LEVERAGING IN-BAND TELEMETRY AND ML FOR A RESPONSIBLE INTERNET

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# DIGITAL SOVEREIGNTY IN PRACTICE

# BUILDING A RESPONSIBLE AND RESILIENT INTERNET

**Preserving Digital Autonomy**

- Ensure societal autonomy by protecting critical systems from external manipulation and surveillance.

**User Empowerment and Choice**

- Enable individuals and critical service providers to select and control the equipment managing their data.

**Data Sovereignty**

- Allow users to define clear requirements for their data, including trusted networking hardware and geographic preferences.

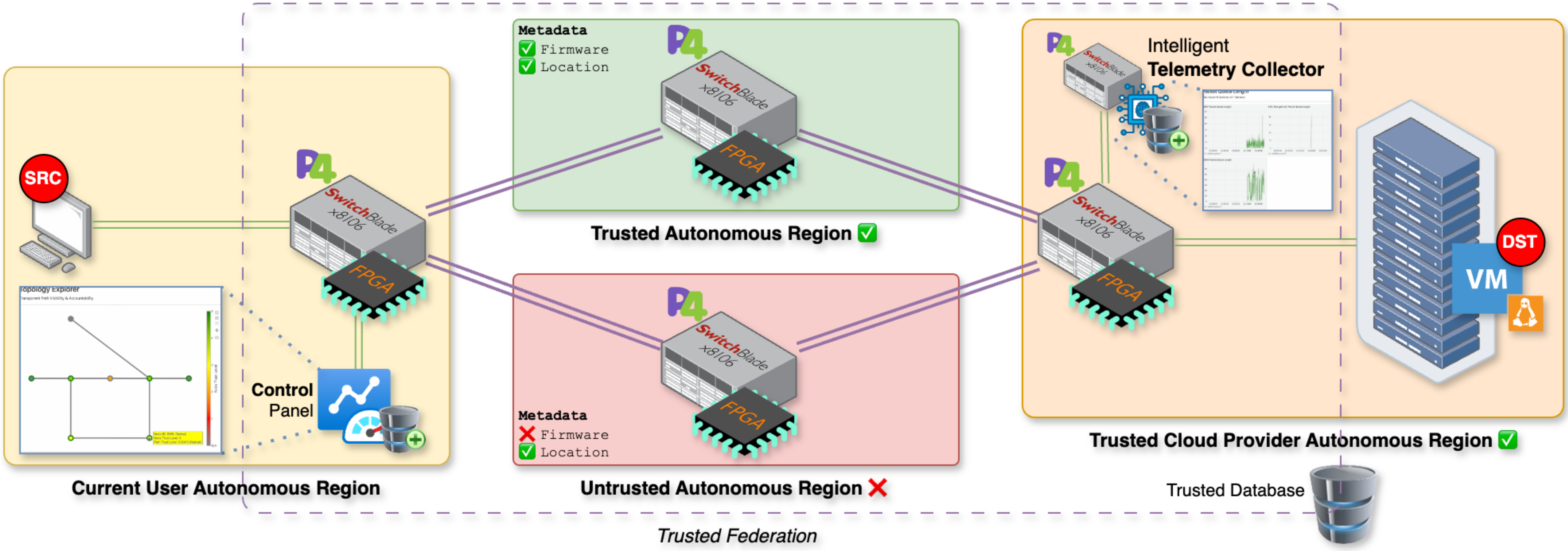
**Transparency and Accountability**

- Provide mechanisms for users to verify operator integrity and effectively trace incidents or cyber-attacks to their origins.

**Resilient and Responsible Internet**

- Promote an internet infrastructure that is resilient, secure, and aligned with users' privacy and security expectations.

# NETWORK ELEMENT TRUST LEVEL


SRC
P4
SwitchBlade x8106
FPGA
Topology Explorer
Control Panel
Current User Autonomous Region
Metadata
✓ Firmware
✓ Location
Trusted Autonomous Region ✓
Metadata
✗ Firmware
✓ Location
Untrusted Autonomous Region ✗
Intelligent Telemetry Collector
DST
VM
Trusted Cloud Provider Autonomous Region ✓
Trusted Database
Trusted Federation

DEMONSTRATOR DESCRIPTION & OPERATION

# PROOF-OF-CONCEPT

# POC DEMO DESCRIPTION

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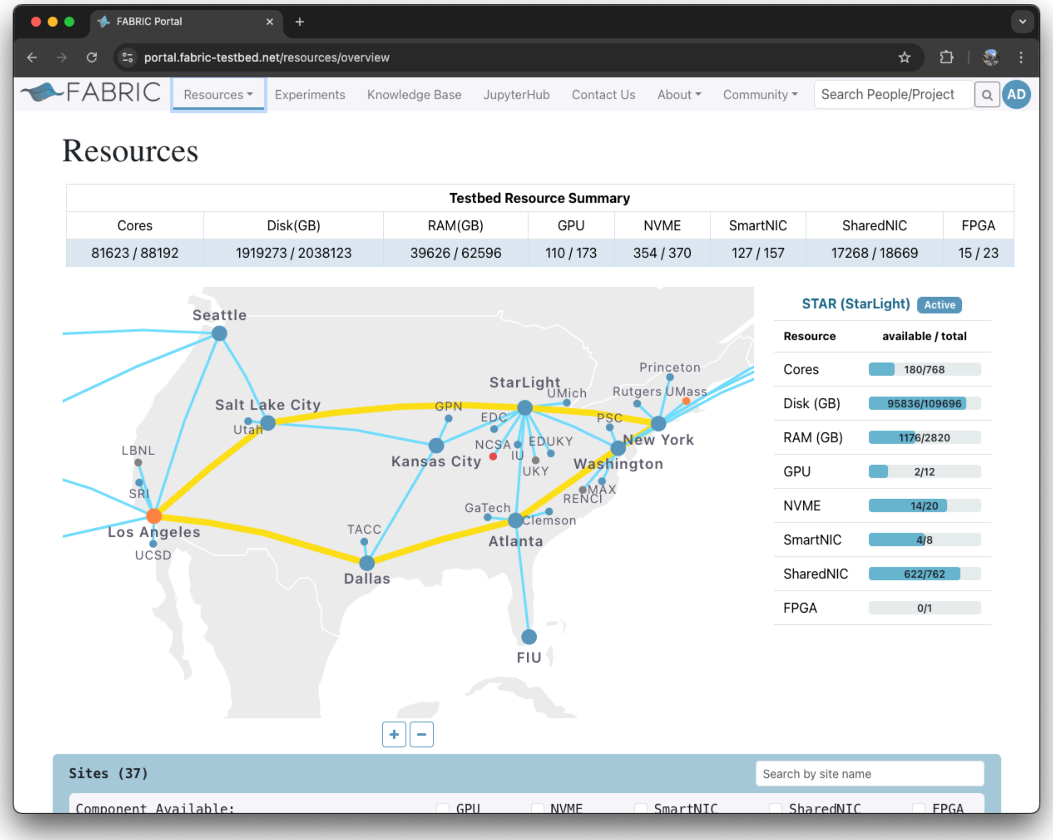
## FABRIC TESTBED



Resources

| Testbed Resource Summary | | | | | | | |
|---|---|---|---|---|---|---|---|
| Cores | Disk(GB) | RAM(GB) | GPU | NVME | SmartNIC | SharedNIC | FPGA |
| 81623 / 88192 | 1919273 / 2038123 | 39626 / 62596 | 110 / 173 | 354 / 370 | 127 / 157 | 17268 / 18669 | 15 / 23 |

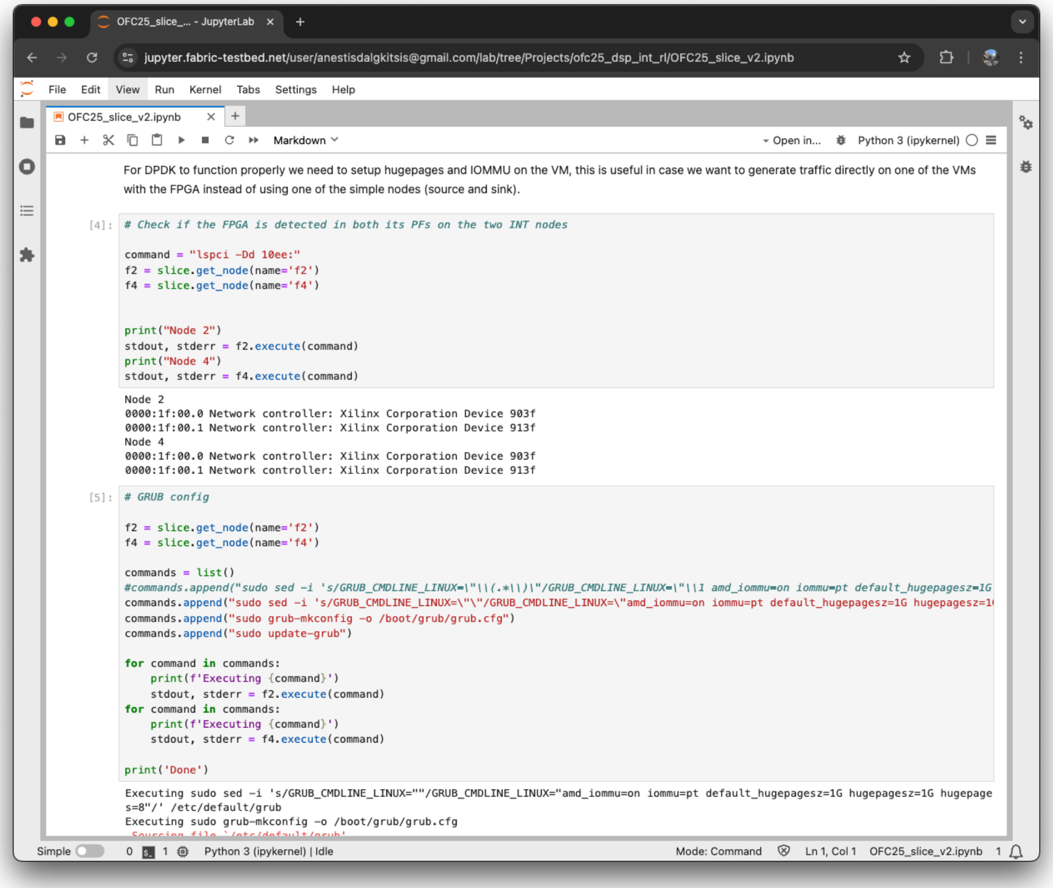
STAR (StarLight) Active

| Resource | available / total |
|---|---|
| Cores | 180/768 |
| Disk (GB) | 95836/109696 |
| RAM (GB) | 1176/2820 |
| GPU | 2/12 |
| NVME | 14/20 |
| SmartNIC | 4/8 |
| SharedNIC | 622/762 |
| FPGA | 0/1 |

Sites (37)

Search by site name

Component Available: □ GPU □ NVME □ SmartNIC □ SharedNIC □ FPGA



OFC25_slice_... - JupyterLab
jupyter.fabric-testbed.net/user/anestisdalgkitsis@gmail.com/lab/tree/Projects/ofc25_dsp_int_rl/OFC25_slice_v2.ipynb
File
Edit
View
Run
Kernel
Tabs
Settings
Help
OFC25_slice_v2.ipynb
Markdown
Open in...
Python 3 (ipykernel)

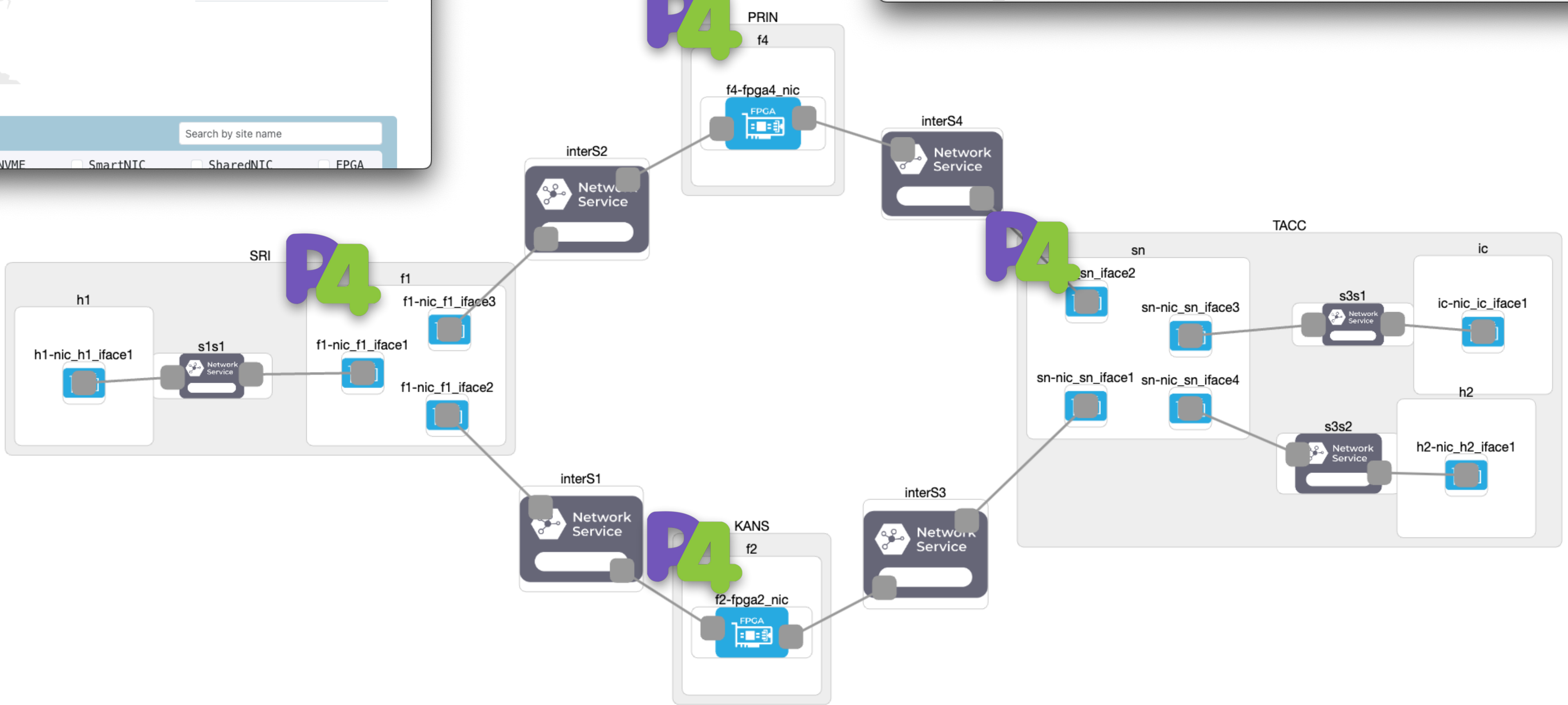
For DPDK to function properly we need to setup hugepages and IOMMU on the VM, this is useful in case we want to generate traffic directly on one of the VMs with the FPGA instead of using one of the simple nodes (source and sink).

```
[4]: # Check if the FPGA is detected in both its PFs on the two INT nodes

     command = "lspci -Dd 10ee:"
     f2 = slice.get_node(name='f2')
     f4 = slice.get_node(name='f4')


     print("Node 2")
     stdout, stderr = f2.execute(command)
     print("Node 4")
     stdout, stderr = f4.execute(command)
```

```
Node 2
0000:1f:00.0 Network controller: Xilinx Corporation Device 903f
0000:1f:00.1 Network controller: Xilinx Corporation Device 913f
Node 4
0000:1f:00.0 Network controller: Xilinx Corporation Device 903f
0000:1f:00.1 Network controller: Xilinx Corporation Device 913f
```

```
[5]: # GRUB config

     f2 = slice.get_node(name='f2')
     f4 = slice.get_node(name='f4')

     commands = list()
     #commands.append("sudo sed -i 's/GRUB_CMDLINE_LINUX=\"\\(.*\\)\"/GRUB_CMDLINE_LINUX=\"\\1 amd_iommu=on iommu=pt default_hugepagesz=1G
     commands.append("sudo sed -i 's/GRUB_CMDLINE_LINUX=\"\"/GRUB_CMDLINE_LINUX=\"amd_iommu=on iommu=pt default_hugepagesz=1G hugepagesz=1
     commands.append("sudo grub-mkconfig -o /boot/grub/grub.cfg")
     commands.append("sudo update-grub")

     for command in commands:
         print(f'Executing {command}')
         stdout, stderr = f2.execute(command)
     for command in commands:
         print(f'Executing {command}')
         stdout, stderr = f4.execute(command)

     print('Done')
```

```
Executing sudo sed -i 's/GRUB_CMDLINE_LINUX=""/GRUB_CMDLINE_LINUX="amd_iommu=on iommu=pt default_hugepagesz=1G hugepagesz=1G hugepage
s=8"/' /etc/default/grub
Executing sudo grub-mkconfig -o /boot/grub/grub.cfg
Sourcing file `/etc/default/grub'
```



# NETWORK ELEMENT TRUST LEVEL

**Trust Calculation**

**Location**
Weight: .5

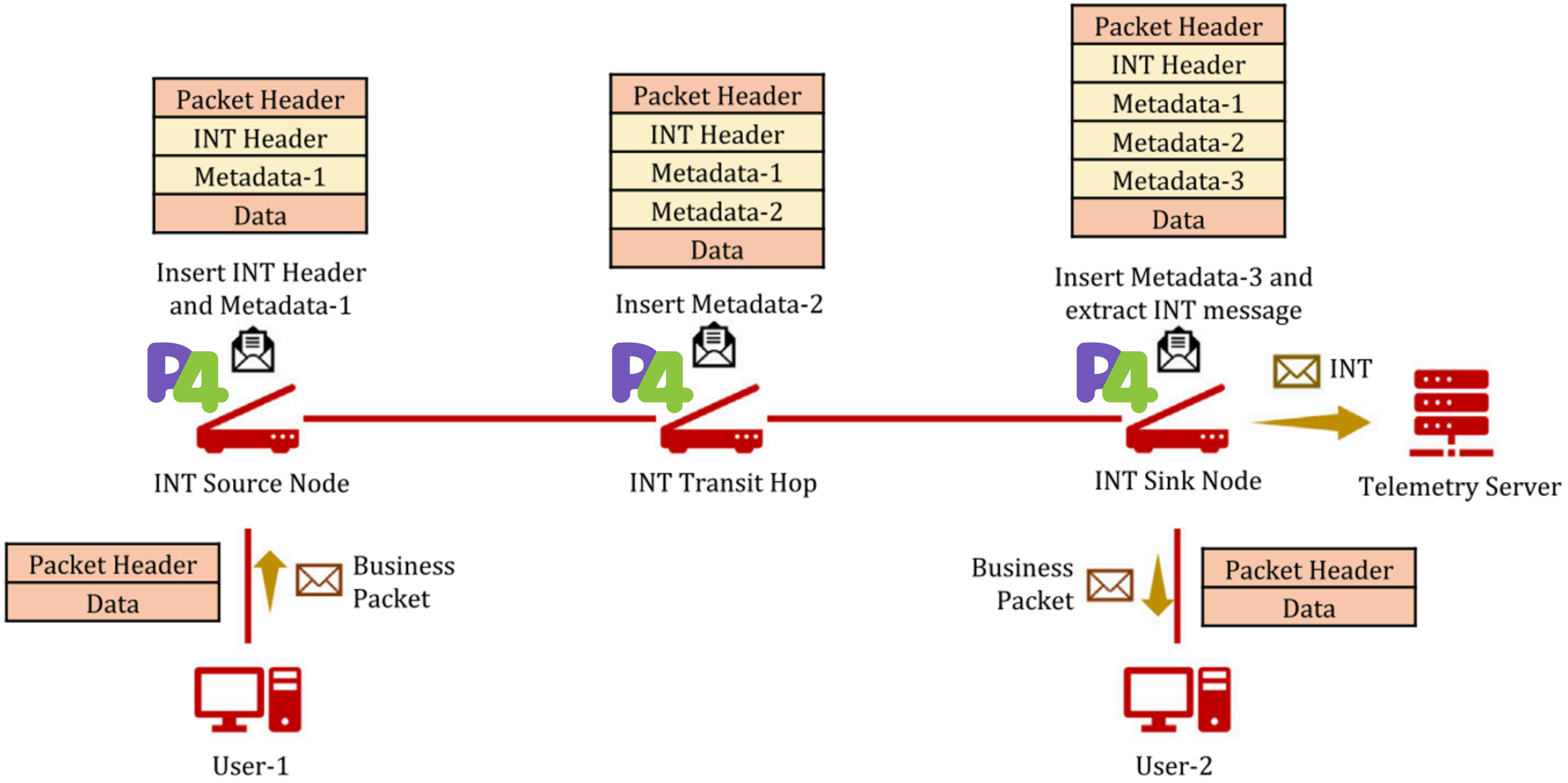
**Vendor**
Weight: .2

**Firmware**
Weight: .3

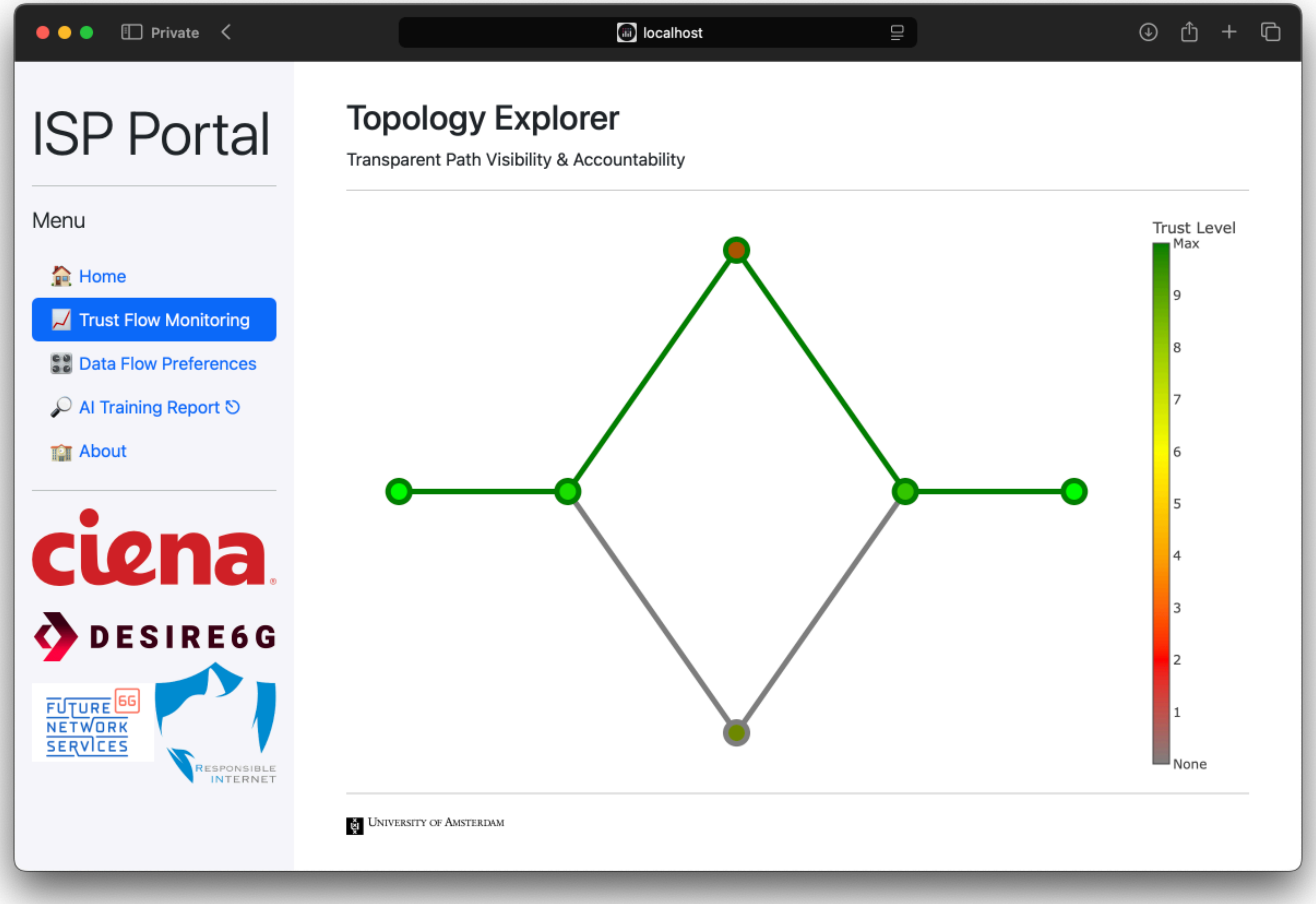
## TRUST LEVEL

✓INTERACTIONS WITH THE OTHER NETWORK ENTITIES
✓LOCATION
✓FIRMWARE VERSION
✓LEVEL OF HARDWARE HARDENING
✓ETC

# IN-BAND NETWORK TELEMETRY



# POC DEMO DESCRIPTION

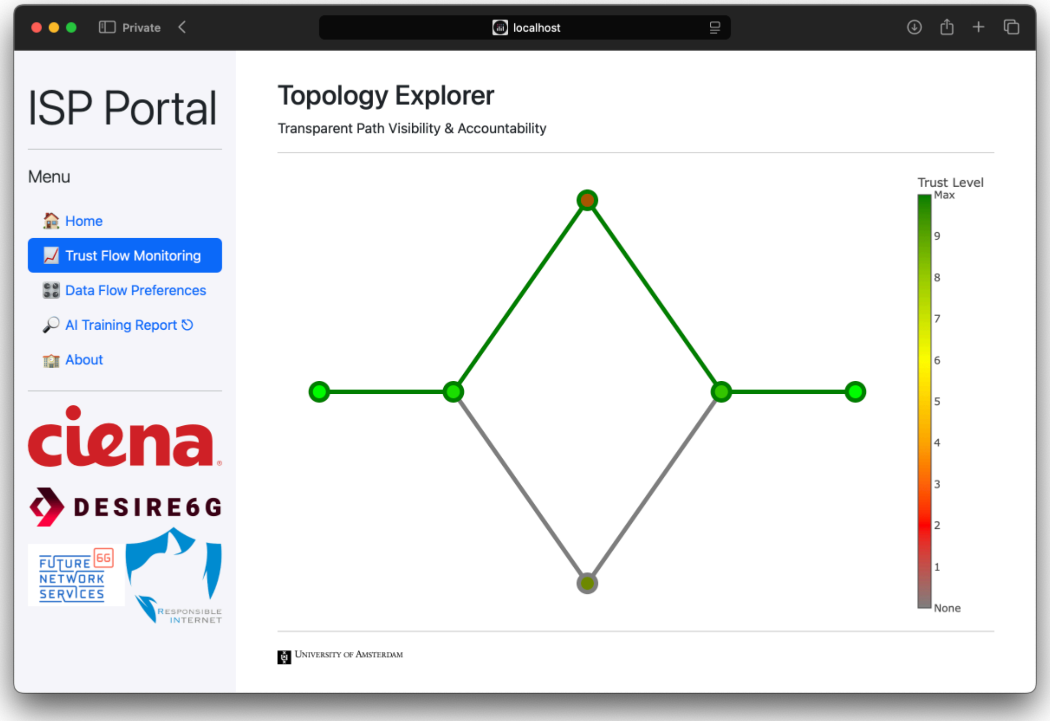


ISP Portal

## Topology Explorer

Transparent Path Visibility & Accountability

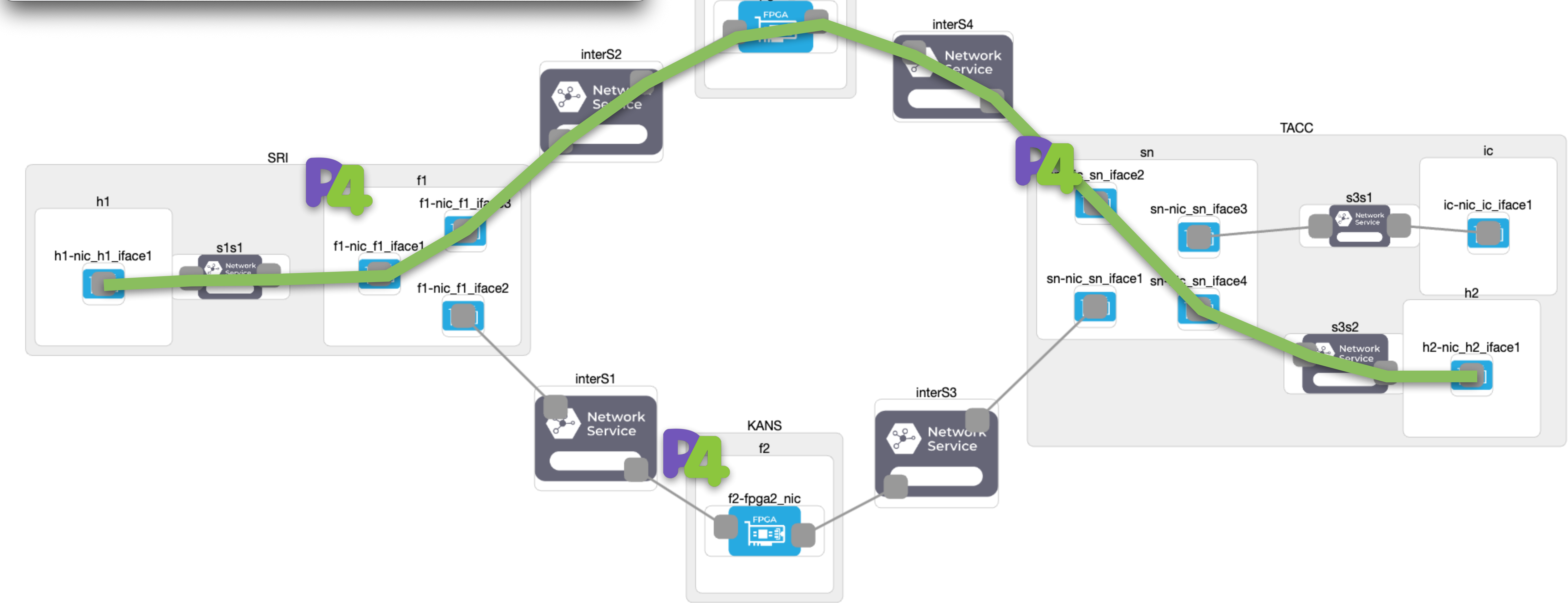
# POC DEMO DESCRIPTION



ISP Portal

## Topology Explorer

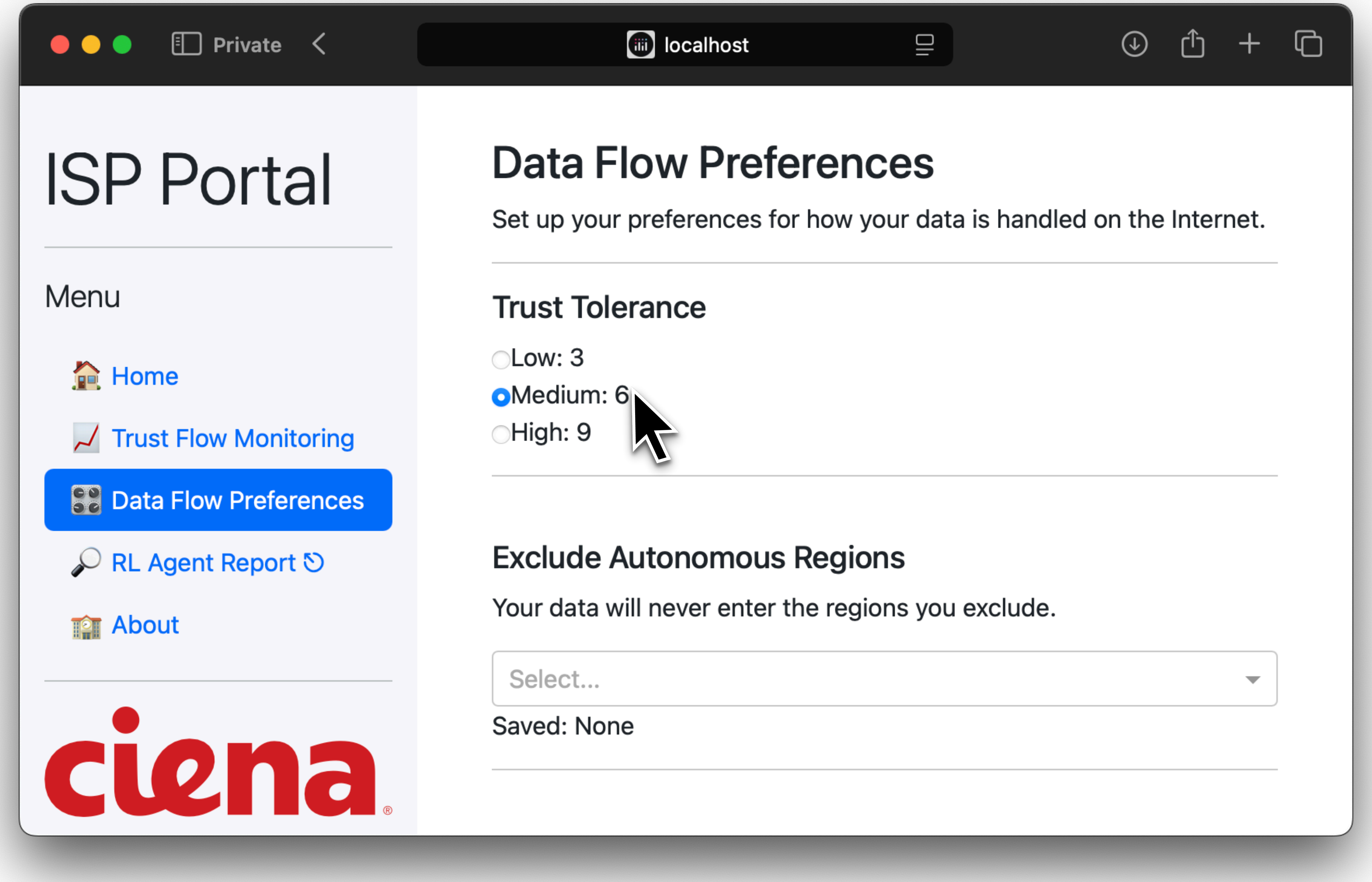
Transparent Path Visibility & Accountability



## AUTONOMOUS LEARNING-DRIVEN IN-NETWORK CONTROL

# SCENARIO I

# AUTONOMOUS LEARNING-DRIVEN IN-NETWORK CONTROL



## Data Flow Preferences

Set up your preferences for how your data is handled on the Internet.

### Trust Tolerance

○ Low: 3
● Medium: 6
○ High: 9

### Exclude Autonomous Regions

Your data will never enter the regions you exclude.

Select...

Saved: None

DEMO: SCENARIO II

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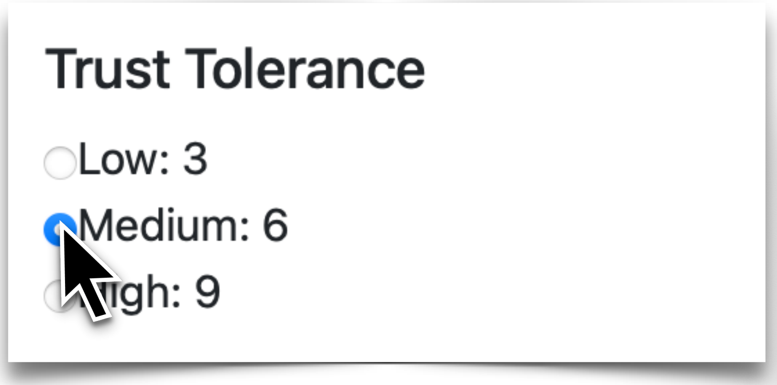
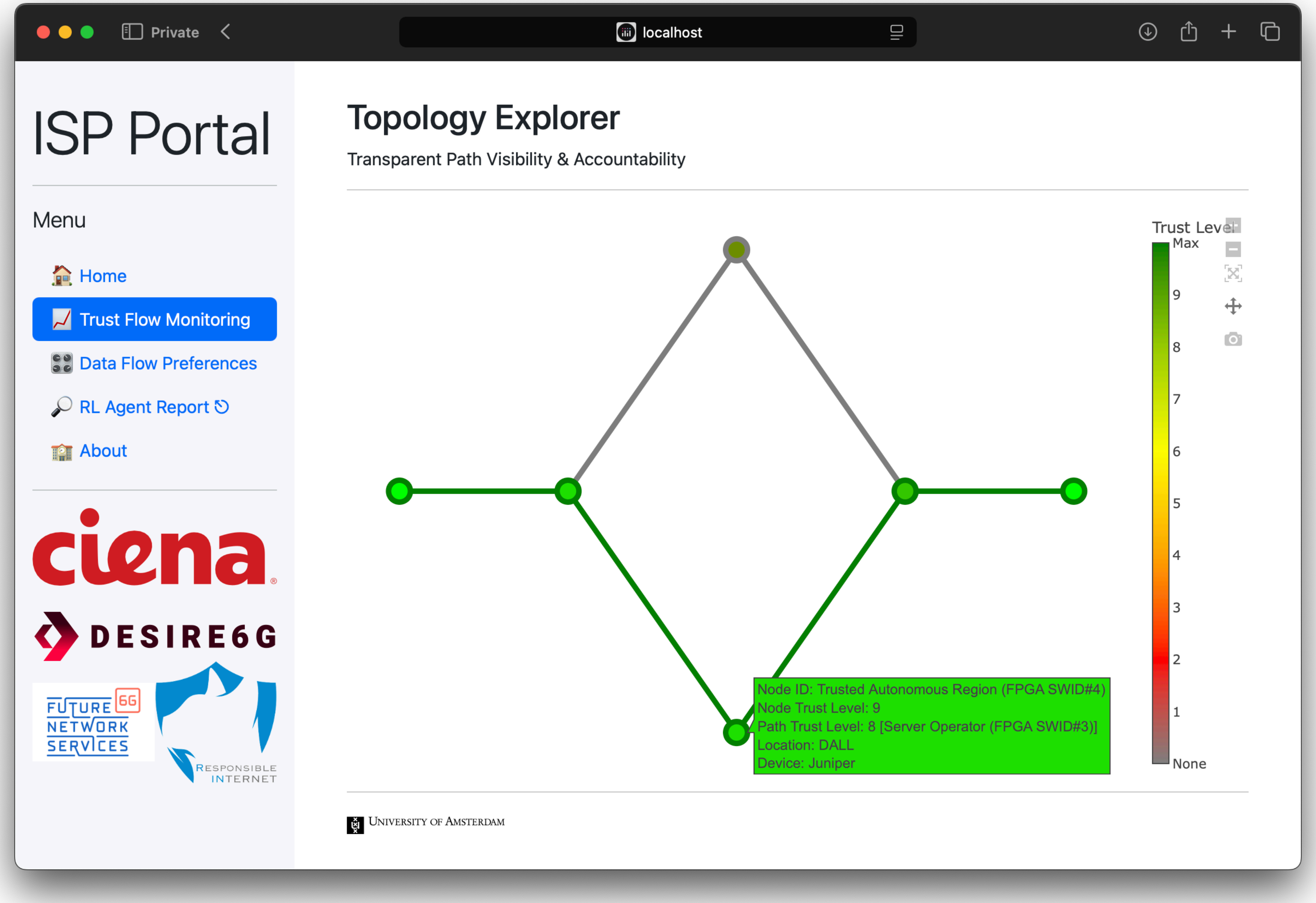
# AUTONOMOUS LEARNING-DRIVEN IN-NETWORK CONTROL



### Trust Tolerance

○ Low: 3
● Medium: 6
○ High: 9



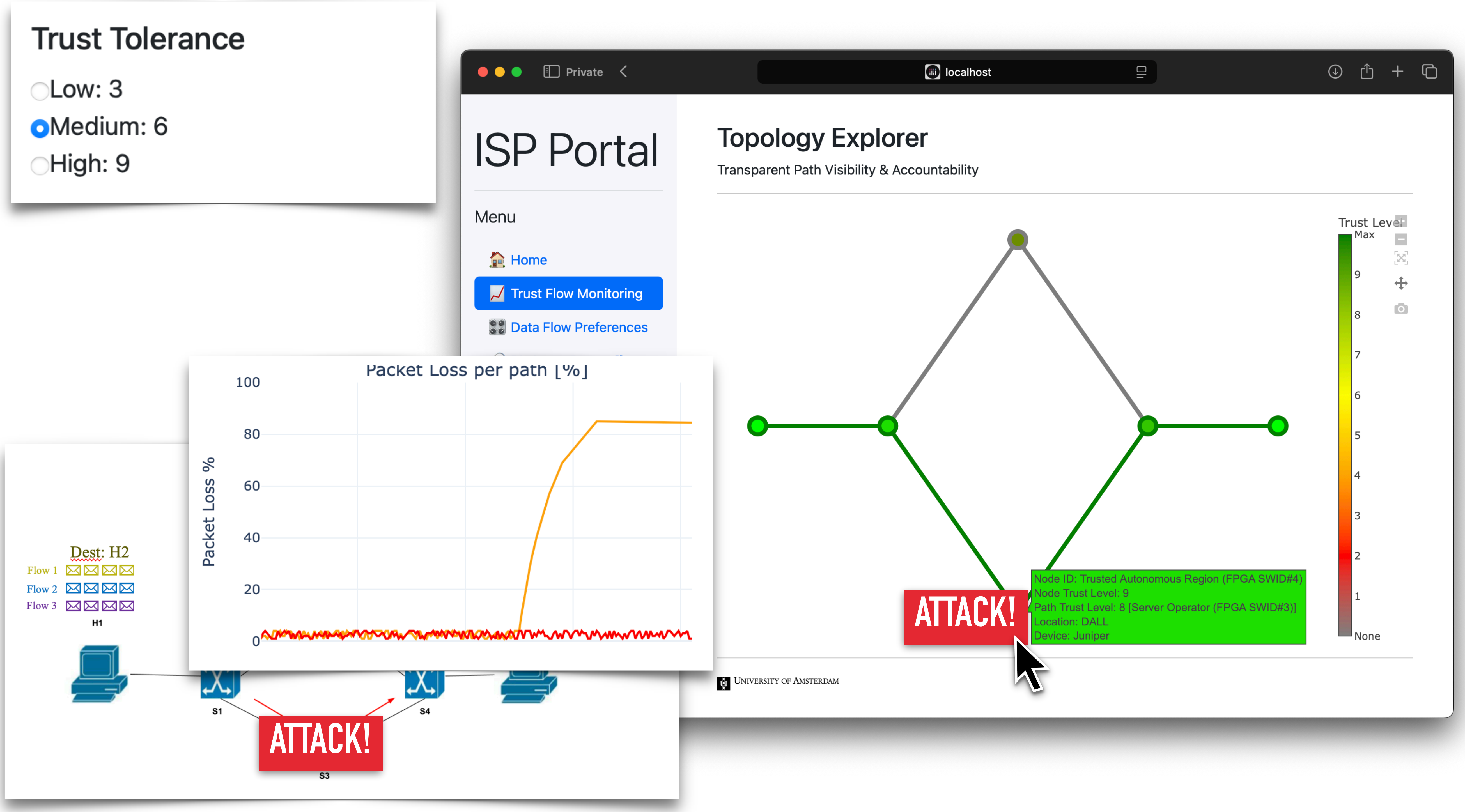
## ISP Portal

## Topology Explorer

Transparent Path Visibility & Accountability

Node ID: Trusted Autonomous Region (FPGA SWID#4)
Node Trust Level: 9
Path Trust Level: 8 [Server Operator (FPGA SWID#3)]
Location: DALL
Device: Juniper

# AUTONOMOUS LEARNING-DRIVEN IN-NETWORK CONTROL

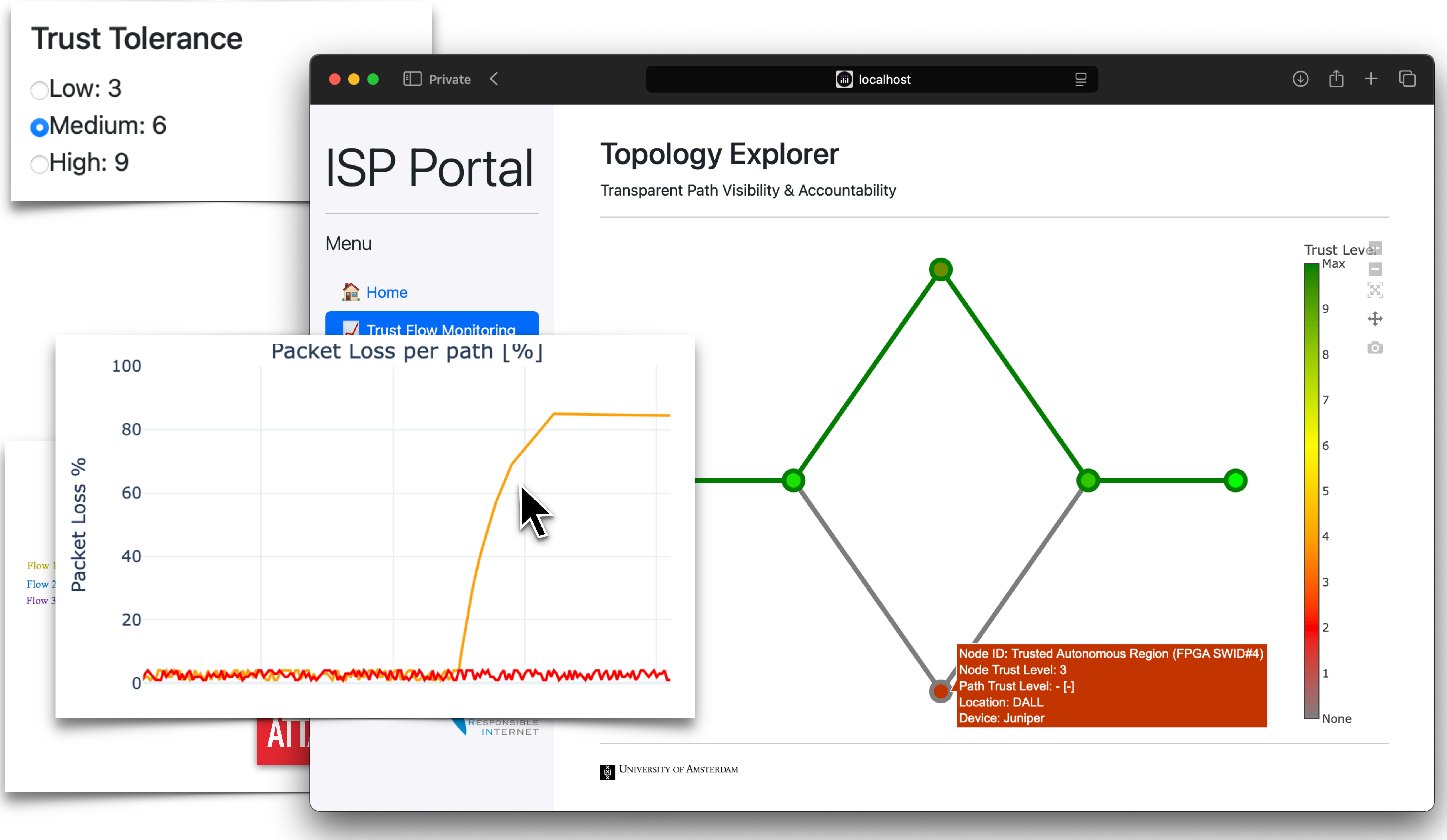


Trust Tolerance

○ Low: 3
● Medium: 6
○ High: 9

Node ID: Trusted Autonomous Region (FPGA SWID#4)
Node Trust Level: 9
Path Trust Level: 8 [Server Operator (FPGA SWID#3)]
Location: DALL
Device: Juniper

# AUTONOMOUS LEARNING-DRIVEN IN-NETWORK CONTROL



## Trust Tolerance

○Low: 3
●Medium: 6
○High: 9

# ISP Portal

Menu

- 🏠 Home
- Trust Flow Monitoring

## Topology Explorer

Transparent Path Visibility & Accountability

Node ID: Trusted Autonomous Region (FPGA SWID#4)
Node Trust Level: 3
Path Trust Level: - [-]
Location: DALL
Device: Juniper

DEMO: SCENARIO II

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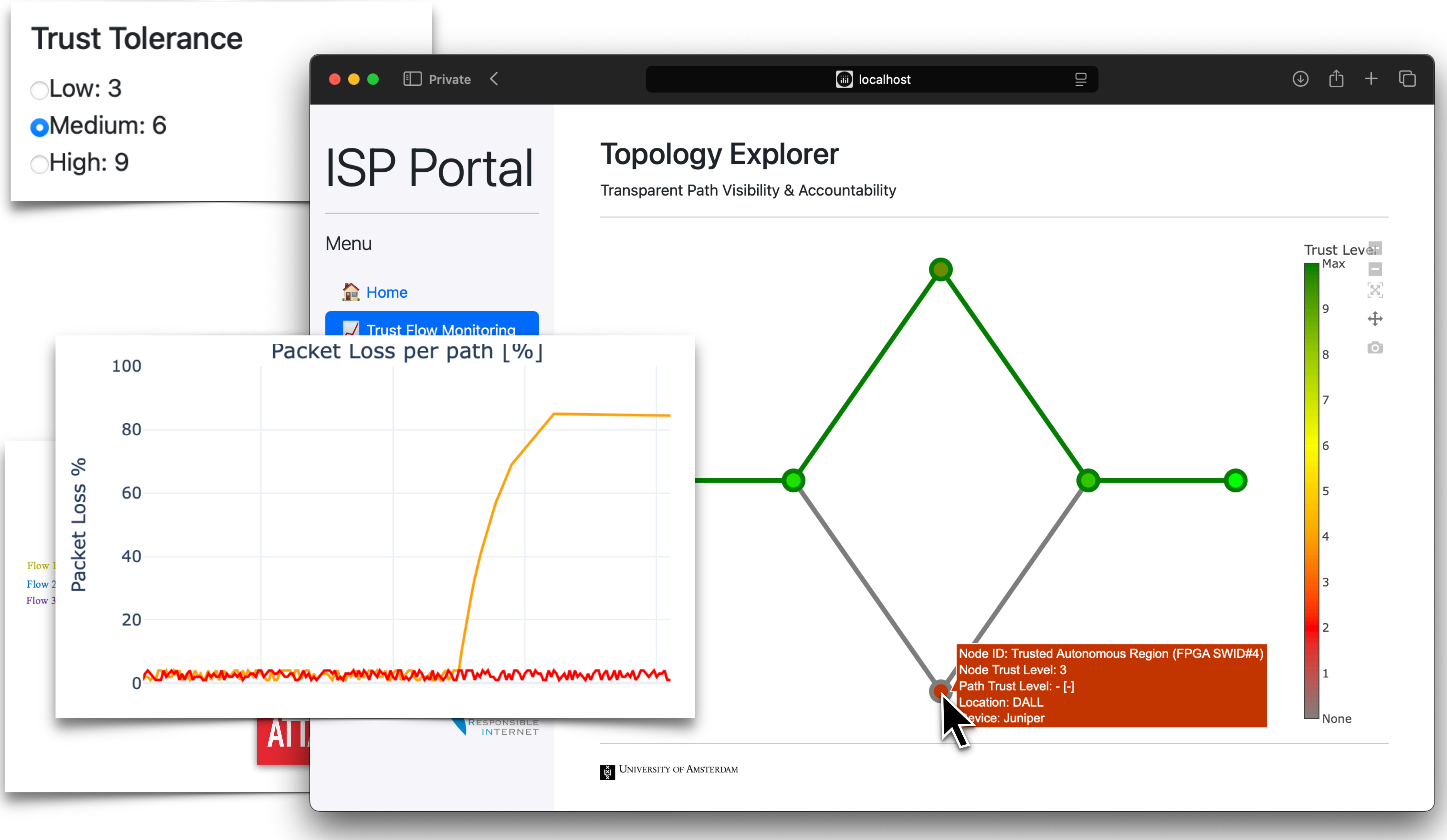
# AUTONOMOUS LEARNING-DRIVEN IN-NETWORK CONTROL



## Trust Tolerance

○ Low: 3
● Medium: 6
○ High: 9

## ISP Portal

Menu

- 🏠 Home
- 📈 Trust Flow Monitoring

## Topology Explorer

Transparent Path Visibility & Accountability

Node ID: Trusted Autonomous Region (FPGA SWID#4)
Node Trust Level: 3
Path Trust Level: - [-]
Location: DALL
evice: Juniper

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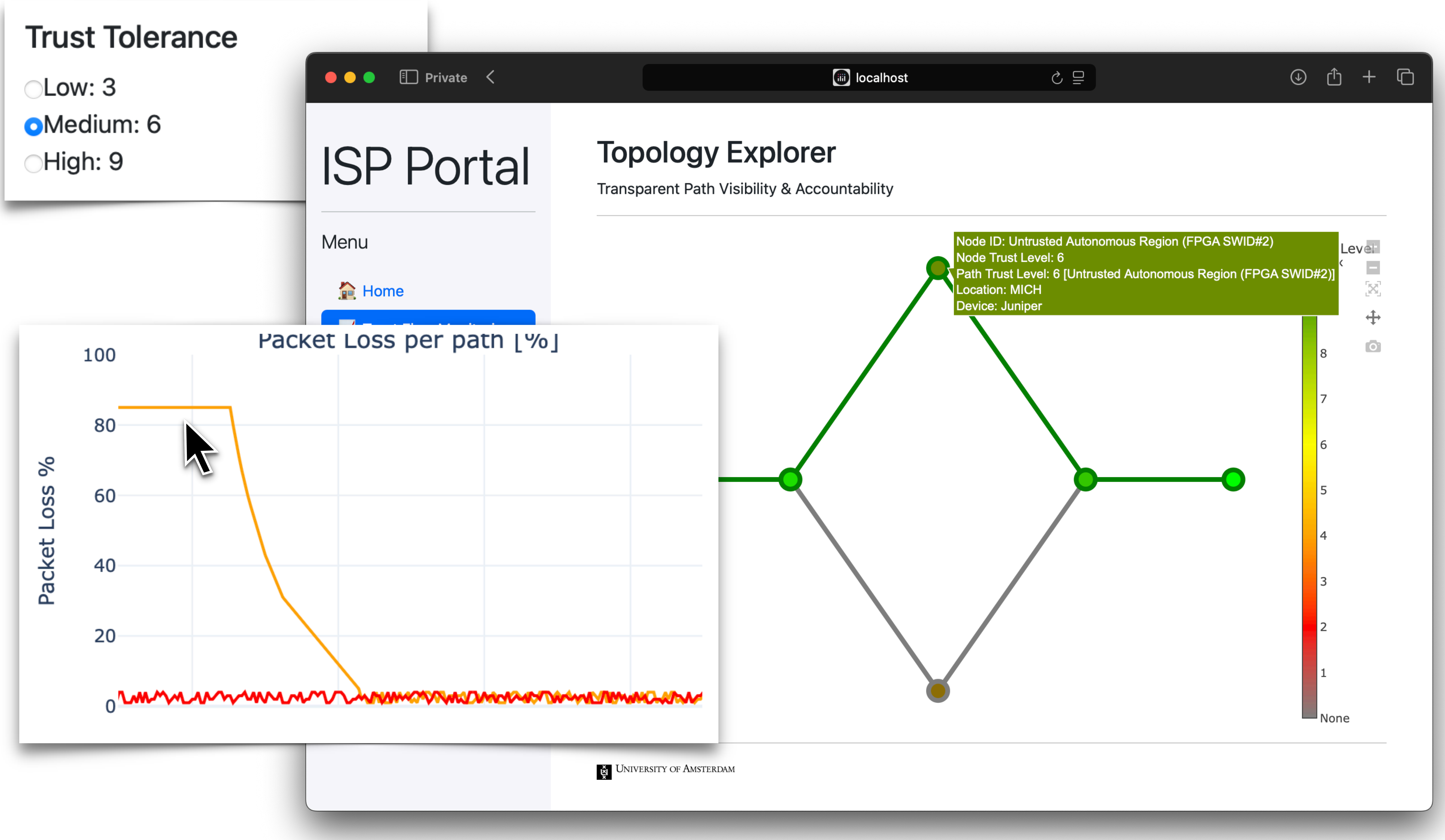
# AUTONOMOUS LEARNING-DRIVEN IN-NETWORK CONTROL



## Trust Tolerance

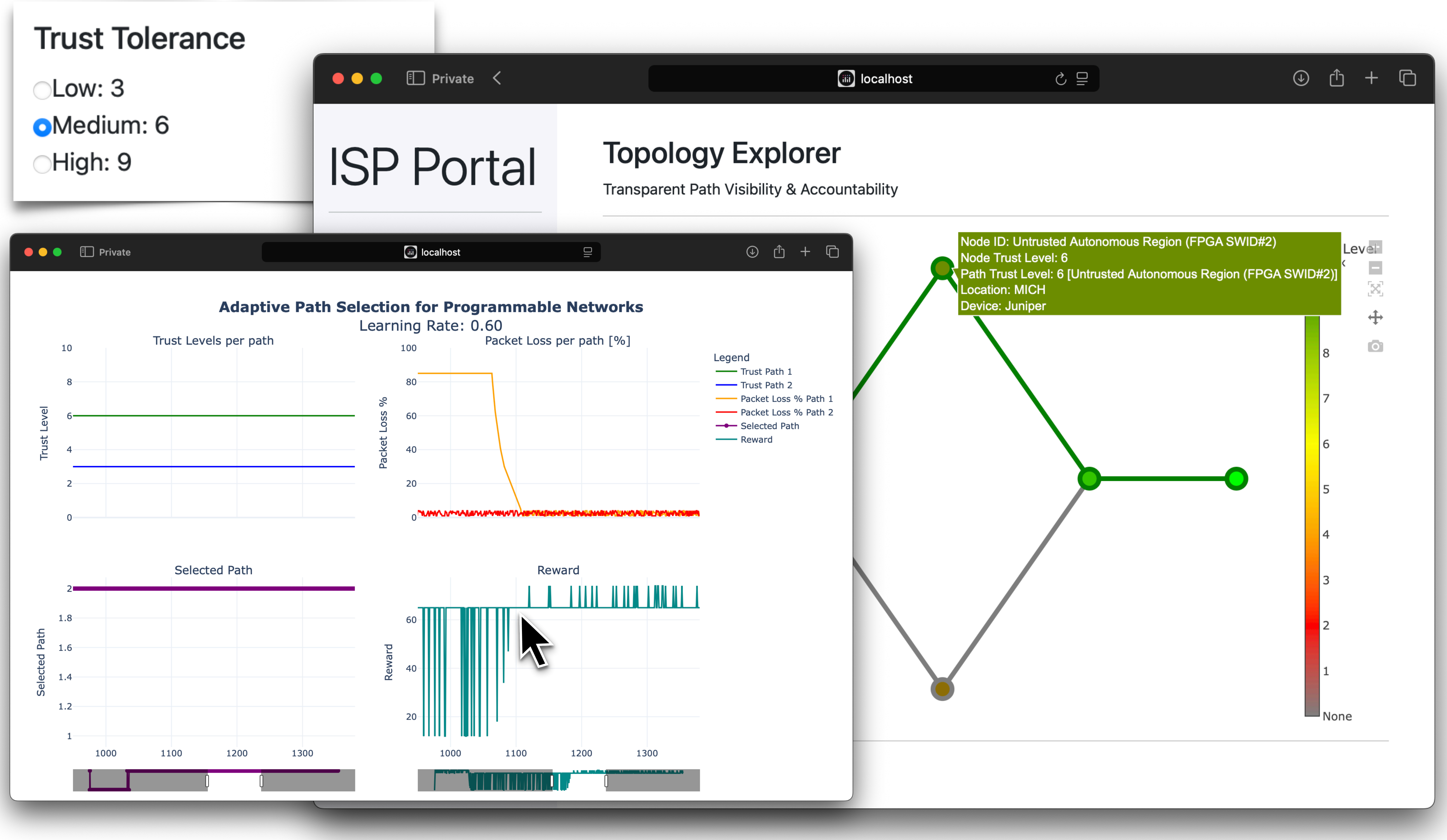
○ Low: 3
● Medium: 6
○ High: 9

## Topology Explorer

Transparent Path Visibility & Accountability

Node ID: Untrusted Autonomous Region (FPGA SWID#2)
Node Trust Level: 6
Path Trust Level: 6 [Untrusted Autonomous Region (FPGA SWID#2)]
Location: MICH
Device: Juniper

# AUTONOMOUS LEARNING-DRIVEN IN-NETWORK CONTROL



Trust Tolerance

○ Low: 3
● Medium: 6
○ High: 9

ISP Portal

Topology Explorer

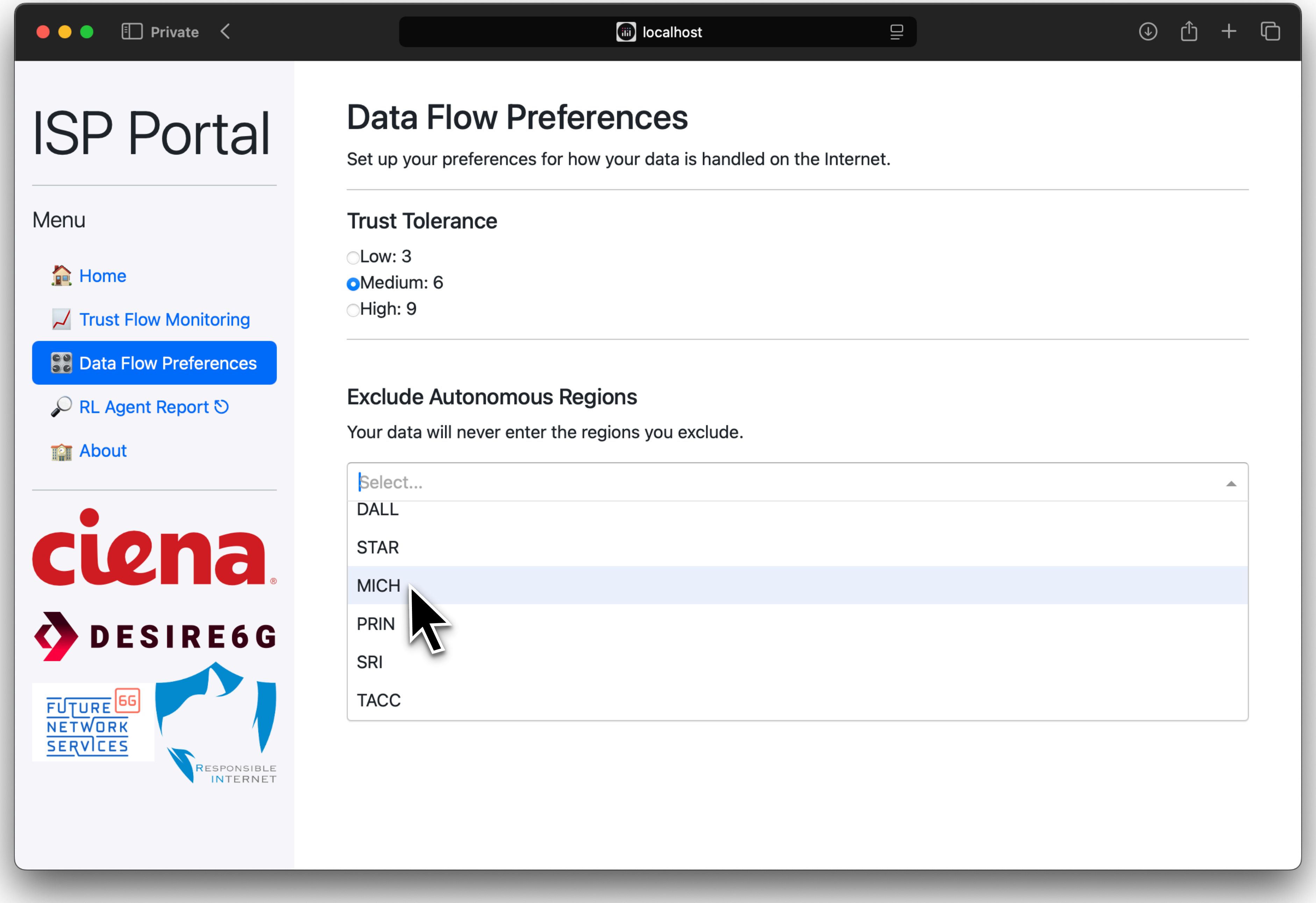
Transparent Path Visibility & Accountability

Node ID: Untrusted Autonomous Region (FPGA SWID#2)
Node Trust Level: 6
Path Trust Level: 6 [Untrusted Autonomous Region (FPGA SWID#2)]
Location: MICH
Device: Juniper

USER INTENT-DRIVEN NETWORK CONTROL

# SCENARIO II

# USER INTENT-DRIVEN NETWORK CONTROL



## Data Flow Preferences

Set up your preferences for how your data is handled on the Internet.

### Trust Tolerance

○ Low: 3
● Medium: 6
○ High: 9

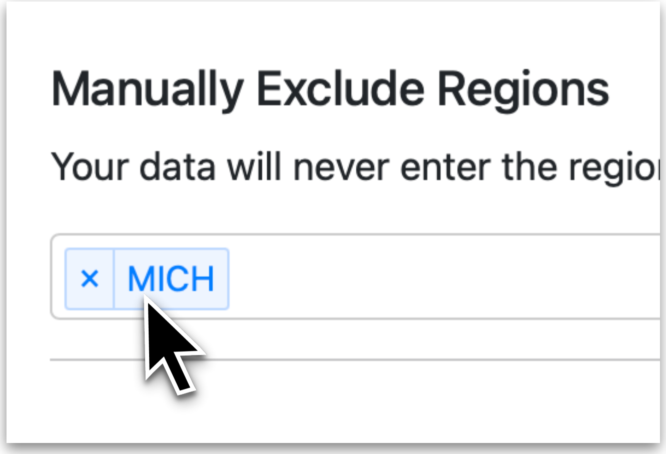
### Exclude Autonomous Regions

Your data will never enter the regions you exclude.

Select...

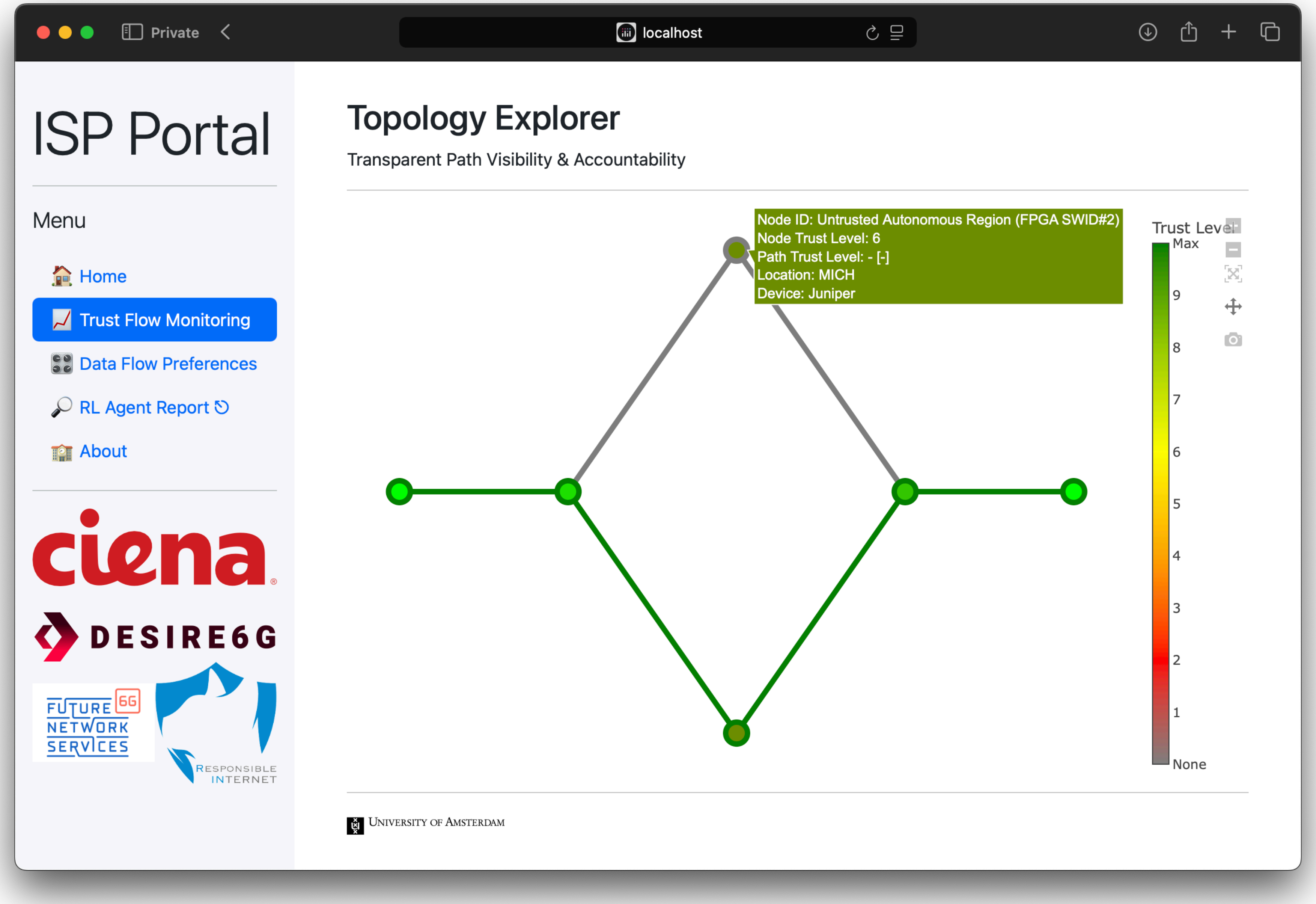
- DALL
- STAR
- MICH
- PRIN
- SRI
- TACC

# USER INTENT-DRIVEN NETWORK CONTROL



Manually Exclude Regions

Your data will never enter the regio

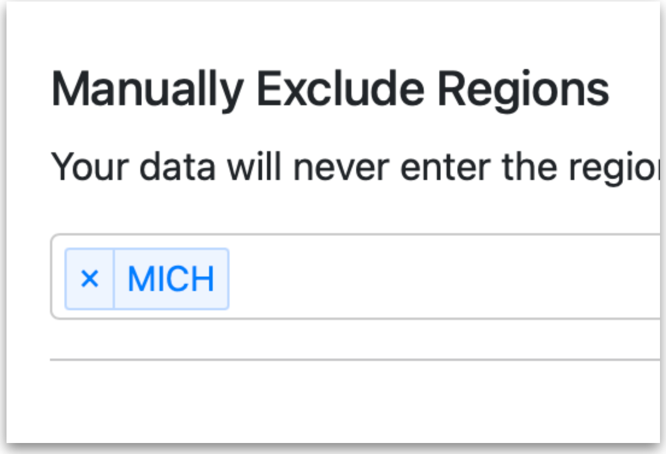


Topology Explorer

Transparent Path Visibility & Accountability

Node ID: Untrusted Autonomous Region (FPGA SWID#2)
Node Trust Level: 6
Path Trust Level: - [-]
Location: MICH
Device: Juniper

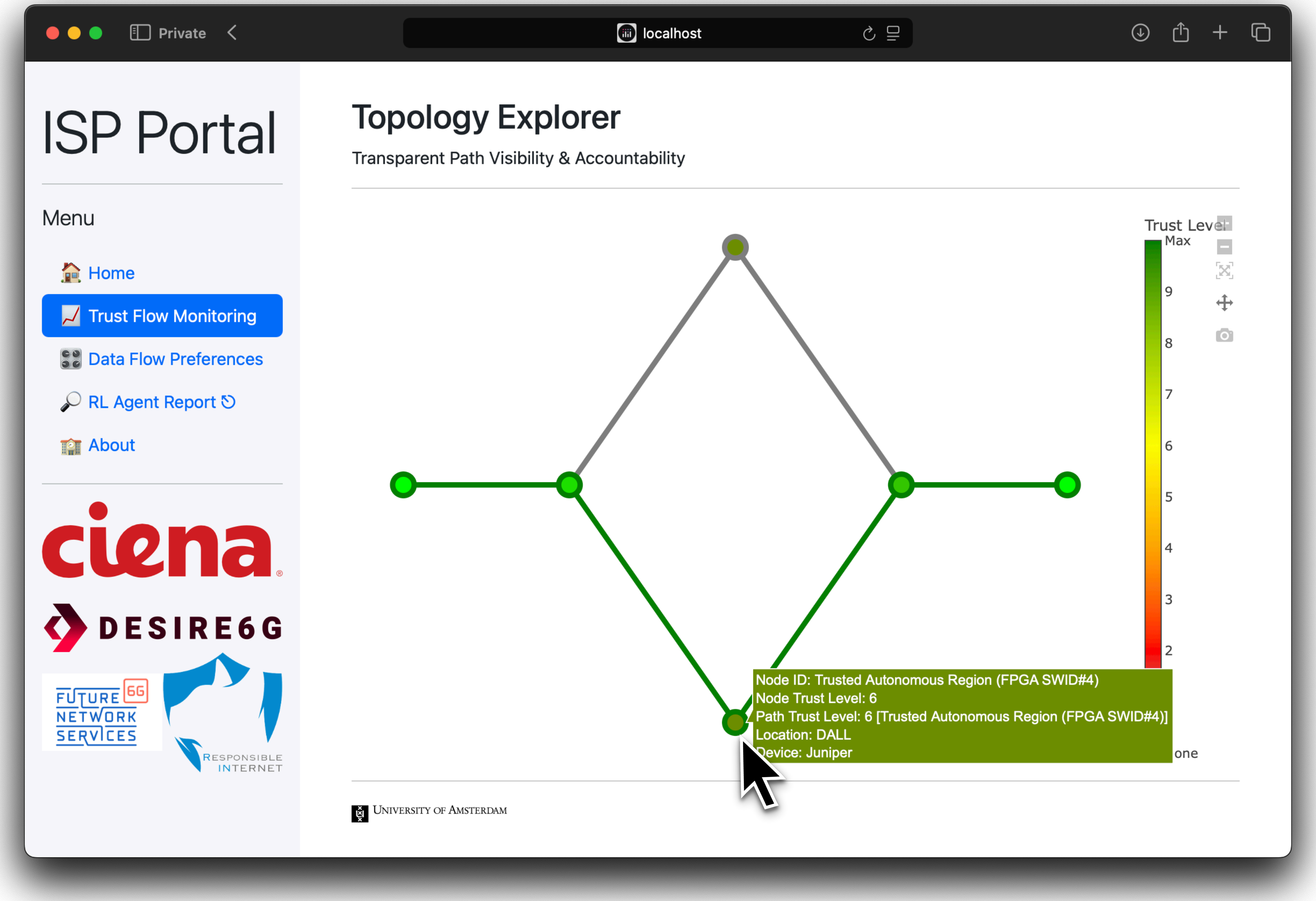
# USER INTENT-DRIVEN NETWORK CONTROL



## Manually Exclude Regions

Your data will never enter the regio

× MICH



## Topology Explorer

Transparent Path Visibility & Accountability

Node ID: Trusted Autonomous Region (FPGA SWID#4)
Node Trust Level: 6
Path Trust Level: 6 [Trusted Autonomous Region (FPGA SWID#4)]
Location: DALL
Device: Juniper

# CONTRIBUTIONS

**Empowered Users via Transparency & Control**

- Enabled users to specify their trust preferences and then verify the data path integrity in real-time using In-band Network Telemetry (INT).

**In-Network RL Path Optimization in the Data Plane**

- Integrated Reinforcement Learning (RL) agents directly into the programmable data plane, enabling autonomous, security-aware flow steering decisions, without control plane intervention.

**Validated in a Realistic Infrastructure**

- Deployed and tested on the FABRIC testbed programmable switches, demonstrating the feasibility of a secure, intent-driven data flow control and dynamic path optimization.

ANESTIS DALGKITSIS, JOSE ZERNA TORRES, ANGELOS DIMOGLIS, LUCA CETINO, MARIOS AVGERIS, CHRYSA PAPAGIANNI, PAOLA GROSSO, CEES DE LAAT

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# THANK YOU