NetFPGA Summer Course

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Technion

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http://NetFPGA.org

USING NETFPGA AS AN APPLICATION

Agenda

- NetFPGA as an application
- OpenFlow as an example
- OSNT
- BlueSwitch

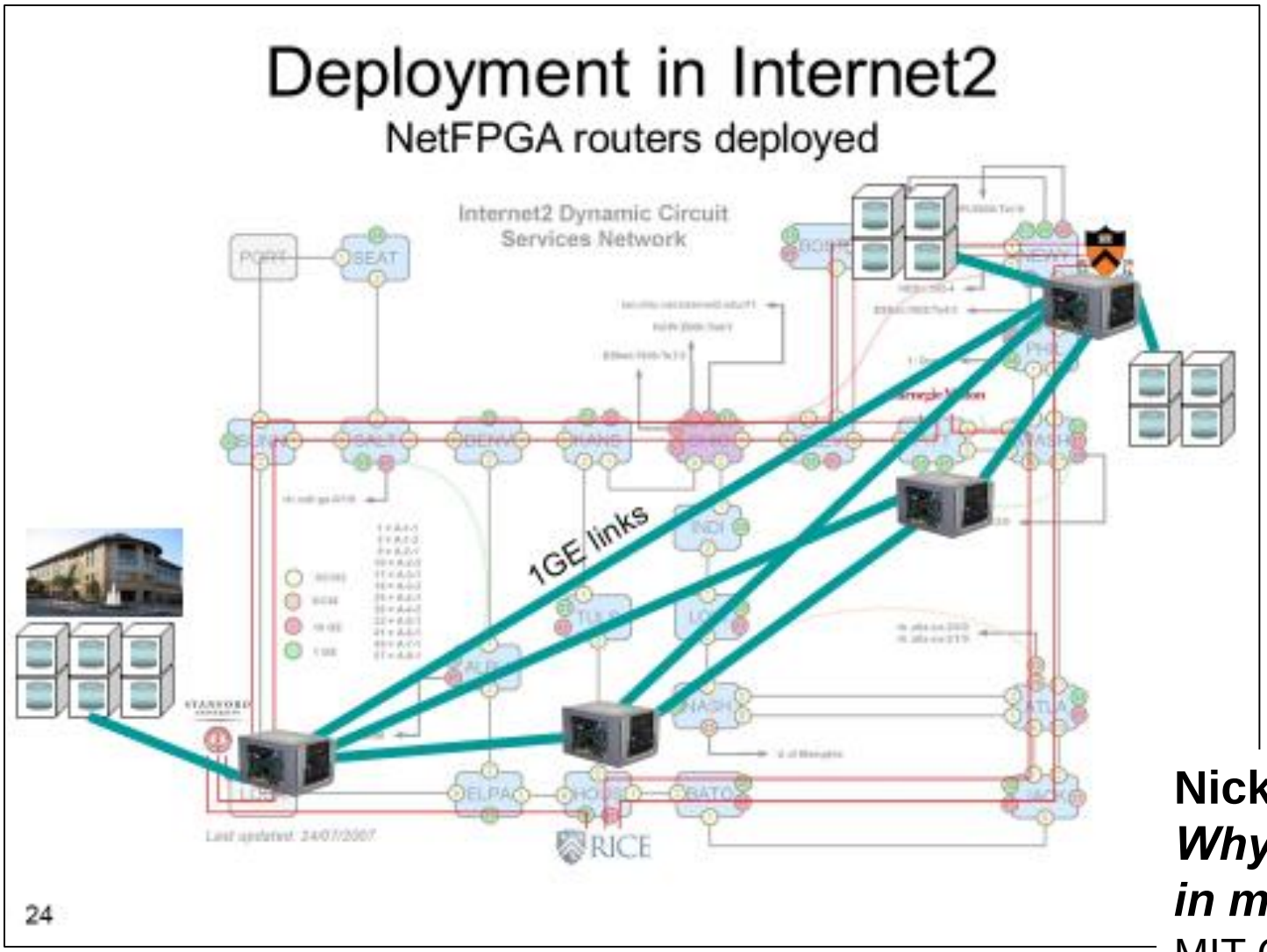
NetFPGA as an Application

- **Hardware development is just one aspect of research**
- **Many need flexible, open source platforms**
- **Idea: take a project developed over NetFPGA and be an end-user**

OpenFlow as an Example

- **Have you heard of Software Defined Networking?**
- **OpenFlow is a southbound interface between the data and a control plane**
- **NetFPGA enabled OpenFlow**
  - Provided a widely available open-source development platform
  - Capable of line-rate
- **NetFPGA was, until its commercial uptake, the reference platform for OpenFlow**

Early OpenFlow Deployments



Nick McKeown
Why can't I innovate in my wiring closet?
MIT CSAIL Colloquium,
April 17 2008

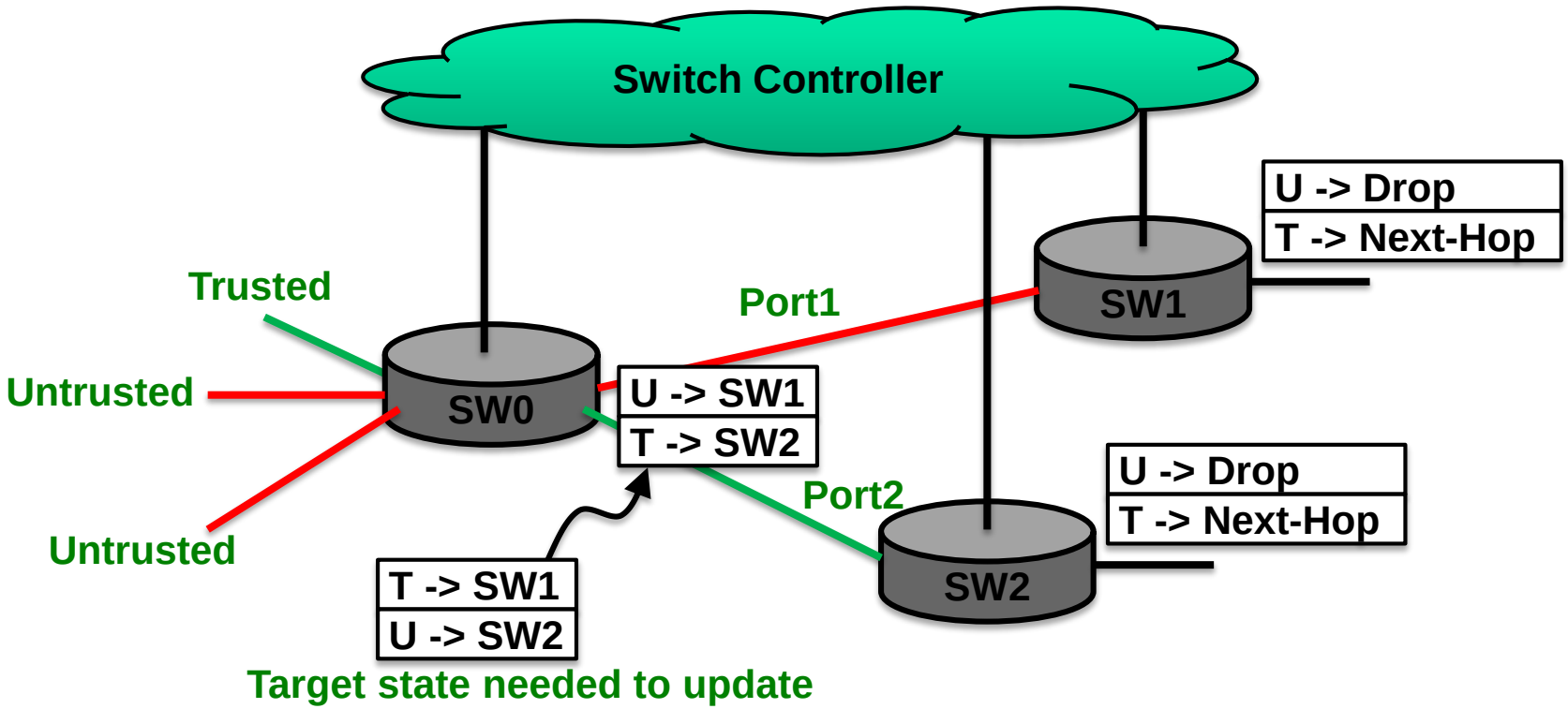
BLUESWITCH

BlueSwitch

- **An openFlow switch**
- **Parameterized modular design**
- **Multi-Table**
- **Provides packet consistency**
  - In the internal datapath of the switch
- **Supports openFlow v1.4 *Bundle* feature**
  - Atomic updates to switch configuration
- **Currently running over NetFPGA-10G**

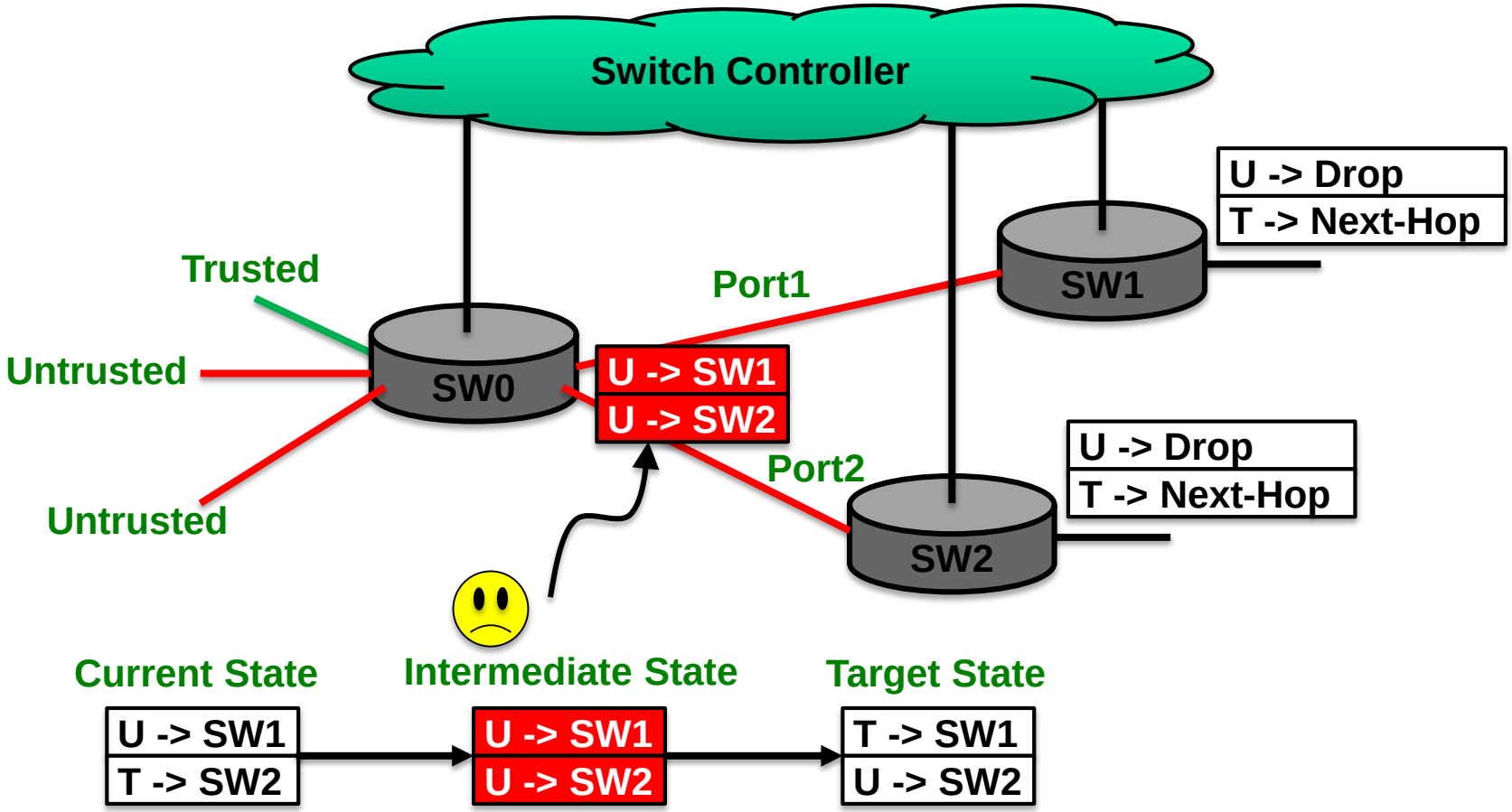
Inconsistent Policy Update Problem

- Inconsistent policy update in SDN - Security and Resilience



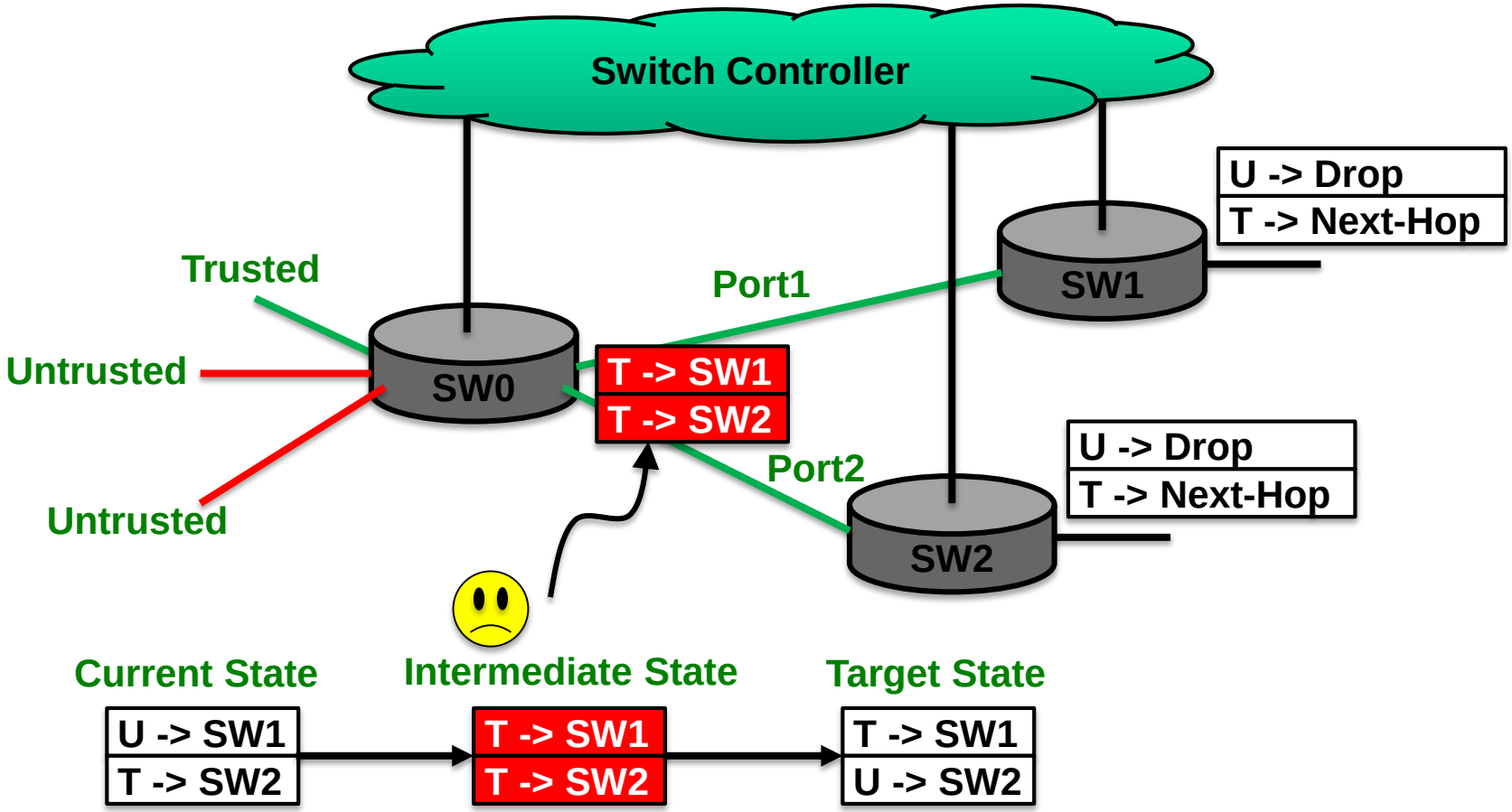
Inconsistent Policy Update Problem

- Risky Rule Update I – Update per Rule



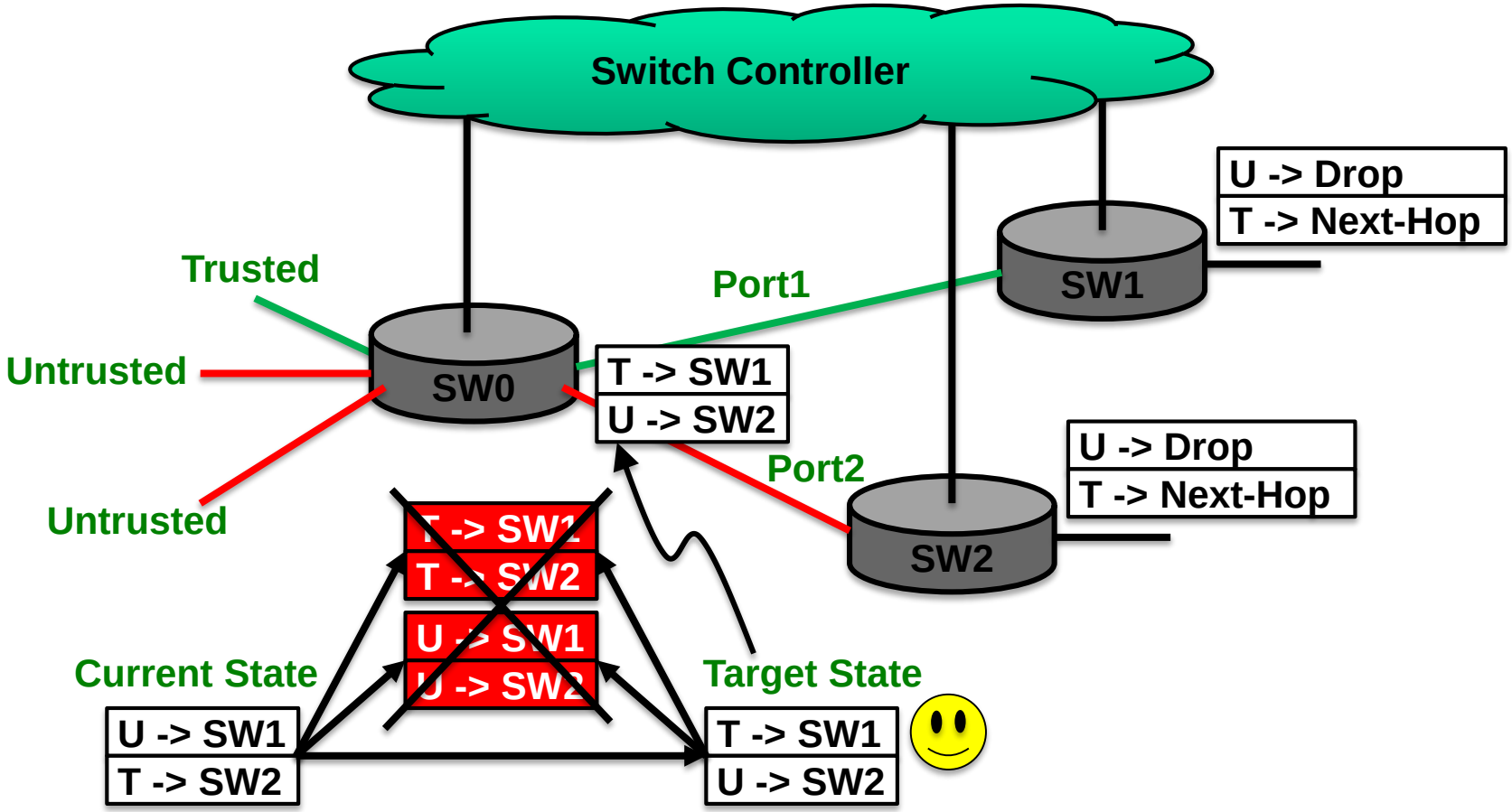
Inconsistent Policy Update Problem

- Risky Rule Update II – Update per Rule



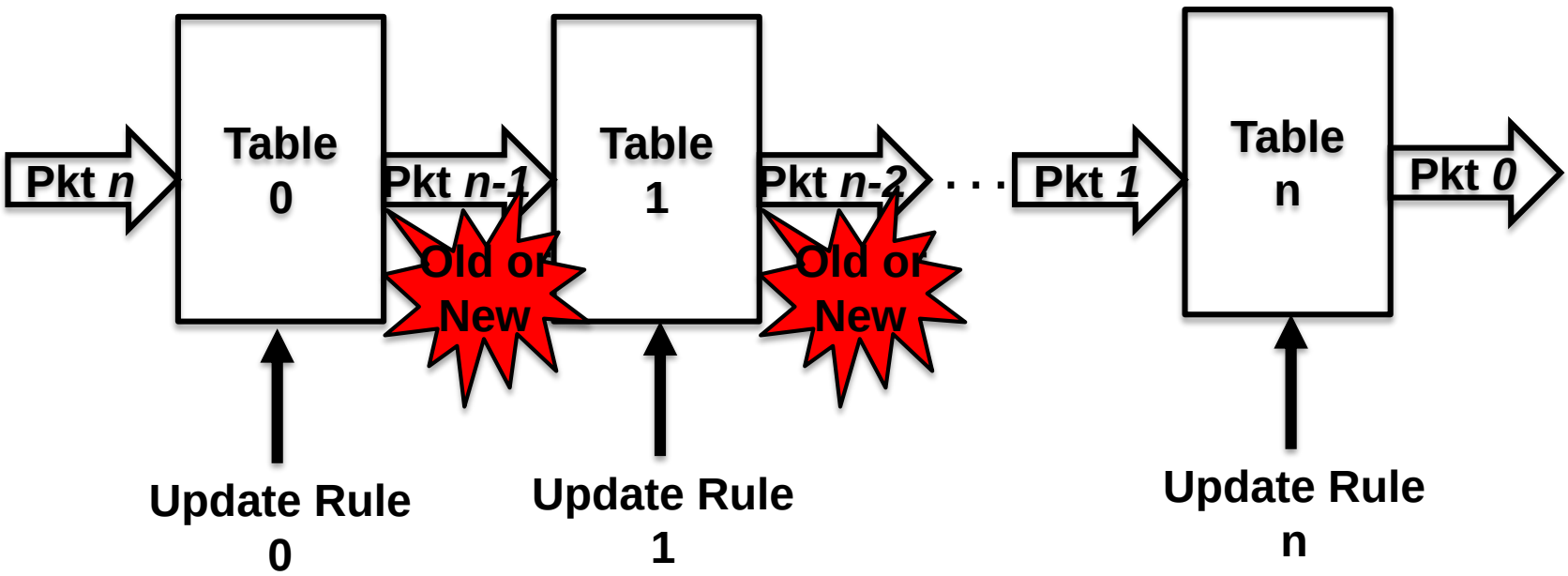
Inconsistent Policy Update Problem

- Safe Atomic Update – Update All Rules



Problem in Multi-Table OF Switch

- OpenFlow Switch Multi-Table Inconsistency Problem



Configuration Consistency

- **No commodity switch hardware is consistent**
- **Transitions from state *A* to *B* can move through intermediate (non-deterministic) states**
- **Not a new problem but SDN can fix this with principled hardware/software co-design**

Consistency in Blueswitch

- **Consistent double-buffered multi-flow-table structure**

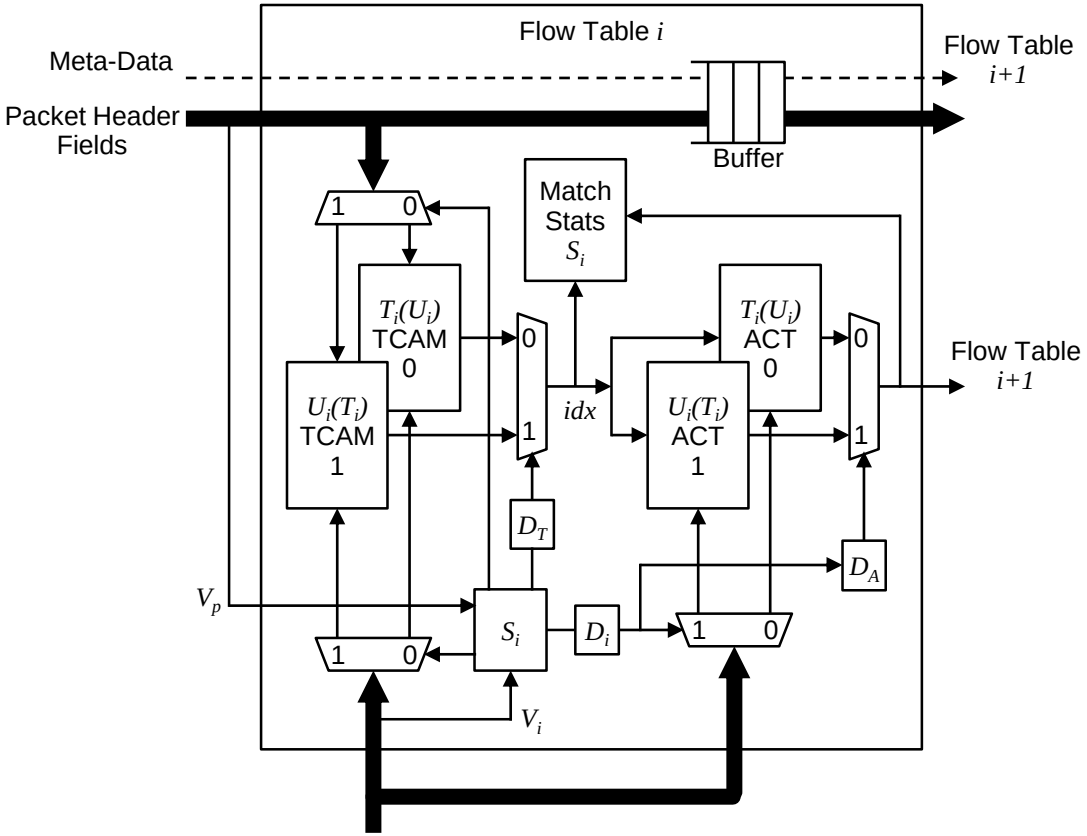
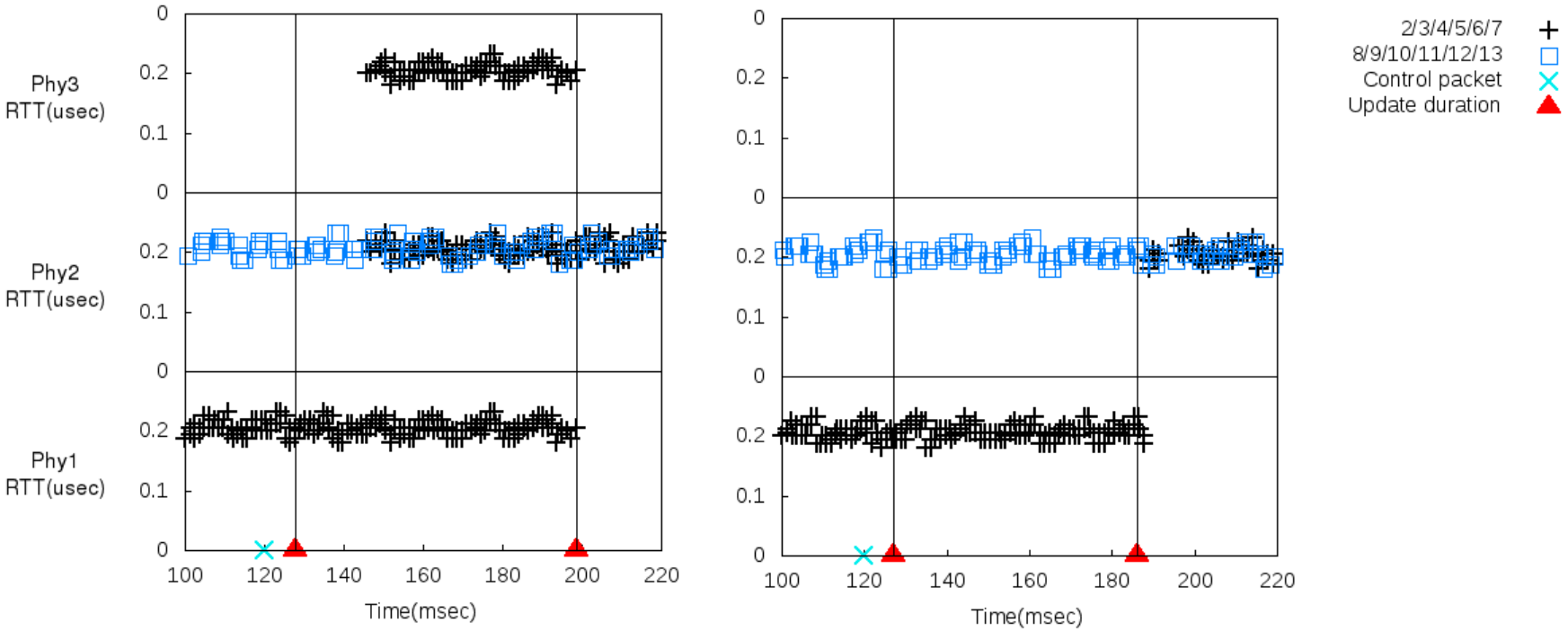


Table update interface (from API via DMA/PCIe)

Blueswitch consistent rule update

Inconsistent and consistent data-plane packet behavior results during new policy update



HW Implementation Results

- **Results on NF10**

Resource	Reference Switch	Reference Router	Blueswitch (overhead)
Slices	18.3K	20.3K	22.9K (25%)
Slice Registers	44.3K	47.2K	57.2K (29%)
LUTs	39.0K	43.1K	43.3K (11%)
LUT-Flip Flop	56.6K	61.7K	72.4K (28%)
No. of TCAMs	1	1	6

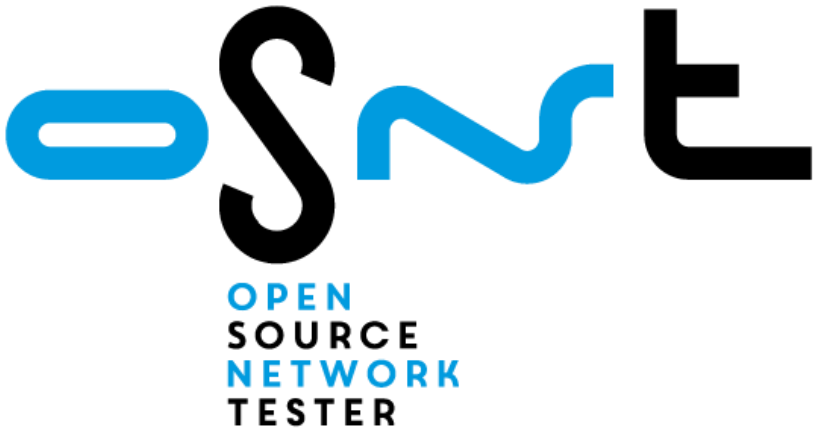
BlueSwitch – More Information

- Han J.H *et al* - Blueswitch: Enabling provably consistent configuration of network switches, ANCS 2015
- BlueSwitch source code - NetFPGA GitHub repository
- OpenVSwitch for BlueSwitch - https://github.com/pmundkur/ovs

OSNT

Long development cycles and high cost create a requirement for open-source network testing

- **Open-source hardware/software co-design**
  - **For research and teaching community**



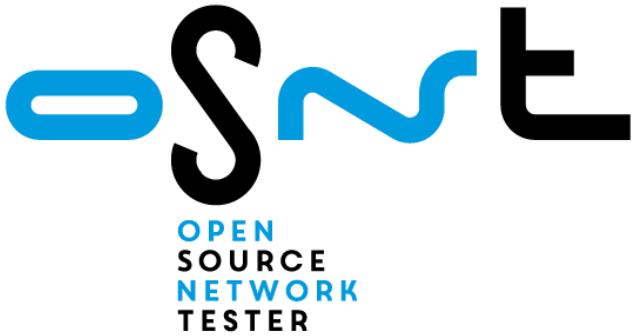
- flexible
- scalable
- community-based

www.osnt.org

- **the first OSNT prototype is based upon the NetFPGA-10G open-source hardware platform**

- **OSNT is portable across a number of HW platforms**
  - maximizing reuse
  - minimizing reimplementation costs (as new HW, physical interfaces become available)

- **we invite everyone from the community to audit our implementation and adapt it to your needs**



- **NetFPGA platform enabled the first prototype of OSNT.**
- **The open nature of NetFPGA ecosystem represents the best starting point for open HW/SW community-oriented projects.**
- **OSNT aims to build a community as NetFPGA did.**

OSNT architecture on NetFPGA-10G

OSNT flexibility provides support for a wide range of use-cases

- **OSNT-TG**
  - a single card, capable of generating packets on four 10GbE ports
  - to test a single networking system or a small network

- **OSNT-MON**
  - a single card, capable of capturing packets arriving through four 10GbE ports
  - to provide loss limited capture system with both high-resolution and high precision timestamping

OSNT architecture on NetFPGA-10G

- **Hybrid OSNT**
  - the combination of Traffic Generator and Traffic Monitor into single FPGA device and single card
  - to perform full line-rate, per-flow characterization of a network (device) under test

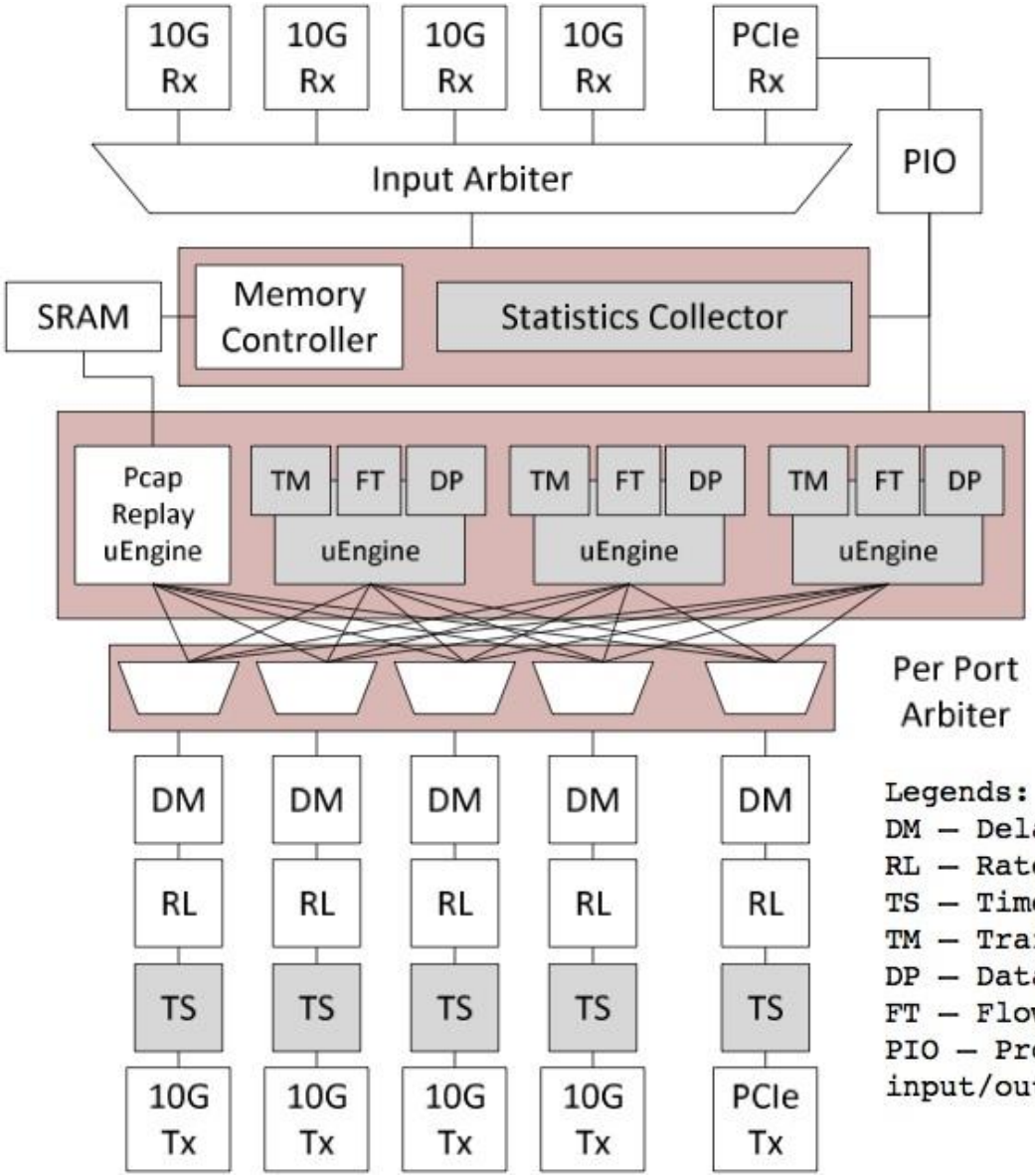
- **Scalable OSNT**
  - our approach for coordinating large numbers of multiple generators and monitors synchronized by a common time-base
  - still largely under work

OSNT-TG

The OSNT-TG generates packets according user-defined parameters

- **PCAP replay function**
- **micro-engines generate packets according (TBD)**
  - traffic model
  - list of flow values (header templates)
  - data patterns
- **generation process may depend on**
  - packet size
  - inter-packet delay

OSNT-TG architecture

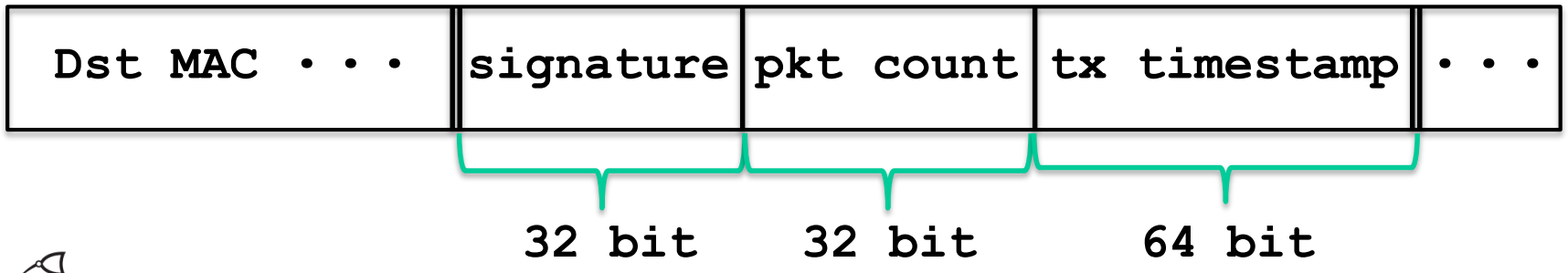


- DM and RL guarantee the output packet rate is the one assigned by the user
- 27MB of SRAM used to store the packets

OSNT-TG timestamp

Evaluating device functionalities using packet level information requires accurate timestamping functionality

- **timestamping just before the transmit 10GbE MAC**
- **configurable offset**
- **timing-related measurements**
  - latency
  - jitter



OSNT timestamp

free-running counter?

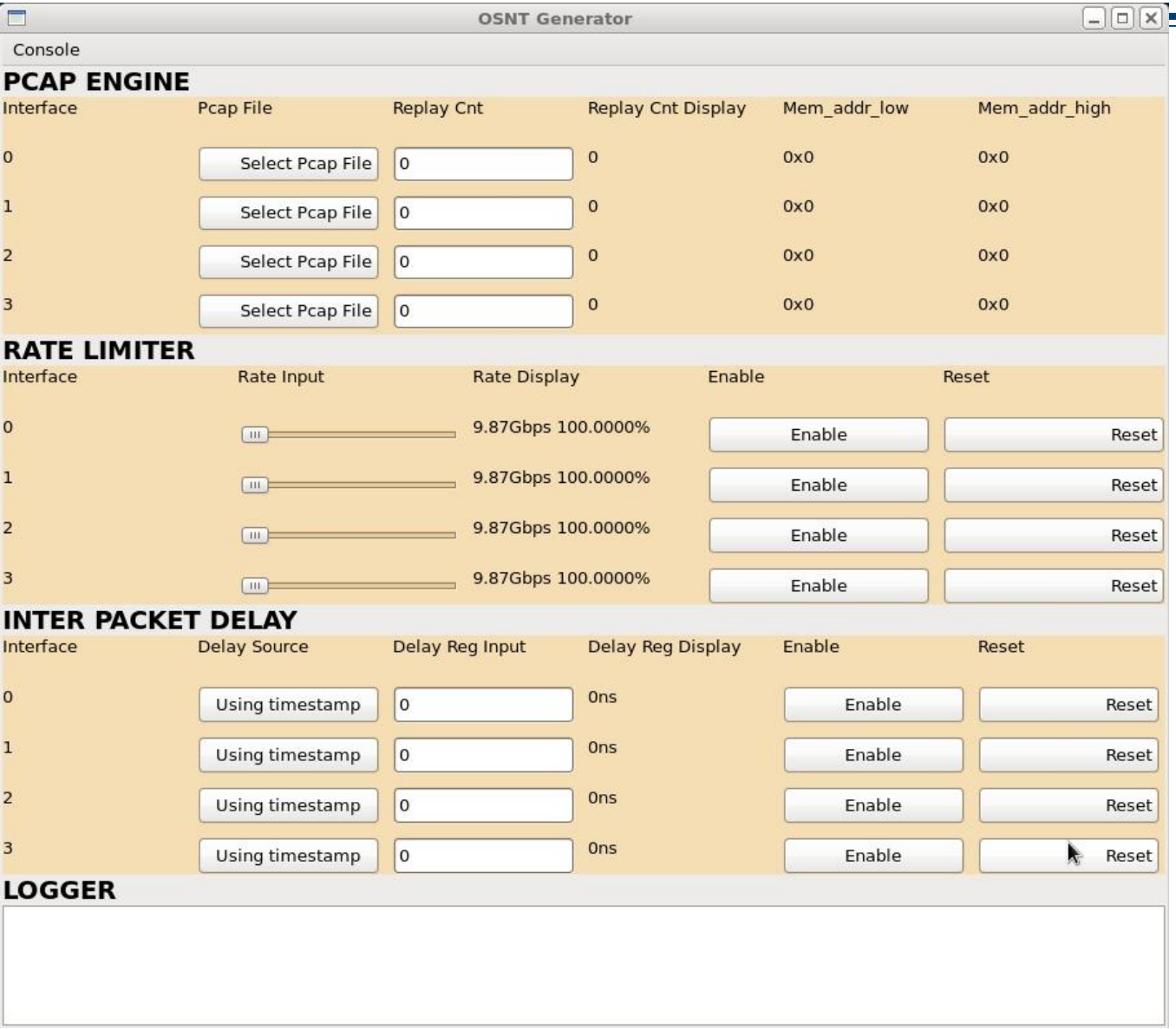
- **we could use a 64-bit counter driven by the 160MHz system clock (naïve solution)**
  - provides no means by which to correct oscillator frequency drift
  - produces timestamps expressed in unit of 6.25 ns
  - fixed-point representation of time in seconds more useful to host

OSNT timestamp

a more accurate solution…

- **DDS (Direct Digital Synthesis)**
  - technique by which arbitrary variable frequencies can be generated using FPGA-friendly logic (how DAG works)
  - need a time reference to correct DDS rate
  - optimal solution: PPS from GPS receiver

OSNT-TG GUI



- python GUI
- basic functionality management
- logger to track down last events

OSNT-TG evaluation

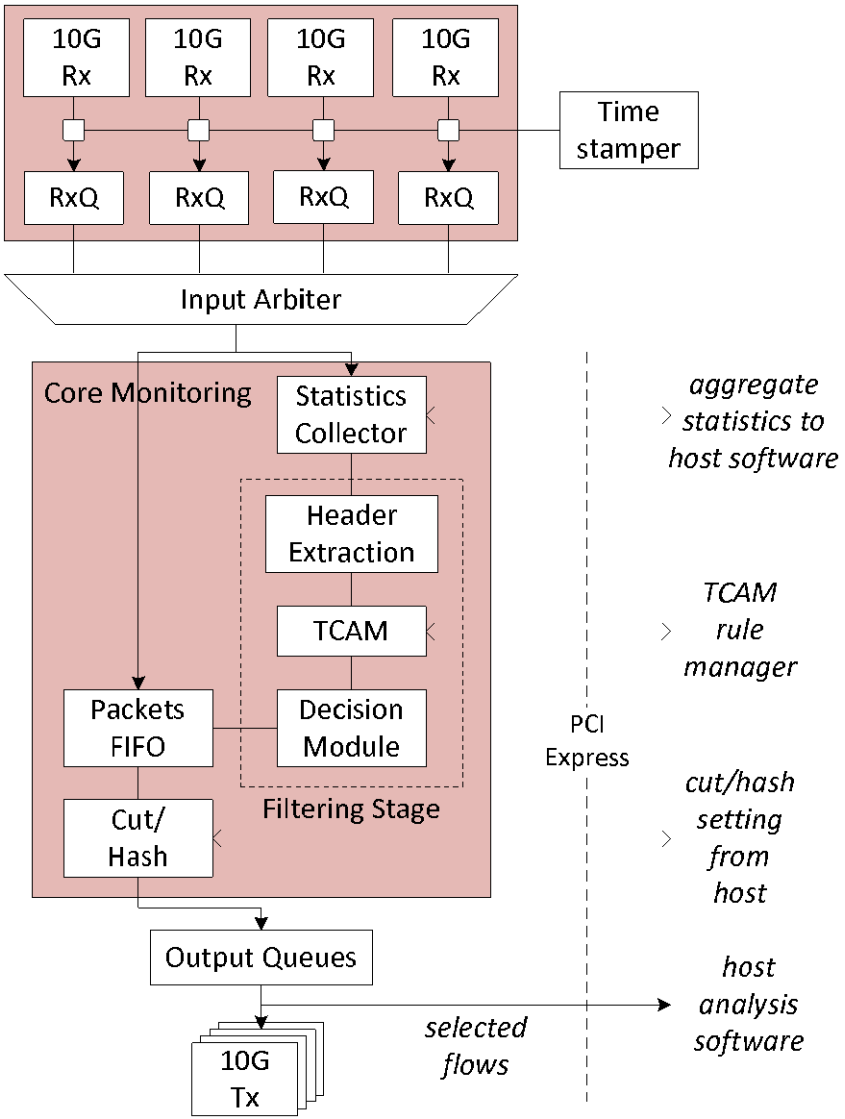
- performance tests against IXIA box
- full line rate regardless packet length on 2 ports
- full line rate over the 4 ports is work in progress (main limitation due to the Virtex5 FPGA resources)
- IFG (Inter Frame Gap) is statically set to 96 bit

OSNT-MON

The OSNT-MON provides four main functions

- **packet capture**
- **packet filtering permitting selection of traffic-of-interest (5-tuple)**
- **high precision, accurate, packet timestamping**
- **high-level traffic statistics**

OSNT-MON architecture



- timestamp before the receive queues
- statistic collector (packets, bytes, IP, UDP, TCP..)
- extensible packet parser able to recognize VLAN
- TCAM for packet filtering
- cut/hash feature

OSNT-MON architecture

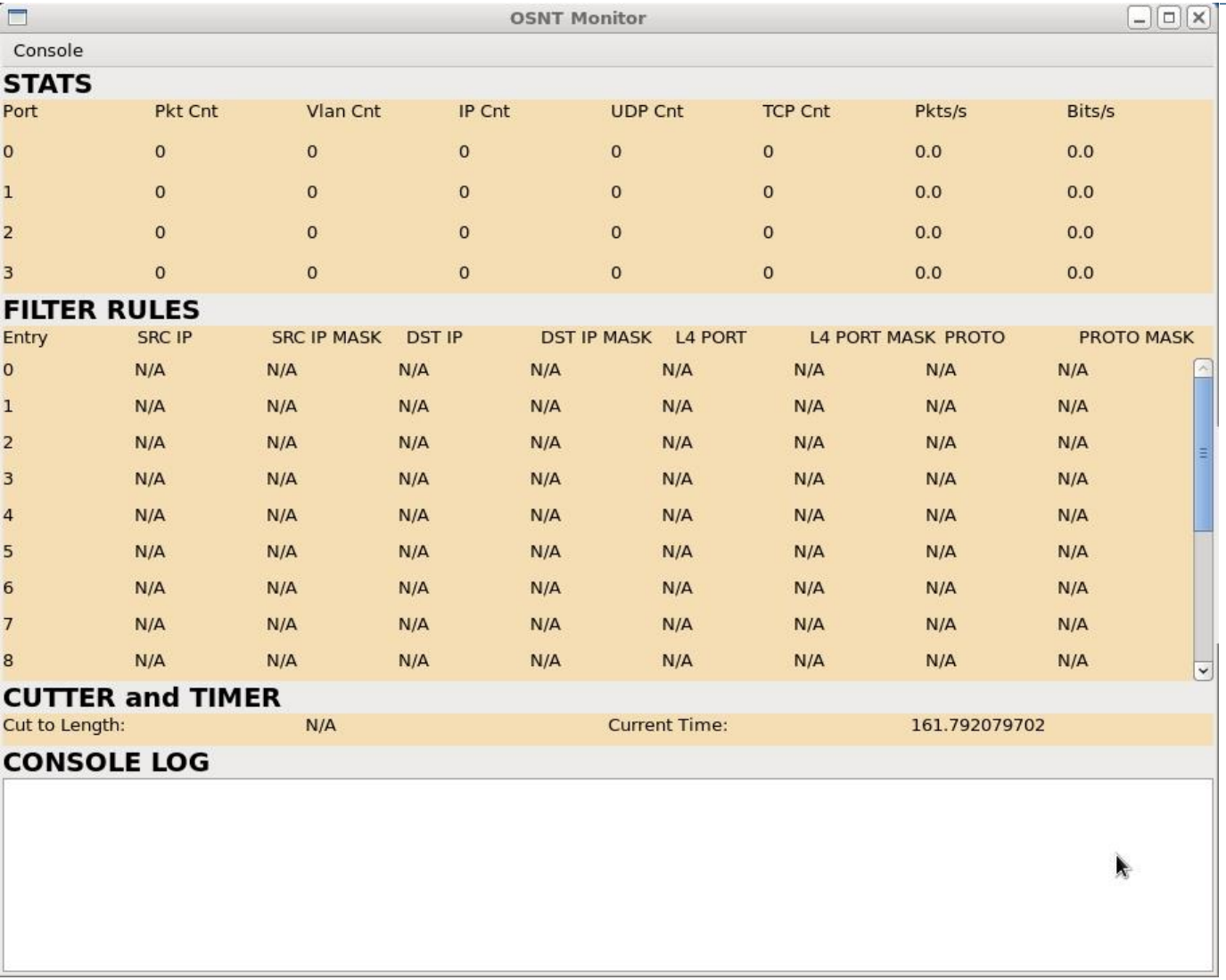
the NetFPGA-10G PCIe lacks the bandwidth to record all traffic

- **two traffic-thinning approaches**
  - packet filtering
  - snap length

- **5-Tuple filter stage (packets that match a rule are copied with their HW timestamp to the host)**

- **possibility of recording a fixed-length part of each packet along with a hash of the discarded part**

OSNT-MON GUI



- python GUI
- basic functionality management
- logger to track down last events

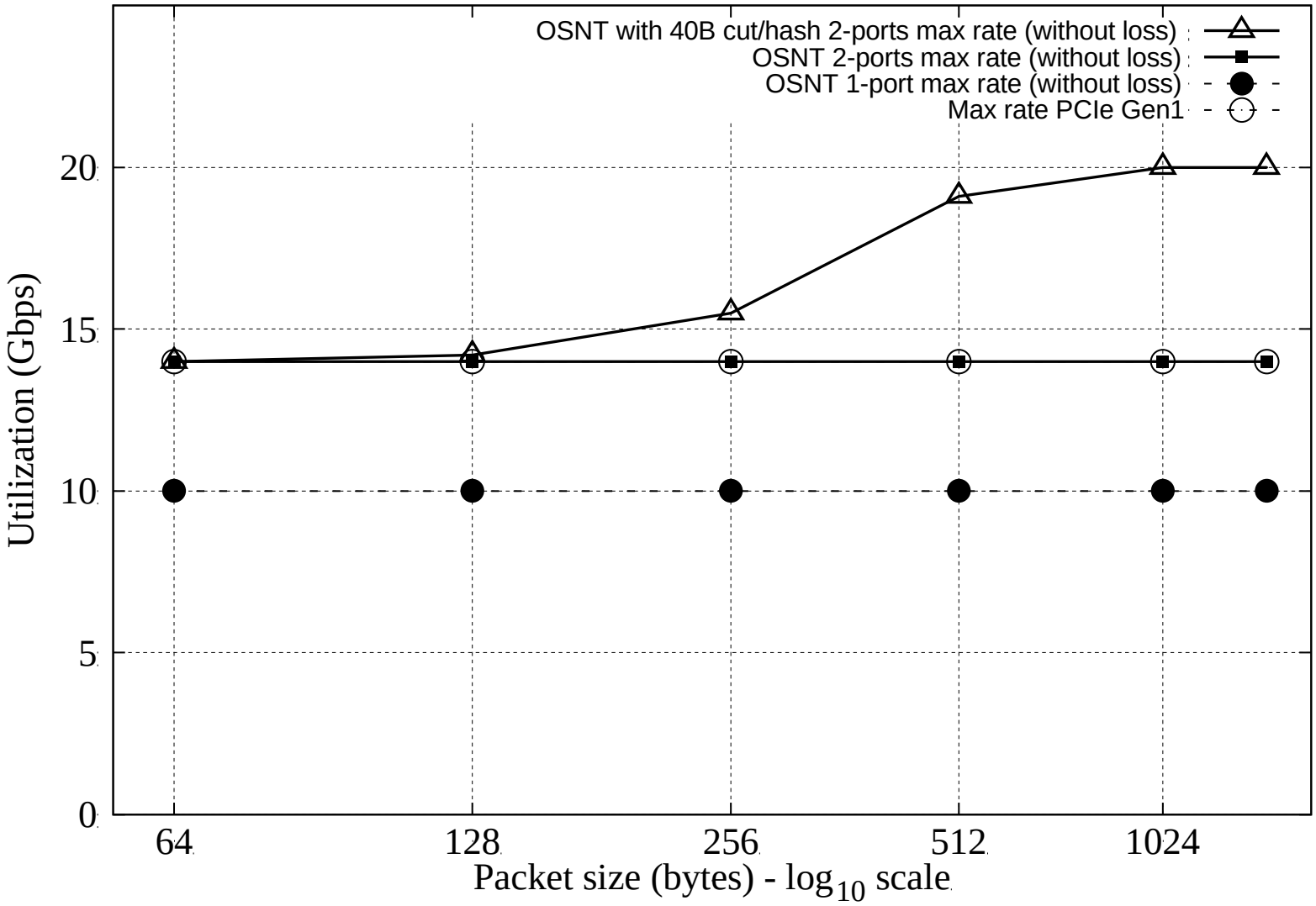
OSNT-MON SW plane

- **libpcap based tools do not work directly with OSNT: the device driver secures performance by bypassing the kernel network stack**
- **a modified version of libpcap with nanosecond granularity is provided to records PCAP traces in nanosecond resolution (if the appropriate user-space SW is written)**

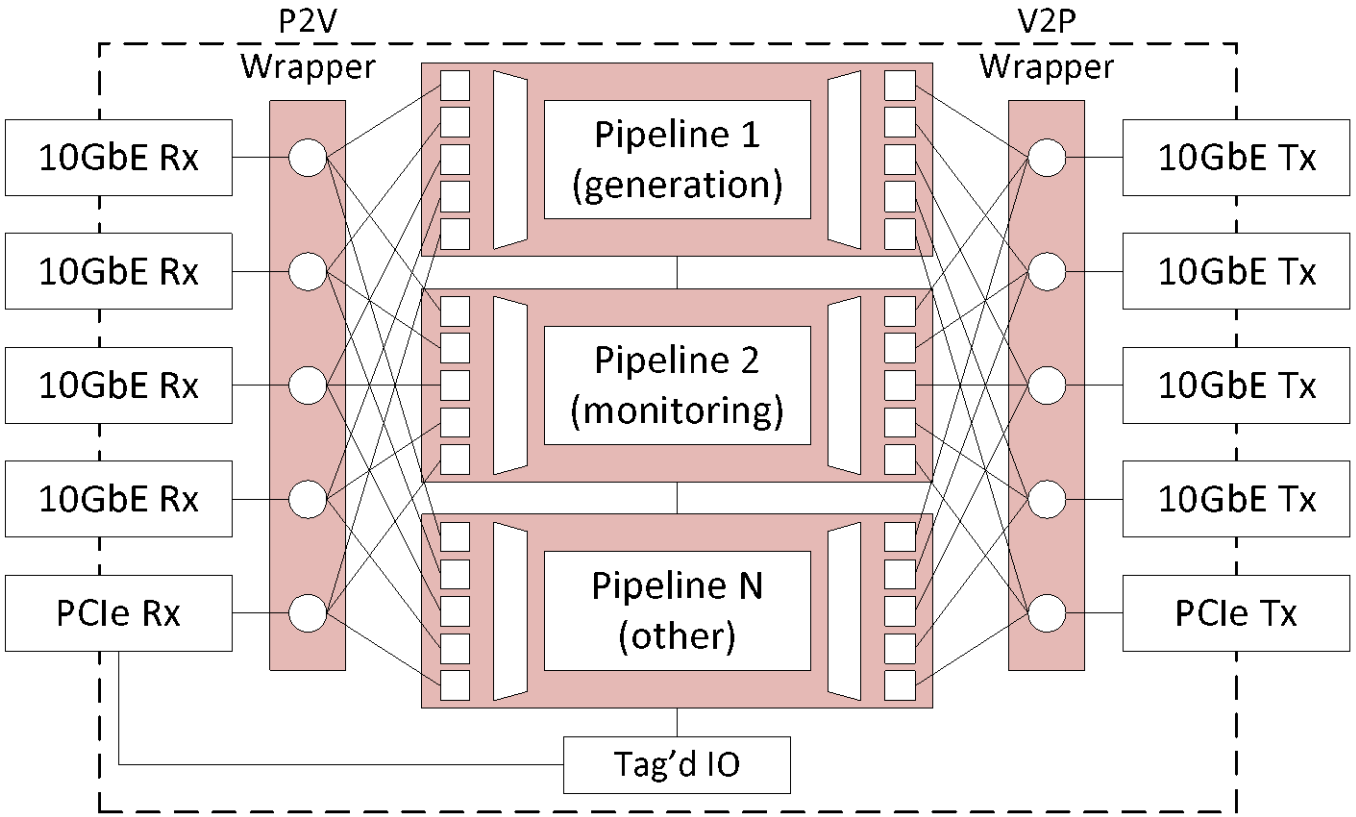
OSNT-MON SW plane

- **CLI-based approach (for those who do not like GUIs)**
  - set rules
  - check statistics
  - set snap-length
  - enable GPS correction

OSNT-MON evaluation



Hybrid OSNT



- multiple pipelines can co-exist
- it is possible to generate/monitor at the same time on a given port

Device Testing with OSNT

what can we do from here?

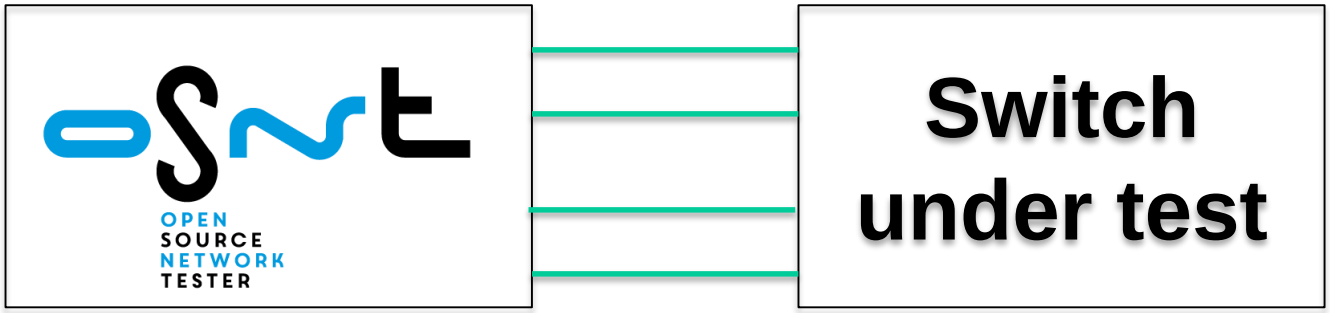
how can we effectively use OSNT?

- traffic characterization (OSNT is an high precision traffic capture system)
- networking device testing (OSNT is an high performance traffic generator)
- adapt OSNT to your needs (OSNT is open, OSNT is a starting point)
- **What about using OSNT for switch performance evaluation/characterization? (i.e., latency)**

Device Testing with OSNT

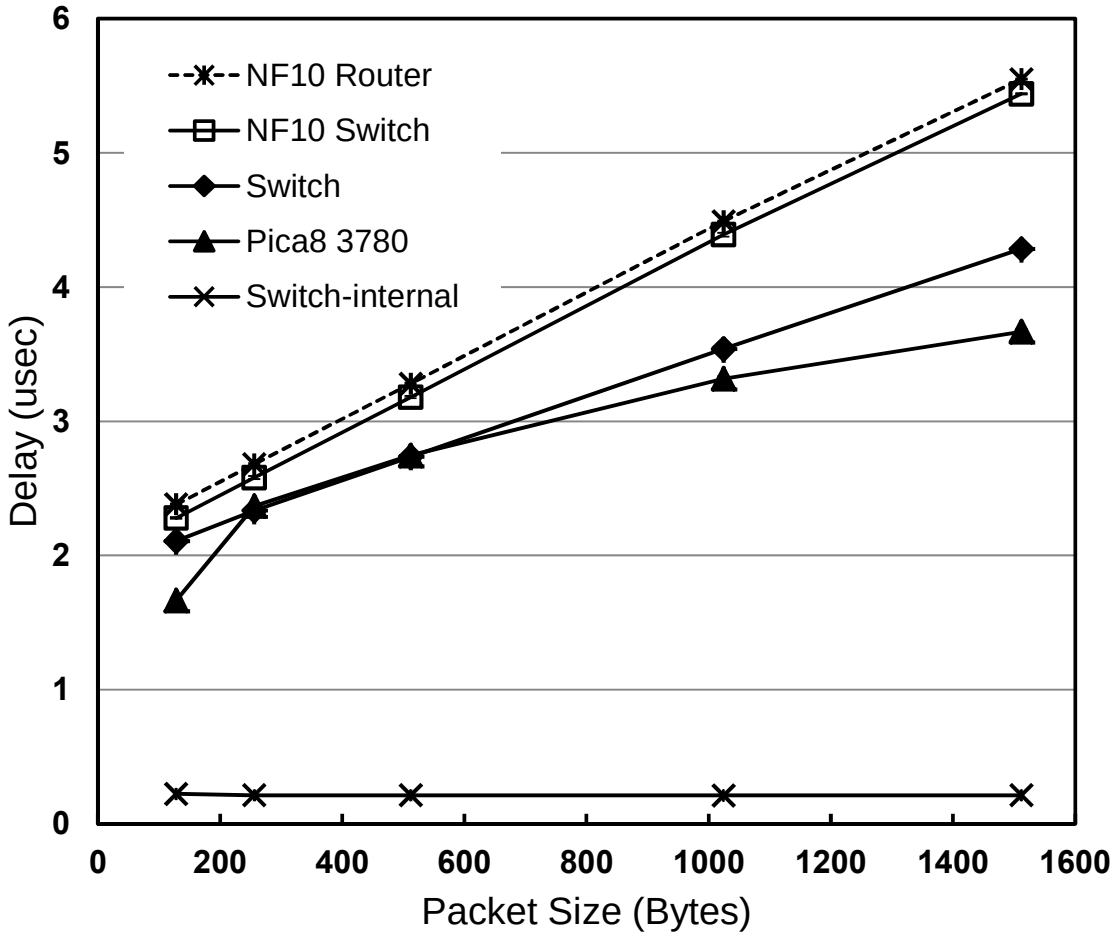
how is it possible to characterize a networking device latency with OSNT?

- we can embed the transmission timestamp into the packet
- OSNT can send packets at high rates and wait them back
- Compare the TX timestamp with the RX one.



Device Testing with OSNT

woooot!!!!! I can accurately measure switching latency!



ok…this is cool, but what's next?

- **participate, contribute to the open source network testing community**
- **extend OSNT with new features**

yes, ok..but…

- **Where can we go from here?**
- **How can we fully exploit OSNT?**

the effective integration of the OpenFlow protocol in production requires a flexible and high-precision open-source measurement platform which provide a deep understanding of switch capabilities

OFLOPS

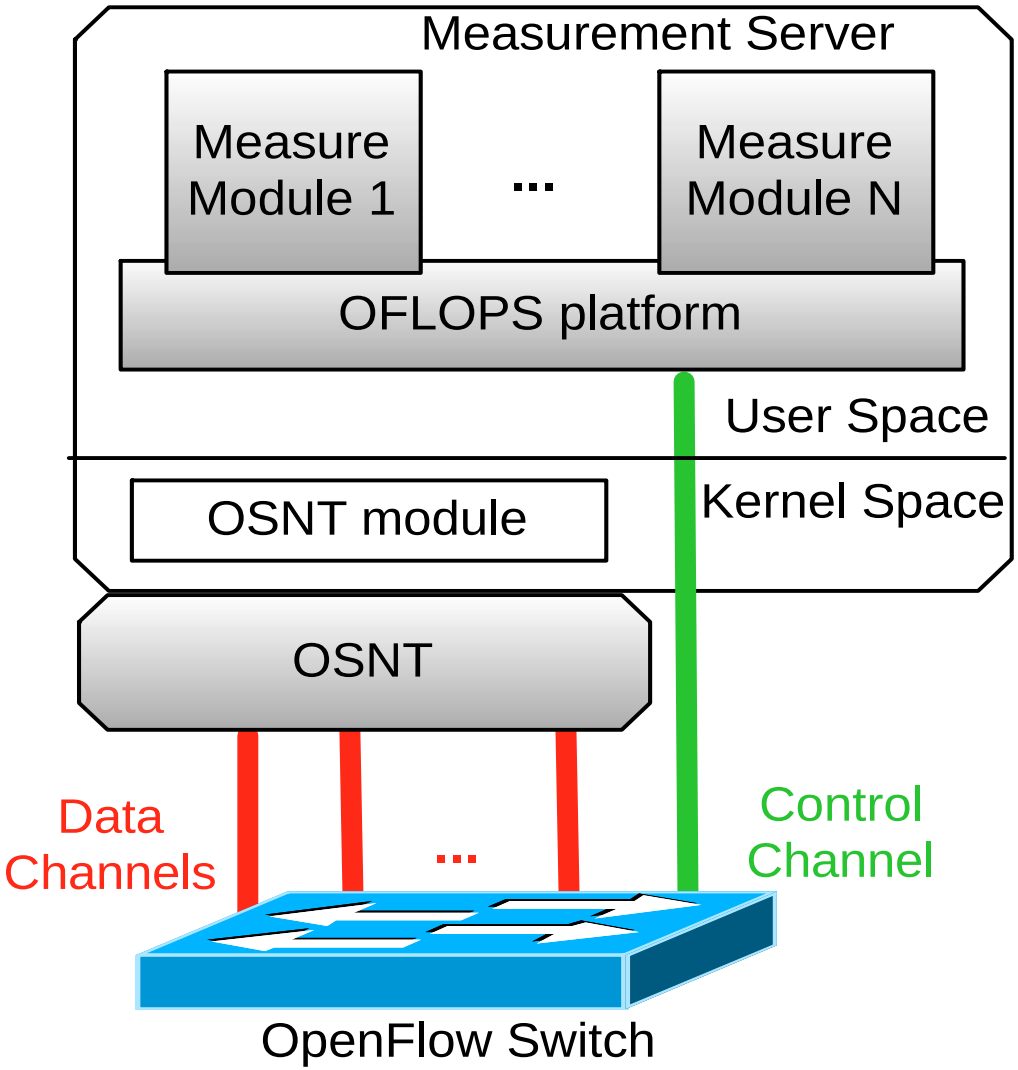
- **Holistic switch evaluation framework.**
  - API to interact with switch: SNMP, control and data plane.
  - Designed to minimize measurement noise.
- **Exploit OSNT traffic generation and capture capabilities (throughput, accuracy).**
- **Measurement modules to define experiment scenario and measurement.**
- **Use Cases:**
  - C. Rotsos, et.al. *OFLOPS: an open framework for openflow switch evaluation*. PAM'12
  - D. Pediaditakis, et.al. *Faithful reproduction of network experiments*. ANCS '14
  - J. Han, et.al. *Blueswitch: Enabling provably consistent configuration of network switches*. ANCS'15
  - C. Rotsos, et.al. *OFLOPS-Turbo: Testing the Next-Generation OpenFlow switch*. ICC'15

OFLOPS

- NetFPGA enables OSNT
- OSNT enables OFLOPS-Turbo

OFLOPS-Turbo

OFLOPS-turbo design

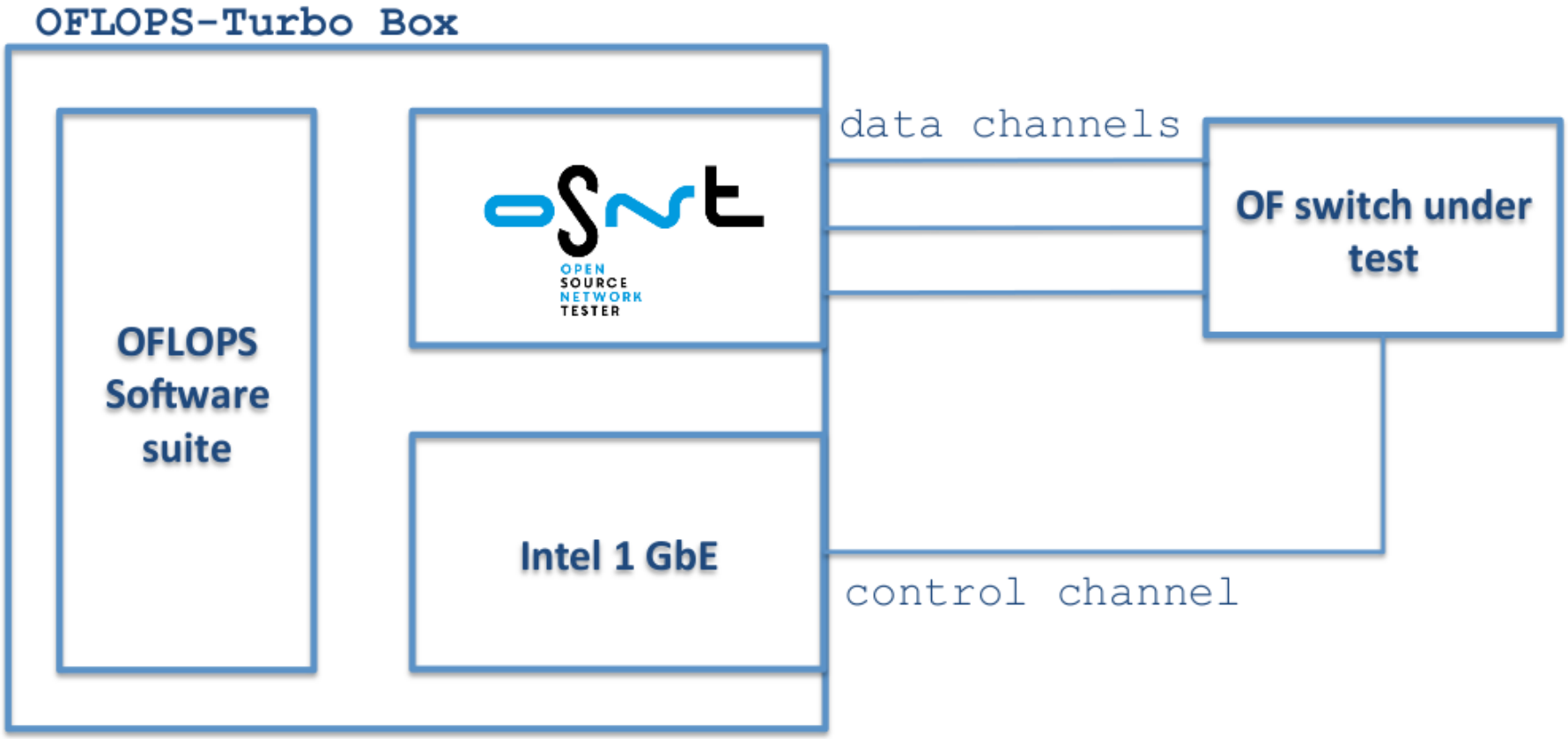


what can we do from here?

how can we effectively use OFLOPS-Turbo?

- **OpenFlow flow table insertion measurements**
- **OpenFlow flow table modification measurements**
- **Create your own test in SW and test multi Gigabit switches!**

Let's consider a testing scenario



Conclusion

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