ACHIEVING SEAMLESS MIGRATION TO PRIVATE-CLOUD INFRASTRUCTURE FOR MULTI-CAMPUS UNIVERSITIES

Niki Kyriakou[1], Zoi Lachana[2], Dimitrios N. Skoutas[3], Charalampos Skianis[4] and Yannis Charalabidis[5]

Department of Information and Communication Systems Engineering, University of the Aegean, Samos, Greece

ABSTRACT

Maintaining IT infrastructure is a major challenge for multi-campus universities. The difficulties they face include inflexibility, inefficiency, outdated technology, and redundant resources, all of which negatively impact the quality of services provided to students, faculty, and researchers. Consequently, there is a growing need for a more agile, efficient, and cost-effective solution that can cater to the everchanging IT service demands of these institutions. Universities can boost their agility, scalability, and cost-effectiveness while enhancing service quality by utilizing cloud services. Cloud computing enables universities to quickly and easily access computing resources that can be scaled up or down as per their IT requirements, providing them with the necessary flexibility to meet dynamic demands. Private cloud migration further offers universities complete control over their internal security and SLA obligations, allowing them to guarantee a high level of service delivery. This paper contends that private cloud migration is an effective solution that can help multi-campus universities surmount their IT infrastructure challenges and enhance their IT service delivery capabilities.

This paper presents a case study analysis of the University of the Aegean's migration to a private cloud and offers insights into the factors that influence successful private cloud migration in multi-campus universities. The paper argues that private cloud migration and cloud computing are effective solutions for resolving IT infrastructure issues and improving service delivery in higher education institutions.
The paper provides recommendations for universities considering private cloud migration, offering a roadmap for successful migration. Additionally, the study identifies critical success factors that can help universities achieve a successful migration.

In future work, this study could be expanded to include more universities and explore the challenges and benefits of private cloud migration in a broader context. Furthermore, it would be interesting to investigate the impact of private cloud migration on student outcomes, faculty satisfaction, and institutional performance.

KEYWORDS

Private-cloud infrastructure, multi-campus universities, University of the Aegean, datacenter, Cloud computing

1. INTRODUCTION

Multi-campus universities face significant challenges in managing their IT infrastructure, including inflexibility, inefficiency, outdated technology, and duplication of resources, which ultimately hinder their ability to provide quality services to students, faculty, and researchers [1].

These challenges motivate the need for a more flexible, efficient, and cost-effective solution that can meet the dynamic IT service requirements of these institutions.

Cloud computing and private cloud migration offer potential benefits to multi-campus universities in addressing their IT infrastructure challenges. Cloud computing provides easily provisioned computing resources that can be released, offering universities the flexibility they need to meet changing IT requirements, while private cloud migration allows universities to control their destiny and guarantee internal security and service level agreement (SLA) requirements [2-4].

The research problem statement of this paper is to investigate the challenges faced by multicampus universities in managing their IT infrastructure and to explore the potential benefits of private cloud migration for addressing these challenges. The primary objective of this paper is to provide a comprehensive analysis of the factors that influence private cloud migration success in multi-campus universities. Specifically, this paper aims to identify critical success factors that can help universities achieve a successful private cloud migration and enhance their overall IT service delivery.

To achieve the research objectives, a case study analysis was conducted on the University of the Aegean. The paper's structure is organized as follows: Section II provides a literature review of multi-campus universities' IT infrastructure challenges and the potential benefits of cloud computing and private cloud migration. Section III presents the methodology used in the study, including data collection and analysis methods. Section IV discusses the study's findings, including the critical success factors that influence private cloud migration success in multicampus universities. Section V presents the study's implications and recommendations for universities considering private cloud migration. Finally, Section VI concludes the paper and suggests avenues for future research.

In summary, the current challenges faced by multi-campus universities in managing their IT infrastructure motivate this study. The research aims to explore the potential benefits of private cloud migration as a solution to these challenges and identify critical success factors that can help universities achieve a successful migration and enhance their overall IT service delivery.

2. LITERATURE REVIEW

2.1. Cloud Computing Implementation in Educational Institutions

As a disruptive technology in the education sector, Cloud Computing has surfaced as a vital resource, offering a broad spectrum of services and resources to students, educators, and administrators [5, 6]. This section discusses the various applications of Cloud Computing in educational institutions.

Multi-campus infrastructure: Multi-campus educational institutions are an ideal fit for Cloud Computing with various campuses distributed across vast areas. Cloud Computing offers high availability, scalability, and increased performance [7], allowing educational institutions to provide high-quality IT learning infrastructure for each campus. It is also an ideal choice for multicampus education institutions as it provides immediate update of software, to an extensive variety of educational tools, applications and resources that can be used in cost effective ways with the learning process [8].

E-learning: The utilization of Cloud Computing can be instrumental in the advancement of elearning, which is reliant on the availability of Information and Communications Technology

(ICT). Nevertheless, the maintenance and support of infrastructure for e-learning systems can be costly. Cloud Computing presents an economical alternative, providing superior performance, real-time software updates, and access to diverse educational resources, applications, and tools [9]. Through Cloud Computing, individuals can operate applications from the cloud using their PC, mobile phones, tablet PCs, and smartphones, allowing them to accomplish tasks and assessments more effectively [6]. Additionally, Cloud Computing streamlines the process of searching through expanding resources, accelerates the discovery and organization of information, and facilitates access to information from various locations.

Social applications: Cloud Computing opens up a new era for university social applications, such as cloud-based storage of academic and social networks between faculty, students, and researchers [6]. This enables them to efficiently exchange shared conference interests, establish peer review connections, collaborate on publications, and discover academic library resources.

Digital library projects: The aim of employing Cloud Computing in digital library projects is to improve the library management system through upgrades, rebuilding, or integration with alternative systems. This utilization enables educational institutions to manage and organize their library resources more effectively.

E-science applications: As e-science applications continue to evolve, they demand access to extensive computational resources, specialized remote instruments, distributed data and software. The migration of e-science applications to Cloud Computing infrastructures can result in expedited execution. Therefore, Cloud Computing has the potential to facilitate future escience applications by offering the requisite computational resources and specialized software.

In conclusion, Cloud Computing has significant potential in the educational domain. It provides services and resources for students, educators, and administrators, enabling them to work more efficiently and effectively. Cloud Computing is particularly well-suited for multi-campus educational institutions, e-learning, social applications, digital library projects, and e-science applications. Cloud Computing can bring substantial advantages to educational institutions by enhancing the benefits for students, teachers, and administrators.

2.2. Cloud Computing and Multi-Campus Universities

Cloud computing is a paradigm that enables ubiquitous access to shared resources, including data, applications, and services, over the internet. Cloud computing offers many benefits for multi-campus universities, including cost savings, scalability, agility, and flexibility [8, 10]. Cloud computing can help multi-campus universities reduce their IT infrastructure maintenance and upgrade costs by furnishing computing resources that can be readily provisioned and decommissioned as per demand. Cloud computing can also improve scalability and agility, allowing multi-campus universities to respond quickly to changes in demand [11]. Additionally, cloud computing can increase flexibility by enabling multi-campus universities to access computing resources from anywhere at any time.

Despite the potential benefits of cloud computing, many universities face several challenges in adopting and migrating to cloud-based infrastructures. These challenges include technical, security, organizational, and legal factors [12]. Technical challenges include the compatibility and interoperability of existing systems with cloud-based services, the complexity of cloud service management, and the lack of IT staff with cloud computing expertise. Security challenges include data privacy, confidentiality, integrity concerns, and compliance with regulatory and legal requirements [13]. Organizational challenges include resistance to change, lack of awareness or understanding of cloud computing, and the need for cultural and organizational transformation.

Legal challenges include contractual issues, such as service-level agreements (SLAs), liability, and intellectual property rights [4].

Private cloud migration can address some challenges multi-campus universities face when adopting and migrating to the cloud. Private cloud migration provides multi-campus universities with greater control over their computing resources, which can help address data security and privacy concerns. Private cloud migration can also provide multi-campus universities with greater flexibility and scalability. However, private cloud migration also presents technical considerations like infrastructure design, software selection, and workload placement. Security concerns related to private cloud migration include data protection, compliance, and auditing. Organizational factors, such as governance, policies, and procedures, also play a critical role in the success of private cloud migration for multi-campus universities.

To sum up, cloud computing provides numerous advantages for universities with multiple campuses, including cost-effectiveness, scalability, agility, and flexibility. However, multicampus universities face challenges when adopting and migrating to the cloud, such as complexity, data security, and lack of control over cloud resources. Private cloud migration can address some of these challenges but also presents technical, security, and organizational considerations. Therefore, planning and evaluation are essential for multi-campus universities considering private cloud migration.

3. METHODOLOGY

3.1. Data and Method

This study aimed to investigate the challenges and benefits of private cloud migration for multicampus universities, with the University of the Aegean (UoA) serving as a case study. A qualitative research design was utilized to achieve this goal, which involved data collection through interviews with the IT staff at UoA.

The selection of a case study university was based on several criteria. The case study university had to be a multi-campus institution with an extensive IT infrastructure and diverse user groups, including students, faculty, and researchers. It was essential to select a university that had experienced limitations and challenges with its existing IT infrastructure, including inflexibility, inefficiency, and outdated technology. Based on these criteria, the University of the Aegean (UoA) was selected as the case study university.

The data collection process involved three stages:

1. The IT staff provided information about the older network connections among all campuses, including their architecture, hardware, and software components.
2. The IT staff provided information about the old network infrastructure in each campus, including its capacity, reliability, and security features.
3. The IT staff gave information about the new connection network among all the campuses, including its architecture, hardware, and software components, and its capacity, reliability, and security features.

Additionally, the IT staff provided information about the new university data center and its infrastructure, including its hardware, software, and security features. This information was crucial in assessing the benefits and challenges of private cloud migration for multi-campus universities.

Data analysis was performed using thematic analysis, which involved identifying key themes, concepts, and patterns from the data collected. The information provided by the IT staff was analyzed to identify the challenges and benefits of private cloud migration for multi-campus universities, including technical considerations, security concerns, and organizational factors.

The study describes the complex and challenging tasks that require careful planning and execution when migrating from a traditional IT infrastructure to a private cloud-based infrastructure.

3.2. University of the Aegean

The UoA has implemented the largest University Telecommunications Network, covering all six islands of the Aegean Sea (Figure 1), where its undergraduate and postgraduate departments operate. Through the telecommunications network, all Data and Telephony services are covered.
The educational-research nature of the network is highlighted by its extensive use by the educational and research laboratories of the Schools, the personal computer laboratories, the offices of Teachers and Researchers, the multimedia rooms, the distance learning rooms, as well as the library of the Foundation, in all islands.

The management of the network has been undertaken by the Central Directorate of Informatics and Communications, in collaboration with the Regional Departments of Informatics and Communications, constantly ensuring that the Telecommunications Network of the Institution is kept at the cutting edge of technology to support its Academic & Research work.

Figure 1. Location of the Units/Schools of University of the Aegean

4. PRIVATE CLOUD IMPLEMENTATION

4.1. Evaluating IT Infrastructure

The University of the Aegean has a complex and varied IT infrastructure that had to be considered during the planning and design phase of the private cloud migration process. The first step in this process was to thoroughly evaluate each campus's existing IT infrastructure, network connections, and data center infrastructure.

In 1990, the university's wide area network had five nodes in Athens, Lesvos, Chios, Samos, and Rhodes. The connections between the nodes were relatively slow, with Lesvos-Athens having a 64Kbps connection, Chios-Athens having a 128 Kbps connection, Chios-Athens having a 9.6Kbps connection, Samos-Athens having a 14.4 Kbps connection, and Rhodes using a dial-up connection. At that time, the university had approximately 400 users.

In 1998, there were significant changes to the university's network connections. The nodes' connections were upgraded to 2 Mbps, allowing faster data transmission. In 2000, a new node was added in Syros, and the nodes' connections were upgraded again, this time to ATM 2-10 Mbps (Lesvos-Athens, Chios-Athens, Samos-Athens, Rhodes-Athens, Syros-Athens), and the number of users increased to almost 8,000.

Further upgrades were made in 2003, with the connections between nodes being upgraded to ATM 10-20 Mbps, and the number of users had increased to almost 10,000. Finally, in 2015, the University's network infrastructure was upgraded to include a broadband connection with high reliability and transmission speeds of 1 or 2 Gbps, provided by GRNET. The equipment was upgraded to support 10 Gbps speeds to connect to ESET 4.

The network topology per campus served as the foundation of any private cloud infrastructure. The topology was divided into two distinct networks, the external network and the internal network (Figure 2).

The external network provided a connection to the more extensive campus network and allowed users to authenticate, gain access to different services, and utilize the virtual machines (VMs) hosted within. Additionally, all servers could download necessary package updates and security patches through this network.

Meanwhile, the internal network consisted of individual servers and a controller. Each server had its own storage and network infrastructure, which led to redundancies, inefficiencies, and maintenance overheads. In addition, the network had limited scalability and was prone to failures due to its distributed nature. The controller, which included the Domain Controller, DHCP Server, and DNS Server, was responsible for managing the authentication, IP address assignment, and name resolution for all the devices on the network and executing the VMs. It ensured the direct connection between the service nodes away from the external network, thereby avoiding the consumption of network bandwidth that would occur if the external network was utilized for user access and data management.

This approach to network topology design provided a secure and efficient way to manage the infrastructure while optimizing resource utilization. The separate networks enabled different functions to be performed independently, reducing the potential for network congestion and increasing overall network performance.

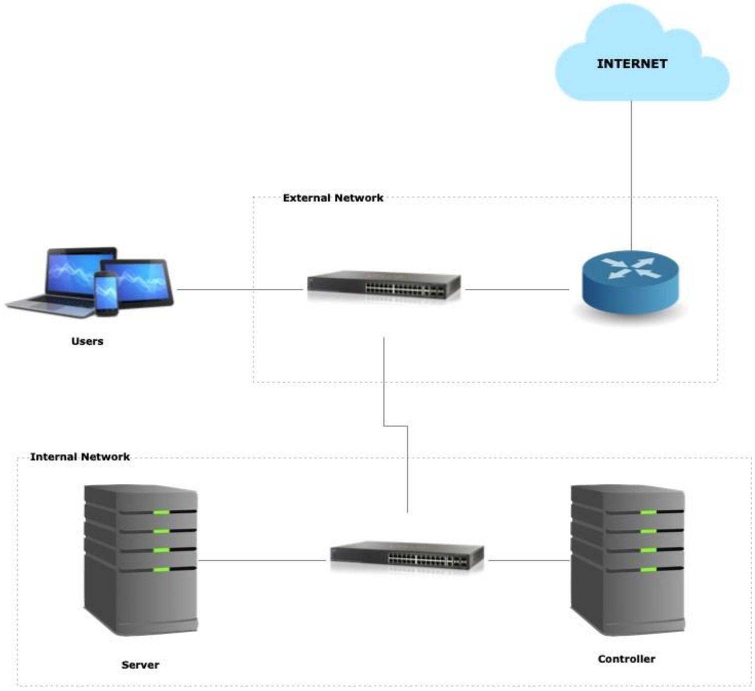

Figure 2. Network topology per island

During the planning and design phase, the University of the Aegean IT staff used this information to create a detailed inventory of the existing IT infrastructure, including network connections and data center infrastructure in each campus. This information was used to develop a comprehensive migration plan that would consider each campus's specific needs and requirements of each campus while also ensuring that the University's overall IT infrastructure was optimized for efficiency and security.

4.2. Proposed Solutions for Overcoming Limitations and Challenges in IT Infrastructure

The existing IT infrastructure in educational institutions such as University of the Aegean (UoA) faces numerous limitations and challenges that hinder its ability to provide quality services to students, faculty, researchers, and staff. One of the main challenges is the inflexibility, inefficiency, and outdated nature of the infrastructure, which fails to meet current IT service needs and requirements. The lack of agility, elasticity, and rapid deployment capabilities challenging to accommodate the evolving IT needs of the institution.

Additionally, the replication of resources across regional campuses poses significant drawbacks since the precise number of students enrolled in each campus per semester is not accurately determined. The research experiments and their results are increasing and need more and more resources and energy. Thus, the IT department in each campus over-provisions the infrastructure to guarantee an acceptable quality of service (QoS) and remain competitive. This results in unforeseen costs, as the computing power of the servers is often not enough, and the infrastructure needs to be more flexible to allow for quick adjustments.

Constructing dedicated infrastructure for service demands results in prolonged delivery time, augmented expenses due to redundant resources, and unfulfilled expectations of cost reduction and agility. The busy staff in regional campuses, or the demanding researchers who need space for their data and computing resources to process it, also struggle with the lack of proper IT support, resulting in a waste of time, energy, and motivation. Improper management results in expenditures on unplanned IT equipment, and it is costly to recruit trained, certified IT professionals for each campus. Acquiring software licenses for multi-DCs with physical servers and support for multi-campus agreements and infrastructure computing resources requires a substantial annual investment and continual dispersed efforts to upgrade, maintain, and manage responsibilities across all campuses.

Migrating to a public or private cloud-based infrastructure can address these challenges and end such scenarios. Cloud computing provides easily provisioned computing resources that can be released when needed. The benefits of cloud computing include efficiency and flexibility, which can help universities, including multi-campus institutions like UoA, reduce IT infrastructure maintenance and upgrade costs.

Moreover, cloud computing empowers UoA's computing resources to become more flexible and versatile, aiding them in navigating financial instabilities within the university. It provides the benefits of private cloud computing, allowing them to control their destiny and guarantee internal security and service level agreement (SLA) requirements.

Due to the rising demands of modern DC services, the existing infrastructure of UoA's legacy DCs can no longer meet expectations, necessitating the transition to cloud computing. The implementation of new applications that demand high-performance computing and agility, along with virtualization and cloud computing, cannot operate effectively on the present enterprise storage, servers, and networking DC infrastructure. Therefore, UoA must shift its current IT infrastructure from a campus-based to a cloud-based infrastructure to decrease entry costs, minimize the risk of IT infrastructure failure, improve ROI, respond swiftly to changes in demand, and prioritize the institution's core business, considering these limitations and challenges.

4.3. Private Cloud Interconnections

Phase 1

The University's data network is connected to the Geant European Research Network through the National Infrastructures for Research and Technology (GRNET) (Figure 3). GRNET provides the central telecommunications hub of each University Unit per island with a broadband connection with high reliability and transmission speeds of 1-10 Gbit.

These connections replaced leased lines and wireless connections between buildings. In this way, on the one hand, users are provided with a connection speed of at least 1Gbps, and on the other hand, the connection speed of the central buildings of the hubs (as well as the buildings where critical services are provided) was upgraded to 10Gbps. At the same time, new border routers were supplied to the nodes of the UoA. Also, wireless access to the institution's premises was expanded through the supply of 206 access points, which will comprehensively cover the needs of 29 buildings.

The border routers of each node per island of the University of the Aegean constitute the backbone network. Interconnection of routers is achieved using Dot1Q Tunneling technologies. The routing of the packets to the GRNET is done with the help of the BGP-v4 protocol, as the University of the Aegean has its own Autonomous System (AS 8617). OSFP and OSFPv3 are used for internal routing.

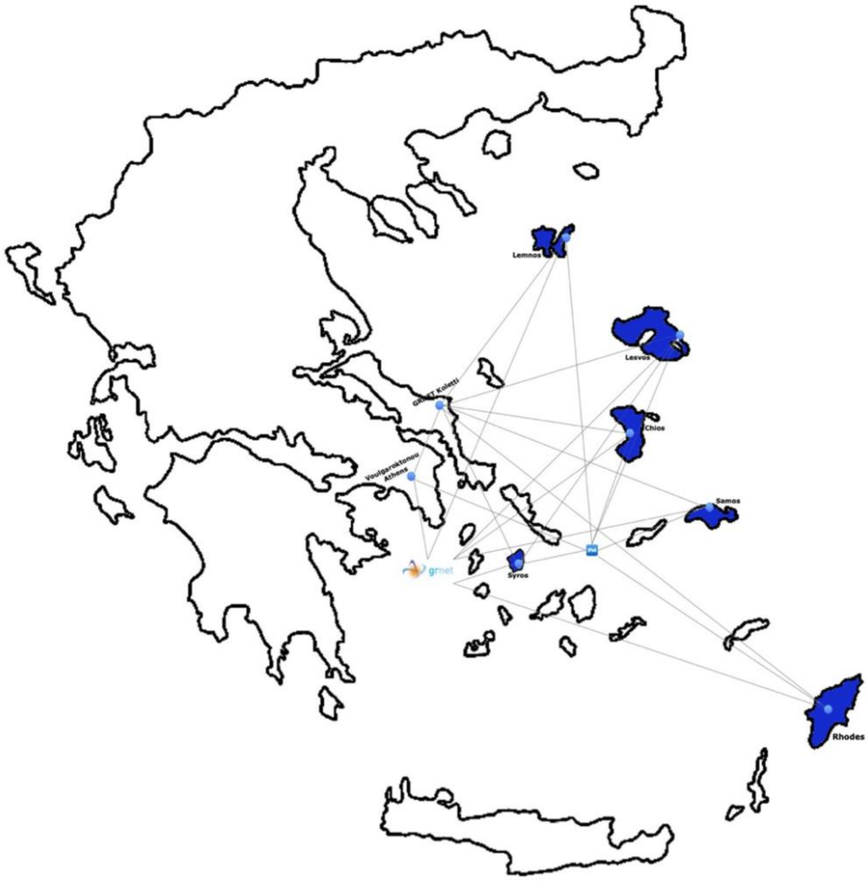

Figure 3. UoA's data network

On those islands where there are increased needs, and there are groups of neighboring buildings, a high-speed distribution network has been implemented with which, among other things, alternative routing is implemented in cases of breakdowns/outages where possible. The distribution network is implemented through Ethernet (Gigabit/TenGigabit) technology routers and switches.

The distribution network uses proprietary optical fibers, dark connections via MAN (Mytilini, Chios, and Syros), illuminated connections via MAN (Mytilini), connections with laser optics at 100 Mbps and 1 Gbps (Samos), METRO Ethernet connections 20-30 Mbps and finally leased copper circuits with SHDSL equipment at 5-10 Mbps where deemed necessary.

Phase 2

In Phase 2, in the central building of each node (where there is a connection to the ESET), two switches/routers were supplied, which form the backbone network and operate as a single unit for the entire uninterrupted operation of the network of each node with high-speed interconnections between them (25Gbps). At the same time, in case of material failure, there are double roads so that the connection of the central building with the rest is not interrupted. The distribution network is supported by switches that gather traffic from the rest of the switches in the building. For the access network, switches were procured to which users' machines are connected. In addition, many switches are PoE (Power over Ethernet) capable of powering VoIP phones and the growing WiFi access points of buildings and expected APs through the Hephaistos Program. In summary, the implementation of the specific design allows the upgrading of the speed of the connections of the University of the Aegean network while at the same time taking into account all the critical parameters for the existence of backup systems and alternative routes for the network traffic.

In addition to the network upgrade (Figure 4), a new network topology was implemented, where all the servers and the controller were replaced by a small datacenter. This datacenter was designed to converge on-premise assets such as servers, storage networks, and storage arrays into a streamlined infrastructure, leaving the door open for up-gradation into a hybrid IT infrastructure. The datacenter was equipped with high-performance servers, storage arrays, and network switches, providing a centralized and efficient management platform for the campus network.

Finally, the telephony was upgraded by upgrading the server and replacing old analog devices that do not have digital facilities and are incompatible with the latest versions of the server.

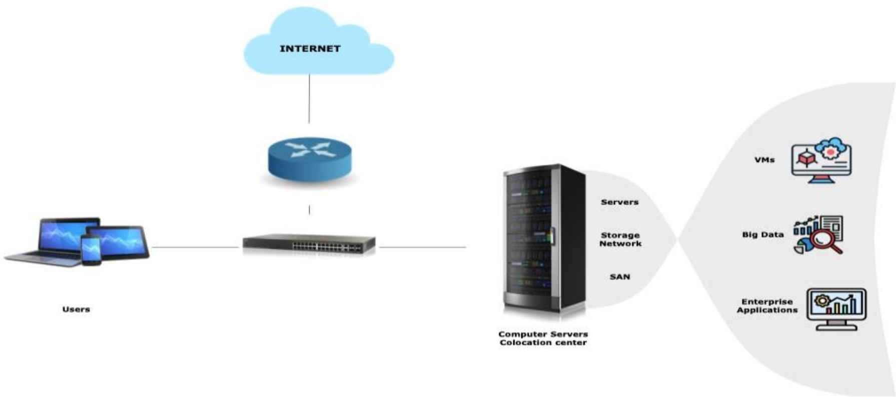

Figure 4. Network upgrade per island

Phase 3

The last step in the implementation phase was establishing the data center infrastructure in Lesvos, explicitly designed for this purpose with special requirements for access, cooling, electricity supply, and backup. The University's IT staff worked closely with the private cloud provider's technical team to ensure the new network infrastructure was deployed efficiently and without disrupting its operations.

One of the key features in the design and implementation was the easy expandability and increased availability of all its systems. The computing center of Lesvos uses computing arrays of servers to host many virtual machines that are created and go through their life cycle, supporting a multitude of systems, services, and needs for the operation of the institution (Figure 5).

The capacity of the arrays was enriched as new production arrays and their accompanying supporting equipment were installed. All computing arrays were based on VMware VSphere ESXi software. The mainframe of the previous generation consists of twelve servers and hosts critical core systems, such as student records and their peripheral systems, document management, personnel management, payroll, email, communications, file servers, websites, education support systems, etc. Under the formation of a private "cloud" of virtual machines, this mainframe also serves the university's organizational and research objectives. The central cluster has a population of 375 virtual machines, with about 224 active VMs consuming almost all the available memory of the cluster.

The machine population constantly grew as new items, projects, and services were added to the University. The previous generation secondary computing array (high-performance cluster) was explicitly intended for serving high-demand computing needs, such as research projects. It consisted of six servers that hosted a variable population of high-end virtual machines. Variability and high demands were the characteristics of using this array.

Once the data center infrastructure was in place, the University's IT staff began migrating their data and applications to the new private cloud infrastructure. The migration was carried out in phases to minimize disruption to the University's operations.

As for the other campuses, they still have their controller for the DHCP Server and the Active Directory, and all the other services moved in the main data center in Lesvos. Finally, in the Syros campus, a backup data center is implemented.

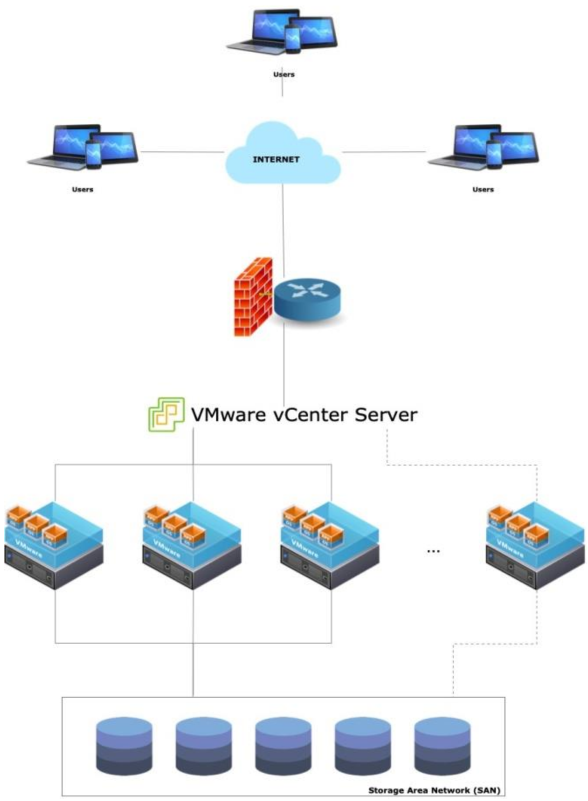

Figure 5. Lesvos' Datacenter

Challenges and Solutions for the Private Cloud Interconnections

This section presents a table summarizing the challenges faced during the implementation phases of private cloud interconnections in the context of the University of the Aegean and the solutions proposed in the literature to overcome them. The table provides an overview of the various challenges and solutions, which can serve as a valuable reference for organizations planning to implement private cloud interconnections.

Specifically, we focus on challenges related to network bandwidth, security and privacy, legacy system integration, standardization, limited resources and expertise, cost management, high availability and reliability, interoperability and data portability, and scalability and resource allocation. For each challenge, we discuss the specific issues that may arise and the potential solutions suggested to overcome them.

Table 1. Challenges and Solution for the Private Cloud Implementation of University of the Aegean

Challenge	Solution
Limited network bandwidth	Implementing a high-speed, low-latency network infrastructure, such as software-defined networking (SD) or a dedicated fiber optic network, to enable fast and efficient data transfer between private clouds.
Scalability and resource allocation	Use of virtualization and containerization technologies to optimize resource utilization and improve scalability. Implement load balancing and auto-scaling mechanisms to ensure that resources are allocated efficiently.
Security and privacy concerns	Implementing strong security measures, such as firewalls, intrusion detection and prevention systems, and encryption protocols, to ensure the privacy and integrity of data transferred between private clouds. Implementing access control policies and monitoring tools to detect and respond to security threats.
Lack of standardization	Implementing industry-standard protocols and APIs to ensure compatibility and interoperability between private clouds and establish clear guidelines and policies for private cloud deployment and management.
Integration with legacy systems	Implementing middleware or integration tools that enable communication and data exchange between private clouds and existing legacy systems.
Interoperability and data portability	Use open-source and open-standard technologies to ensure interoperability and enable data portability between different cloud platforms. Implement data migration and synchronization tools to enable seamless data transfer between cloud platforms.
Limited resources and expertise	Leveraging external expertise and resources, such as cloud service providers or consulting firms, to assist in planning, deploying, and managing private cloud interconnections and providing training and support for in-house staff.
Managing costs associated with private cloud infrastructure	Implementing cost optimization strategies such as resource utilization monitoring, rightsizing virtual machines, and implementing automated shutdown of unused resources to reduce costs.
Ensuring high availability and reliability of private cloud services	Implementing load balancing, redundancy, failover mechanisms, and backup and recovery strategies to ensure continuous availability of services.

This section aims to provide a comprehensive overview of the challenges and solutions associated with private cloud interconnections, highlighting best practices and critical considerations for organizations looking to implement or improve their private cloud interconnection strategies.

5. CONCLUSIONS

The technological landscape has rapidly evolved in recent years, and organizations have had to keep up with these changes to remain competitive. One area where this is particularly true is in the field of networking. This paper discusses the changes made to the network topology at the University of the Aegean (UoA).

Previously, our organization had a network topology that was organized by campus. Each campus had its own set of servers and controllers (Domain Controller, DHCP Server, DNS Server). This setup worked well when the organization was smaller, but it became increasingly difficult to manage as it grew. We found redundancies across the different campuses and were not making the most efficient use of our resources. We also faced challenges regarding upgrades, as we had to upgrade each campus separately, which was time-consuming and costly.

UoA replaced all servers and the controller with a small data center to address these challenges. This data center integrates on-premise servers, storage networks, and storage arrays (such as SAN) into a unified infrastructure. This has allowed UoA to make better use of resources, as UoA can now allocate them more efficiently across the organization. It has also reduced redundancies and improved our disaster recovery capabilities.

One of the key advantages of this new topology is that it leaves the door open for upgrading to a hybrid IT infrastructure. This enables UoA to incorporate cloud services into its network, allowing for greater flexibility and scalability. It can also utilize new technologies, such as virtualization, allowing end-users to utilize their resources more efficiently.

In general, implementing private cloud interconnections can offer many benefits to organizations, such as improved data sharing, increased efficiency, and reduced costs. However, several challenges need to be addressed during the implementation phase. These challenges include limited network bandwidth, security and privacy concerns, integration with legacy systems, lack of standardization, managing costs, ensuring high availability and reliability, interoperability and data portability, and scalability and resource allocation.

Fortunately, several solutions are available to address these challenges, including implementing high-speed and low-latency network infrastructure, strong security measures, middleware or integration tools, industry-standard protocols and APIs, cost optimization strategies, load balancing and load balancing redundancy, open-source and open-standard technologies, and virtualization and containerization technologies.

Overall, the successful implementation of private cloud interconnections requires careful planning and consideration of these challenges and solutions and ongoing monitoring and optimization to ensure continued success. With proper implementation and management, private cloud interconnections can provide organizations with a flexible, scalable, and cost-effective solution for their computing needs.

While the implementation of a private cloud infrastructure at the University of the Aegean has been successful in addressing the challenges faced by the organization, there is still scope for future work to further improve the infrastructure's efficiency and effectiveness.

One area of future work is the integration of cloud services into the network to create a hybrid IT infrastructure. This can offer greater flexibility and scalability, allowing for the allocation of resources on an as-needed basis. The implementation of virtualization and containerization technologies can also improve resource utilization and enable end-users to access resources more efficiently.

ACKNOWLEDGEMENTS

This work was funded by the Research e-Infrastructure [e-Aegean R&D Network] (Code Number MIS 5046494), which is implemented within the framework of the ‘‘Regional Excellence’’ Action of the Operational Program ‘‘Competitiveness, Entrepreneurship and Innovation’’. This action was co-funded by the European Regional Development Fund (ERDF) and the Greek State [Partnership and Cooperation Agreement 2014-2020].

REFERENCES

[1] Groenwald, S. L., (2018), “The challenges and opportunities in leading a multi-campus university”, Journal of Professional Nursing, Vol. 34, No. 2, pp. 134-141.

[2] Akin, O. C., Matthew, F., & Comfort, D., (2014) “The impact and challenges of cloud computing adoption on public universities in Southwestern Nigeria”, *International Journal of Advanced Computer Science and Applications*, Vol. 5, No. 8, pp. 13-19.

[3] Ercan, T. (2010), “Effective use of cloud computing in educational institutions”, *Procedia-Social and Behavioral Sciences*, Vol. 2, No. 2, pp. 938-942.

[4] Okai, S., Uddin, M., Arshad, A., Alsaqour, R. & Shah, A., (2014), “Cloud computing adoption model for universities to increase ICT proficiency”, *SAGE Open*, Vol. 4 No. 3, pp. 1-10.

[5] Ramachandran, N., Sivaprakasam, P., Thangamani, G. & Anand, G., (2014), “Selecting a suitable cloud computing technology deployment model for an academic institute”, *CampusWide Information Systems*, Vol. 31 No. 5, pp. 319-345.

[6] Kyriakou, N., Kompos, N., Loukis, E. & Leoutsakos, T., (2022), “Evaluating Greek Government Digital Distance Learning Policies in Higher Education for the Covid-19 Period”. *European Mediterranean Conference on Information Systems (EMCIS 2022).*

[7] Kyriakou, N., & Loukis, E. N., (2019), “Do strategy, processes, personnel and technology affect firm’s propensity to adopt cloud computing? An empirical investigation”, Journal of enterprise information management, Vol. 32, No. 3, pp. 517-534.

[8] Saidhbi, S., (2012), “A cloud computing framework for Ethiopian higher education institutions”, *IOSR Journal of Computer Engineering*, Vol. 6 No. 6, pp. 1-9.

[9] Riahi, G., (2015), “E-learning systems based on cloud computing: A review. Procedia Computer Science”, Vol. 62, pp. 352-359.

[10] Pardeshi, V., (2014), “Architecture and adoption model for cloud in higher education: Indian perspective”, *Bonfring International Journal of Industrial Engineering and Management Science,* Vol. 4 No. 2, pp. 43-47.

[11] Sabi, H. M., Uzoka, F. M. E., & Mlay, S. V., (2018), “Staff perception towards cloud computing adoption at universities in a developing country”, *Education and Information Technologies*, Vol. 23, pp. 1825-1848.

[12] Qadri, M. N., & Quadri, S. M. K., (2018)., “Mapping cloud computing in university egovernance system”, *International Journal of Intelligent Computing and Cybernetics*, Vol. 11, No. 1, pp. 141-162.

[13] Mohammed, F., Mohammed, F., Ibrahim, O., Ibrahim, O., Ithnin, N. & Ithnin, N., (2016), “Factors influencing cloud computing adoption for e-government implementation in developing countries: instrument development”, *Journal of Systems and Information Technology*, Vol. 18 No. 3, pp. 297-327.