

## SLICES-DE Research Infrastructure

### Our Motivation:

*How can we make ICT research more effective?*

- ▶ Research prototypes are often developed as isolated islands
- ▶ Experiment workflows are rarely transferred between research groups
- **Create a shared research infrastructure (RI)** used by academia and industry

*How to create an RI for the ICT community?*

- ▶ Flexible RI covering many research fields
- ▶ Provide valuable services (reproducibility, data management)
- **Create a European RI** collaborating with national initiatives (e.g., SLICES-DE)

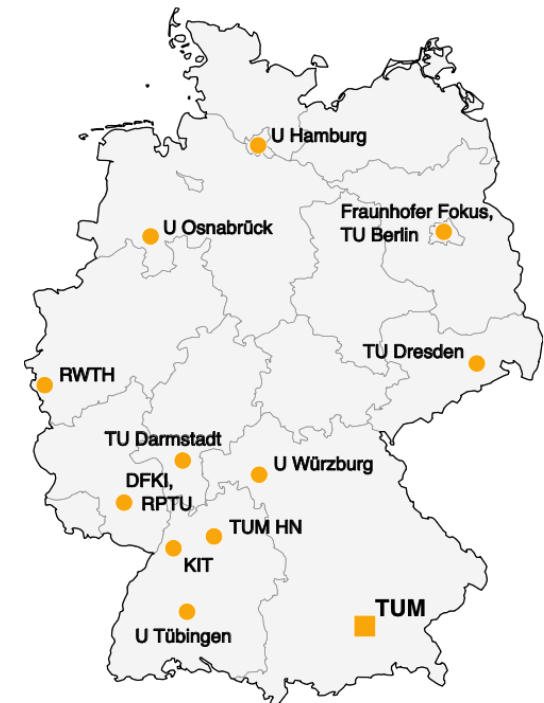
### SLICES research infrastructure

#### SLICES-RI (Europe)

- ▶ Participation from 16 European countries
- ▶ Long-term funding (>10 years) through ESFRI framework of the European Union
- ▶ Joint platform with a shared experiment API [1] and research data management

#### SLICES-DE (Germany)

- ▶ Participation from 12 German partners
- ▶ TUM is the designated lead organization
- ▶ SLICES-DE is part of the German RI roadmap (prospective funding by BMFTR)



SLICES-DE partners

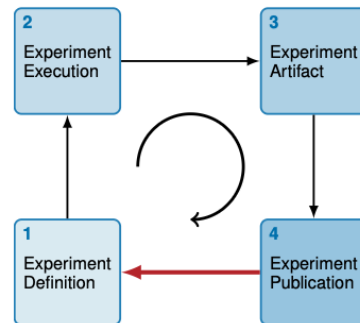
## Motivation for Reproducibility in Testbeds

**Reproducibility** is a cornerstone of the scientific process

- ▶ In many testbed experiments, reproduction is the missing link in the experimental loop → remains a tedious and manual process
- ▶ Lack of standardized packaging and documentation hinders reproducibility of experiment results → missing experiment metadata

### Closing the Reproducibility Gap [3]

- ▶ Introduce structured, machine-readable format to provide experiment context and metadata
- ▶ Provide necessary metadata about used hardware, topology and scripts
- ▶ Enable a closed feedback loop from *experiment definition* to *publication*



Closing the loop between  
publication and re-execution

## RO-Crate Metadata Packaging

**RO-Crate** is a lightweight format for **FAIR research data** using JSON-LD

### Automatic packaging [2] of

- ▶ Configuration files and input scripts
- ▶ Output logs and files (such as `.stdout` and `.stderr`)
- ▶ Node-specific parameters and experiment variables
- ▶ Environment metadata (such as OS image, authors, etc.)

### Benefits

- ▶ Improves reproducibility and sharing in the research community
- ▶ Achieving cross-testbed compatibility and portability

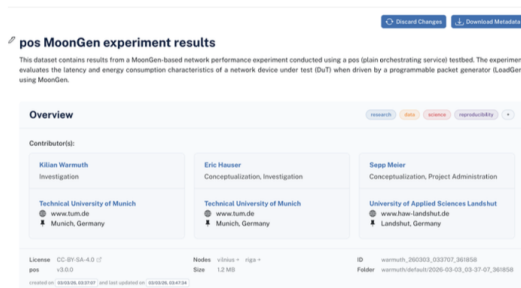


<https://ro-crate.org/>

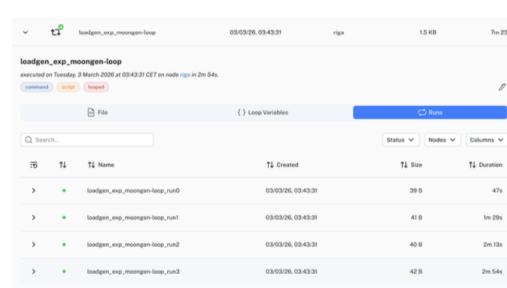
## RO-Crate Visualization

### RO-Crate recommends to provide a custom HTML visualization

- ▶ Human-friendly overview shipped *inside* each crate
- ▶ Visualization of metadata such as authors and affiliations, license, and keywords
- ▶ Chronological listing of executed scripts with details and filters
- **Reduces complexity** for users and simplifies exploration and sharing of results



General overview of an experiment crate

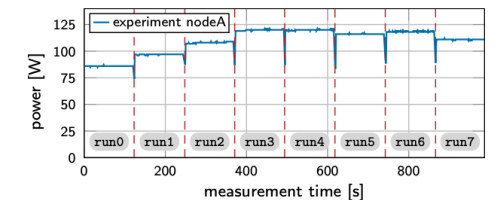


Detail view of executed script results

## Energy Monitoring, Analysis, and Modeling

### Energy-aware experimentation

- ▶ Continuous monitoring of power consumption across testbeds
- ▶ Enables more conscious and efficient use of research infrastructures



Energy consumption monitoring

### Predictive modeling

- ▶ Regression models estimate energy demand before execution
- ▶ Helps researchers compare configurations and reduce carbon footprint
- Enables **sustainable research**



Visualized power prediction

## About SLICES-DE

### What are the goals of SLICES-DE?

- ▶ Aims to create a platform that supports research in a globally unique way
- ▶ Provides open and free, science-led access to hardware, and software
- ▶ Develops an ecosystem for innovation and transfer via protected usage and collaboration models
- **Create a shared research infrastructure (RI)** used by academia and industry

### What does SLICES-DE provide as a platform?

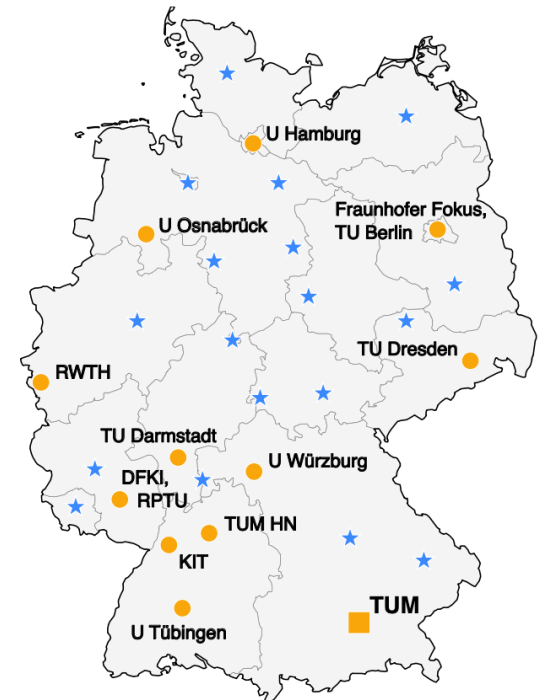
- ▶ Collaboration with open and protected infrastructure components
- ▶ Software Artifacts
- ▶ Data & training materials
- ▶ Analysis services
- Planned to be available for the **whole community**

### Benefits for Academia

- ▶ **Research:** Access to state-of-the-art hardware & software for experiments
- ▶ **Teaching & education:** Individual resources for each student
- ▶ **Collaboration:** Shared infrastructure fostering joint research and innovation

### Benefits for Industry

- ▶ **Collaboration Models:** Flexible cooperation opportunities with academia and research institutions
- ▶ **Reuse of results:** Simplified transfer of results from academia to industry through joint infrastructure



SLICES-DE Community

## Joint Cooperation Models

**SLICES-DE** offers *flexible cooperation models* between universities, research institutions, and industry partners.



### ► **Model A – Direct Collaboration**

Industry partners directly use SLICES-DE resources with data confidentiality ensured according to their requirements

### ► **Model B – Shared Components**

Partners integrate new hardware into existing testbeds, either shared with others or used exclusively

### ► **Model C – Replicated Testbed**

Companies deploy on-site testbeds using the SLICES software stack for isolated but compatible experimentation

### ► **Model D – Joint Projects**

Industry and academia share SLICES-DE infrastructure for collaborative research projects

## Benefits for the SLICES-DE community

### **Benefits for Universities & Research Institutions**

- Access to research infrastructure
- Support for diverse types of academic projects
- Educational materials & training repository
- Quota-based free access
- Extended & protected access options

### **Industry Partners**

- Collaboration models
- Platform contributions
- Innovation support

### **SLICES-DE Community**

- Shared knowledge base
- Sustainable growth
- Cross-sector collaboration

## Expression of Interest

Send us your Letter of Intent (LoI) stating your:



- ▶ Field & expertise
- ▶ Planned use of SLICES-DE
- ▶ Contribution interest (software, data, or hardware)
- ▶ Consent to list your organization on the SLICES-DE website

 **Strong community participation will help secure the success of SLICES-DE**



<https://slices-de.org/community/>

## Website and Contacts

### Contacts

Georg Carle  
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### Links

Website: <https://slices-de.eu>

LinkedIn: <https://linkedin.com/company/slices-de>

Zenodo: <https://zenodo.org/communities/slices-de>

### Address

Chair of Network Architectures and Services  
Technical University of Munich  
Boltzmannstr. 3  
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slices DE



<https://slices-de.eu>

## Demonstration Experiment

using the mobile SLICES research infrastructure

### Multipath Blueprint

- used to deploy a MASQUE client and proxy
- communication over a **fast** and **slow** path

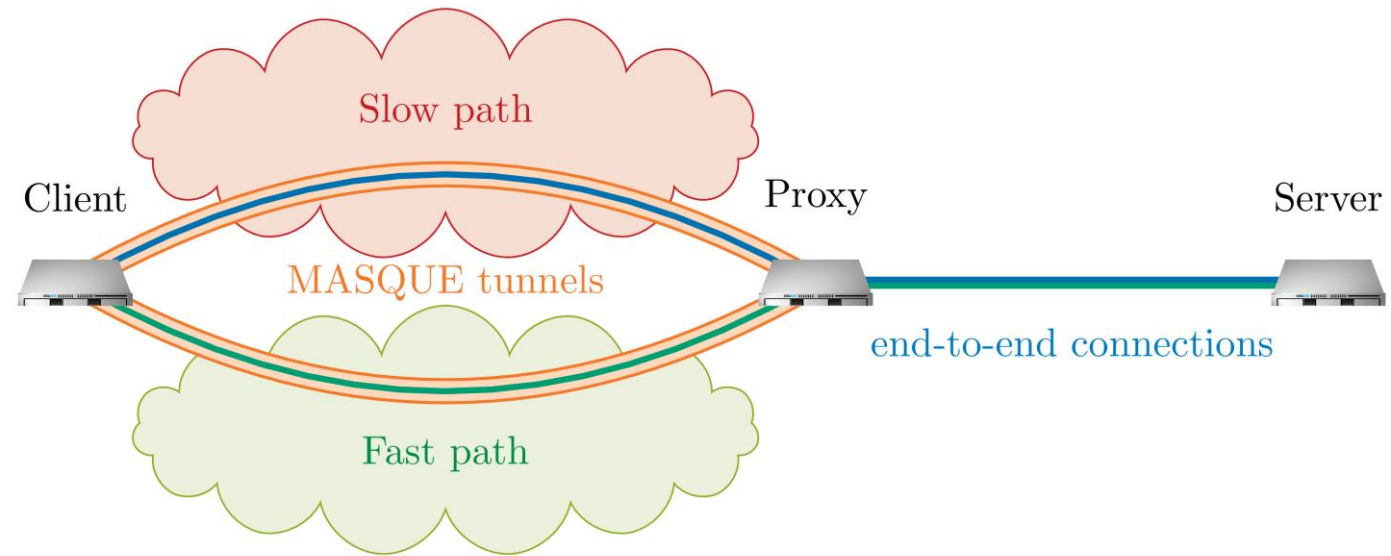
Tunnels are either **reliable** or **unreliable**

#### Reliability

- resilience mechanism protects against losses
- enables **Quality of Service** to be requested for specific flows

Target server is **not** involved

- legacy and difficult-to-extend protocols benefit from modern features



↻ Discard Changes

↓ Download Metadata

## QoS in Multipath MASQUE with a SLICES-DE Blueprint

This experiment uses a SLICES-DE blueprint of a multipath network topology to automatically measure, evaluate, and visualize the capabilities of a MASQUE client and proxy. Three pos testbed nodes are deployed and configured such that a client has two configurable paths to a proxy: a fast (50 Mbps, 5ms RTT) and a slow (10 Mbps, 10ms RTT) one. The server is reachable from the proxy (10ms RTT). The client establishes one tunnel to the proxy, in which nine separate end-to-end flows are established, each retrieving a 1 MB file. Ten runs are executed, with each run recording encryption keys, logs in the qlog format, energy data, and packet captures for later analysis. The experiment shows that, depending on the substrate selected by the client, quality of service can be requested for specific flows by assigning them separate priorities.

### Overview

MASQUE

Multipath QUIC

blueprint

energy-measurements

+

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Duration 17m 26s

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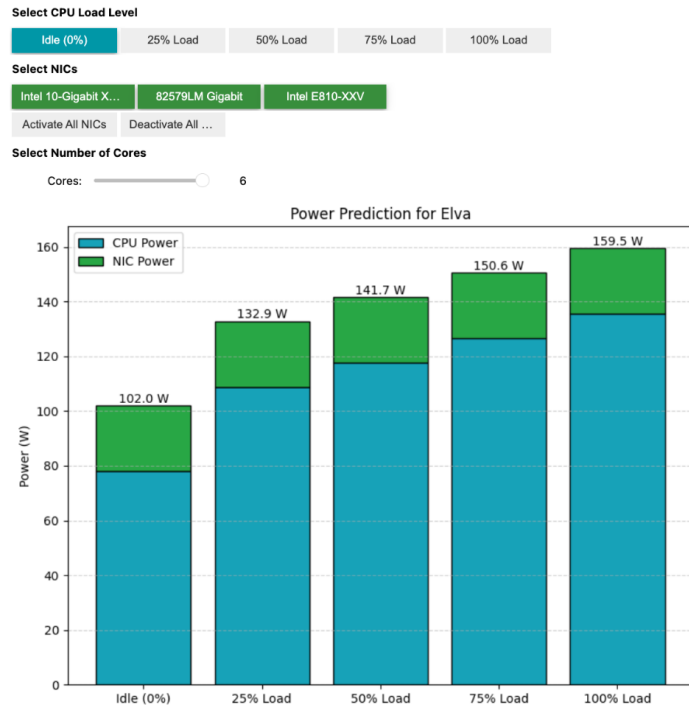
ID warmuth\_260515\_144924\_698443

Nodes rapla [i](#), tapa [i](#), valga [i](#)

Controller pos (v3.0.0)

# Demonstration Video of the Energy Prediction Tooling

## Increasing Awareness with Power Prediction



Combined power prediction across nodes

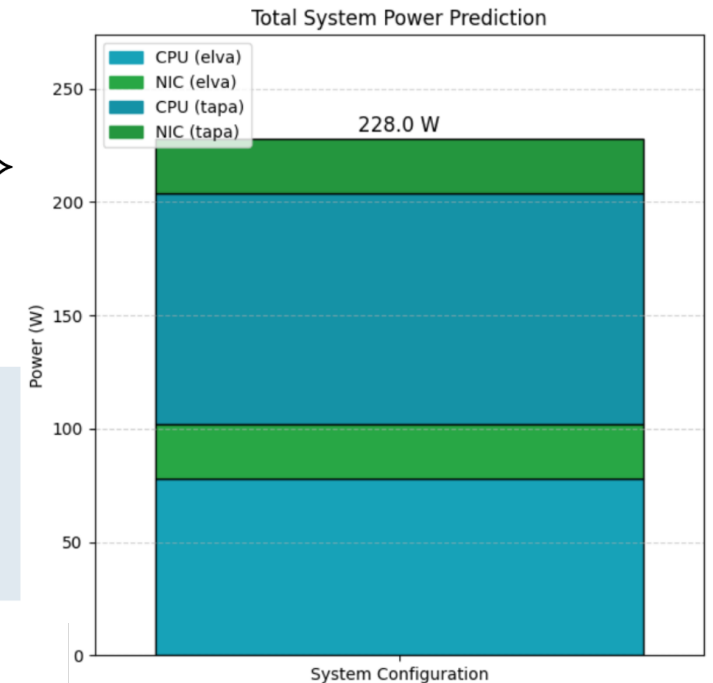
### Combined power prediction

- ▶ Estimate total power draw of selected nodes
- ▶ Compare energy impact of configurations

### Per-node breakdown

- ▶ Visualize CPU, GPU and NIC energy usage
- ▶ Enable node-level energy optimization

$$P_{server} = P_{base} + \sum_{i=1}^n \lambda_i \cdot P_{core,i} + \sum_{j=1}^k \lambda_j \cdot P_{nic,j} + \sum_{l=1}^m \lambda_l \cdot P_{gpu,l}$$



Per-node energy breakdown

CPU: Xeon Silver 4214 @ 2.20GHz

GPU: NVIDIA TU104 [GeForce RTX 2080 SUPER]

Select CPU Load Level

Idle (0%) 25% Load **50% Load** 75% Load 100% Load

Select GPU Load Level

Idle (0%) **25% Load** 50% Load 75% Load 100% Load

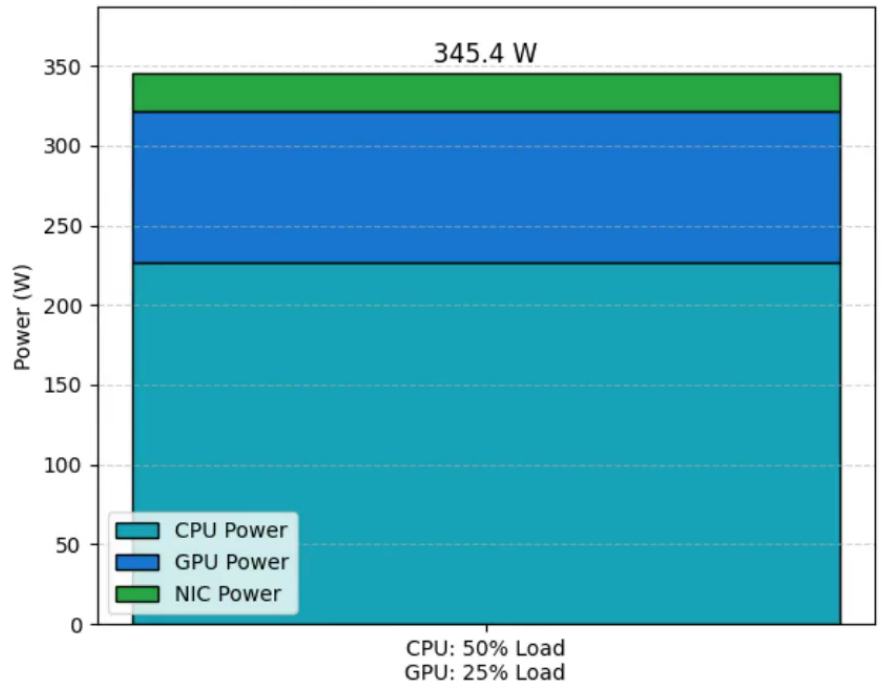
Select NICs

**Intel 10-Gigabit X...** 82579LM Gigabit Intel E810-XXV

Select Number of Cores

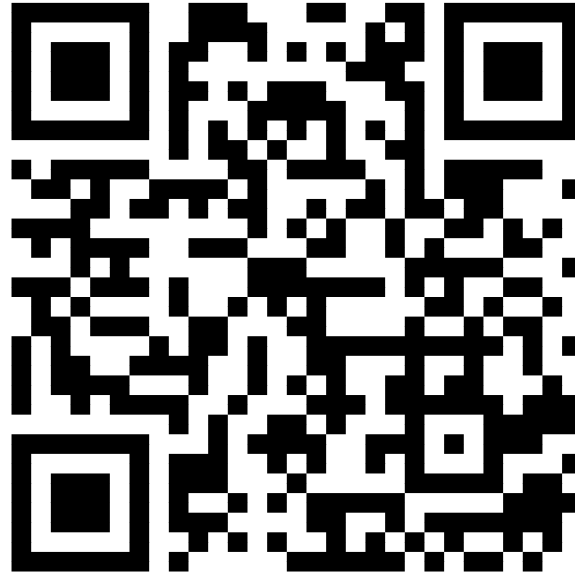
Cores:  12

Power Prediction for Smartcash





Help us with your **input**  
Scan the **QR Code** to participate



<https://forms.gle/qKWop5cSMpL7HwA67>