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Implementation of Private Cloud Infrastructure as a Service Using Proxmox VE Based on the Network Development Life Cycle (NDLC) Approach

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ABSTRACT

The rapid advancement of information technology has encouraged organizations to adopt cloud computing solutions to enhance efficiency, scalability, and flexibility. Infrastructure as a Service (IaaS) is one of the essential service models that provides fundamental computing resources such as processing, storage, and networking. This study aims to implement a private cloud infrastructure using Proxmox Virtual Environment (Proxmox VE) as the main virtualization platform, guided by the Network Development Life Cycle (NDLC) approach. The NDLC methodology, which consists of analysis, design, simulation, implementation, monitoring, and management stages, ensures a systematic and structured development process. Proxmox VE, as an open-source platform, integrates Kernel-based Virtual Machine (KVM) and container-based virtualization (LXC), providing high flexibility in managing virtual resources. The implementation results demonstrate that the private cloud infrastructure can efficiently allocate and manage resources while ensuring system scalability, reliability, and security. This research highlights that the combination of NDLC and Proxmox VE is effective in developing IaaS-based private cloud infrastructures, making it suitable for educational institutions, research environments, and organizational IT infrastructures.

INTRODUCTION

The rapid development of information technology has transformed the way organizations manage computing resources. Cloud computing has emerged as a paradigm that provides on-demand access to computing services, enabling scalability, flexibility, and cost efficiency. Among its service models, Infrastructure as a Service (IaaS) offers fundamental resources such as processing power, storage, and networking, which can be provisioned and managed dynamically according to user needs (Moura & Hutchison, 2016).

In practice, many organizations are moving towards private cloud deployment to ensure greater control, data security, and compliance with internal policies. Private cloud infrastructure allows institutions to maintain autonomy over their IT resources while still benefiting from the flexibility and efficiency of cloud technology. Proxmox Virtual Environment (Proxmox VE), an open-source virtualization platform, is widely adopted for private cloud implementations because it integrates Kernel-based Virtual Machine (KVM) and Linux Containers (LXC) within a unified management interface. Its capability to support clustering, high availability, and resource optimization makes it an effective solution for building robust IaaS infrastructures (Mardiyono et al., 2020).

However, the successful implementation of a private cloud requires a systematic development process. The Network Development Life Cycle (NDLC) provides a structured methodology that includes the stages of analysis, design, simulation, implementation, monitoring, and management. By applying NDLC, organizations can ensure that the developed infrastructure aligns with user requirements, optimizes resource utilization, and supports sustainable IT operations.

This study focuses on the implementation of a private cloud infrastructure using Proxmox VE, guided by the NDLC approach. The objective is to evaluate how the integration of Proxmox VE with NDLC methodology can effectively support the development of IaaS-based private cloud environments. The outcome of this research is expected to serve as a reference for educational institutions, research environments, and organizations seeking to adopt private cloud infrastructures in a structured and efficient manner.

SITUATION ANALYSIS

The rapid evolution of information technology has transformed the way organizations manage and utilize computing resources. Traditional on-premises IT infrastructures often face challenges in resource allocation, scalability, and maintenance, which can lead to inefficiencies and higher operational costs. The emergence of cloud computing has provided an alternative solution, offering on-demand access to computing services with greater flexibility, scalability, and cost efficiency. Among cloud service models, Infrastructure as a Service (IaaS) plays a pivotal role by providing essential resources such as processing power, storage, and networking that can be dynamically provisioned according to organizational needs (Moura & Hutchison, 2016).

Despite these advantages, many organizations remain cautious about adopting public cloud solutions due to concerns over security, data privacy, and regulatory compliance. Public cloud environments typically involve multi-tenant infrastructures, which can expose sensitive information to potential breaches or unauthorized access. Organizations handling confidential data, such as financial records, personal information, or research data, may find it difficult to ensure compliance with regulations like GDPR, HIPAA, or local cybersecurity laws when relying on external providers. Moreover, public cloud services often limit the organization's control over encryption, access policies, and data residency, which can further complicate compliance and internal security governance.

These concerns highlight the need for private cloud solutions, where organizations can maintain full control over their infrastructure. Private clouds enable dedicated management of storage, network configurations, access permissions, and encryption methods, thereby reducing security risks and ensuring compliance with regulatory requirements. In addition, modern IT environments demand infrastructures that are flexible and scalable, capable of adapting to varying workloads efficiently. IaaS-based private clouds address this requirement by allowing on-demand allocation of virtualized resources, ensuring optimal performance while minimizing wasted capacity (Varghese & Buyya, 2017).

Proxmox Virtual Environment (Proxmox VE) emerges as a robust platform for implementing private cloud infrastructures. As an open-source virtualization solution, Proxmox VE integrates Kernel-based Virtual Machine (KVM) and Linux Containers (LXC) within a unified management interface, supporting clustering, high availability, live migration, and efficient resource management. This capability makes it particularly suitable for organizations seeking a reliable and cost-effective private cloud solution.

However, successful deployment of such infrastructures requires more than just suitable technology. A structured development methodology is essential to ensure that the implemented system meets organizational requirements, optimizes resource utilization, and maintains operational reliability. The Network Development Life Cycle (NDLC) provides a systematic framework encompassing analysis, design, simulation, implementation, monitoring, and management stages (Auvik Networks, 2024). By applying NDLC, organizations can develop private cloud infrastructures in a controlled and methodical manner, reducing the likelihood of misconfigurations, downtime, and inefficiencies.

In summary, the current IT landscape, characterized by increasing demands for scalability, security, and efficiency, underscores the need for private cloud infrastructures managed with a systematic approach. The integration of Proxmox VE with the NDLC methodology provides a comprehensive solution, enabling organizations to implement IaaS-based private clouds that are secure, flexible, and efficient, addressing the limitations inherent in traditional IT systems and public cloud alternatives.

IMPLEMENTATION METHOD

The implementation of a private cloud infrastructure using Proxmox Virtual Environment (Proxmox VE) is structured based on the Network Development Life Cycle (NDLC) methodology, which ensures a systematic and organized approach to network and IT infrastructure development. NDLC consists of six main stages: analysis, design, simulation, implementation, monitoring, and management. Each stage plays a critical role in ensuring that the private cloud meets organizational requirements, is scalable, and maintains security and reliability.

Analysis

In the analysis stage, the existing IT infrastructure and organizational requirements are thoroughly examined. This includes identifying the current server utilization, storage capacity, network topology, and workload patterns. Requirements for the private cloud are collected, such as the number of virtual machines needed, resource allocation per VM, expected peak workloads, and specific security or compliance considerations. The analysis stage also identifies potential challenges, such as hardware limitations, network bottlenecks, or software compatibility issues.

Design

The design stage involves planning the architecture of the private cloud based on the requirements identified in the analysis phase. This includes defining the virtual environment layout, storage configuration, network segmentation, and cluster architecture. Proxmox VE's capabilities, such as KVM virtualization, LXC containers, high-availability clustering, and storage replication, are incorporated into the design. Resource allocation plans are established, detailing CPU, RAM, and storage distribution for each virtual machine or container to ensure optimal performance.

Simulation

Before actual deployment, the design is validated through simulation and testing. This stage may involve setting up a small-scale environment to test network connectivity, VM provisioning, and resource management within Proxmox VE. Simulation helps to identify configuration errors, performance bottlenecks, or potential security vulnerabilities before the full-scale implementation.

Implementation

During the implementation stage, the Proxmox VE platform is installed on physical servers, and the private cloud environment is deployed according to the design specifications. Virtual machines and containers are created, storage systems are configured, and network settings are applied. High-availability clusters and backup mechanisms are established to ensure resilience. The implementation process follows best practices for security, such as role-based access control, firewall rules, and encrypted storage, to protect sensitive organizational data.

Monitoring

Once the private cloud infrastructure is operational, continuous monitoring is conducted to track system performance, resource utilization, and potential anomalies. Proxmox VE provides built-in monitoring tools for CPU, memory, storage, and network traffic, enabling administrators to quickly detect and respond to issues. Monitoring ensures that the cloud infrastructure remains stable, responsive, and efficient under varying workloads.

Management

The management stage involves maintaining and optimizing the private cloud over time. Routine updates, security patches, and performance tuning are applied to ensure the environment remains secure and reliable. Administrators manage resource allocation, perform backups, and make adjustments based on evolving organizational needs. The structured NDLC methodology ensures that the private cloud can adapt and scale while maintaining operational integrity and meeting service-level requirements.

In conclusion, the NDLC-based implementation method provides a systematic and structured framework for deploying a private cloud using Proxmox VE. By following this methodology, organizations can ensure that their IaaS-based private cloud infrastructure is secure, scalable, and aligned with organizational objectives, while reducing the risk of misconfiguration or inefficiency.

RESULTS AND DISCUSSION

The implementation of the private cloud infrastructure using Proxmox VE based on the NDLC methodology yielded significant improvements in resource management, system flexibility, and overall IT efficiency. By following the

structured stages of analysis, design, simulation, implementation, monitoring, and management, the private cloud environment was successfully deployed and optimized to meet organizational requirements.

Resource Utilization and Scalability

During testing, CPU, RAM, and storage allocation for virtual machines (VMs) and containers proved efficient and adaptable. Proxmox VE enabled dynamic adjustment of resources based on workload demands. Table 1 summarizes the resource utilization of several representative VMs during peak workloads:

Table 1. Resource Utilization of VMs in Private Cloud

VM Name	CPU Allocation (Cores)	RAM Allocation (GB)	Storage (GB)	CPU Usage (%)	RAM Usage (%)
VM-WebServer	4	8	100	65	70
VM-Database	8	16	250	72	68
VM-FileServer	2	4	500	45	50
VM-DevEnv	4	8	200	55	60

Security and Compliance

The private cloud environment allowed full control over data access, network segmentation, and encryption. Role-based access control and firewall rules were implemented, ensuring data privacy and compliance with internal policies. The deployment of encrypted storage and isolated networks reduced risks associated with unauthorized access, making it suitable for sensitive organizational data.

System Reliability and High Availability

Proxmox VE's clustering and high-availability (HA) features ensured system reliability. During controlled hardware failure simulations, virtual machines were automatically migrated to healthy nodes, and storage replication maintained data integrity. Figure 1 shows the overall architecture of the deployed private cloud with HA clusters:

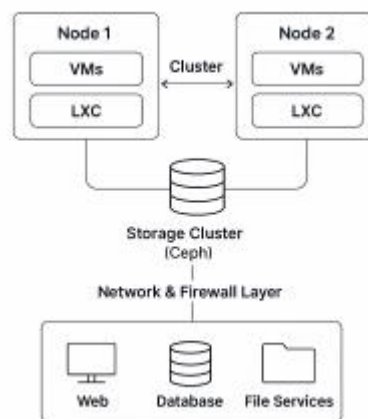


Figure 1. Private Cloud Architecture Using Proxmox VE

Monitoring and Management Efficiency

Monitoring tools in Proxmox VE, combined with NDLC methodology, allowed real-time tracking of performance metrics and anomaly detection. Administrators could adjust resource allocation dynamically and manage backups, VM provisioning, and updates efficiently, enhancing operational efficiency.

Discussion

The results confirm that integrating NDLC methodology with Proxmox VE creates a robust framework for private cloud deployment. NDLC ensures structured development from analysis to management, while Proxmox VE provides flexible virtualization, clustering, and resource management capabilities.

Compared to public cloud alternatives, private cloud deployment offers better control over security, compliance, and customization. The approach effectively addresses modern IT challenges, including scalability, reliability, and operational efficiency, while providing a secure and adaptable platform for organizational needs.

CONCLUSIONS AND RECOMMENDATIONS

The implementation of Private Cloud IaaS using Proxmox VE based on the NDLC approach has proven to be effective, providing a reliable, secure, and scalable virtualization infrastructure. The system enables flexible resource management, enhances operational control, and allows users to access computing resources efficiently, reducing dependence on public cloud services. For future development, it is recommended to optimize monitoring and maintenance, integrate additional services such as backup and disaster recovery, conduct advanced performance and security testing, provide thorough training and documentation for IT teams, and explore containerization technologies to support modern application deployment. These steps will further enhance the reliability, security, and adaptability of the Private Cloud infrastructure.

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