Offline-First strategies in heterogeneous, distributed and virtualized infrastructures

Methods for the efficient detection, assignment and use of distributed ressources

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Contents

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Project SKILL

- Project *SKILL* (Strategic Competence Platform - Innovative Learning and Teaching)[1] at the Frankfurt University of Applied Sciences[2]
- Designing a virtual environment for education
- Organized into 4 subprojects

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

[2] `https://stiftung-hochschullehre.de/projekt/skill/`

Project SKILL Subprojects

- **ELLE-Center**[3] – Center for Teaching and Learning (Original: Zentrum für Lehre und Lernen)
- **Case studies** – Social Studies Department (Fb 4) (Original:FallbeiSpiele)
- **Design Thinking** and **Data Literacy** - Business Information Systems (Fb 3)
- **Virtualization of distributed environments for teaching** – Computer Science (Fb 2) (Original: Virtualisierung verteilter Umgebungen für die Lehre)

[3] https://www.frankfurt-university.de/de/hochschule/fachbereich-3-wirtschaft-und-recht/forschung-und-transfer/aktuelle-forschungsprojekte-am-fb-3/skill/

Virtualization of distributed environments for teaching

Key features of SKILL/VL plattform:

- Hyper converged infrastructure (cluster of 10 servers)
- Software Defined Storage
- Software Defined Networking
- KVM/QEMU 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

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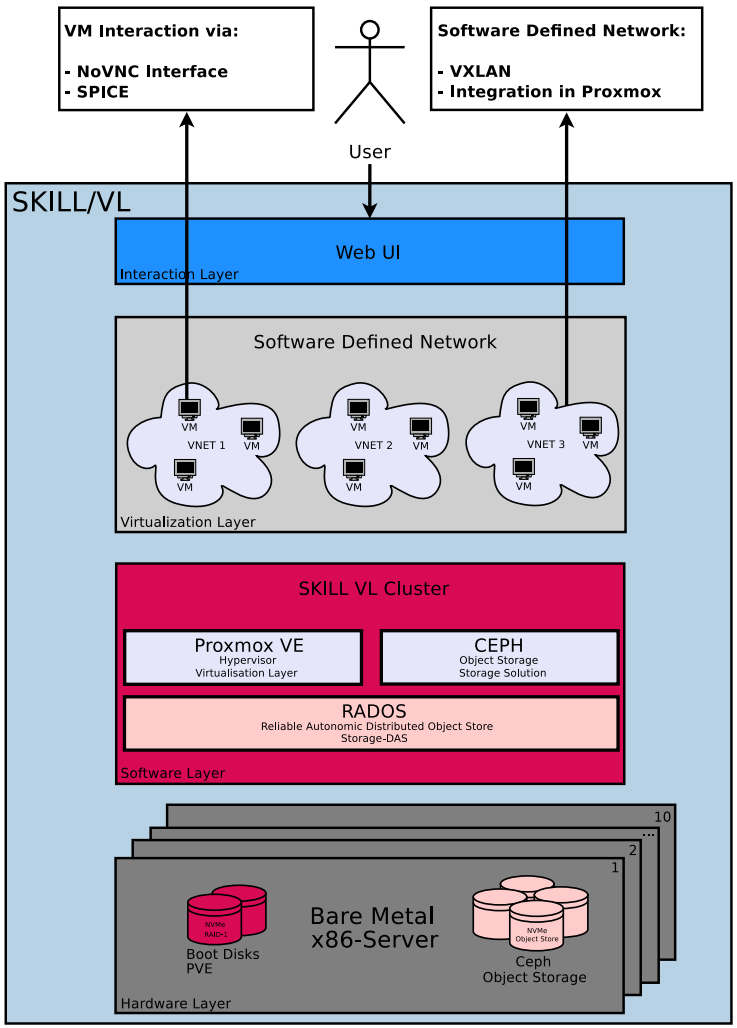
SKILL/VL Architecture



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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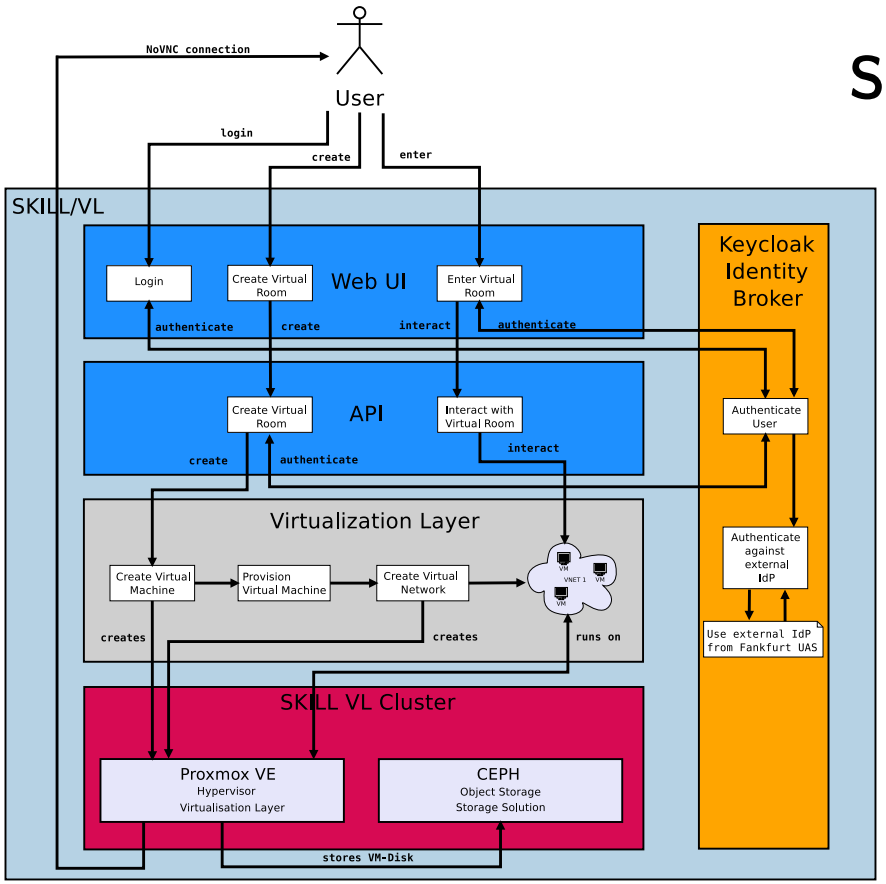
SKILL/VL internal workflow 1/2



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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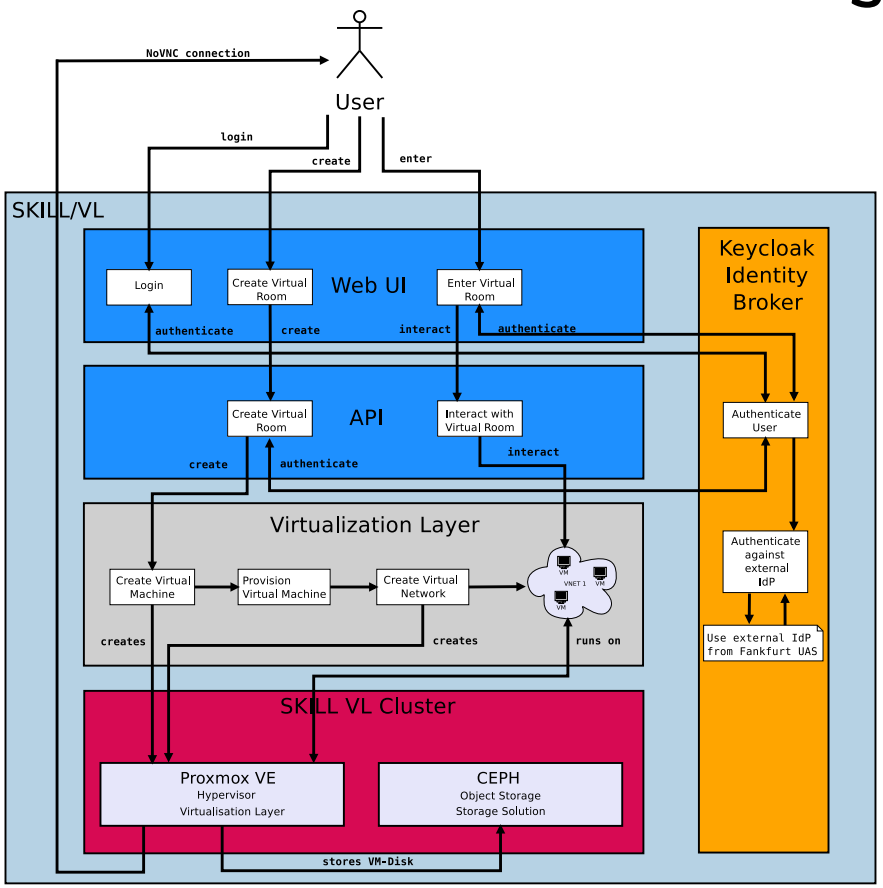
SKILL/VL internal workflow 2/2



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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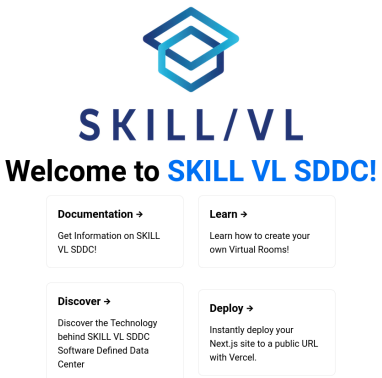
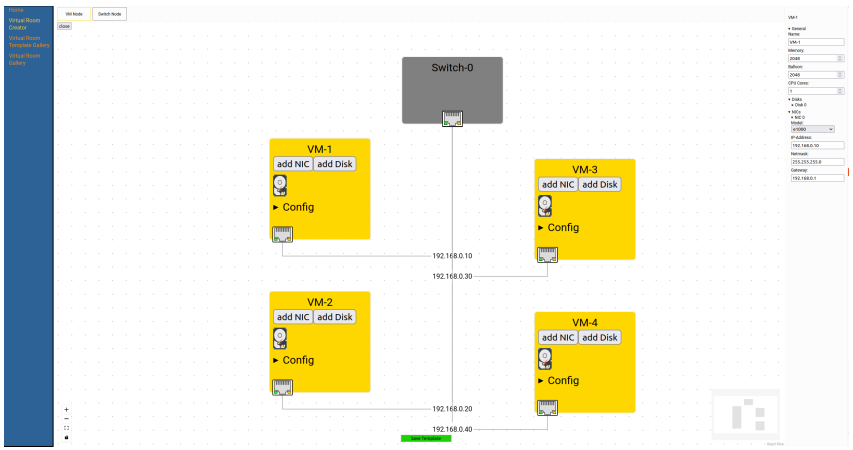
SKILL/VL – SDDC (Software Defined Data Center)





The SKILL/VL SDDC offers:

- the creation of complex virtual network scenarios.
- an easy configuration of virtual machines over UI.
- a graphical illustration of complex network topologies.
- an understandable UI without necessity of knowledge of IT-infrastructures.

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Use Case SKILL/VL

- Students access the SKILL/VL environment over network
- Students use the SKILL/VL environment for lectures
- Students use client hardware to interact with SKILL/VL infrastructure

Problem

The access and use of the SKILL/VL infrastructure generates load on the server infrastructure and network! The network causes latencies in the interaction with the server!

Opportunity

The resources accessed by users (virtual machines, networking, software) are virtualized!

Idea

Use client hardware as an enhancement of the service!

My Thesis project proposal

- Use client infrastructure to enhance cloud service.
- Migrate services from cloud to client whenever possible.

Benefits

- Reduced network latency
- Reduced server load
- Increased autonomy and resilience
- Increased vertical scalability

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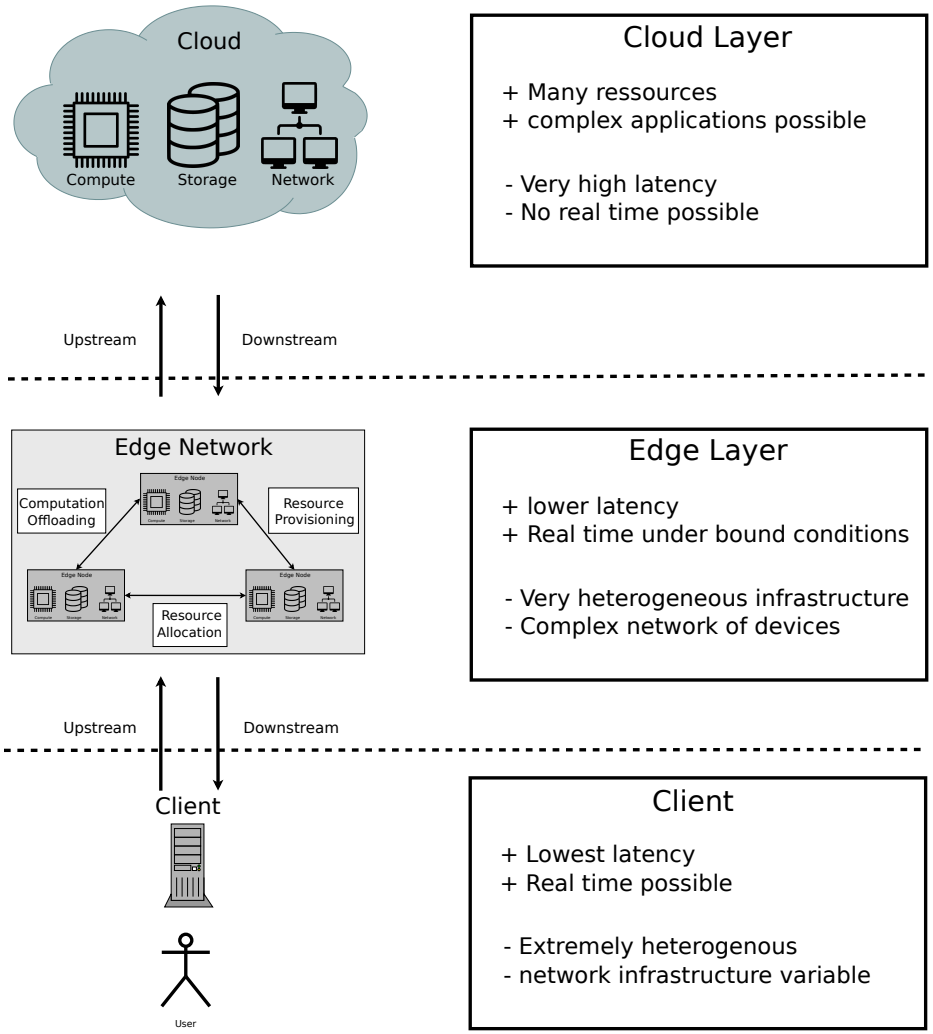

Figure: Processing layers

Research questions

1. How can resources on clients be used to save cloud resources and consequently bring applications closer to the end user?
2. When does the migration to clients make sense and how does it contribute in reducing the load on the core service?
3. How does outsourcing services to the client affect the quality of services?

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Key areas

- **Offline-First Strategy** – enhancement and challenge in cloud computing.
- **Distribution and allocation of resources** – harnessing distributed resources.
- **Service Migration** – placement of service offerings for users.
- **Resilient service offerings** – reliability and availability of service offerings.

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Goals

- **Independence from cloud service** – offline operation.
- **Cooperation with cloud service** – enhancement of cloud service.
- **Vertical and horizontal service migration** – dynamic and demand-driven service placement.
- **Service quality awareness** – real time placement decision depending on quality.

Summary

Consideration of the methods and practical possibilities of operating applications beyond the cloud on local end devices. Thus, the local resources should be usable as an extension of the cloud service and provide a resilient service to the end user.

Service Migration

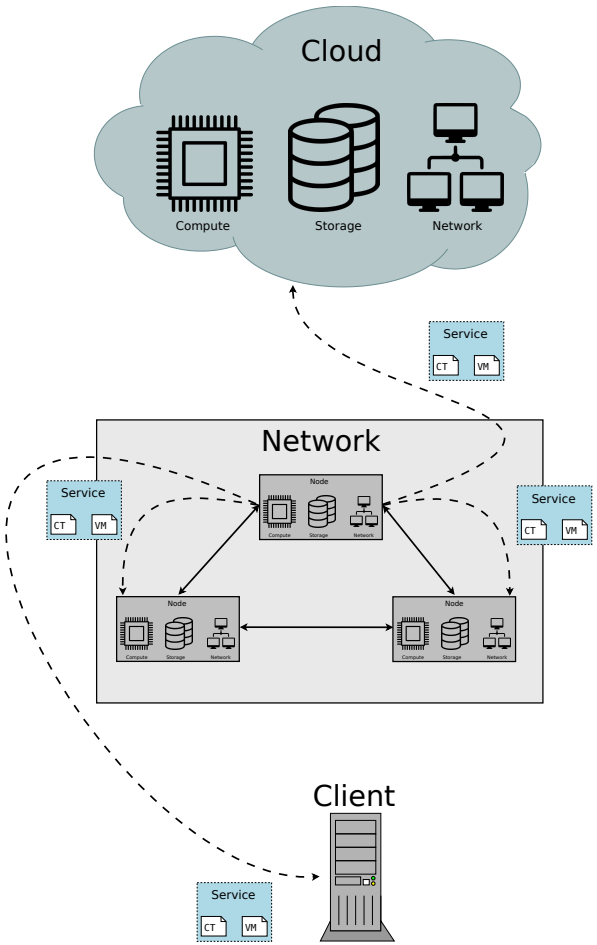

Figure: Service Migration

VM migration over WAN

In a first attempt the two key areas from section 3 shall be explored:

- **Distribution and allocation of resources**
- **Service Migration**

VM migration over WAN

In a first attempt VM migration over WAN (Wide Area Network) shall be investigated in order to inspect how resources can be allocated and distributed. Moreover *Service Migration* in a real life scenario shall be investigated.

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Experimental setup 1/4

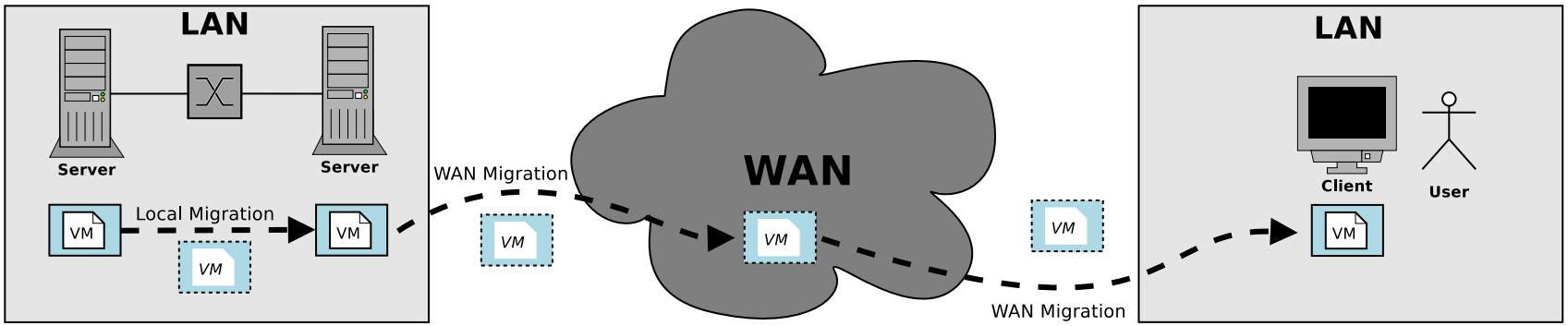

Figure: Overview of VM migration over WAN

- Setup a server with a hypervisor
- Setup a network connection between server and client
- Distribution of resources over network (RAM and Disk)
- Operation of VM on client

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Experimental setup 2/4

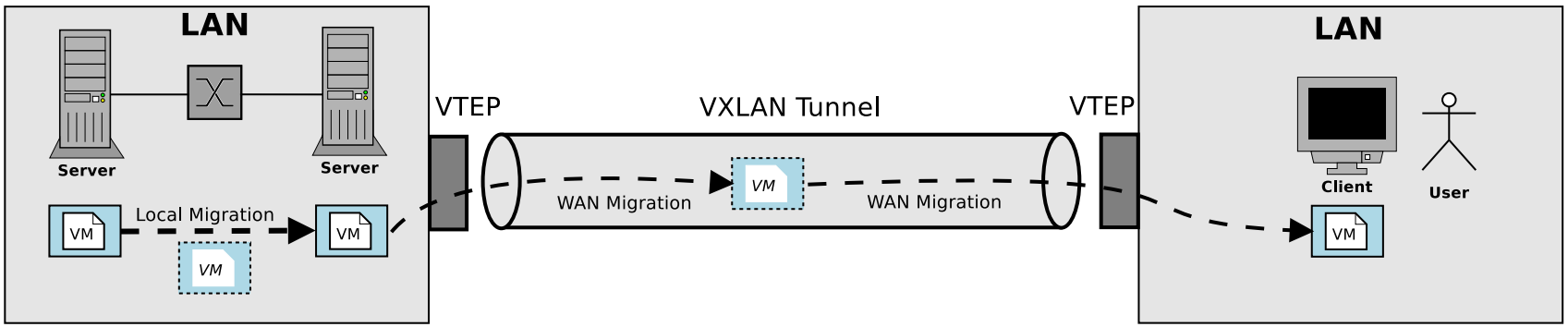

Figure: Experimental setup for VM migration over WAN

- Setup a server with Proxmox (KVM/QEMU)
- Setup a network using VXLAN (Virtual Extensible LAN)
- Connect server and client network through tunnel

Real-world experiment

Since the SKILL/VL environment already uses Proxmox (KVM/QEMU) and VXLAN an extension of these components for the experiments is at hand.

Experimental setup 3/4

Network of the experimental setup

- Network switches with VXLAN capabilities
- Network switches with VTEP (VXLAN Tunnel Endpoints)
- VXLAN Tunnel between server and client network

Virtual overlay network

The virtual network spans an overlay network between the server and client infrastructure over the WAN.

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Experimental setup 4/4

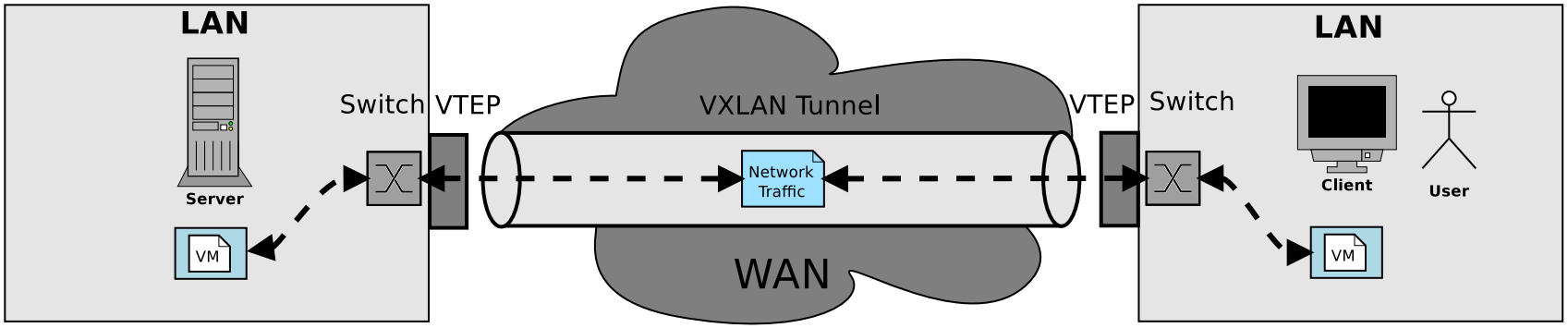

Figure: Logical flow of data over WAN

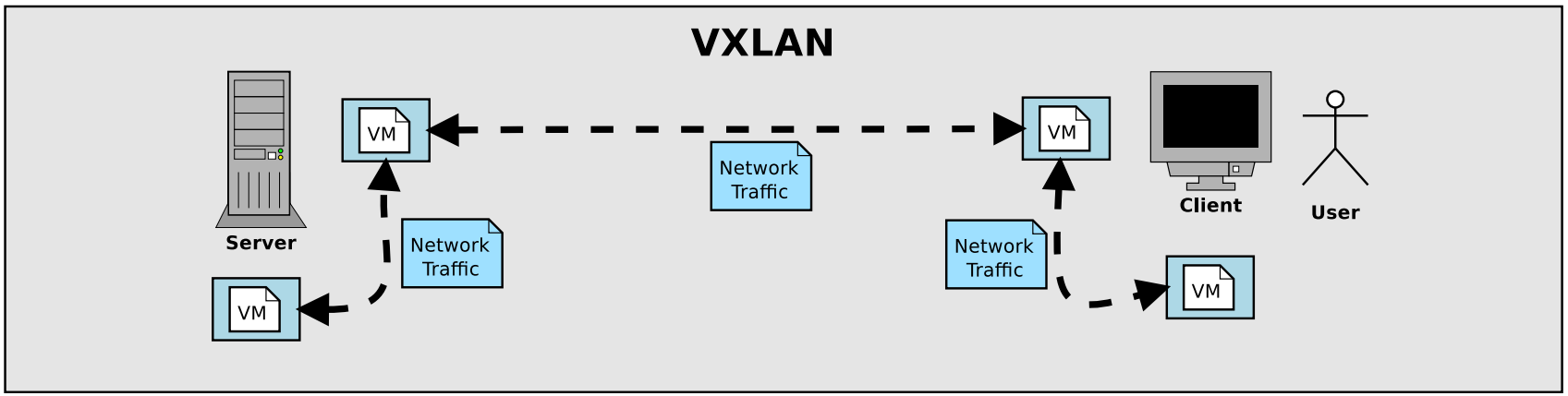

Figure: Flow of data over VXLAN

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VXLAN header

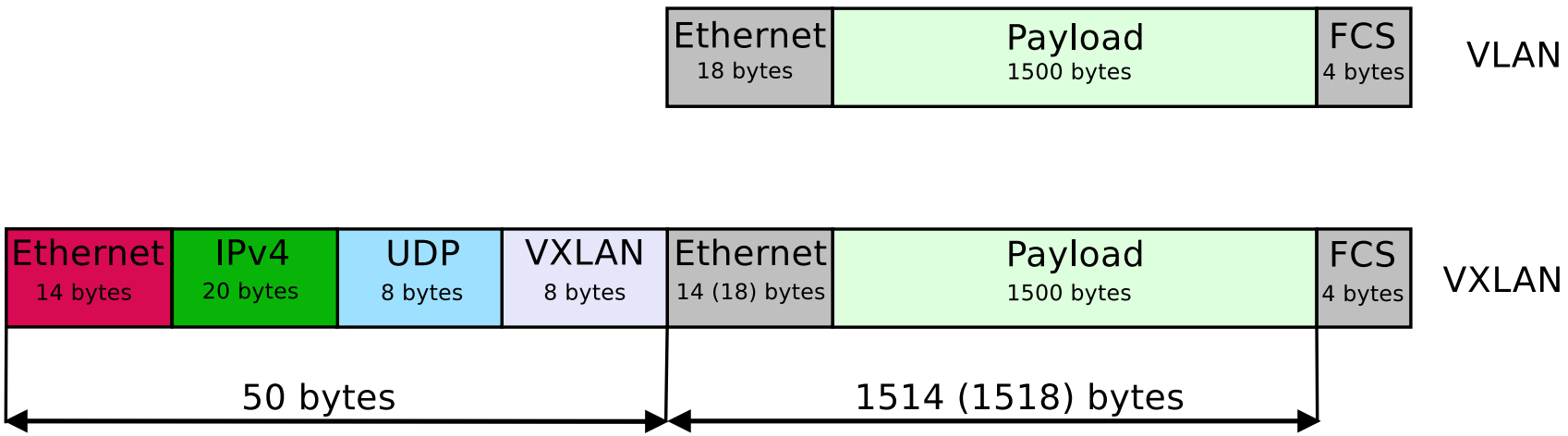

Figure: VXLAN UDP segments

VXLAN and VTEP

VXLAN encapsulates Ethernet frames (OSI Layer 2) into UDP Segments (OSI Layer 4). This makes the extension of networks over physical boundaries possible. VTEP connect two networks and makes the geographically distributed communication between participants possible.

VXLAN protocol encapsulation

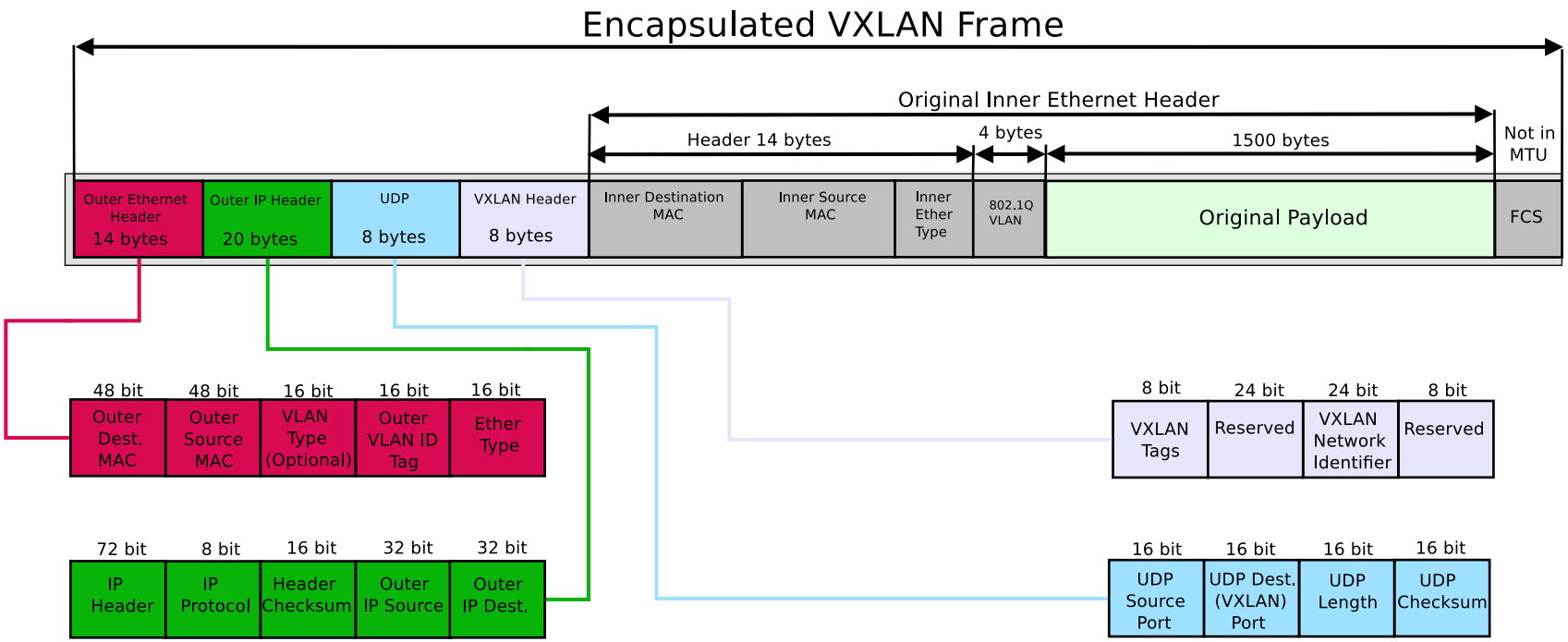

Figure: VXLAN protocol encapsulation

Experimental setup - Summary

Benefits of the experimental setup

- Transparent network for the virtual machines
- Extensible network for the infrastructure
- Seamless integration of all infrastructure components

Common ground for experiments

The presented setup sets the ground for experiments in the infrastructure. This helps in creating comparable conditions for the experiments.

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Challenges with VM migration over WAN

- **Efficient transfer of the VM**
  - → Main memory transfer
  - → Virtual hard disk transfer
- **Migration between networks**
  - → Secure connection between server
  - → Latency between server (transfer VM and operation!)
- **Network configurations**
  - → Configuration of networks between server
  - → Configuration of the VM virtual NICs (Network Interface Controller)
  - → Communication between VMs via WAN

Specifically for my project

Migration of VMs between server and client is possible in principle, but there are many limitations!

Conducting Experiments

Experiments shall investigate the following characteristics:

- Network performance over WAN
- Individual performance of applications
- Overall performance of service
- Applicability of Offline-First Strategy

Applicability of Offline-First Strategy

The main question of the service migration over WAN is the applicability. When does it make sense to migrate services over WAN?

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Migration experiments

Migration of VMs with different characteristics

- Multiple RAM sizes (e.g. 2GB, 4GB, 8GB)
- Multiple HDD sizes (e.g. 10GB, 20GB, 50GB)

Measurement of migration time

- Migration time for one VM
- Migration time for multiple VMs

Adjustment of network traffic

- Limitation of bandwidth for migration
- Dependability on service offered

Effect of VXLAN on service migration

The use of VXLAN opens up many parameters for adjusting and inspecting the behaviour of VM migration over WAN!

Network experiments

Performance of VMs over WAN

- Measurement of latency between VMs (Server $\leftrightarrow$ Client)
- Measurement of performance of applications (Server $\leftrightarrow$ Client)

Performance of overall service

- Measurement of service performance over WAN
- Influence of migration on service performance

Resilience of service

- Measurement of impact on service quality
- Applicability of strategy on service

Effect of VXLAN on service performance

The use of VXLAN opens up many parameters for adjusting and inspecting the behaviour of service performance and reliability over WAN!

Summary

The VXLAN setup. . .

- is a potential answer to RQ 1 form slide 13.
- is a beneficial infrastructure setup.
- is a good basis for experiments on migration and performance.
- is a good first start for an Offline-First Strategy.

The experiments. . .

- shall give results on relevant parameters.
- shall give insights on the applicability of an Offline-First Strategy.
- shall give answers to RQ 2 and 3 form slide 13

Next steps

- **Answering RQ 2 and 3 from Section 2**
  - RQ2 – Application in real-life scenarios
  - RQ3 – Measurements of different scenarios
- **Validation of the current experimental setup**
- **Collecting insights for a publication**

In a nutshell...

extensive experimentation! :-)

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Thank You For Your Attention!

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