CERN

Programming switches for flow label accounting, forwarding and routing

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Recapitulation

Programming protocol-independent packet processors: P4 language

Language for programming the data plane of network devices

- Define how packets are processed
- P4 program structure: header types, parser/deparser, match-action tables, user-defined metadata and intrinsic metadata

Domain-specific language designed to be implementable on a large variety of targets

- Programmable network interface cards, FPGAs, software switches and hardware ASICs.

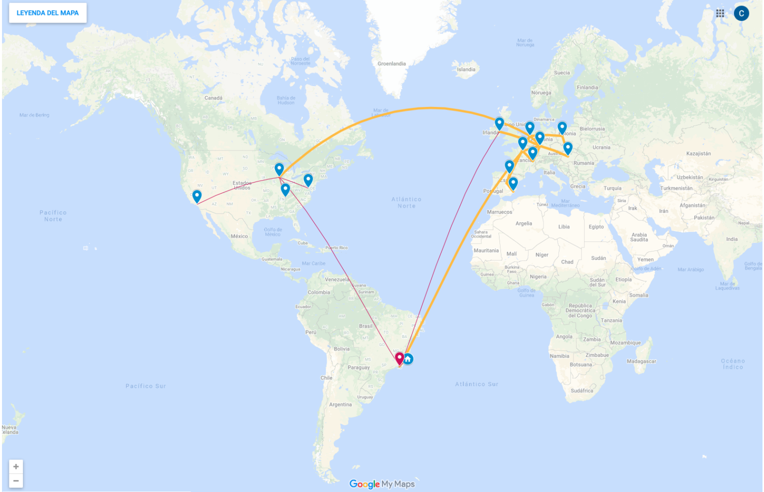
EdgeCore Wedge100BF-32QS

- 100GbE Data Center Switch
    - Bare-Metal Hardware
    - L2/L3 Switching
    - 32xQSFP28 Ports
- Data-Plane Programmability
    - Intel Tofino Switch Silicon
    - Barefoot Networks
- Quad-Pipe Programmable Packet Processing Pipeline
    - 6.4 Tbps Total Bandwidth
- CPU: Intelx86 Xeon 2.0GHz
    - 8-core/48GB/2TB SSD

Figure: Intel Tofino P4-programmable Ethernet Switch ASIC

Figure: EdgeCore Wedge100BF-32QS

GÉANT P4Lab


LEYENDA DEL MAPA
Groenlandia
Islandia
Canadá
Estados Unidos
México
Atlántico Norte
Pacífico Norte
Pacífico Sur
Atlántico Sur
Brasil
Argentina
Perú
Bolivia
Paraguay
Chile
Colombia
Venezuela
Noruega
Suecia
Finlandia
Irlanda
Bielorrusia
Ucrania
Kazajistán
Rumanía
Italia
Portugal
Grecia
Turquía
Marruecos
Argelia
Libia
Egipto
Mauritania
Malí
Níger
Chad
Sudán
Nigeria
Etiopía
Somalia
Kenia
Tanzania
Angola
Zambia
Namibia
Botsuana
Sudáfrica
Madagascar
Mozambique
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Network Operating System

RARE/FreeRtr

- Controls the data plane by managing entries in routing tables
- Free and open source router operating system
- Export forwarding tables to DPDK or hardware switches
  - via OpenFlow or P4lang
- No global routing table
  - Every routed interface must be in a virtual routing table

Packet and flow marking specification

Flow label field of IPv6 header: 20 bits [Packet marking specification ref. [1, 2]]

- 5 entropy bits to match RFC 6436
- 9 bits to define the science domain
- 6 bits to define the application/type of traffic

Bits 12 - 13 Entropy	Bits 14 - 22 Science Domain	Bit 23 Entropy	Bits 24 - 29 Application	Bits 30 - 31 Entropy

```
Astro/HEP Science Domains:
Reserved - 0
Default  - 65536
ATLAS    - 32768
CMS      - 98304
LHCb     - 16384
ALICE    - 81920
Bellell  - 49152
SKA      - 114688
LSST     - 73728
DUNE     - 8192
```

```
Application:
Reserved      - 0
Default       - 4
perfSONAR     - 8
Cache         - 12
DataChallege - 16
```

Accounting and forwarding

First approach: layer 3

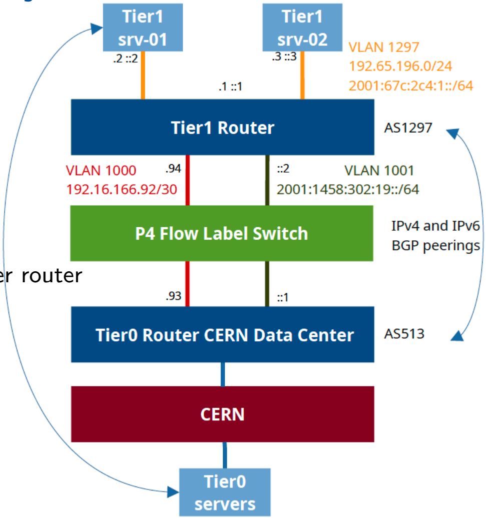
Network configuration:

- Virtual Routing Forwarding
- Policy-based routing based on flow label field value
  - Flow label 10 → VLAN 40
  - Flow label 20 → VLAN 41
- SRV-01 managed by Cisco TRex Realistic Traffic Generator
  - Python script Scapy library: generate IPv6 packets flow label tagged
  - Cisco TRex Client: Python script → Scapy library
  - Cisco TRex Server: get statistic of the traffic in real-time
- SRV-02 managed by DPDK FreeRtr

Second approach: layer 2

Network configuration:

- Emulates a Tier 1/0 link
- Tier1/0 routers
  - IPv4/IPv6 BGP peerings
- Tier0 router
  - LHCOPN production border router
- Pure layer 2 bridges
  - VLAN 1000: IPv4 traffic
  - VLAN 1001: IPv6 traffic
- Tier0 servers
  - OpenStack product servers



Second approach: layer 2

P4 switch network configuration: pure layer 2 bridges

```
access-list acl_all_ipv6_flowlabels
     # Match <Experiment> and <ANY Application>
     sequence 10 permit all any all any all flow 131076 & 261884
     sequence 11 permit all any all any all flow 65540  & 261884
     sequence 12 permit all any all any all flow 196612 & 261884
     sequence 13 permit all any all any all flow 32772  & 261884
     # Match <Experiment> and <perfSONAR Application>
     sequence 20 permit all any all any all flow 131072 & 261632
     sequence 21 permit all any all any all flow 65536  & 261632
     sequence 22 permit all any all any all flow 196608 & 261632
     sequence 23 permit all any all any all flow 32768  & 261632
     # Permit the rest of the traffic
     sequence 30 permit all any all any all
     exit
```

ATLAS <any>
CMS <any>
LHCb <any>
ALICE <any>

ATLAS <perfSONAR>
CMS <perfSONAR>
LHCb <perfSONAR>
ALICE <perfSONAR>

```
interface sdn1.1000
     description [VLAN ID=1000]
     bridge-group 1
     no shutdown
     no log-link-change
     exit
```

VLAN 1000 belongs to bridge 1

```
interface sdn1.1001
     description [VLAN ID=1001]
     bridge-group 2
     bridge-filter ipv6in acl_all_ipv6_flowlabels
     no shutdown
     no log-link-change
     exit
```

VLAN 1001 belongs to bridge 2
Filter IPv6 traffic at the input based on the access-list sentences

Second approach: layer 2

IPv6 packets flow label tagged were generated by using:

- iperf3
- ipv6_flow_label library developed by Marian Babik
- eBPF_flow_label library developed by Tristan Sullivan

```
E513-E-YECWH-1#show access-list acl_all_ipv6_flowlabels
seq  txb  txp  rxb            rxp         last      timout    cfg
10   0+0  0+0  0+12374638771  0+8743031   00:03:02  00:00:00  permit all any all any all flow 131076&261884   ATLAS <any>
11   0+0  0+0  0+37019728635  0+24984028  00:02:30  00:00:00  permit all any all any all flow 65540&261884    CMS   <any>
12   0+0  0+0  0+23940164205  0+15797973  00:02:00  00:00:00  permit all any all any all flow 196612&261884   LHCb  <any>
13   0+0  0+0  0+18150017192  0+12017039  00:02:00  00:00:00  permit all any all any all flow 32772&261884    ALICE <any>

20   0+0  0+0  0+30346726207  0+20005622  00:01:29  00:00:00  permit all any all any all flow 131072&261632   ATLAS <perfSONAR>
21   0+0  0+0  0+25281078379  0+16663278  00:01:29  00:00:00  permit all any all any all flow 65536&261632    CMS   <perfSONAR>
22   0+0  0+0  0+28556351375  0+19008806  00:00:58  00:00:00  permit all any all any all flow 196608&261632   LHCb  <perfSONAR>
23   0+0  0+0  0+37078713993  0+25770785  00:00:26  00:00:00  permit all any all any all flow 32768&261632    ALICE <perfSONAR>
30   0+0  0+0  0+2715536713   0+1802921   00:00:26  00:00:00  permit all any all any all
```

Figure: Counters of the access-list on the P4 switch

Demo SC22

- We demonstrated the accounting of tagged packets is feasible.

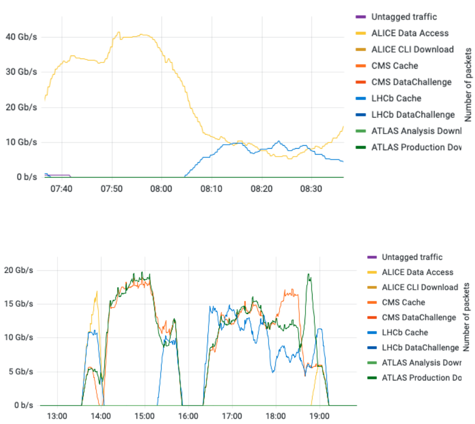


Figure: Counters of an access-list in bits/s

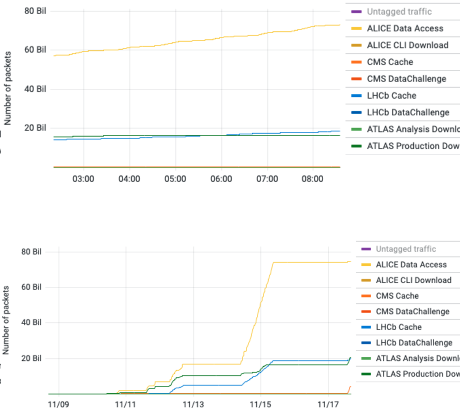


Figure: Counters of an access-list in number of packets

Routing

MultiONE proposal

Separate the traffic into different VPNs based on the IPv6 flow label value.

- MultiONE network: 3 VPNs (blue, green, red)

  + a default VPN for IPv4 and untagged traffic
  - COTS routers with BGP and IPv6.
  - Peering with the site routers and redistribute the received prefixes.
- P4 site routers: to access the proper multiONE VPN based on the routes received from BGP a

  flow label tag of the packets.
  - P4 programmable switches [P4Lab].
  - Announce the IPv6 prefixes of the local servers to the connected VRFs via BGP.
- Site servers: generate and receive tagged traffic.

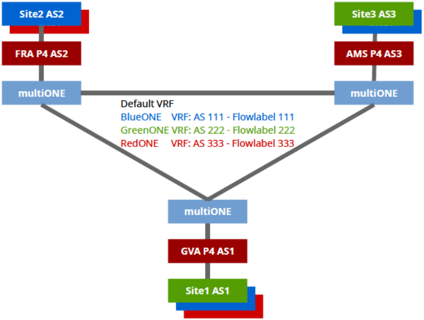
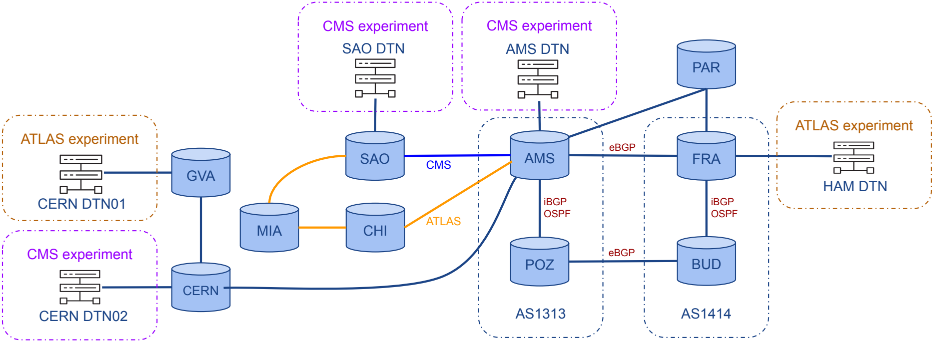


Figure: MultiONE testbed.

MultiONE testbed in GP4Lab



- SAO P4 switch routes the traffic with PBR rules based on an access-list.
  - CMS traffic routing: SAO DTN → SAO → AMS → AMS DTN
  - ATLAS traffic routing: SAO DTN → SAO → MIA → CHI → AMS → AMS DTN
- CERN DTNs generates tagged traffic to AMS DTN and HAM DTN.
  - The traffic is routed in the squared topology to ATLAS or CMS VPN so that LHCONE sites can only access other sites belonging to the same experiment.

MultiONE testbed in GP4Lab

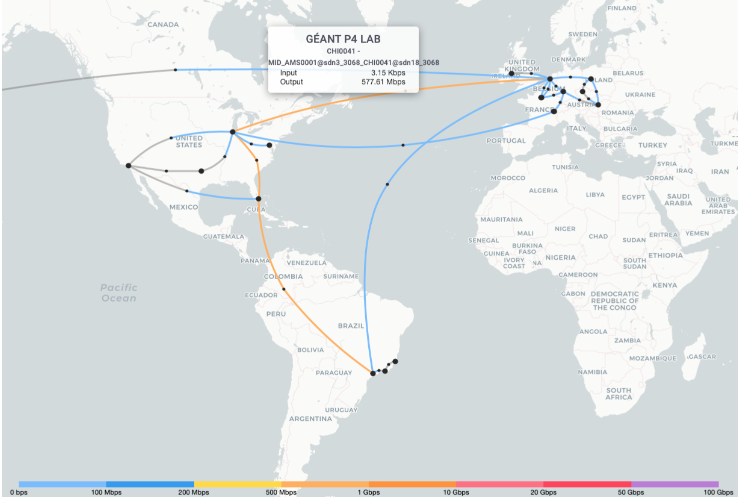


Figure: ATLAS traffic routing from Sao Paulo to Amsterdam via Chicago and Miami.

MultiONE testbed in GP4Lab

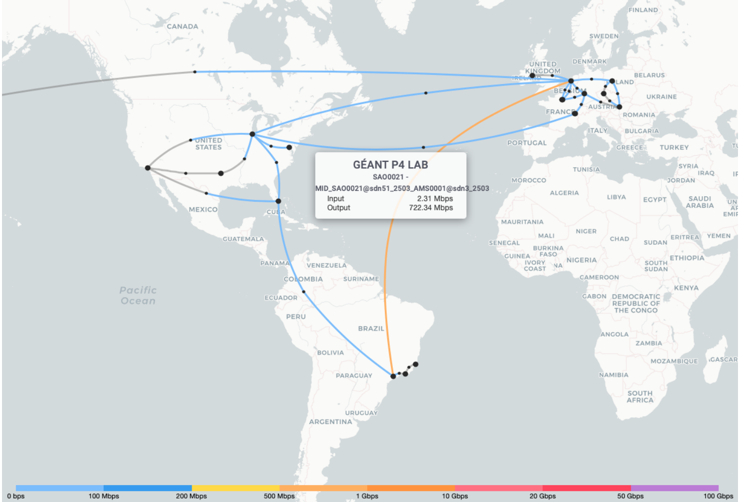
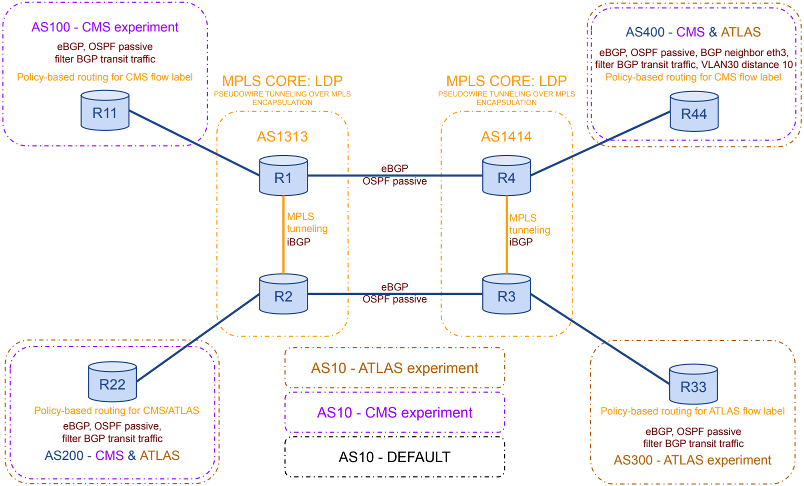


Figure: CMS traffic routing from Sao Paolo directly to Amsterdam.

MultiONE MPLS core simulation



MultiONE MPLS core simulation

LHCONE providers: R1, R2, R3, R4

- MPLS Core with Layer 3 VPNs:
  - One VPN per experiment
  - A default VPN for IPv4 and untagged traffic
- {R1, R2}: AS 1313, iBGP, OSPF
  {R3, R4}: AS 1414, iBGP, OSPF
  Normal routing, eBGP peering and redistribution of prefixes

LHCONE sites: R11, R22, R33, R44

- Belongs to one or more experiments
- P4 programmable switches
- PBR rules

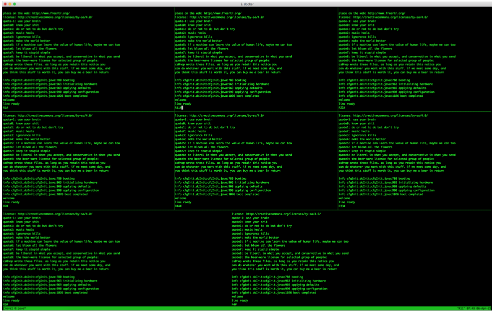


Figure: MultiONE simulation running in a docker container (Debian OS, FreeRtr NOS).

Survey of network processors

Survey of network processors

- Juniper: matching possible on Express4 and Trio5, may be limited to 16 bits (out of 20). On the roadmap for JunosEVO 24.2
- Broadcom: Trident4 and Jericho2 seem to be capable but there is no software implementation. Feature requested to Juniper for their Broadcom switches, but no commitment yet. SONiC probably does not support the flow label - work to be done.
- Cisco: capability to look into the field through their UserDefinedField ACL security matching – present on CloudScale ASICs. It can match sets of 16 bits with arbitrary offset and mask. Today this is not packaged into a feature that is ready to be used with PBR - work to be done.
- Nokia: not supported.
- NVIDIA: no interest

Conclusions and future lines

- The IPv6 flow label accounting and forwarding can be implemented at layer 3 and layer 2.
- By using the real hardware of GP4Lab we demonstrated that MultiONE can be implemented by using PBR rules based on an access-list with the flow label definitions on the clients to control the access to each VPN.
- MultiONE simulation with an MPLS core L3VPNs running on a Docker container .

Thanks for your attention!

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