DESIGN AND IMPLEMENTATION OF A VIRTUAL LAB PLATFORM FOR ACADEMIC TEACHING

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Introduction

- The COVID-19 pandemic had a huge impact on teaching!
- Practical laboratories for important lectures were impossible!
- The need for high-quality, flexible teaching solutions that can be accessed anytime, anywhere has never been more urgent!

The Issue

However, the success of these initiatives is critically dependent on the availability of user-friendly IT infrastructures that can adapt to fluctuating resource demands.

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Background

SKILL/VL platform

As a reaction to the COVID-19 pandemic the **Frankfurt University of Applied Sciences** has developed a virtual learning platform for academic teaching in computer science classes. The project SKILL was funded by the **Stiftung Innovation in der Hochschullehre** as part of the program *„Hochschullehre durch Digitalisierung stärken“*.

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Goals

Simplicity Make complex systems and infrastructures usable by students and teachers.

Reliability The platform should be reliable and incorporate components, that are long-lasting.

Usability Creating and using virtual learning spaces so that they can be easily understood by non-IT-savvy users.

Open Source Use of open source solutions such as KVM (Kernel-based Virtual Machine) and Ceph for the platform.

The SKILL platform is available to user groups (students, faculty and staff) to enhance teaching with a digital offering. Ease of use is a high priority goal of the platform, as it allows faculty and staff to integrate the virtual learning spaces into their courses. The students get tools at hand through the resources of the virtual learning spaces, which enable them a new form of interaction.

Project SKILL

- Project *SKILL* (Strategic Competence Platform - Innovative Learning and Teaching)[1] at the Frankfurt University of Applied Sciences – (project duration: 08/2021 - 10/2024)
- Digital environment for education.
- Designing a virtual environment for education.
- Organized into 4 subprojects.
- **Virtualization of distributed environments for teaching** – Computer Science (Fb 2) (Original: Virtualisierung verteilter Umgebungen für die Lehre).

[1] German: Strategische Kompetenzplattform - Innovativ Lernen und Lehren

Characteristics of physical and virtual lab (Alam, A., et al., 2023)

Characteristics	Physical Lab	Virtual Lab
Realism	High	High
Content	Stable	Dynamic
Focus on Study	Lecture	Student
Form	Synchronous	Asynchronous
Number of Students	Limited	Without (physical) limits
Time	Scheduled	Anytime
Focus of course	Group	Individual
Accessibility	Low	High
Cost	Very high	Low
Maintenance Effort	Very high	Low
Remote Work	Not possible	Possible

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Solutions on the market

Criteria	SKILL/VL	Cisco Packet Tracer	Mininet	GNS3
Open Source	Yes	No	Yes	Yes
Simulator	Yes	Yes	No	Yes
Emulator	No	No	Yes	Yes
Scalability	Yes (by extending Web service)	No	limited (using more processes)	No
Automatic setup	Yes	No	No	No
Graphical User Interface	Yes	Yes	No	Yes
Extensible beyond Networks	Yes	No	No	No

Comparison of SKILL/VL to exisitng solutions

With the exception of Cisco, all the solutions we inspected are open-source and free of use. However, GNS3, is the only solution that offers a graphical user interface. This is particularly important as the tool should be accessible to students with little experience in the field of networking technologie. GNS3 has a limitation that it can only be used in computer networks classes.

The SKILL/VL platform should be extensible beyond the computer networks' application field. It should also offer capabilities for use in classes in distributed systems or software engineering, for example.

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Project Virtualization of distributed environments for teaching[1]

SKILL/VL

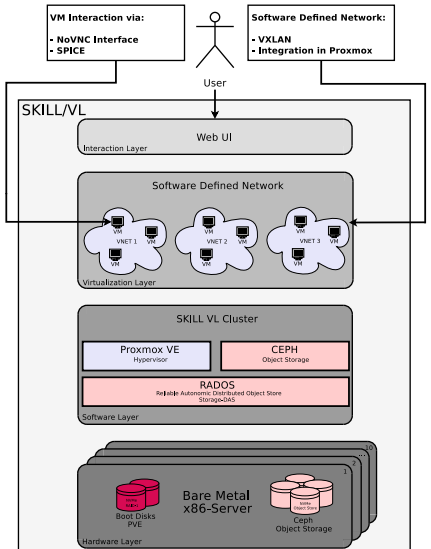
Key features of SKILL/VL plattform[2]:

- Hyper converged infrastructure (cluster of 12 servers)
- Software Defined Storage
- Software Defined Networking
- QEMU/KVM as virtualization engine
- Strict use of open source software:
  - *Proxmox VE* as hypervisor (*KVM-based*)
  - *Ceph* as distributed object storage
  - *QEMU-Guest Agent* integration for configuration of VMs
  - *VXLAN* (Virtual Extensible LAN) integration for (virtual) network configuration

[1] Original: Strategische Kompetenzplattform - Innovativ Lernen und Lehren – Virtualisierung verteilter Umgebungen für die Lehre

[2] `http://www.virtuellelehre.de/`

SKILL/VL Architecture



SKILL/VL plattform:

- **Interaction Layer** – React web UI.
- **Virtualization Layer** – VMs and SDN network environment.
- **Software Layer** – Proxmox VE and Ceph as plattform for virtual resources.
- **Hardware Layer** – x86 server, physical network and storage.

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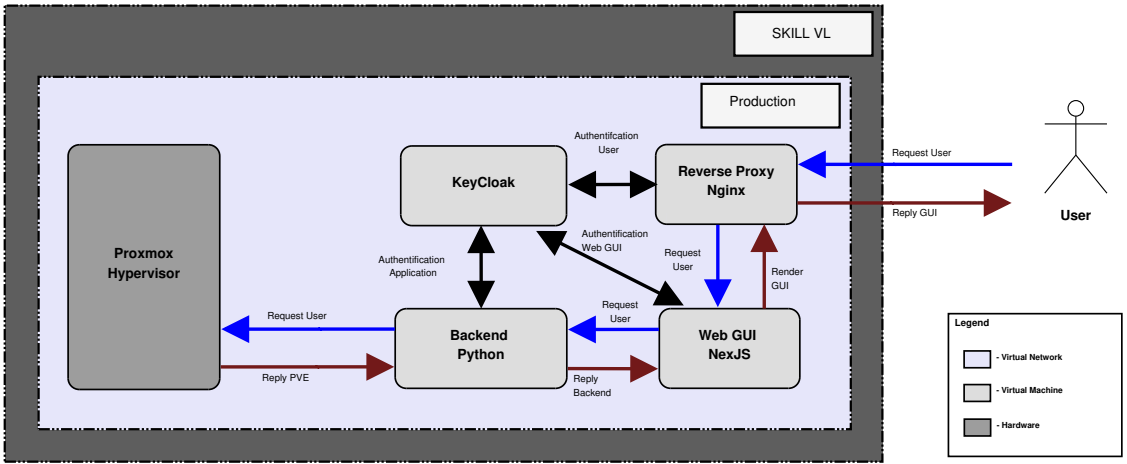
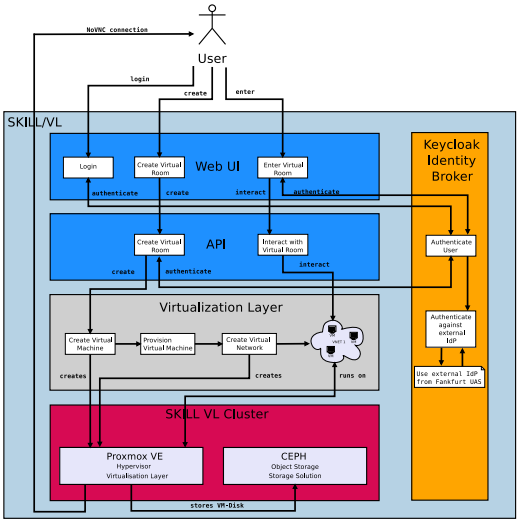
SKILL/VL Architecture – Open Source Software Components



SKILL/VL internal workflow 1/2



SKILL/VL workflow:

- **Interaction Layer** –
  - Login to the SKILL/VL platform.
  - User creates virtual room via web UI.
  - User interacts with virtual room via web UI.
- **API** – handles requests from UI.

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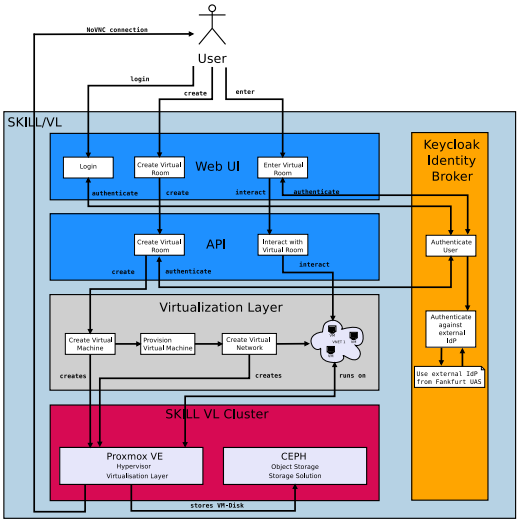
SKILL/VL internal workflow



SKILL/VL workflow:

- **Virtualization Layer** –
  - create and provision virtual machine.
  - create virtual network for VMs.
  - run VMs and virtual network on Proxmox.
- **SKILL/VL Cluster** –
  - creates and runs VMs and networks in Proxmox.
  - stores VM disks in Ceph.

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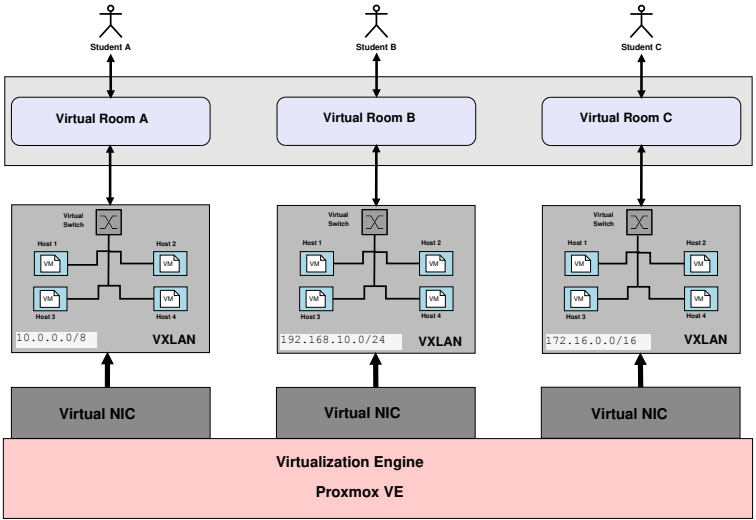
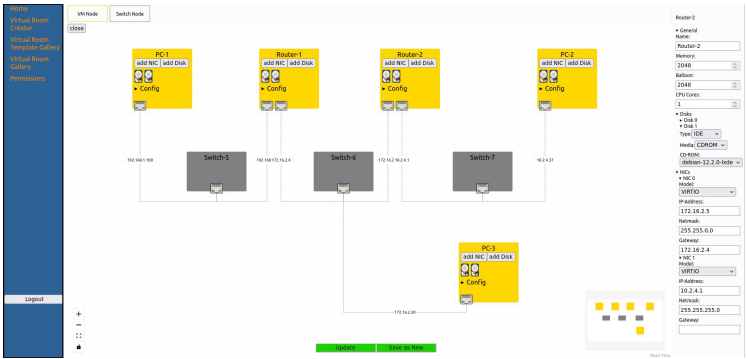
Mapping virtual learning spaces to physical components



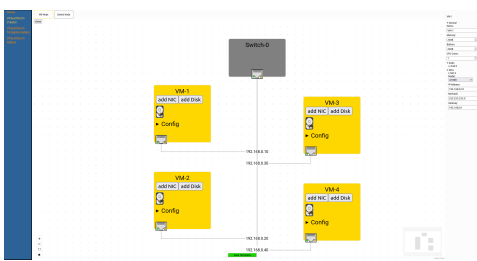
SKILL/VL – SDDC (Software Defined Data Center) 1/2

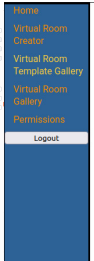


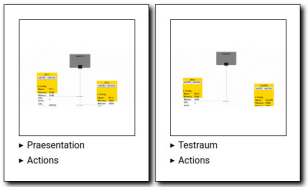
SKILL/VL SDDC:

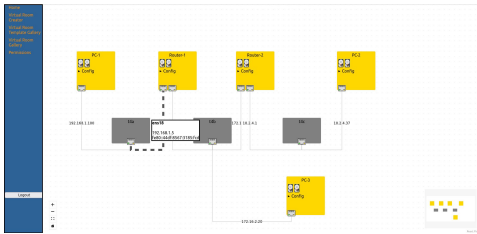
- Creation of complex virtual network scenarios.
- Management of individual permissions of resources.
- Easy configuration of virtual machines over UI.
- Graphical illustration of complex network topologies.
- Easy to understand without knowledge of infrastructures.

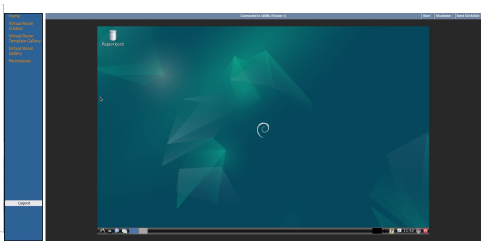
SKILL/VL – SDDC (Software Defined Data Center) 2/2











Application scenario: Computer networks

- 24 individual workstations for students.
- The resources of the lab are limited!
- Interesting application scenario: **Expansion of physical resources with virtual, logical resources!**

Lab 1-237

Computer networks laboratory in room 1-237 with 24 workstation set up for experiments. Each machine has multiple NICs (Network Interface Cards). Designed for practical application scenarios in computer networks.

Conclusion

- The feasibility of the project was demonstrated and the proof-of-concept was successful!
- The platform was successfully evaluated the web interface and the setup of the underlying infrastructure.
- The productive use and integration of the platform in various courses is on the way.
- Close monitoring through performance measurements and evaluations is planned to obtain data on the technical characteristics.

Summary

The realization of a virtual learning platform for university teaching, which in particular allows creating and using complex IT structures for non-experts in teaching, was successfully realized using only free software.

Future Work

- Improving the accessibility of the user-interface following Web Content Accessibility Guidelines 2.1 (WCAG) guidelines.
- Expanding the platform's capabilities includes offering various Linux distributions.
- Refactoring software toward a container platform will boost efficiency and speed up release cycles using a cloud-native setup.

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Thank You For Your Attention!

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