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High-Performance Virtualized SDN Switches for Experimental Network Testbeds

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Motivation

- SDN has reached wide academic acceptance
  - OpenFlow has been cited **4876** times so far
  - Many SDN controllers have been proposed and used
- SDN/OpenFlow research continues!
  - In hardware (ironically),
  - In management & control plane services
  - In application layer
- How do we efficiently share SDN switching hardware in a scalable and secure fashion?

Sharing the Switch

- OF offers a One switch-One Controller model
- Thus, sharing an OpenFLow switch has been the “elephant in the room” for years
- Many approaches have been tried
    - Proxie intercept
    - VLAN slicing (layer 2)
    - Port delegation
    - Controller based services

- We assert the problem is lack of virtualization support in OpenFlow switching platforms

Contributions

- This work has brought NORDUnet, GEANT and Corsa Technologies together to design and implement Virtual Switch Instances (VSIs)

- This paper presents
  - The functionality and benefits of VSIs
  - How we integrated VSIs into the GEANT Testbeds Service (GTS)

The Problem(s):

- SDN switches do not allow multiple controllers, simultaneously.
- Different SDN applications have different requirements:
  - Forwarding requirements,
  - Switching fanout requirements, and topology
  - Protocol requirements
- This is especially true of “on-ramp” R&D environments
  - E.g. AL2S, GENI, FIRE, AL2S, GEANT Testbeds Service, …

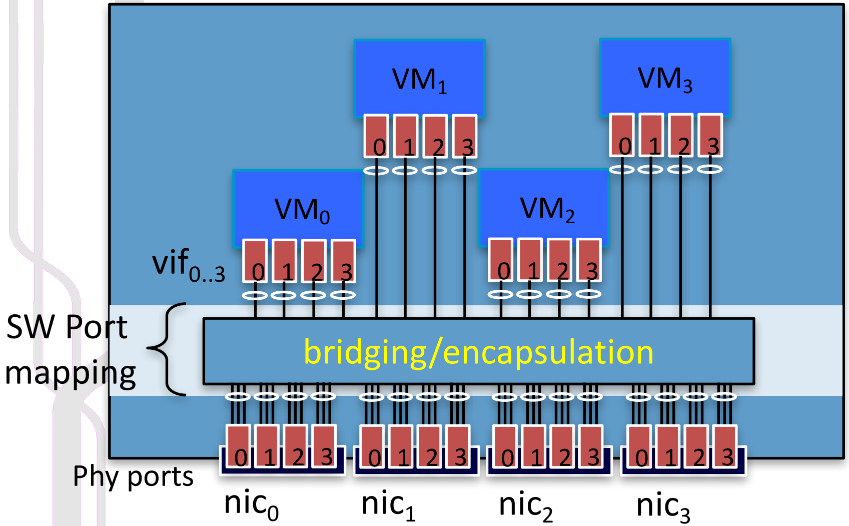
Virtual Switch Instances

- Solution: Dis-associate and abstract switch attributes from the physical mapping
- -> Virtualized Switching Instances (VSIs)

- Each VSI has its own OpenFlow context
  - Separate controller, protocol version, IPaddr
  - Full network flow space, counters, etc.
  - Deterministic fabric forwarding performance
- Each VSI has its own set of Virtual Ports
  - Implications are complex

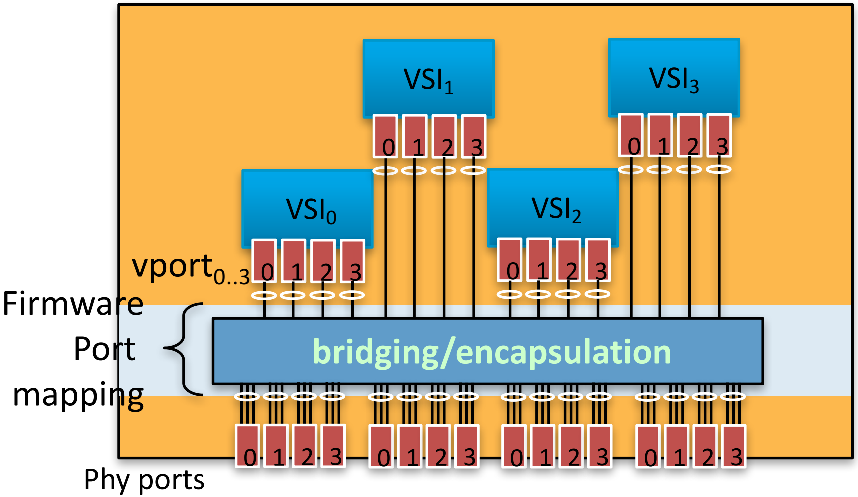
Physical to Virtual VSI Model

Physical **Server** Platform



VM Port mapping: phyPort/VLAN > VM/vif,
Pop tagging (inbound) or push tagging (outbound)

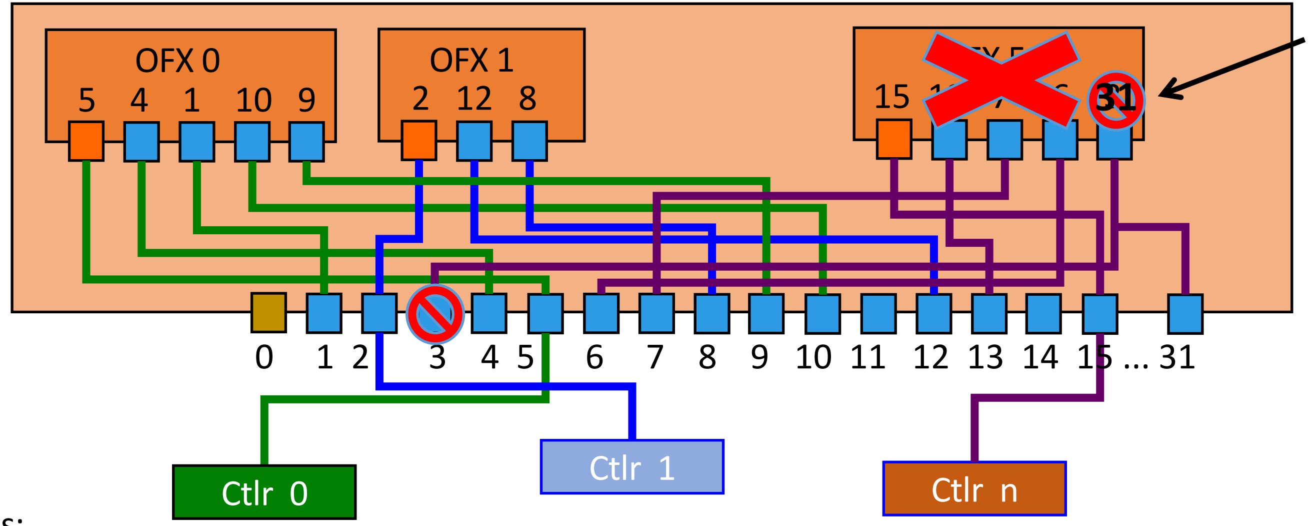
Physical **Switch** Platform



VSI Port mapping: phyPort/VLAN > VSI/vport,
Pop tagging(inbound) or push tagging (outbound)

Switch Partitioning

OFX Instances with port partioning



Breaks application [physical] flow specs

Pros:

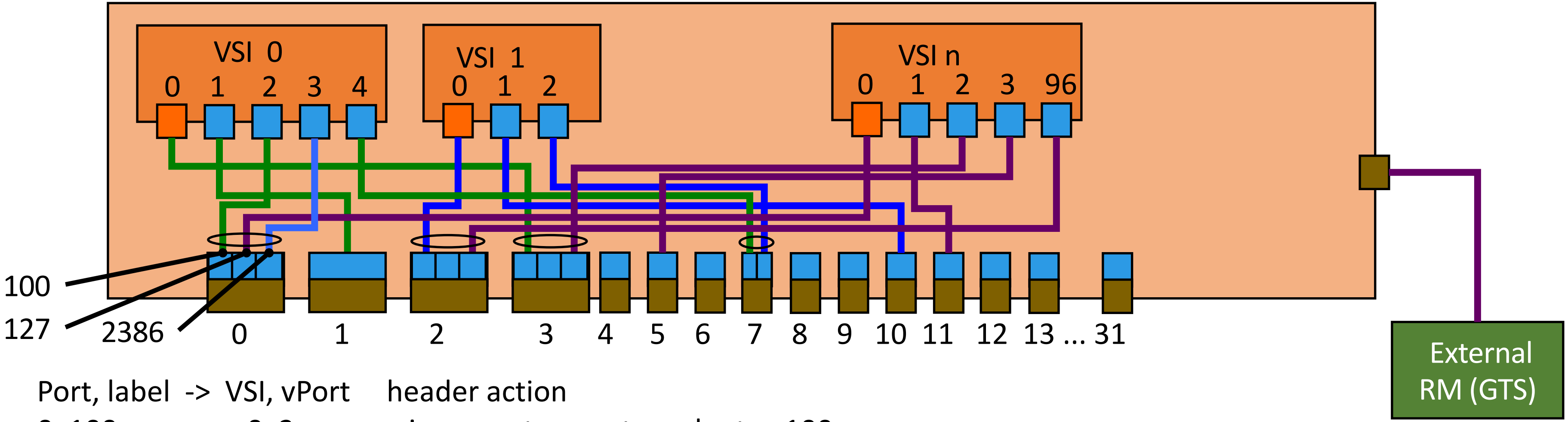
- Each instance has its own controller
- Except for port dimension, the user has full network flow space (no VLAN slicing is needed)

Cons:

- User flowspecs are ***physical port*** based flowspecs – the instance will break the flowspecs
- Ports cannot be split – the entire port is assigned to an instance

Virtual Switch Instances – The model

Virtual Switch with Virtual Circuit port mapping



Port, label	-> VSI, vPort	header action
0, 100	0, 2	in: pop qtag; out: push qtag 100;
0, 127	n, 0	In: pop qtag; out: push qtag 127;
0, 2386	0, 3	in: pop qtag; out: push qtag 2386;
1, *	0, 1	in: no action; out: no action;
2, 100	n, 96	in: pop qtag; out: push qtag 96;
2, 3140	1, 0	in: pop qtag; out: push qtag 3140;
3, 25	0, 0	in: pop qtag; out: push qtag 25;
3, 1870	n, 2	in: pop qtag; out: push qtag 1870;

VSIs use virtual flowspecs
Allows instances to share a physical port
Allows transport tagging to be used for VCs, and to be popped before user sees it.
Enables full network flow space. Enables migration and grooming.

Why is this so hard?

- For user virtual flow specs to work the inbound frame must be mapped to the appropriate VSI and appropriate port at line rate.
    - Must be done in the “fast path” – at 100G!
    - Must be a simple *FAST* operation
    - Must be done for both inbound and outbound traffic

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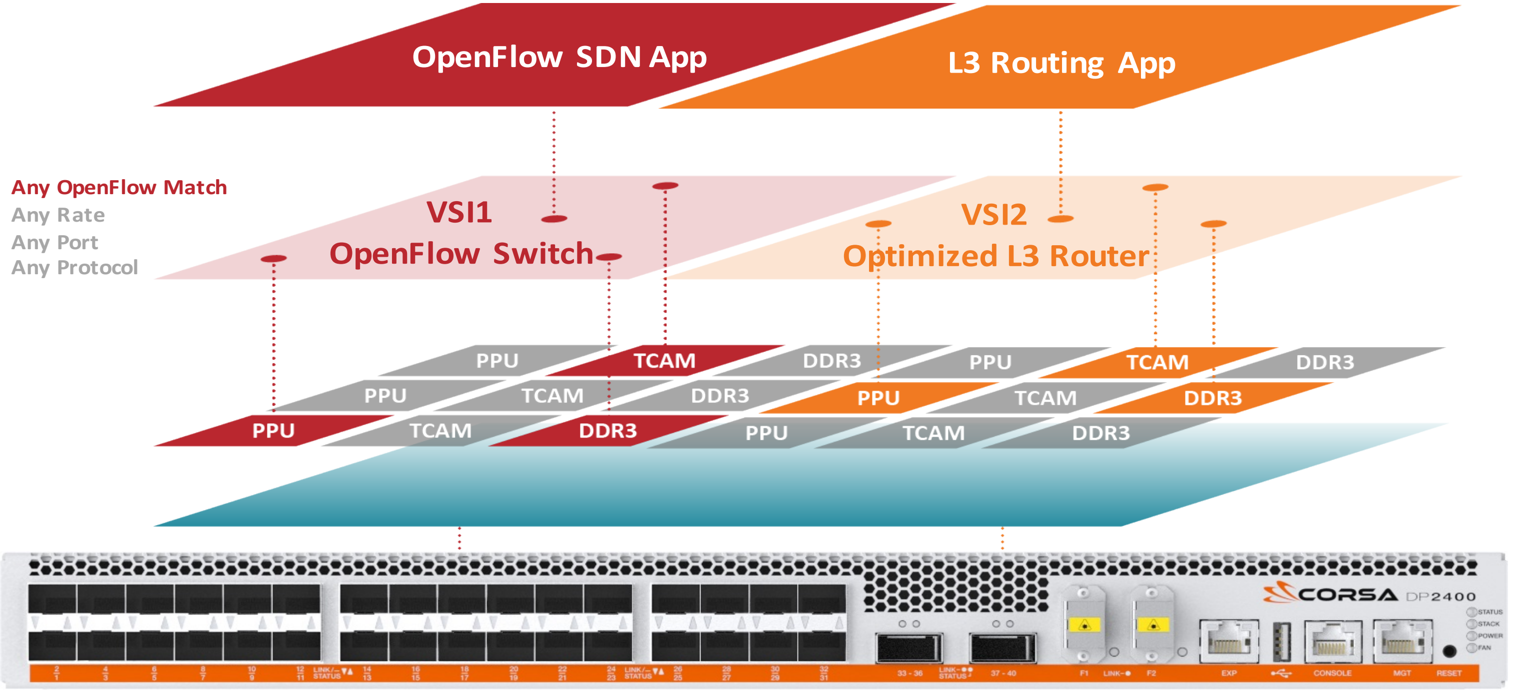
Solution

- Key operation: 2-tuple swap – in the fast path
- On ingress:
  - phyPort / transTag -> VSI / vport; pop* transTag
- On egress:
  - VSI / vport -> phyPort / transTag; push* transTag;

- Look up is ~=cost as an MPLS label swap … Very fast
- Pop & Push actions are configurable
- TransTag can be outer VLAN or MPLS label

Multiple VSIs on one switch

ıltiple SDN
plications
ıtrolling VFCs



OpenFlow SDN App

L3 Routing App

Any OpenFlow Match
Any Rate
Any Port
Any Protocol

VSI1
OpenFlow Switch

VSI2
Optimized L3 Router

tual Switch
stances

rdware
source Pool

ıgle piece
hardware

Hardware design challenges

- Corsa has done some impressive advanced hardware design to support VSIs:
- Increased number of OpenFlow tables
  - Reduction in memory usage
- New algorithmic lookup for flow entries
  - This allows increase in flow table size to 1 Million entries
- Virtualization of QoS, metering and statistics
  - Specialised ASIC performs these

- We will let Corsa describe their work themselves (in another talk☺)

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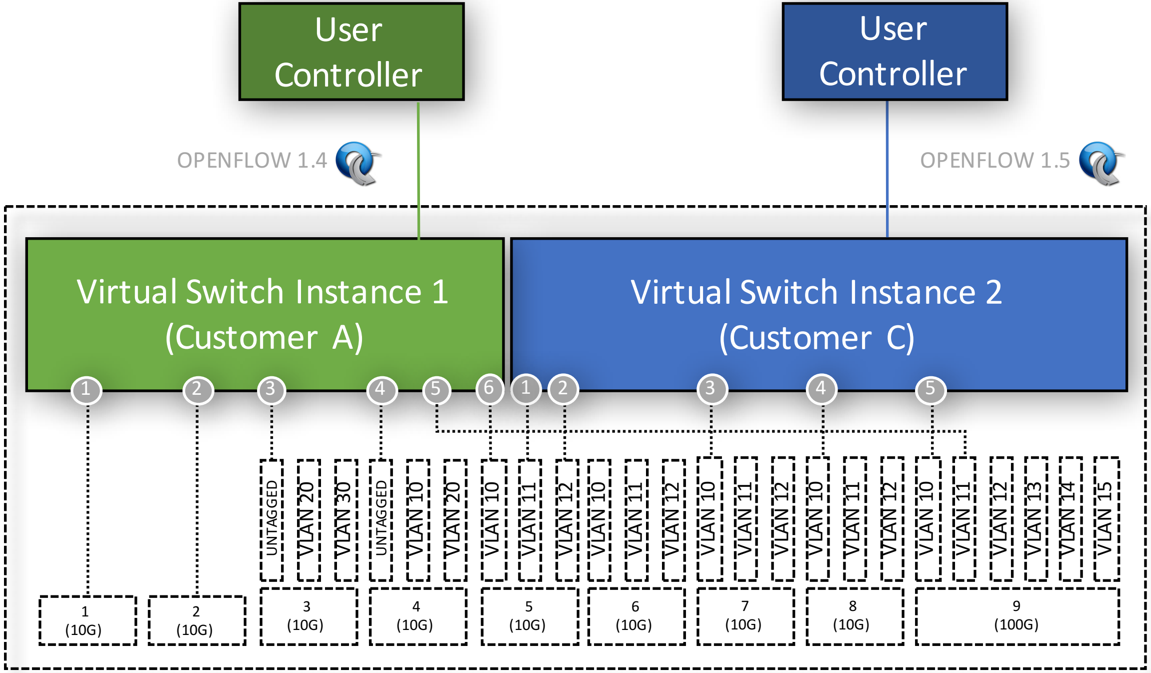
The result



User Controller

User Controller

OPENFLOW 1.4

OPENFLOW 1.5

Virtual Switch Instance 1
(Customer A)

Virtual Switch Instance 2
(Customer C)

1 2 3 4 5 6

1 2 3 4 5

UNTAGGED
VLAN 20
VLAN 30
UNTAGGED
VLAN 10
VLAN 20
VLAN 10
VLAN 11
VLAN 12
VLAN 10
VLAN 11
VLAN 12
VLAN 10
VLAN 11
VLAN 12
VLAN 10
VLAN 11
VLAN 12
VLAN 10
VLAN 11
VLAN 12
VLAN 13
VLAN 14
VLAN 15

1 (10G)
2 (10G)
3 (10G)
4 (10G)
5 (10G)
6 (10G)
7 (10G)
8 (10G)
9 (100G)

VSI Benefits for providers

- **VSI**s are “well bounded” service objects
  - They can be allocated securely to arbitrary users
  - Users only see their own traffic
  - Multiple VSIs are hosted on a single device
  - Support full transport encapsulation
- **VSI**s can be migrated
  - Enables operational maintenance of HW
  - Enables grooming of VSI for HW efficiency
- **VSI** 2-tuple mapping enable port / link sharing
- **VSI**s can be applied to native transport tags

VSI Benefit for users

- VSIs are seen as dedicated OpenFlow switches
- VSIs run at line rate – even up to 100Gbps(!)
- VSI virtual ports reduced complexity for controllers/applications
- VSIs solve a major festering SDN scaling problem:
  - Inter-domain control authorization
  - Inter-domain topology visibility
- VSI are specified by users to fit their requirements

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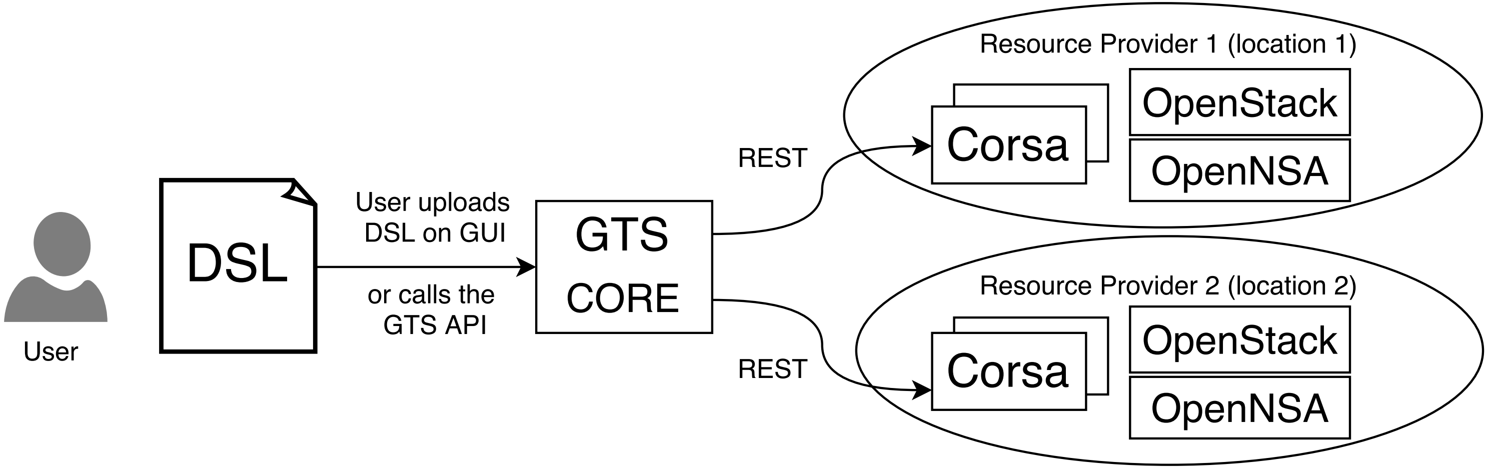
Software integration

- VSIs have been integrated to GTS



GTS High-level overview

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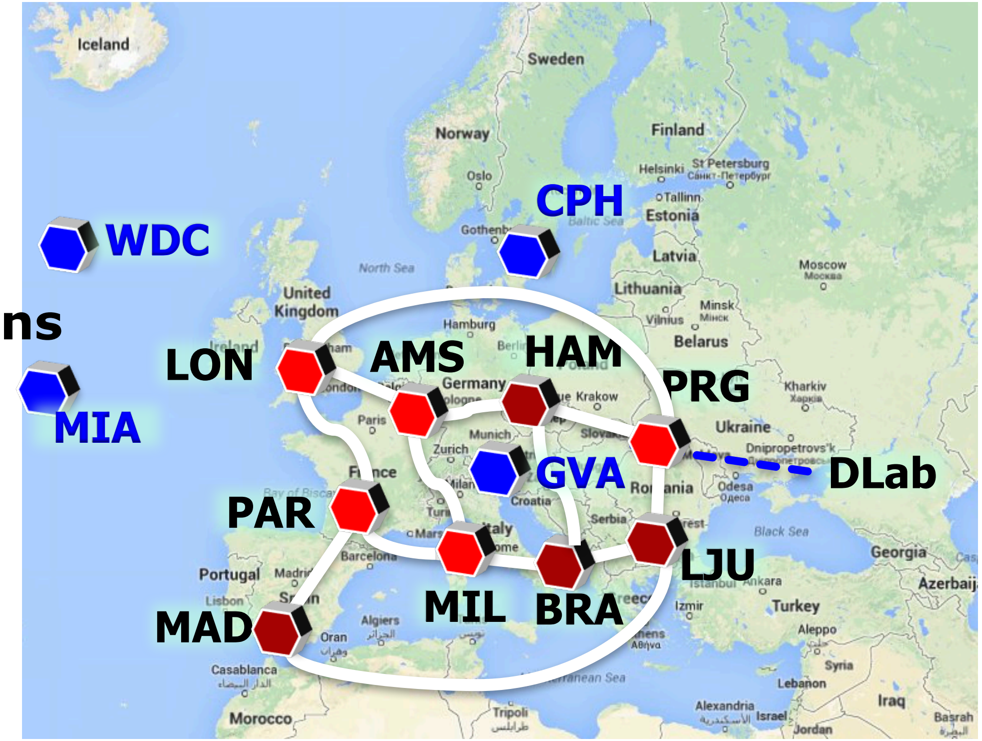
Current VSI Deployment – 2016-Q4

- **Current GTS Pod locations:**
  - In-service: **Amsterdam, Bratislava, Ljubljana, Prague, London, Milan, Hamburg, Paris, Madrid**
- **Current NORDUnet GVS locations**
  - **In Service: Copenhagen, Geneva, WashingtonDC, Miami**
- **Others in the pilots:**
  - **HEAnet:** Dublin
  - **CESnet:** Prague, Bruno
  - **DFN:** Nuremburg (Erlangen),
- Other interest:
  - StarLight (Chicago), CENIC (Sunnyvale), Ciena(US & CA), others in discussion…



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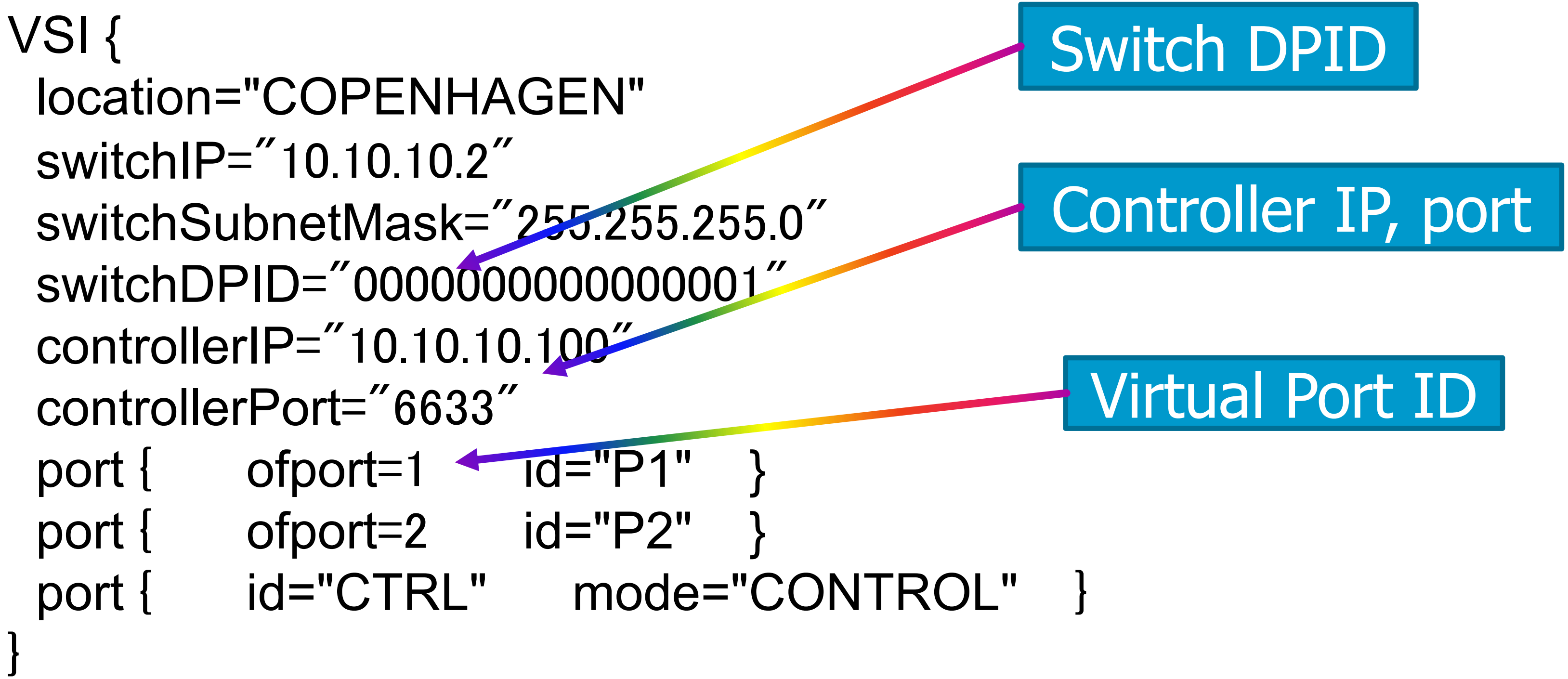
DSL for VSIs

- A DSL can define every parameter of the user’s VSI



```
VSI {
  location="COPENHAGEN"
  switchIP=″10.10.10.2″
  switchSubnetMask=″255.255.255.0″
  switchDPID=″0000000000000001″
  controllerIP=″10.10.10.100″
  controllerPort=″6633″
  port {      ofport=1      id="P1"    }
  port {      ofport=2      id="P2"    }
  port {      id="CTRL"      mode="CONTROL"    }
}
```

Initial Performance Evaluation

- Performance of VSIs is crucial(!)
- We evaluated throughput of VSIs with various packet sizes
- Used:
  - “Software-Defined Exchange” pipeline on the switches
  - DPDK-pktgen to generate and measure received packets

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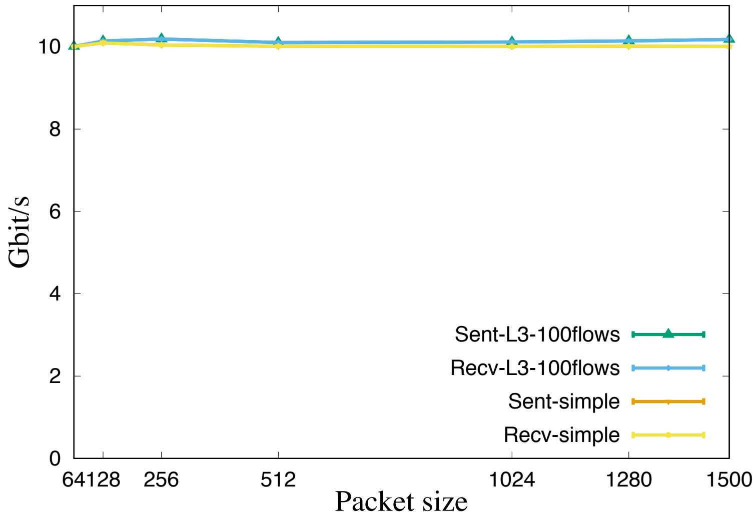
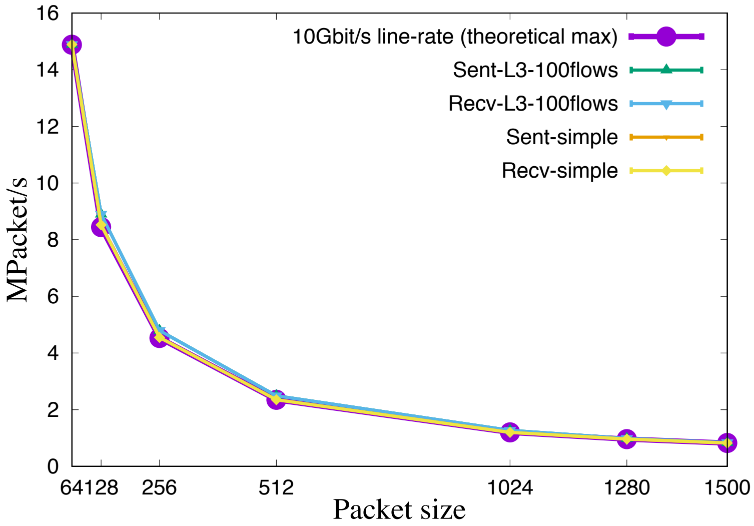
Throughput of a single VSI

Two experiments:

- 100flows: 100 L3 flow entries matched
- Simple: input port-output port flow entry matched





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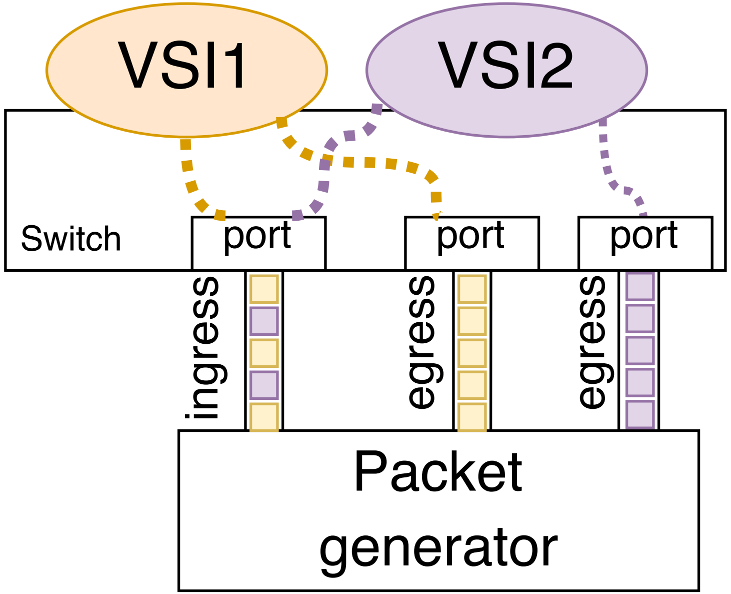
Multiple VSIs

VSIs can share the same physical ports.
We used this setup to evaluate resource sharing:



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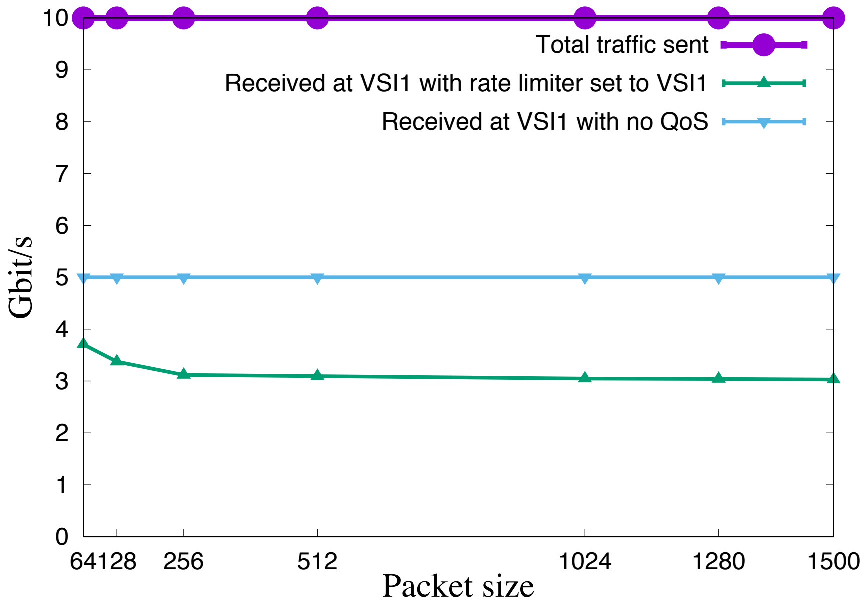
Multiple VSIs - results

Two scenarios measured:

1. No rate limiting set (equal sharing of link)
2. 3Gbit/s rate limiter set to VSI1



Conclusions and Next Steps

- The VSI works and solves a number of SDN challenges
  - Many thanks to **Corsa Technologies** for their collaboration on this!
- The “VSI” is an open concept.
  - It is not proprietary, we hope other vendors will adopt it
- VSIs are being deploy[ing] now:
  - Now: NORDUnet Global Virtualization Service, GEANT Testbeds Service (GTS)
  - Future: DFN, CESnet, HEAnet, US in discussions...
- Y’all come play!   Help us refine VSIs!