the effects of personal interaction and IT (Information Technology) integration and how, thanks to interaction with customers, the necessary knowledge is obtained, which subsequently facilitates the process of developing a new CC service. The research found that face-to-face interaction still plays a key role in supporting IT integration and empowering such innovative activities as service development. The authors in [3] focused on productivity, efficiency, and access to public CC services. They are dedicated to supporting the use of the PCP (Pre-Commercial Procurement) model, which supports the benefit of innovation and thereby increases the quality of the developed service. The PCP model was used in the development of the information service (in the phase before commercial use) and this model is considered the basis of success in the implementation of CC services [3]. The study [4] deals with the ability to effectively manage the life cycle of services within SOA (Service Oriented Architecture) already in the design and development phase before its introduction to the market. The authors summarized the needs for the given service, followed by their prioritization and identification for the design phase. The strategy of dividing the development process into several smaller tasks was dealt with by the authors [5] who decomposed the cloud service into several layers according to the tasks. Thus, they brought layers of subsystem tasks, component tasks, individual part tasks, and function tasks. Individual task solutions are combined to create a new CC service.

From the analysis of works devoted to the issue of development, it follows that the development of CC products and services has three basic phases: design, implementation, and maintenance. During the analysis, it was found that these phases are adapted by different authors according to needs, whether it is a larger number of phases, a different naming of individual steps, or categorization into phases [4, 6, 7, 8] stage [7], cycle [6] or tasks [5].

Currently, there is a whole range of models [5, 9, 10] and methodologies [11] that serve to optimize the development of CC services. These models aim to simplify the development of the service process and improve its time efficiency, flexibility in response to changes in requirements and fulfillment of the agreed budget.

To deploy the developed CC service, it is necessary to consider the cloud provider. Choosing a suitable CC service provider is a challenging process, mainly due to the large number of Cloud Service Providers (CSPs) that offer these services. Therefore,

several studies describe methods [12] or applications [13, 14] aimed at facilitating the selection of a suitable CSP provider. During and after the selection of a CSP, an interactive relationship between the user and the CSP is important, because the more the customer is involved in the service development process, the more he specifies his requirements and introduces changes during the development process, thus preventing the introduction of changes after the development itself. This avoids higher costs, non-compliance with the planned product delivery and the resulting unsatisfactory product [15]. The conclusion of a mutual contract between the user and the CSP not only improves mutual trust, but also ensures clear and well-defined obligations and responsibilities of both parties involved, as well as data protection and privacy rights and obligations [8]. Another of the studies [2] points to the diversity of requirements and adaptation to their implementation during the development of services, which according to several studies is a problematic part [2, 15].

During When choosing a CSP, it is necessary to establish the parameters of cloud services [16]. Among them we recommend the following.

Technical parameters: The study [17] is devoted to the description of the architecture of the developed cloud service from the point of view of access to data and computing resources and defining the hardware and system requirements for the computing nodes of the developed application.

Economic parameters: The authors [18, 19] monitor the initial costs for the introduction of cloud services, the saving of operating costs and time when renting cloud services, the return on the provided investments and the item in the form of payment for the rented service. Subsequently, they monitor the effectiveness of the investment for the established solution.

Security: The study [11] focused on security from the point of view of the risk of service failure due to insufficient protection against dangers such as DNS (Domain Name System) server failure, natural disaster, etc. The authors [1] focused on emphasizing security requirements already in the phase of development and subsequent deployment of CC services. Among the most important part of security is network security, where the customer must rely on the security provided by the CSP provider. From the point of view of security, the parameters were divided into data protection, operational security, network protection and physical security [18]. Another study focused on data control and the main problems arising from dependence on CSP providers. Protection of information and infrastructure are considered key. For the provider to ensure information security, it is necessary to solve data separation, data classification and management of information rights. The protection of the infrastructure is based on a CC solution built from safe components, constructed according to valid safety rules, which has treated communication with the environment [19].

Quality: Customer satisfaction is the most important factor in service provision, so providers pay attention to feedback and service evaluation to have the opportunity to reveal strengths and weaknesses in development and thereby obtain better quality service results and satisfied customers. The work [8] mainly focuses on the evaluation of services with detail on the Quality of Service (QoS) and the subjective perception of the end user with the overall acceptability of the application or service (QoE), including the combination of monitoring data and the subjective perception of different users and their unique requirements. The aim of the research [20] is to develop an effective way to evaluate trust in the provider, reliability and product quality based on feedback, thereby ensuring the quality of CC services. The scheme proposed by the study has precisely determined cloud service trust values based on the aggregation of real feedback trust, reputation trust, and service quality. The results of the analysis show that a reliable monitoring system based on feedback is desirable and necessary for the reliable provision of cloud computing services.

4 Analysis of the use of cloud services

The topic of cloud computing and the development of cloud services are dealt with by various working groups in the world and in Slovakia. In the past, several surveys have been prepared on the topic of CC, which analyze cloud computing and the use of its services from different perspectives. Part of the research focused on factors influencing the adoption of cloud computing services, other studies examine the adoption of CC services in specific organizations (health care, government organizations, education, private sector). To process the analysis of the use of cloud services, we used information obtained from surveys conducted in Saudi Arabia and in Slovakia [21, 22].

The mentioned surveys show that:

- CC is used in various sectors, both public and private.
- The deployment of CC is important mainly because of cost reduction and improvement of service availability.
- Public, private, hybrid and community clouds are built and deployed in organizations, which use service deployment models (Service as a Service SaaS, Platform as a Service - PaaS) and infrastructure (Infrastructure as a Service - IaaS).

The findings also revealed:

1. There is no correlation between interest in cloud computing and organization size. This difference is more obvious when using free services among small and medium-sized enterprises, which are more interested in free services.
2. The theory that if the organization uses an external supplier for technical support, it will be more interested in using cloud services has not been confirmed.
3. The assumption was confirmed that the larger the organization is, the more interested it is in storing data in data repositories or servers located directly in the organization.
4. With the wider adoption of CC solutions, caution is needed when transferring data, fear of losing control over data, its security, protection of personal data, guarantee of administration.
5. The biggest barrier in the introduction of CC solutions is "security" (concern about security, data protection and their guarantee) and "trust" (it is difficult to identify which services are trustworthy).
6. Scalability of resources in cloud services, which is directly related to the size of the organization, and "mobility" (unlimited access to services and applications) are identified as benefits of cloud computing.

The surveys show that cloud computing has applications in the future, but it is necessary to invest more in CC education on the one hand and in the development of cloud computing on the other hand. The influence of the external environment is also of great importance, such as competitive pressure, external support, government support, various regulatory policies, and regulations, and just the adoption of the necessary rules and regulations, would facilitate the adoption of CC across organizations.

4.1 Analysis of the use of cloud services in the educational process

The authors in [23] compiled a checklist of cloud services so that academic organizations can choose the most suitable cloud services for them. However, they mainly dealt with services for research in medicine. This list covered areas such as security, functionality, performance, and rights.

In studies [24], a questionnaire survey was processed, which monitored the use of cloud services in an educational environment on 240 respondents from the Faculty of Medicine of the Medical University of Tabriz, Iran. The goal was to find out the attitude and intention to use cloud services and what is the perception of security and privacy in the cloud.

Work [25] focuses on the use of a cloud storage service and how the use was affected by the arrival of the Covid-19 pandemic with an emphasis on students. The analysis of the use of cloud services for data storage was carried out in the form of a questionnaire on 137 students at the University of Žilina. The results showed that, despite some students' concerns about data protection, cloud storage is widely used, whether for school or private purposes.

The studies also show that the use of cloud services contributes to the improvement of the quality of education and the efficiency of this process. Here are some of the identified benefits of using CC in education:

- **Availability** – enabling access to information and services from anywhere via the Internet.
- **Resources** – providing access to a variety of educational documents, books, and videos to help understand the curriculum and issues students or teachers are dealing with.
- **Cost savings** – cloud solutions are often more affordable than buying different licenses, hardware, or books.
- **Flexibility** – sharing of information and documents through cloud services between teachers and students.

4.2 Linking the results of CC utilization analysis to key characteristics

The key characteristics of CC specify the possibilities of CC technology in the development of cloud services in a specific implementation environment. They do not prescribe or limit any method of deployment, service provision or operability.
In the recommendation ITU-T Y.3500 [26] and NIST SP 800-145 [27], the following key/basic characteristics of cloud computing are specified:

- On-demand self-service.
- Access via the network (Broad network access).
- Resource pooling.
- Rapid elasticity and scalability (Rapid elasticity and scalability).
- Measured service.
- Multitenancy (allows multiple customers to use the same service, while each user has access only to their settings and data).

The results of the analyzed surveys overlap with the following key characteristics:

- Self-service on demand.
- Rapid elasticity and scalability.
- Wide availability and easy access via the network.
- Multitenancy.

The overlap of survey results was also demonstrated in the following cross-sectional aspects (defined in ITU-T recommendation Y.3502 [28]):

- Mobility.
- Security.
- Performance.
- Regulation and protection of personal data.

4.3 Conclusion from surveys of the use of cloud services

Cross-sectional aspects and key characteristics of CC are important factors for the development of CC services, especially personalized ones, where services are developed based on user requirements. Specific user requirements require analyzes of a specific implementation environment.

5 System approaches to CC service proposal

A service is a resource that is provided to customers to achieve certain goals, needs or results, and thus value, benefit or experience. It is an immaterial result of human effort that can satisfy some human needs.

Service is characterized by immateriality, irrevocability, inseparability, heterogeneity, and customer involvement [29].

5.1 Cloud service

It is a form of service provided to users on demand and is designed to provide access to applications and resources without the need to purchase and deploy your own internal infrastructure or hardware. The CC service is managed by cloud computing vendors and Cloud Service Providers (CSPs).

According to the ITU-T Y.3500 standard, a cloud service is one or more functionalities offered through cloud computing delivered through defined interfaces.

A cloud service can be infrastructure, platform or software. To connect to cloud services, the user only needs a device with a network connection and an operating system [30].

The main indicators that influence the choice of a cloud deployment model are considered to be the availability of management, requirements during deployment, reliability and security conditions. A cloud deployment model identifies a specific type of cloud environment based on ownership, scale and access, as well as the nature and purpose of the cloud. The location of servers that users use and who manages them are defined by cloud service deployment models [31].

5.2 Lifecycle of cloud service development

The cloud affects the service development lifecycle and presents developers with multiple challenges and issues to address. When developing CC services, it is important to pay attention to cost optimization, management of possible risks, service security and service quality assurance.

The lifecycle of a cloud service consists of six basic phases as shown in Figure 1.

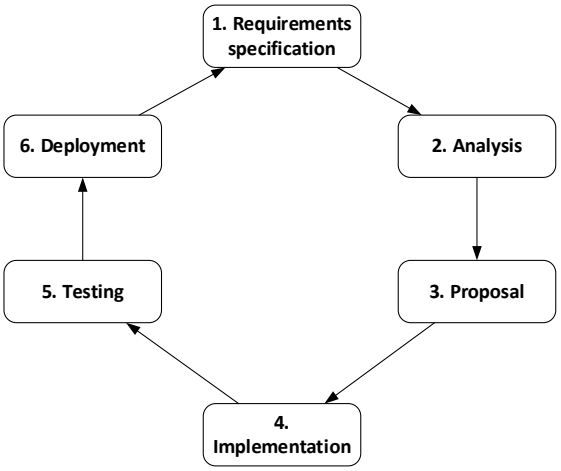

Figure 1 Lifecycle of cloud service

In order to improve the overall quality of the service and to guarantee its security, it is essential to consider security aspects in all phases of service development. Service development begins with business, security and functional requirements, which are later included in the implementation [1]. Service providers are responsible for the implementation and reliable operation of the services. Organizations that want to use the service are responsible for the appropriate selection of the service, integration of the service into their applications and systems, and ensuring continuity of operation [6].

After the service is put into operation, it is followed by its monitoring and possible optimization, in order to ensure the continuous operation of the service and that the service still

meets the customer's requirements. The termination of the service occurs at the moment when the service no longer fulfills its function.

5.3 CC service proposal

Currently, there are several models and procedures for designing and creating a service. In general, we distinguish between two approaches to development, namely systematic and non-systematic. The basic difference is that the systematic approach looks at the problem as a whole and takes into account all relationships. A non-systematic approach focuses rather on individual components and parts, regardless of possible connections and mutual influence.

When developing a particular service, it is important to consider which approach will be most appropriate for the given outcome. A non-systematic approach may be easier to implement, but leads to more deficiencies in individual parts of the service, as the service is not tested as a whole.
The basic feature of the system approach is to define the problem, determine the result (what needs to be achieved) and then decide how to get to this goal, as Figure 2 shows.

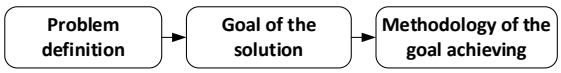

Figure 2 System methodology principle

Problem definition deals with understanding and defining the problem that needs to be solved. This includes determining its scope, causes, consequences, and significance to the organization.

The goal of the solution determines what specific goal must be achieved in order to solve the problem. The goal must be clear and measurable for the organization.

The method of achieving the goal - the methodology - deals with the selection and implementation of specific measures to achieve the goal. These measures include the use of specific technologies, methods, processes, procedures, or tools to help solve a given problem and achieve a stated goal.

The system approach includes a sequence of steps and processes that help to identify, analyze, solve problems in the development of a new service and will allow to obtain comprehensive views of the given problem and find effective and sustainable solutions.

The system approach has the following features:

- Complexity – Focus on examining the whole and considering the interaction between individual parts and the environment in which they are located, which affect the resulting solution.
- Hierarchy – A greater number of subordinate and superior parts that are interconnected.
- Dynamism – Development is not a static process, but a dynamic one that changes according to needs and circumstances and is capable of operational response.
- Sequence – The gradual introduction of new functionalities and subsequent testing and verification brings new knowledge and experience.
- Orientation on performance and efficiency – The system approach tries to achieve maximum performance and efficiency by taking into account not only the functionality but also the economic aspects of the organization.
- Applicability in various areas – the system principle is so general that it can be used in various areas, not just technical ones.

6 Analysis of the implementation academic environment for cloud service deployment - department level (KIS FRI UNIZA)

In order to successfully deploy the cloud service, an analysis of the implementation environment was processed. This process includes an assessment of the existing ICT infrastructure, the cloud services offered, as well as staff availability to determine whether it is possible to provide cloud operations and what are the needs for the deployment of the new service.

The Department of Information Networks (KIS) is one of the seven departments at the Faculty of Management and Informatics and is part of the University of Žilina in Žilina.

In addition to communication solutions, the department's research also focuses on CC, CC integration and networks, and of course education in these areas, which is offered in all three degrees of study through twenty-seven subjects.

The main reasons for introducing CC at the KIS department is to provide a better way of teaching by offering services through virtual machines. Among the benefits of introducing CC, it is expected to reduce the workload of employees and students, increase the possibility to learn, test and experiment on new technology with the possibility to research new technologies.

At the same time, the department has been trying for several years to solve the problem with the insufficient amount of suitable test platforms on which it is possible to experiment without restrictions. Before the introduction of the cloud at the department, the XenServer/XCP-ng virtualization solution implemented on several servers, or VirtualBox, was used. Due to the limitations of the solutions, the department began to deal with the CC issue in 2014, where it started building a new cloud platform.

Among the specified main requirements for the implementation of a particular cloud solution were:

- Flexible provision of virtual Linux/Windows servers.
- Use in the solution primarily of the operating system Debian and Ubuntu.
- A solution with public connectivity and continuous connectivity.
- Building the environment by users using a simple GUI.
- Cloud with open source.
- Support for virtualization of network devices.

In 2014, according to the specified requirements, a private cloud solution was deployed on the OpenStack platform.

The cloud is currently used for research in the topic of CC, for hosting VMs for other research needs, teaching or solving final theses. CC primarily uses an IaaS service that provides virtual servers.

The Horizon web interface is used for the administration of the entire cloud, mainly for creating user accounts and creating topologies. The business owner of the departmental cloud is the head of the department, with whom the administrators consult on priorities, tasks, changes, what services need to be added, etc.

6.1 Hardware equipment

The current departmental cloud uses the following hardware components that enable its proper functioning. Security and access control, in addition to OpenStack resources, is provided by the NextGen Fortigate 100F firewall, which also provides private addressing for internal communication and redirection of network traffic to the outside using NAT technology. It includes 10 GbE ports for connecting to the Internet and connecting to a Nexus switch.

Network connectivity is formed by a cluster of two Cisco Nexus data-center switches, which serves to connect all servers and the

firewall. This network is internally divided into VLAN subnets that separate internal communication of OpenStack components and VxLAN tunnels for customer/student data traffic.

The network connection also includes one gigabit Cisco Catalyst switch for IPMI (Intelligent Platform Management Interface) out-of-band management solution.

The server infrastructure itself consists of a dedicated server for the controller, a virtualization machine for service things such as monitoring, logging, management of hardware resources, and nine computing nodes. In total, the hardware solution consists of eleven servers that support hardware virtualization. The controller and virtualization server are from Cisco, the computing servers are a combination of IBM, Lenovo and HP.

Figure 3 shows the current physical topology of the departmental cloud. Each server has two 10GbE (Gigabit Ethernet) network cards bundled together for higher reliability and data transfer speed. This solution ensures that the servers can effectively communicate with each other. Also, each server contains one 1GbE RJ45 port for hardware management using the IPMI protocol.

The virtualization server runs several additional virtual machines, including MAAS (a software tool that enables the management of physical servers and their resources) and Juju (a tool for configuring, managing and deploying applications in cloud environments) [33]. In the near future, we work to introduce a monitoring solution by the Prometheus system and possibly other support services.

Computing nodes serve to provide computing capacities and storage space for virtual machines. Each of them contains 2 CPU units with multiple cores and threads, a large amount of operational memory and a combination of spinning and SSD hard drives for system operation and data storage. Each server has the Ubuntu operating system installed.

This section describes the devices that are part of a cloud suitable for a small academic organization such as a department and ensure its proper functioning. Each of these devices has a specific role, such as securing the cloud from threats from the Internet, networking servers, providing computing capacity and storage space for virtual machines, and managing the cloud.

Given the growing threats in cyberspace, it is important to have a data backup and recovery plan to minimize potential losses in the event of a disaster. The goal for the future is the introduction of private IPv6 for local communication, which would help increase the security of the department's cloud, the introduction of support for lighter containerization solutions within the CC platform and, above all, the expanded offer of CC services.

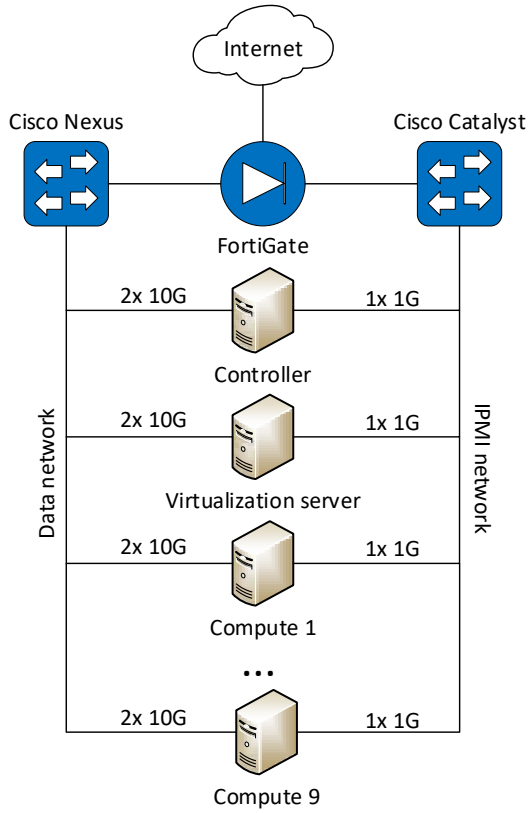

Figure 3 Physical cloud topology

Based on the analysis of the current state and the plan to expand the range of services in our private cloud, it appears to be necessary to transition from the current non-systemic approach to a systemic approach with the design and use of suitable methodologies for the design and deployment of a cloud service, which will be similar to the methodology for introducing a commercial cloud service. It also includes the processing of processes, for example quality, where it is necessary to design evaluation forms that will help ensure the quality of the service provided, as well as decommissioning an inefficient service.

7 Methodology for the development of a new CC service

Deploying a new cloud service is a challenging and complicated task. Therefore, we proposed a methodology for the development of a cloud service, which consists of nine steps, the observance of which will ensure the effective development and subsequent provision of a new service. The methodology contains recommendations, processes, and procedures for the provision of the service, its implementation, testing and management.

For the development of the CC service, we suggest following the following steps:

Goals definitions – Based on the needs of students and staff. It is necessary to find out the requirements and expectations from students and faculty employees, with the help of which the goals of the service are defined and through the analysis the functionalities and the overall purpose of the service are proposed.
Team creation – Creation of a team that will cooperate with each other on the design and implementation of a new cloud service and subsequently manage, maintain, monitor and provide service support to users when necessary.
Defining functionalities and requirements – Individual functionalities and service options must be precisely defined. Subsequently, the technical and functional requirements must be

specified, which must be measurable, in order to evaluate and monitor the service, and the financial requirements.
User interface design – It is necessary to design a user interface that is intuitive and simple from the point of view of users (students/teachers). Such an interface can be referred to as CAS (Cloud Administration System).
Cloud service design and development – The design and development of the cloud service itself according to established procedures and its subsequent testing on a small group of selected students provides feedback on the functionality, advantages, and possible shortcomings of the service.
Service security – Secure the service by obtaining security certificates ISO/IEC 27001 (Information security, cyber security, and privacy protection) and ISO/IEC 27018 (Certification for increasing the security of sensitive data in the cloud) and comply with Act 69/2018 on cyber security.
Implementation and deployment – After the successful design and testing of the service, the service is put into operation, and it is necessary to ensure the constant quality and the greatest possible error-free service.
Testing and feedback – Testing the service will ensure the functionality of the service provided. When testing, it is important to write a document that will contain a description of the testing process and all methods that will be used to verify the functionality of the service provided. Feedback will provide information about satisfaction with the service or suggestions for possible improvements.
Monitoring – Monitoring of service operation is carried out on measurable parameters that are declared in the Service Provision Agreement (SPA). It is necessary to keep monitoring records for the entire period of service operation.

8 Methodology for implementing a cloud service on KIS

The methodology of the new service which will be used at the department contains procedures that must be followed for the successful introduction of the service and compliance with the rules determined by the legislation of the Slovak Republic.
Analysis of the implementation environment – It is important to analyze the environment in which the service will be deployed so that it is technically ready and sufficient and ready to put the service into operation. It is also necessary to collect and evaluate the requirements for the introduction of the service and process the draft of functional and non-functional requirements for the given service.
Deploying the service to the cloud – The base is the preparation and therefore the determination of the non-functional requirements for the architecture such as the operating system, licenses, and hardware requirements (processor, operating memory and disk space). If all hardware and software requirements are met, the stage of installing the ready cloud service and configuring the server begins.
Setting up cloud services for basic use – will take place after the introduction of a new service (including licenses), user and administrator accounts will be created for individual users.
Contracts between the department and users (students/employees) – In the case of commercial deployment, several important agreements need to be concluded between the user and the provider - the user-provider agreement, the Service Level Agreement (SLA) and the license agreement.
Monitoring the quality of services – The quality control of the service is carried out periodically through the monitoring system, possibly also through the evaluation form. Monitoring of service operation is carried out on measurable parameters that are declared in the SPA. Subsequently, user satisfaction with the provided service is checked through a service evaluation form for users. Management can be automated by constantly checking the network, servers, availability, etc., while the automated check notifies the administrator in case of irregularities. Another management method is manual remote management of the entire infrastructure.
Support services – Providing support and managing the service includes monitoring the performance and availability of the service, managing backup and recovery of data, managing changes in requirements, managing incidents and their subsequent resolution. It is important to ensure as much time as possible to provide support to users.
Training of students and employees for effective use – User training can also take place through a user manual prepared by the provider, through video tutorials or personal training.
Adding a service to the service catalog – Inclusion of the newly provided service in the KIS catalog of provided services.

9 Cloud Service Evaluation Forms

For services to be successful and useful for their users, they must be of high quality and reliable. For this, a cloud service quality evaluation form is used to assess various aspects of cloud services. The form provides the provider with a comprehensive view of the provided cloud services and helps to decide whether to continue using the service in the same form, or if something needs to be changed, or if the time has come to remove the given service from the catalog of offered services.

9.1 Evaluation form of the quality of cloud services

The quality assessment form considers following factors:

- Availability: How often was it available and what were the service downtimes?
- Power: How quickly does the service load and how quickly do the tasks performed in it run?
- Security: How is data protected and what security measures are used?
- Scalability: How well can the service adapt to growing demands and increasing load?
- Usability: How easy and intuitive is the service to use?
- Affordability: How affordable is the service and is it worth it?

The overall rating is calculated as the sum of the points for each factor. A higher rating means a better service. If the required number is not reached, the offered service is poor quality.

9.2 Evaluation form to verify the actuality of the offered service

The form determines whether the provided service still fulfills its purpose and should remain in the catalog of offered services. The evaluation is repeated periodically (in the case of the offered cloud services of an academic institution such as KIS FRI UNIZA, it is after the end of the semester and after the end of the academic year) to ensure that the offered services are up to date.
The form considers the following factors:

1. What is the number of users for the last monitored period (e. g. last year)?
2. How many and what kind of complaints have come from users about the service?
3. Is it necessary to change the offered service (if so, how)?
4. Is the given service beneficial for KIS users?
5. Does KIS have sufficient technical security for offering the given service?
6. Does the KIS have personnel security for the further provision of the service?

Evaluation of the form provides a quick and easy verification of whether the given service will continue to be offered, whether it will be in the same state, or whether the service will be modified, or if it is found that the service is no longer used, it will be removed from the offer of the service catalog.

10 Results and discussion

Research of cloud computing and the development of cloud services is of great importance in today's IT world. Working on this topic brings many opportunities for innovation and development of new services.

Developing a new cloud service requires considerable effort, resources, and many more aspects to consider. It is important to choose a systematic approach to its development, which helps ensure success in the development of the service and that it is

subsequently able to meet the needs of customers. A systems approach enables better risk management, improved communication, and coordination between team members, and thus ensures the successful delivery of a quality cloud service.

The use and analysis of the available private cloud solution offered at the KIS department allowed us to realistically explore the potential of using the cloud in an academic environment and to develop methodologies for the design, deployment and implementation of new cloud services suitable for similar academic institutions or wider practice. The methodologies contain all the important and necessary steps and information that the provider should ensure in the design, development and provision of CC services.

Therefore, we created evaluation forms for evaluating the quality and success of the CC service on the part of the provider and the user when using it. These forms help in monitoring and improving the quality of the provided services and at the same time in obtaining feedback from users. Overall, it was shown that for the introduction of services, it is necessary to have in mind not only technical and economic aspects, but also aspects related to security, legal matters, and evaluation of service quality. The article provides a comprehensive overview and practical contribution to the development, implementation, and introduction of services.

11 Recommendations and future plans

Before a similar academic institution offers new CC services, it is necessary to ensure the stability of the CC solution so that it can be maintained and developed without threating the functionality of the entire system and its services. After solving these aspects and ensuring the stability and sustainability of the solution, the interest of expanding this community project is to open its use to the entire faculty. This still requires improvement in overall management, security, and administration.

Another plan for the future is to create a flexible catalog of services as an automated form, where the user will be able to click and select services from the catalog, which contains all available services offered by the cloud. It will also be necessary to introduce the assignment of responsibility for virtual machines to users, in the event of the occurrence of threats.

The last of the plans and improvements is a proposal to implement a tool for receiving requests from users. This tool will be benefit mainly to the administrators of the department's cloud, as problems and requests are currently entered in spoken form or through communication technologies such as email or the Microsoft Teams application. This improvement would collect comments and requests in one place, where administrators could sort them, for example, by severity. Over time, it could be expanded to include several useful functionalities.

Literature:

1. Hudic, A., Flittner, M., Lorünser, T., Radl, P., Bless, R.: *Towards a Unified Secure Cloud Service Development and Deployment Life-Cycle.* (2016). DOI:10.1109/ARES.2016.73.
2. Lindh, C., Nordman, E. R.: *New Service Development and Digitalization: Synergies of Personal Interaction and IT Integration*, (2018) Services Marketing Quarterly, 39:2, 108-123, DOI: 10.1080/15332969.2018.1436777
3. Horjak, M., Horjak, A.: "*Pre-Commercial Procurement as a Key Development Source of It Services in the Public Sector – The Case of Slovenia*." (2018) Tehnicki vjesnik – Technical Gazette, DOI:10.17559/tv-20170331205753
4. Ugochukwu, Ch., Fosu, S.: *Measures to Improve Mitigation of Cybersecurity Risks, Threats and Vulnerabilities in Service-Oriented Architecture*. (2023).
5. Ding, S., Guo, Z., Wang, H., Ma, F.: *Multistage Cloud-Service Matching and Optimization Based on Hierarchical Decomposition of Design Tasks.* (2022). Machines. 10. DOI:10.3390/machines10090775
6. Aslam, F.: *The Benefits and Challenges of Customization within SaaS Cloud Solutions.* (2023). American Journal of Data, Information and Knowledge Management. 4. 14-22. DOI:10.47672/ajdikm.1543
7. Rahmani, H., Hikmawati, E.: *Combining SDLC Method And ITIL Framework by Involving Auditors.* (2020). Jurnal AKSI (Akuntansi dan Sistem Informasi). 5. 6-12. DOI:10.32486/aksi.v5i1.431
8. Papadakis-Vlachopapadopoulos, K. *Trust-aware Life-cycle Management of Federated Edge Clouds.* (2021). DOI:10.12681/eadd/50205
9. Kumar, A., Vesireddy, A., Kumar, R., Shetty, S.: *Cloud computing security issues in delivery service models and solutions.* (2023). DOI:10.13140/RG.2.2.23286.98882.
10. Kansal, M., Singh, P., Singh, M., Varshney, S.: *A Systematic Study of Services and Security Model in Cloud Computing: A Brief Overview*. (2023). DOI:10.4018/979-8-3693-0200-2.ch001.
11. Lalitha, P., Yamaganti, D., Rohita, D.: *Investigation into security challenges and approaches in cloud computing.* (2023). Journal of Engineering Sciences. 14. 2023.
12. Gul, Z., Hussain, Z., Arain, A,, Ali, M.: *Cloud Service Evaluation and Selection based on User Preferences and Location.* (2021). DOI:10.22937/IJCSNS.2021.21.10.4.
13. Rongon, R. K. *AI based recommendation system for cloud service provider*. (2022).
14. Kandamby, I., Sasiprabha, A., Mahaadikara, H., Ganeglda, D.: *Service Provider Allocation and Customers' Service Requests Management System.* (2020). DOI:10.47001/IRJIET/2020.412005.
15. Anisiewicz, U.: *Economic determinants of new product development*. (2023). Journal of Modern Science. 54. 740-757. DOI:10.13166/jms/176402.
16. Odun-Ayo, I., Udemezue, B., Kilanko, A.: *Cloud Service Level Agreements and Resource Management.* (2019). Advances in Science, Technology and Engineering Systems Journal. 4. 228-236. DOI:10.25046/aj040230.
17. Miftakhov, E., Mustafina, S., Mikhailova, T., Podvalny, S.: *Development of a cloud SaaS service for a comprehensive research of polymerization processes.* (2021). Journal of Physics: Conference Series. 1902. 012126. DOI:10.1088/1742-6596/1902/1/012126.
18. Koibichuk, V., Kocherezhchenko, R., Zhovtonizhko, I.: *Overview of the economic activity of cloud providers and research on the theoretical foundations of cloud computing. Herald of Economics.* (2023).DOI:10.35774/visnyk2023.02.074.
19. Ikhelegbe-Ojo, S.: *Cloud Computing, A Tool for Economic Growth in Small and Medium Enterprises (SMEs).* (2023). DOI:10.13140/RG.2.2.20010.18888.
20. Carless, D., Boud, D.: *The development of student feedback literacy: enabling uptake of feedback.* (2018). Assessment & Evaluation in Higher Education. 43. 1315-1325. DOI:10.1080/02602938.2018.1463354.
21. J. Kirchmayer, „cloud-computing.sk," 2018. [Online]. Available: https://www.cloudcomputing.sk/wp-content/uploads/2019/08/cloud_computing_Kirchmayer.pdf. [Cit. 12. 1. 2023].
22. Al-Ruithe, M., Benkhelifa, El., Hameed, K.: *Current State of Cloud Computing Adoption – An Empirical Study in Major Public Sector Organizations of Saudi Arabia (KSA).* (2017). Procedia Computer Science. 110. 378-385. DOI:10.1016/j.procs.2017.06.080.
23. Kobayashi, K., Yoshida, H., Tanjo, T. et al.: *Cloud service checklist for academic communities and customization for genome medical research.* (2022). Hum Genome Var 9, 36 DOI:10.1038/s41439-022-00214-9
24. Asadi, Z., Abdekhoda, M., Nadrian, H.: *Cloud computing services adoption among higher education faculties: development of a standardized questionnaire*. (2020). Educ Inf Technol 25, 175–191. DOI:10.1007/s10639-019-09932-0
25. M. Müller: *Vývoj cloudových úložísk a účel ich využitia*, 2021, [Cit. 3.12.2023]. https://opac.crzp.sk/?fn=detailBiblioFormChildW79M0&sid=4A7927334F9373E92D4DD999785B&seo=CRZP-detail-kniha.
26. https://www.itu.int/rec/T-REC-Y.3500-201408-I
27. https://csrc.nist.gov/pubs/sp/800/145/final
28. https://www.itu.int/rec/T-REC-Y.3502/en

29. Alam, S.M. Ikhtiar: *Definition, Concepts, and Unique Characteristics of Services*. (2022). https://www.researchgate.net/publication/360755160_Definition_Concepts_and_Unique_Characteristics_of_Services
30. Shekar, H P.: *Cloud Computing Services In Libraries: An Overview*. (2023).
31. Rashid, A., Chaturvedi, A.: *Cloud Computing Characteristics and Services: A Brief Review*. (2019). International journal of computer sciences and engineering. 7. 421-426. 10.26438/ijcse/v7i2.421426.
32. Kashfi, H.: *Software Engineering Challenges in Cloud Environment : Software Development Lifecycle Perspective.* (2017). International Journal of Scientific Research in Computer Science Engineering and Information Technology. 2. 2456-3307.
33. Marek Moravcik, Pavel Segec: "Automated deployment of the OpenStack platform," in 21st International Conference on Emerging eLearning Technologies and Applications (ICETA), Stary Smokovec, Slovakia, 2023, pp. 375-380, doi: 10.1109/ICETA61311.2023.10343784, 2023.

Primary Paper Section: I

Secondary Paper Section: IN