Building a Hands-On Infrastructure Lab: An Integrated Proxmox and EVE-NG Approach for Advanced IT and Cybersecurity Education

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Abstract
In today's rapidly evolving technological landscape, practical experience is essential for students seeking to study IT infrastructure, networking, and cybersecurity. This article presents a comprehensive guide to building a robust virtual laboratory environment, leveraging Proxmox Virtual Environment (VE) as the core hypervisor and EVE-NG (Emulated Virtual Environment Next Generation) as the platform for network emulation and simulation. The objective is to provide students with an accessible, high-performance, and manageable infrastructure that facilitates hands-on learning, allowing them to experiment with complex network topologies, security protocols, and system deployments in a safe, isolated space.

The proposed solution goes beyond merely installing Proxmox and EVE-NG. It integrates crucial components that enhance the learning experience by simulating real-world IT environments. This consolidated approach maximizes resource efficiency and streamlines management, making it an ideal setup for educational purposes.

A cornerstone of this architecture is the implementation of a flexible and redundant storage solution. While Proxmox's native ZFS capabilities are valuable, this setup enhances them by integrating dedicated Network Attached Storage (NAS) systems, such as TrueNAS or OpenMediaVault, virtualized directly within Proxmox. This allows students to learn about centralized data management, data redundancy through RAID configurations, and various sharing protocols (NFS, CIFS, iSCSI). This is vital for storing EVE-NG images, virtual machine templates, and essential backups, mimicking enterprise storage solutions. By directly passing through physical disks to these virtualized NAS instances, students gain insights into optimizing storage performance and ensuring data integrity.

Effective management of any IT system requires robust monitoring. For our learning environment, we start with an existing Nagios implementation for foundational monitoring. However, the plan is to transition towards or supplement with Zabbix, a highly scalable monitoring solution. Zabbix, which will be implemented as a Lightweight Container (LXC) within Proxmox, offers a more comprehensive approach to data collection and visualization. It provides in-depth insights into resource utilization (CPU, RAM, disk I/O, network throughput) across the Proxmox host, individual virtual machines, and containers, including the EVE-NG instance itself. This allows students to observe system behavior under various loads, understand performance bottlenecks, and learn how to proactively identify and troubleshoot issues through configurable alerts and customizable dashboards.

Centralized network management is another critical aspect. Integrating a virtualized firewall and router, such as pfSense or OPNsense, within a dedicated virtual machine, provides a secure and segmented network environment. This allows students to design and implement complex network segmentation using VLANs, configure advanced routing, and set up essential network services like DHCP and DNS. Connecting EVE-NG labs to this virtual firewall enables students to simulate realistic network scenarios, including controlled internet access and inter-VLAN routing, providing invaluable practical experience in network design and security.

Finally, a robust backup strategy is paramount for any learning environment to protect student work and configurations. This solution incorporates Proxmox Backup Server (PBS), an open-source backup solution specifically designed for the Proxmox ecosystem. PBS offers efficient data deduplication and rapid recovery capabilities for virtual machines and containers. It can be deployed as a virtual machine or container on the same server, or ideally, on a separate machine for enhanced redundancy, teaching students the importance of resilient backup and recovery procedures in real-world operations.

By strategically combining Proxmox and EVE-NG with dedicated solutions for storage, advanced monitoring, network management, and robust backups, this integrated platform offers an exceptionally powerful, efficient, and resilient virtual laboratory. This architecture provides an ideal hands-on environment for students to deeply engage with, and master, advanced IT technologies in a secure, controlled, and experiential learning setting.

Index Terms
Proxmox VE, EVE-NG, cybersecurity education, virtualization, NAS, ZFS, pfSense, network emulation, hands-on learning, IT infrastructure, Zabbix, Proxmox Backup Server.