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# Automated Test Bench for High-Performance Network Equipment

**Benjamin Steinert**[1,2], Gabriel Paradzik[1,2], Michael Menth[1]
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bwNET

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# Motivation

- ► New devices require thorough testing and evaluation before deployment
  - ▪ Do data sheet specs hold?
  - ▪ Not all important information may be stated on data sheets (e.g., control plane performance)
  - ▪ Need for traffic load at high rates (≥100 Gbit/s)

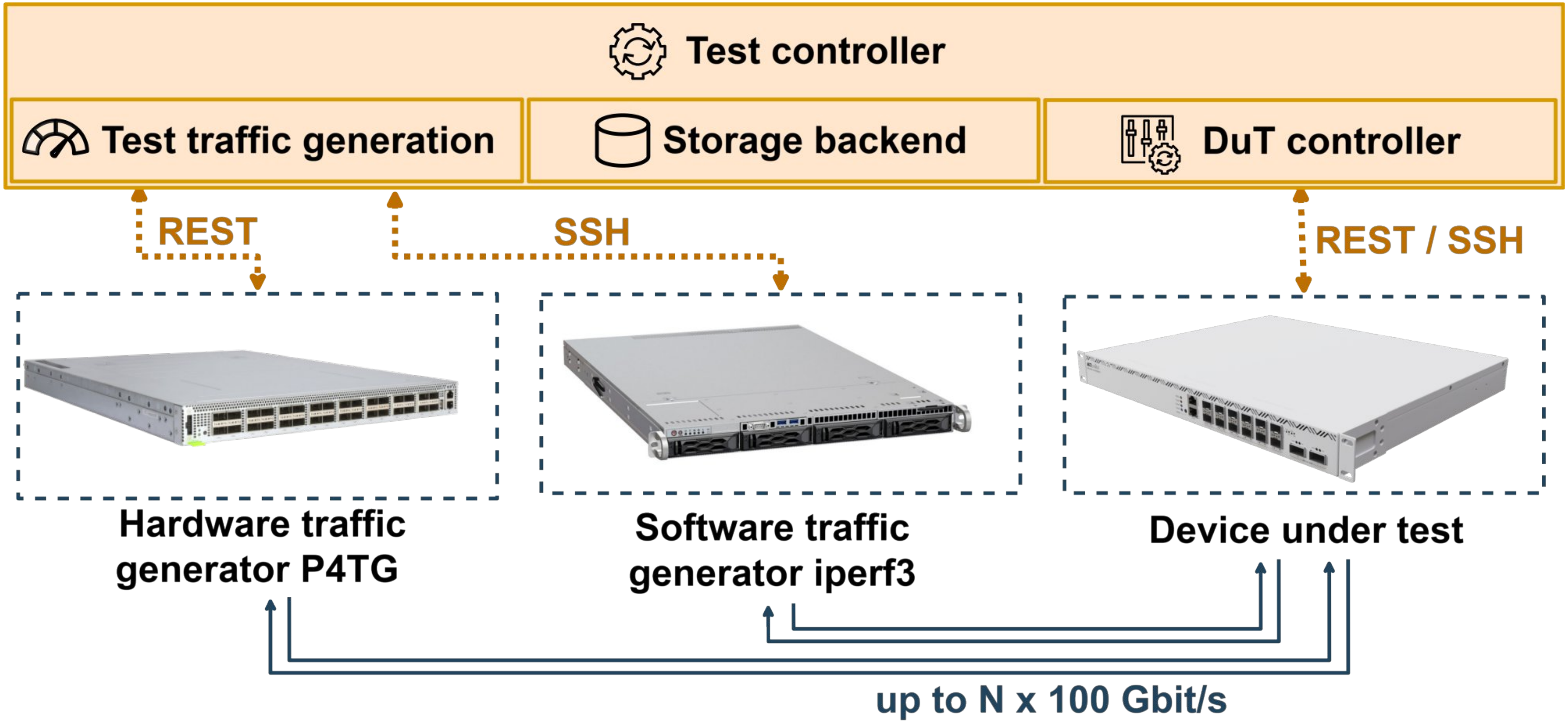
- ► Commercial Ethernet test systems are available, but limited in flexibility, and may be very expensive

- ► Manual testing is error-prone and time-consuming

➡ Leverage automation interfaces and central orchestration for automated benchmarking

# TEST BENCH ARCHITECTURE AND COMPONENTS

# Test Bench Architecture and Components



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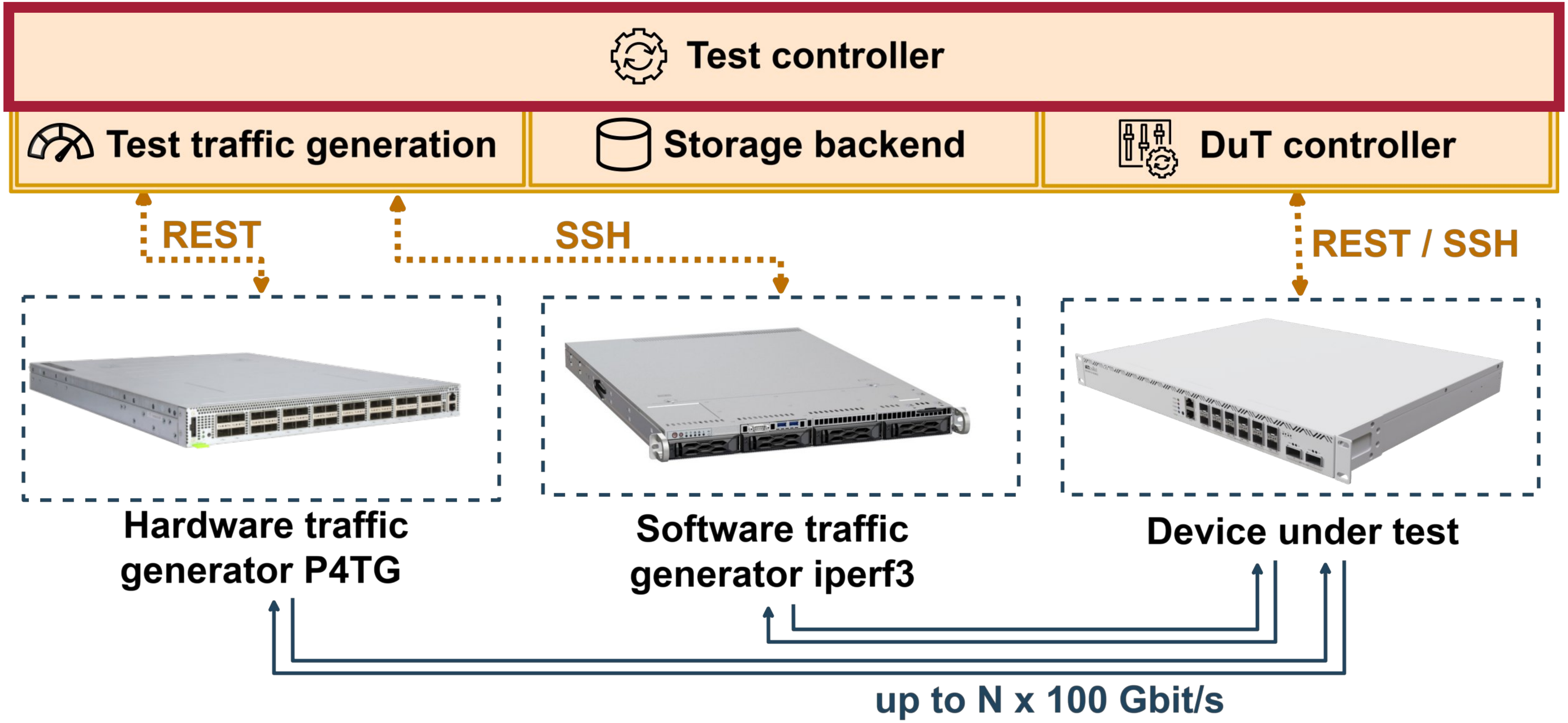


Test controller

Test traffic generation

Storage backend

DuT controller

REST

SSH

REST / SSH

Hardware traffic generator P4TG

Software traffic generator iperf3

Device under test

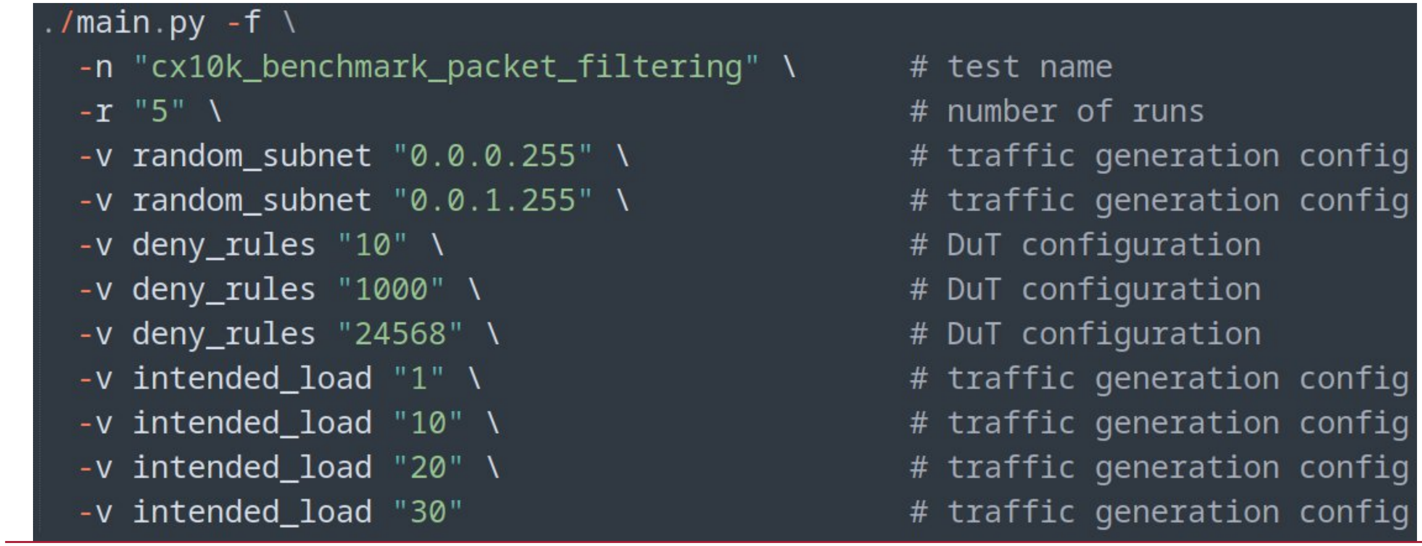
up to N x 100 Gbit/s

# Test Controller

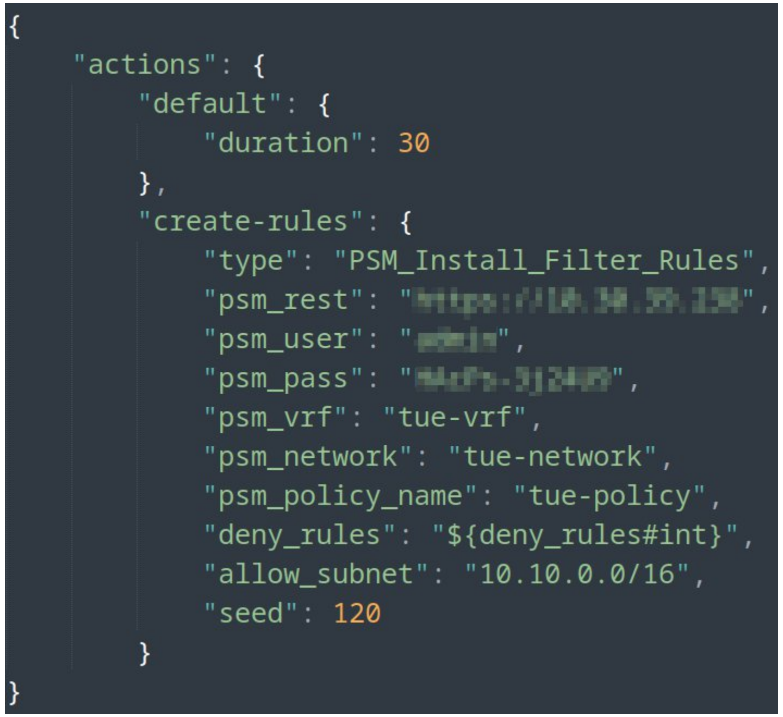
- ▶ Written in Python

- ▶ Orchestrates the different modules for automated experiment runs
  - Automated test traffic generation with configurable traffic generators (e.g., P4TG, iperf3)
  - Automated storage of results with configurable storage backend (e.g., MongoDB)
  - Automated device configuration / metric monitoring with DuT Controller (vendor-specific)

- ▶ Declarative experiment configuration



```
./main.py -f \
  -n "cx10k_benchmark_packet_filtering" \      # test name
  -r "5" \                                     # number of runs
  -v random_subnet "0.0.0.255" \               # traffic generation config
  -v random_subnet "0.0.1.255" \               # traffic generation config
  -v deny_rules "10" \                         # DuT configuration
  -v deny_rules "1000" \                       # DuT configuration
  -v deny_rules "24568" \                      # DuT configuration
  -v intended_load "1" \                       # traffic generation config
  -v intended_load "10" \                      # traffic generation config
  -v intended_load "20" \                      # traffic generation config
  -v intended_load "30"                        # traffic generation config
```



```
{
    "actions": {
        "default": {
            "duration": 30
        },
        "create-rules": {
            "type": "PSM_Install_Filter_Rules",
            "psm_rest": "[redacted]",
            "psm_user": "[redacted]",
            "psm_pass": "[redacted]",
            "psm_vrf": "tue-vrf",
            "psm_network": "tue-network",
            "psm_policy_name": "tue-policy",
            "deny_rules": "${deny_rules#int}",
            "allow_subnet": "10.10.0.0/16",
            "seed": 120
        }
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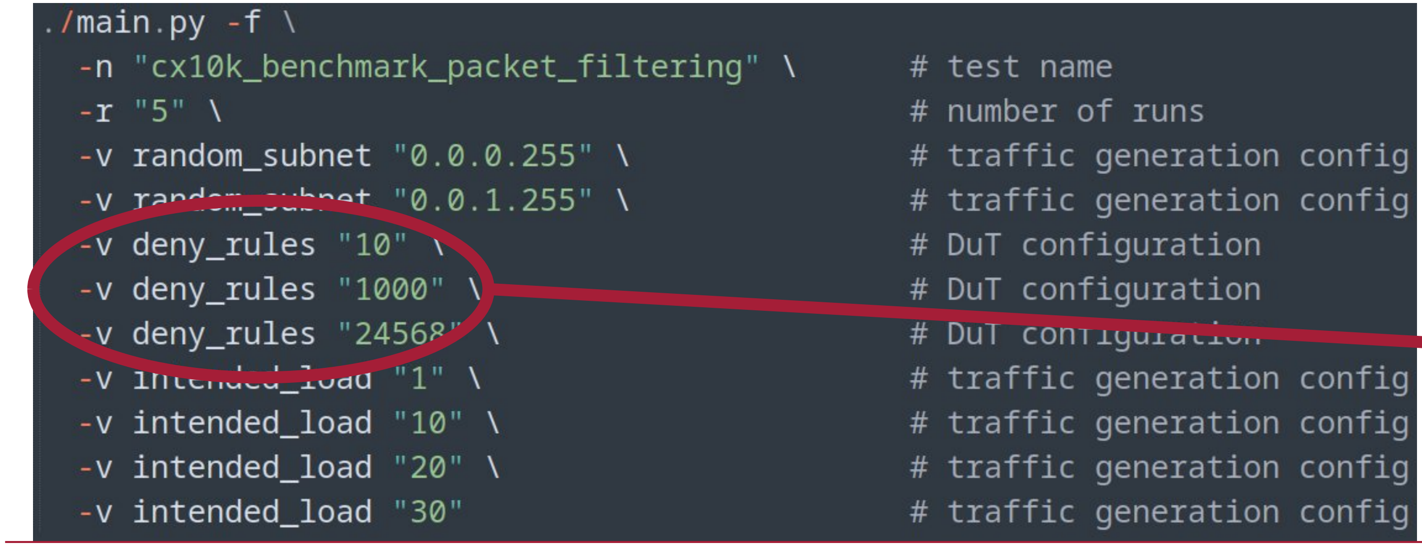

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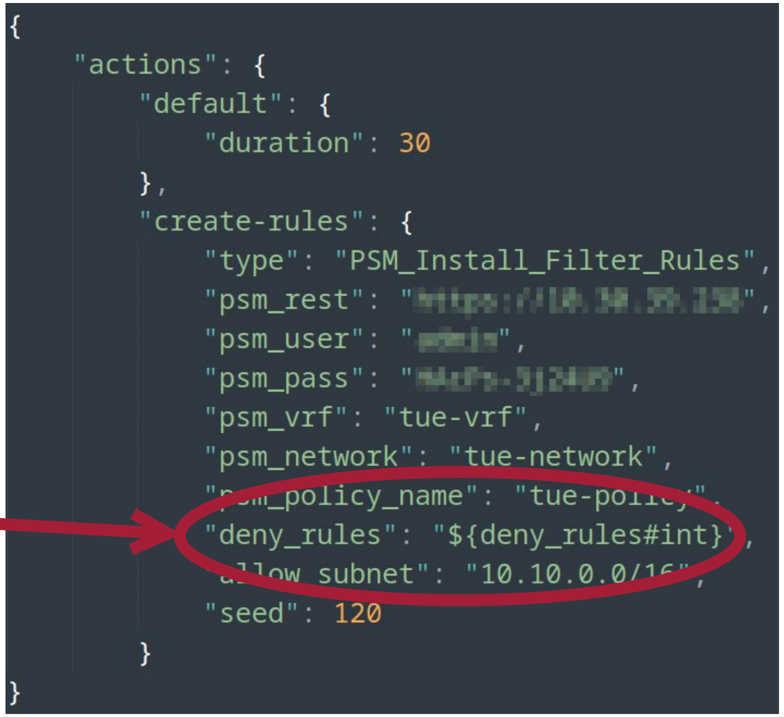

```
{
    "actions": {
        "default": {
            "duration": 30
        },
        "create-rules": {
            "type": "PSM_Install_Filter_Rules",
            "psm_rest": "[redacted]",
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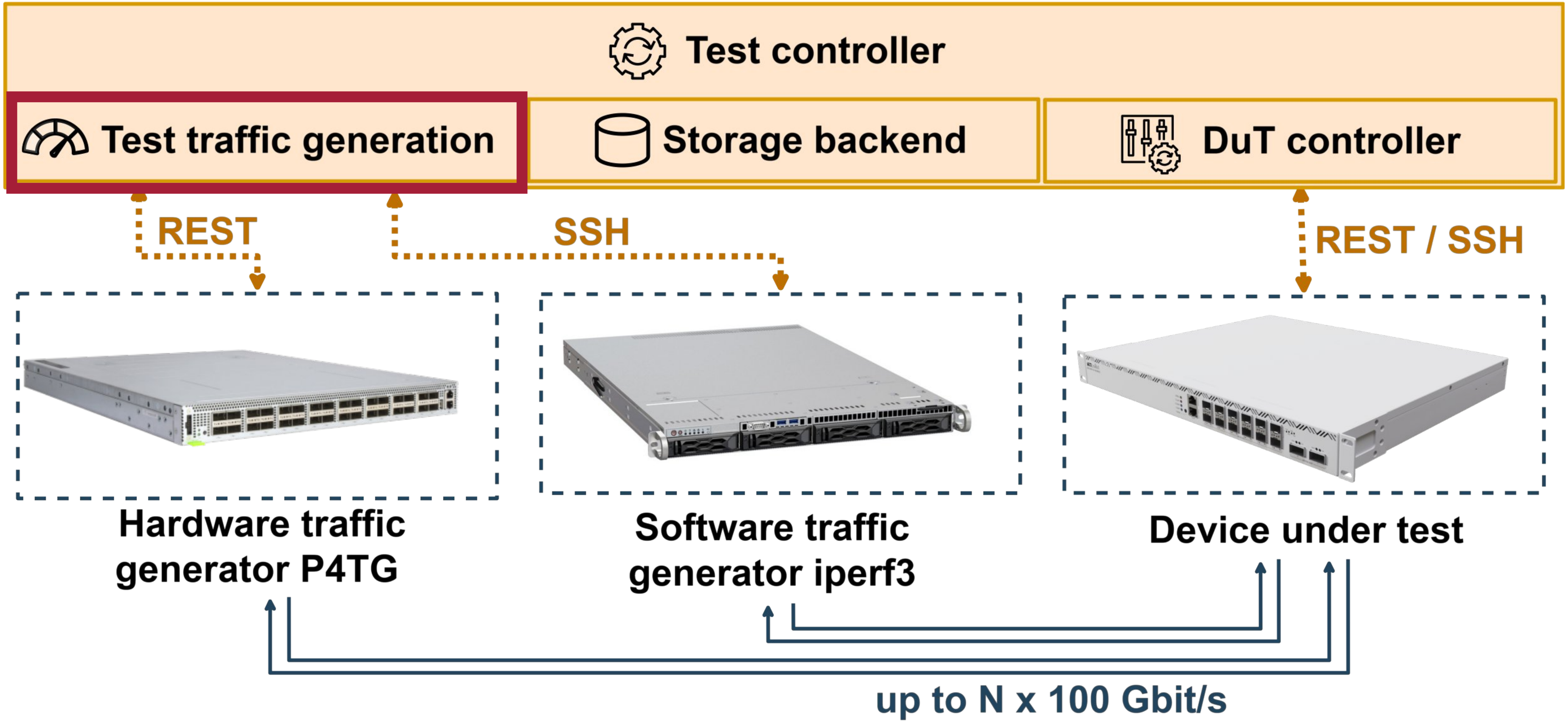
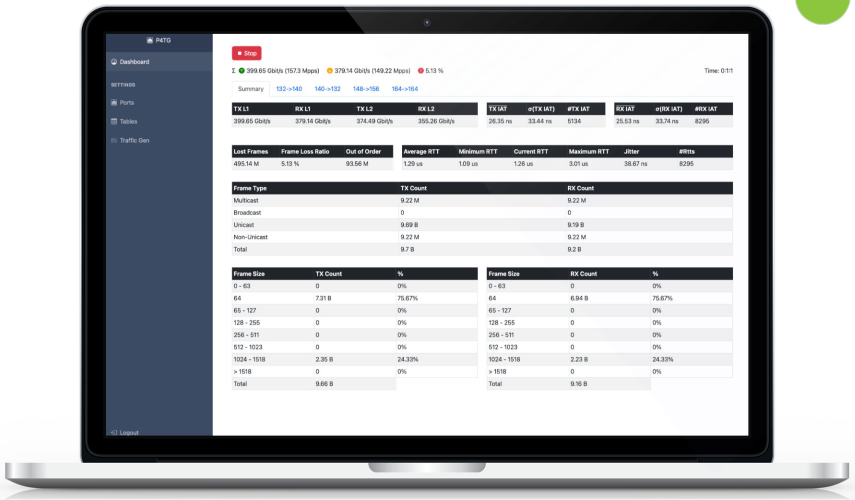
# Test Bench Architecture and Components



# Test Traffic Generation

- P4TG
  - Runs on Edgecore Wedge 100-32X
  - Controlled via REST API of P4TG Controller
  - Offers traffic generation at high data rates
    (up to 100 Gbit/s per port; up to 400 Gbit/s per port for Tofino 2)
  - Low-cost hardware TG
  - Customizable for individual needs
  - Open source: https://github.com/uni-tue-kn/P4TG

- Iperf3
  - Runs on separate server / VM
  - Controlled via SSH



Σ 399.65 Gbit/s (157.3 Mpps) 379.14 Gbit/s (149.22 Mpps) 5.13 %

Time: 0:1:1

| TX L1 | RX L1 | TX L2 | RX L2 |
|---|---|---|---|
| 399.65 Gbit/s | 379.14 Gbit/s | 374.49 Gbit/s | 355.26 Gbit/s |

| $\overline{\text{TX IAT}}$ | σ(TX IAT) | #TX IAT |
|---|---|---|
| 26.35 ns | 33.44 ns | 5134 |

| $\overline{\text{RX IAT}}$ | σ(RX IAT) | #RX IAT |
|---|---|---|
| 25.53 ns | 33.74 ns | 8295 |

| Lost Frames | Frame Loss Ratio | Out of Order |
|---|---|---|
| 495.14 M | 5.13 % | 93.56 M |

| Average RTT | Minimum RTT | Current RTT | Maximum RTT | Jitter | #Rtts |
|---|---|---|---|---|---|
| 1.29 us | 1.09 us | 1.26 us | 3.01 us | 38.67 ns | 8295 |

| Frame Type | TX Count | RX Count |
|---|---|---|
| Multicast | 9.22 M | 9.22 M |
| Broadcast | 0 | 0 |
| Unicast | 9.69 B | 9.19 B |
| Non-Unicast | 9.22 M | 9.22 M |
| Total | 9.7 B | 9.2 B |

| Frame Size | TX Count | % |
|---|---|---|
| 0 - 63 | 0 | 0% |
| 64 | 7.31 B | 75.67% |
| 65 - 127 | 0 | 0% |
| 128 - 255 | 0 | 0% |
| 256 - 511 | 0 | 0% |
| 512 - 1023 | 0 | 0% |
| 1024 - 1518 | 2.35 B | 24.33% |
| > 1518 | 0 | 0% |
| Total | 9.66 B | |

| Frame Size | RX Count | % |
|---|---|---|
| 0 - 63 | 0 | 0% |
| 64 | 6.94 B | 75.67% |
| 65 - 127 | 0 | 0% |
| 128 - 255 | 0 | 0% |
| 256 - 511 | 0 | 0% |
| 512 - 1023 | 0 | 0% |
| 1024 - 1518 | 2.23 B | 24.33% |
| > 1518 | 0 | 0% |
| Total | 9.16 B | |

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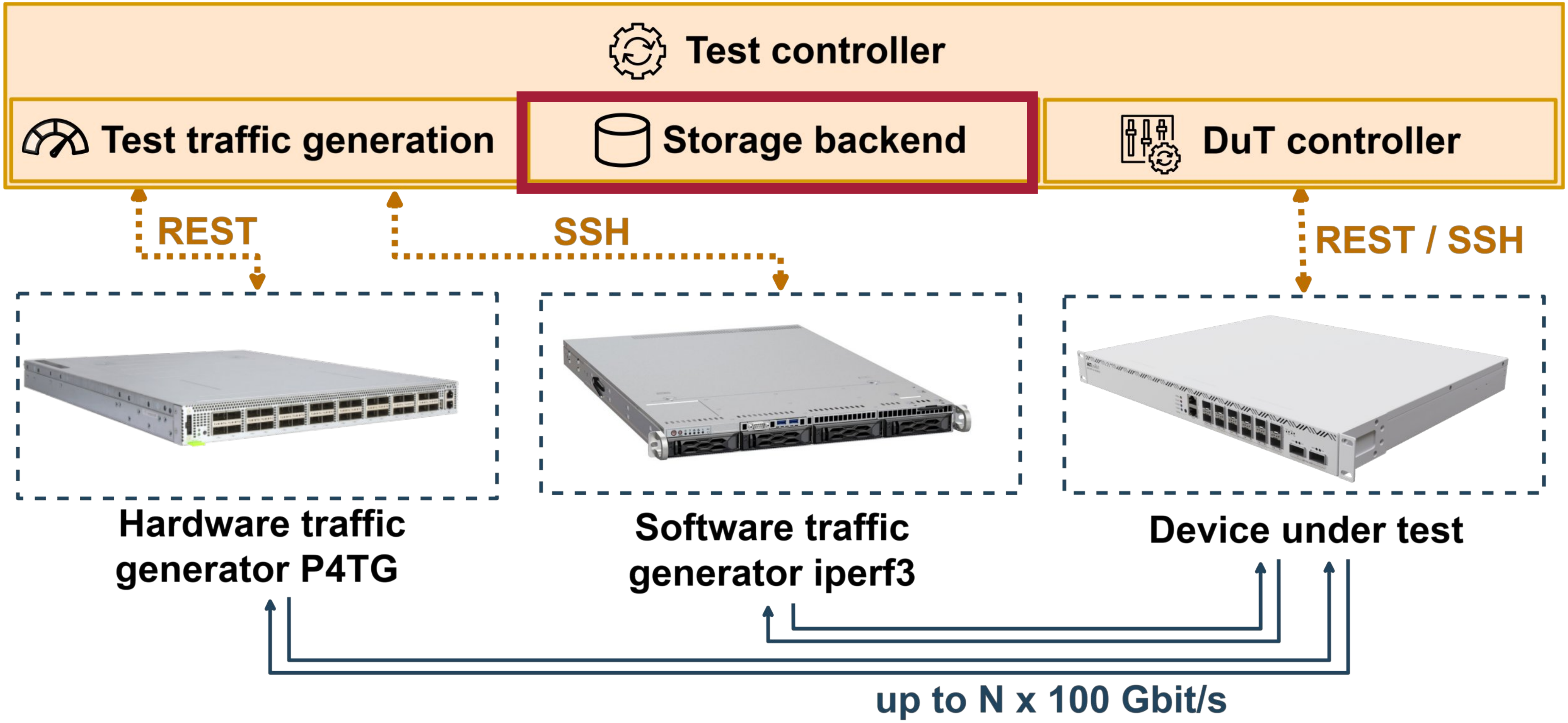
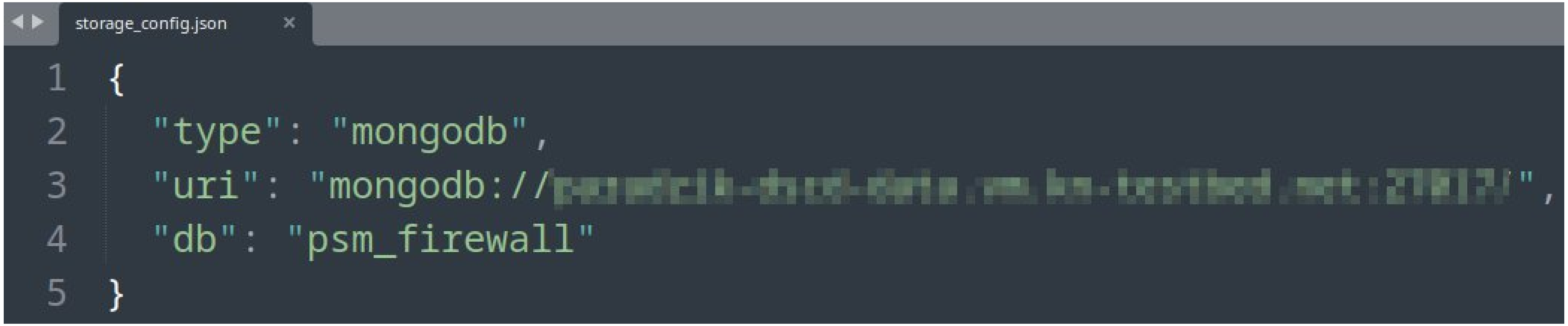


# Storage Backend

- Definition of abstract interface class “`StorageAdapter`“
  - Defines abstract methods like “`read`“, “`write`“, etc.

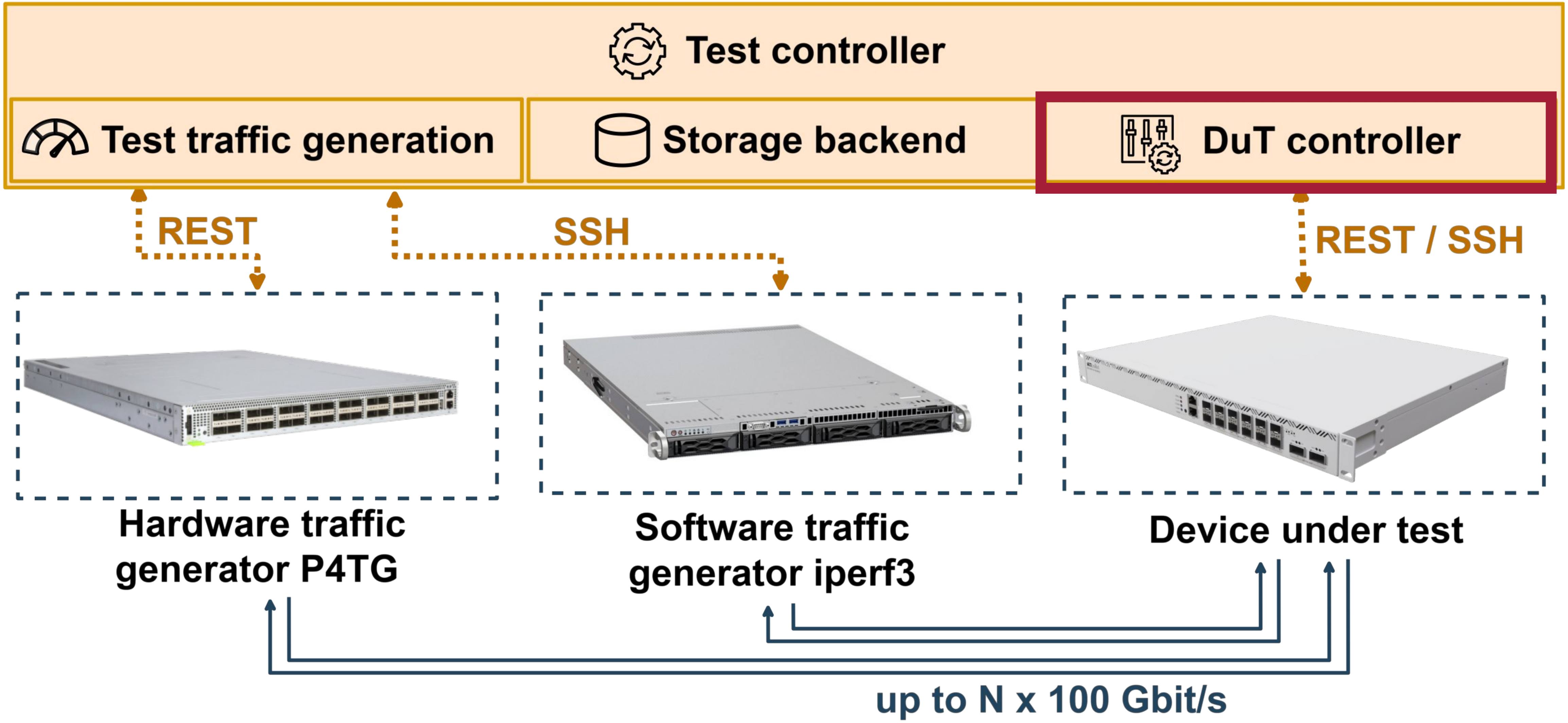
- Interface class is implemented for specific database backend, e.g. “`MongoDBStorageAdapter`“
  - Implements abstract methods

- Desired storage backend can then be configured in test controller



```
{
    "type": "mongodb",
    "uri": "mongodb://[redacted]",
    "db": "psm_firewall"
}
```

# Test Bench Architecture and Components



Test controller

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DuT controller

REST

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REST / SSH

Hardware traffic generator P4TG

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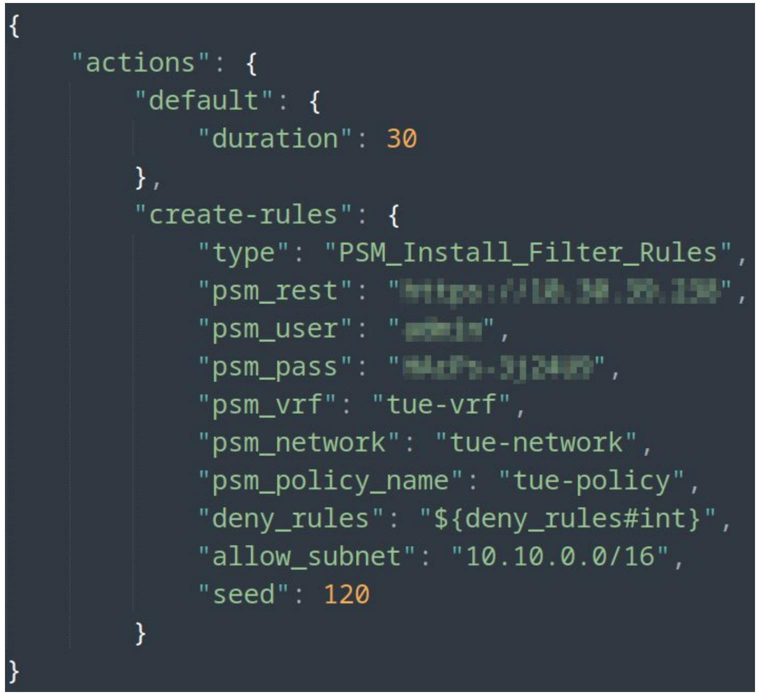
Device under test

up to N x 100 Gbit/s

# DuT Controller

- ► Implements vendor-specific automation interfaces of the DuT, e.g., REST API
  - ▪ Initiates connection with automation interface incl. authentication
  - ▪ Implements desired configuration tasks, e.g., “`PSM_Install_Filter_Rules`“

- ► Possible to add new vendor-specific modules
  - ▪ Implemented for MikroTik RouterOS, Aruba AOS-CX, AMD/Pensando PSM



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# DuT Controller

- Implements vendor-specific automation interfaces of the DuT, e.g., REST API
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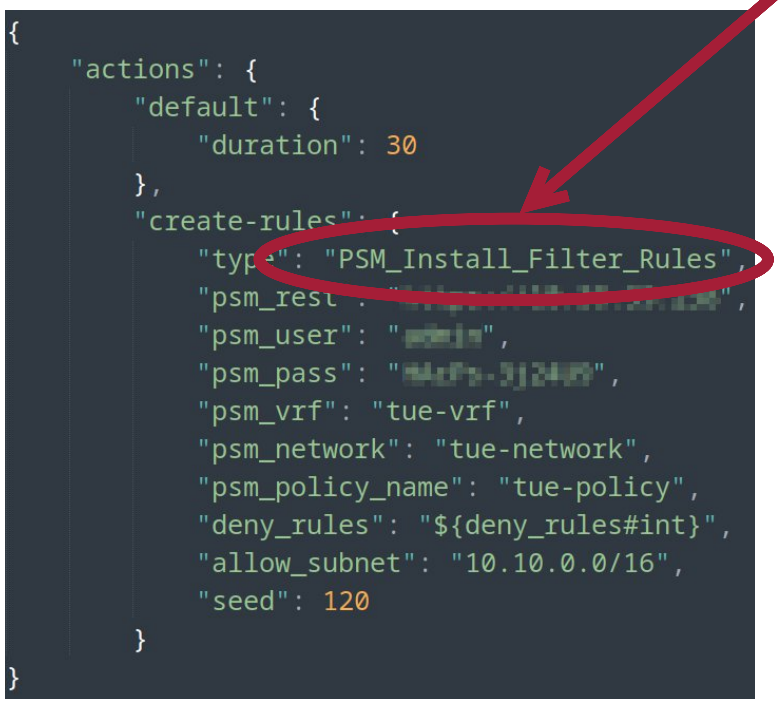

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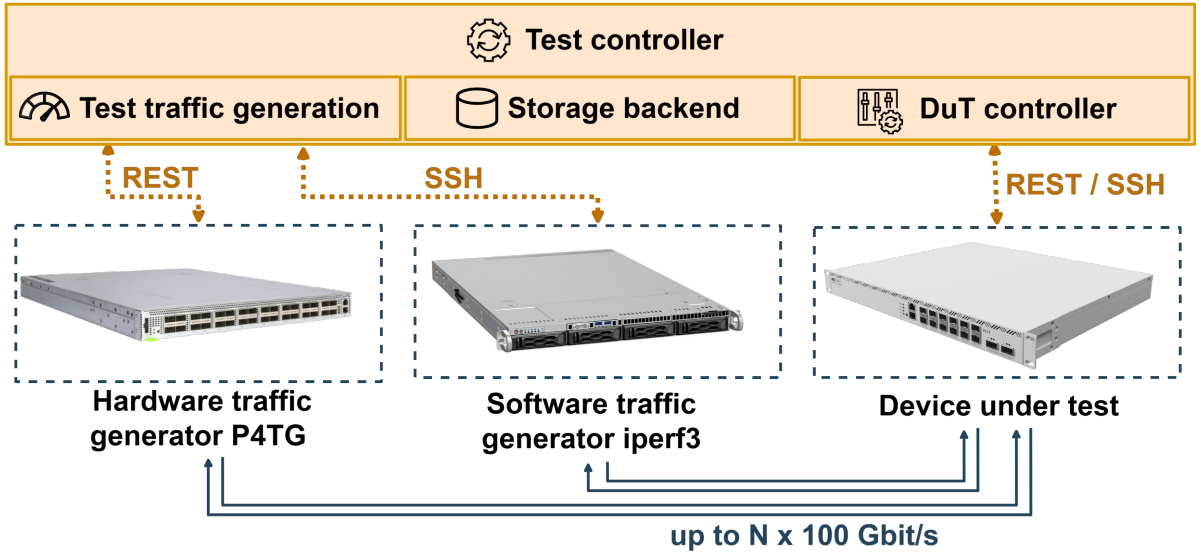
            "seed": 120
        }
}
```

# Workflow

1. Manually set test parameters in test controller & start test
2. Automated configuration of the DuT
3. Automated configuration of the traffic generator(s)
4. Automated experiment runs, gather data of interest
5. Store gathered data in database



# CASE STUDY: HARDWARE EVALUATION -
# L4 PACKET FILTERING ON ARUBA CX 10000

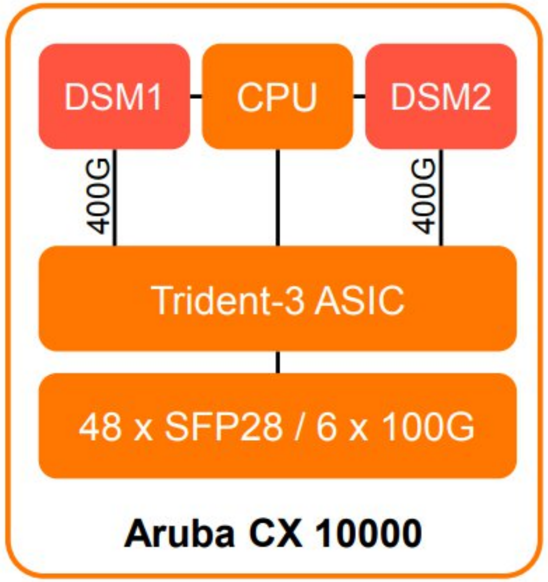
# Evaluated Device – Aruba CX 10000

- Port density: 48x SFP28 25 Gbit/s + 6x QSFP 100 Gbit/s

- Two different built-in ASICs
  - AMD/Pensando P4 DSM ASIC for 100G L4 packet filtering
  - Broadcom Trident-3 for switching & routing

- Two different software for configuration of ASICs
  - AOS-CX software for control of Broadcom chip
  - Pensando Stateful Manager (PSM) software for control of AMD/Pensando chip
  - Different automation interfaces are exposed

aruba + PENSANDO



DSM1

CPU

DSM2

400G

400G

Trident-3 ASIC

48 x SFP28 / 6 x 100G

Aruba CX 10000

# Data Plane Performance – IMIX

- Methodology
  - P4TG is used for test traffic generation of IMIX traffic
  - IMIX: 12% 64 B packets, 54% 512 B packets, 34% 1518 B packets
  - Install different numbers of filter rules (0, 10, 100, 1000, 10000, 24568)
- Result: 100 Gbit/s without drops possible, independent of number of installed filter rules

# Data Plane Performance – CBR

- Methodology
  - P4TG is used for test traffic generation of CBR traffic
  - CBR traffic of one packet size (64 B, 128 B, 256 B, 512 B, 1024 B, 1280 B, 1518 B)
  - Install different numbers of filter rules (0, 10, 100, 1000, 10000, 24568)

- Result
  - Up to ~40 Mpps for small packets <= 256 B
  - Up to ~100 Gbit/s for larger packets >= 512 B

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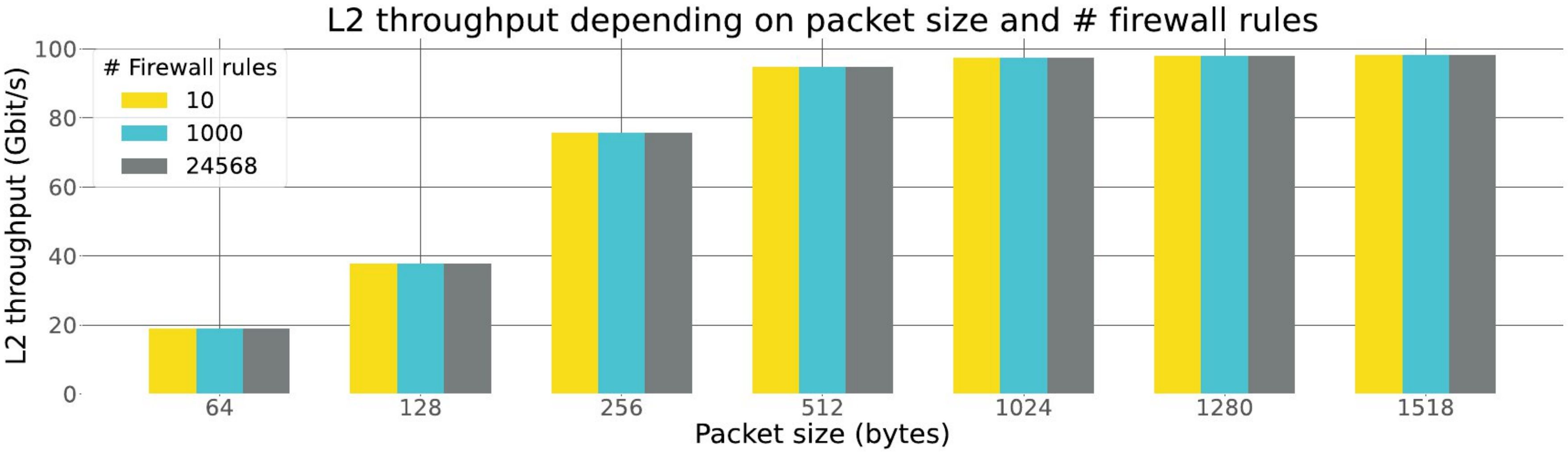
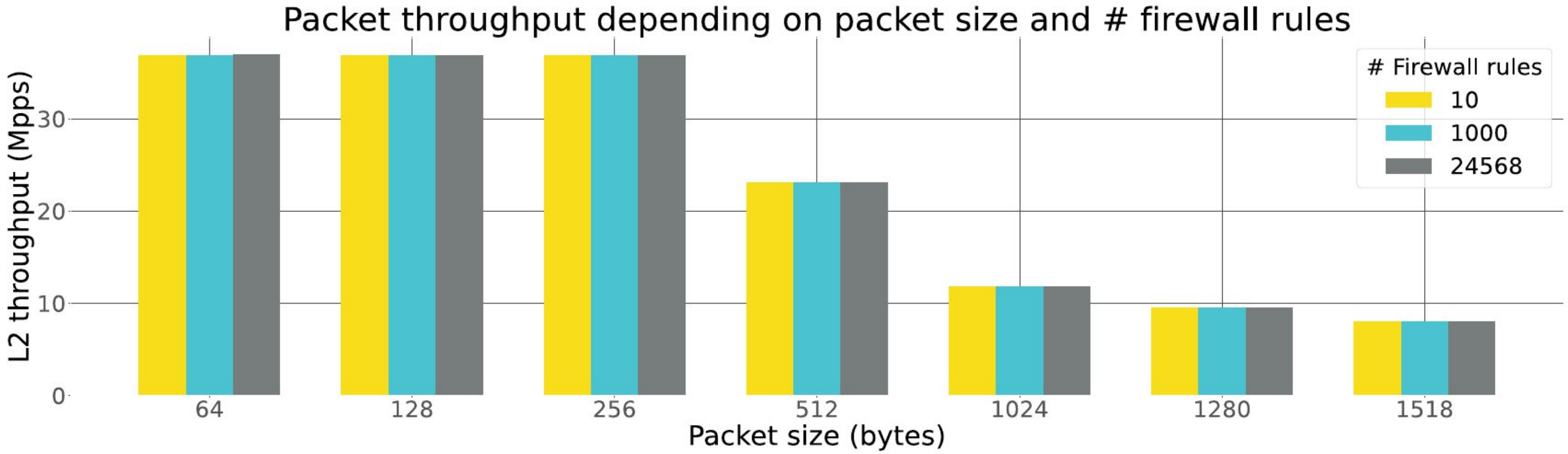
# Data Plane Performance – CBR

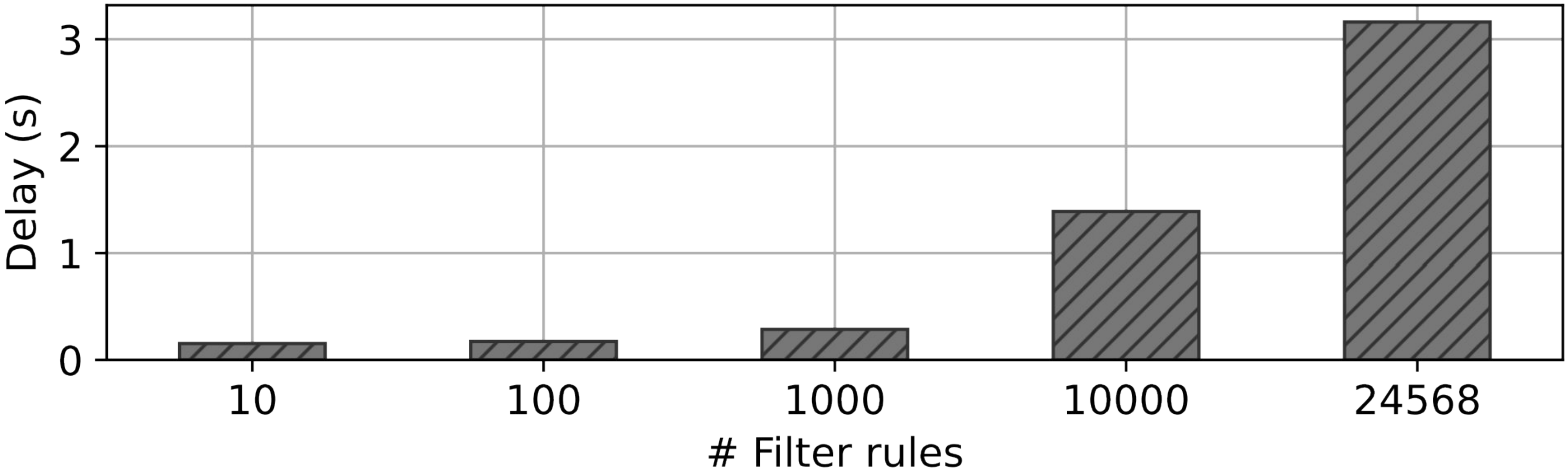

L2 throughput depending on packet size and # firewall rules


Packet throughput depending on packet size and # firewall rules

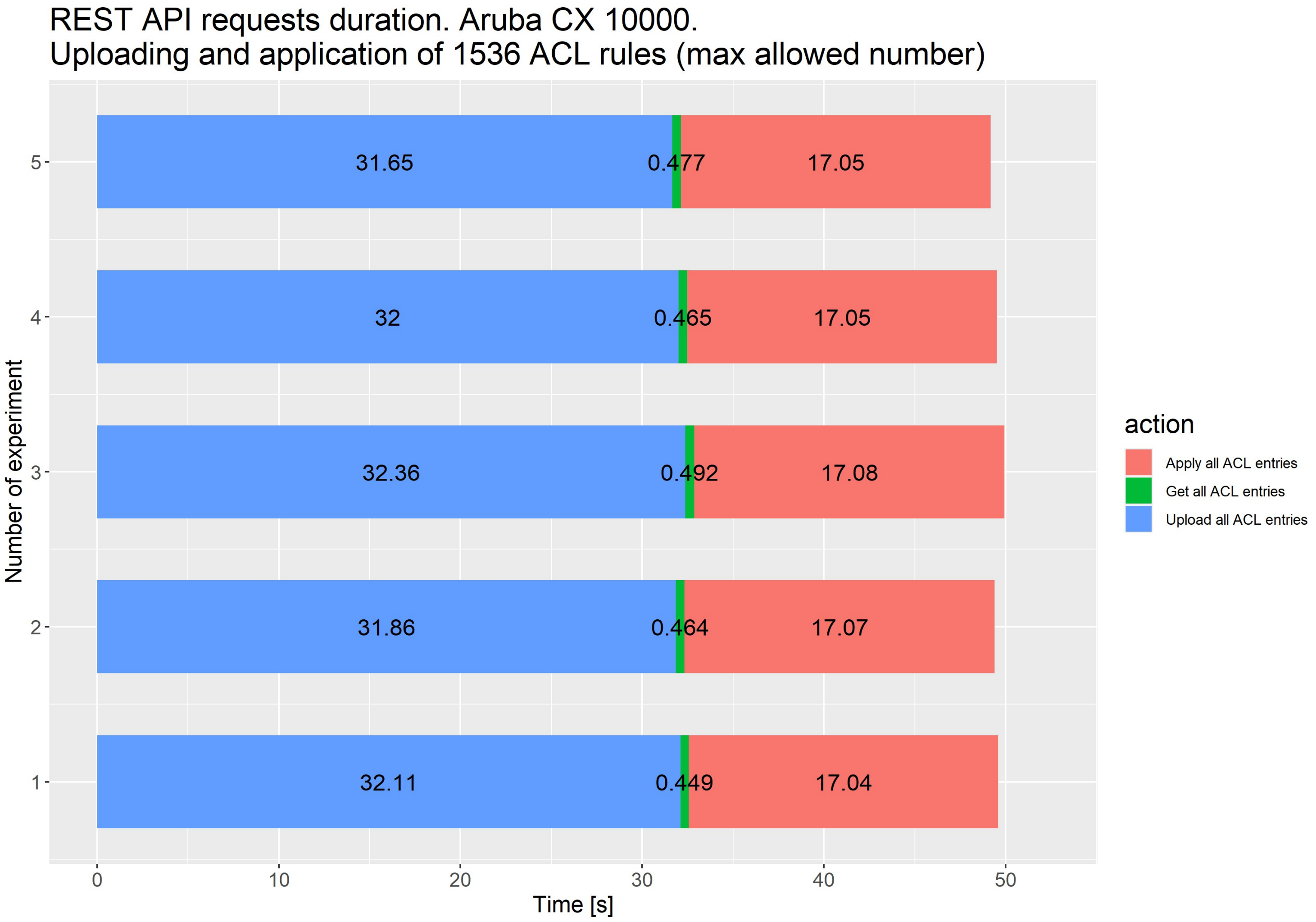
# Control Plane Performance – PSM REST API

- Automated installation of filter rules via DuT controller / PSM REST API

➡ How long is the installation time for those rules to be active the data plane?



# Control Plane Performance – AOS-CX REST API



# Conclusion

- Automated test bench provides an automated, flexible, reproducible framework for benchmarking high-performance network devices
  - Fully automated test traffic generation with P4TG and iperf3
  - Fully automated DuT configuration & metric gathering with DuT controller
  - Modular and extensible architecture – new device modules, traffic generators, or storage backends may be added
  - Declarative definition of test parameters

- Case study demonstrates the feasibility of the approach
  - Exemplary hardware evaluation of high-performance L4 packet filtering feature
  - P4-programmable ASICs built into COTS devices show promising results

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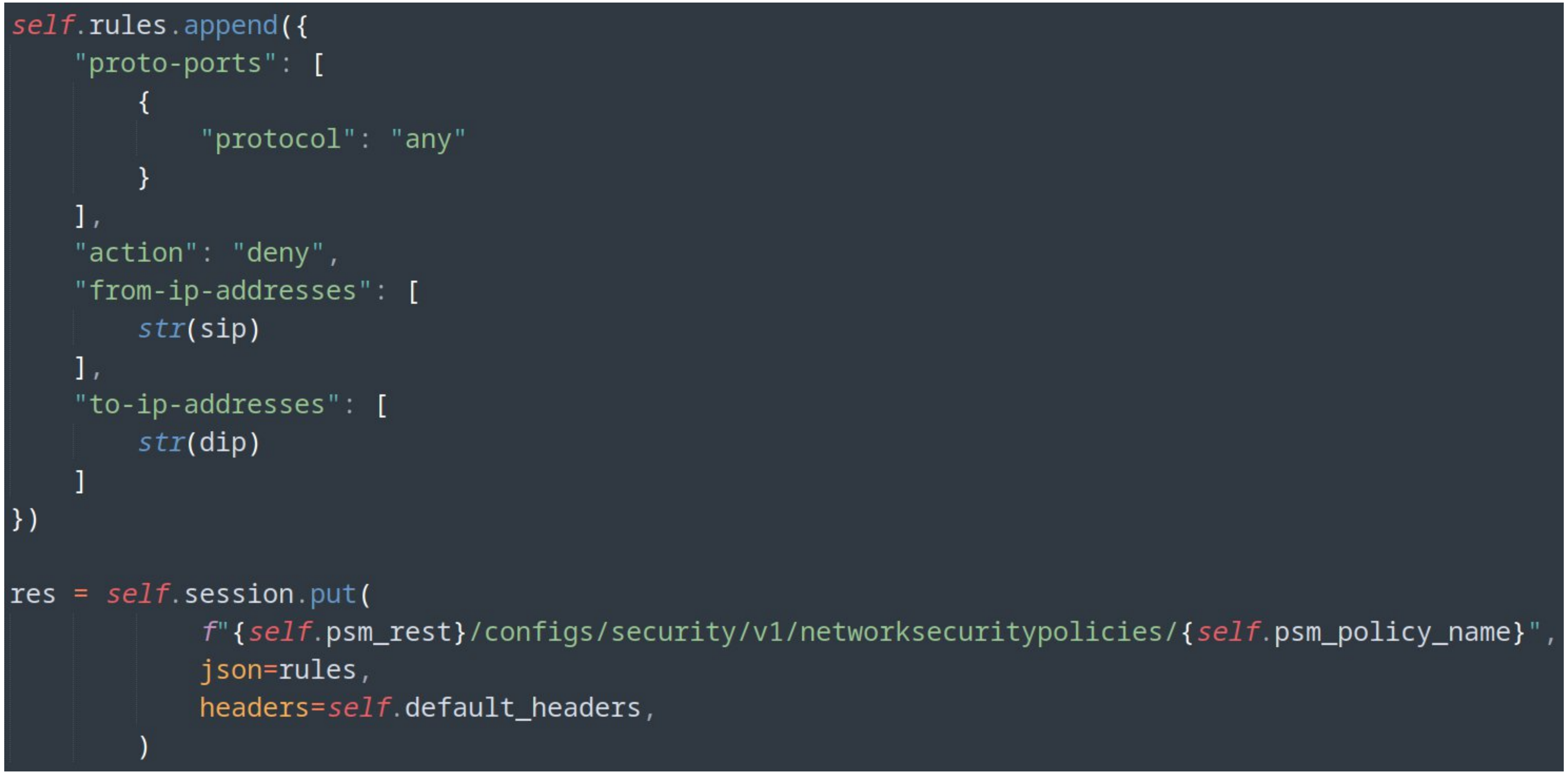
# THANK YOU!

# QUESTIONS?

This work was supported
by the bwNET2.0 project
funded by the MWK



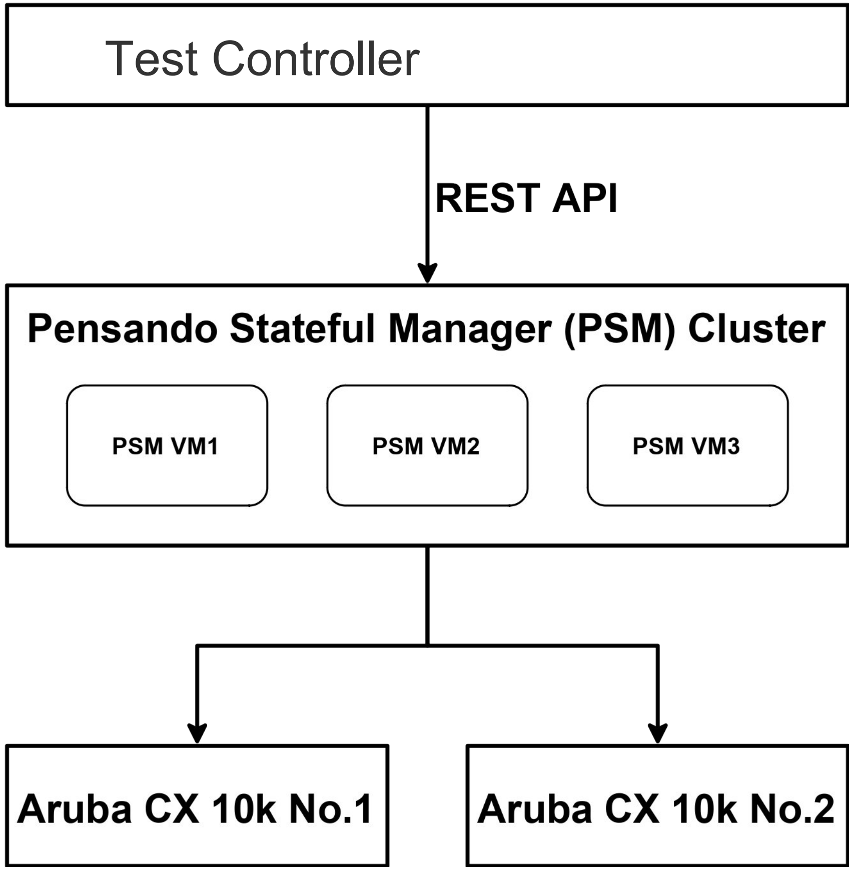
```
self.rules.append({
    "proto-ports": [
        {
            "protocol": "any"
        }
    ],
    "action": "deny",
    "from-ip-addresses": [
        str(sip)
    ],
    "to-ip-addresses": [
        str(dip)
    ]
})

res = self.session.put(
            f"{self.psm_rest}/configs/security/v1/networksecuritypolicies/{self.psm_policy_name}",
            json=rules,
            headers=self.default_headers,
        )
```

# Control Plane Performance - PSM

- Redundant setup
  - 2x Aruba CX 10k
  - 3-Node PSM Cluster
- Automated installation of filter rules via DuT controller / PSM REST API

➡ How long is the installation time for those rules to be active on both devices?


Test Controller
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PSM VM2
PSM VM3
Aruba CX 10k No.1
Aruba CX 10k No.2