VPP: IPv4-lite

A 100Mpps+ BGP/OSPFv3 router with a single IPv4 address

Pim van Pelt • 2024–09-27 • FRNOG • Paris, France

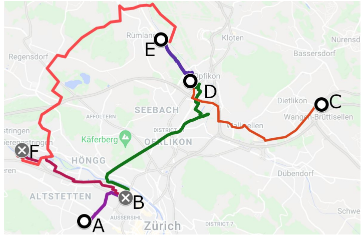
go.ipng.ch/frnog40

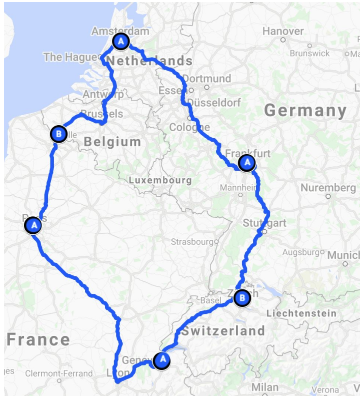
Intro: Pim van Pelt (PBVP1-RIPE)

Pim van Pelt

- Member of the RIPE community since 1999 (RIPE #34)
  - Has used [pim@ipng.nl] for 25 years
  - And also [pim@ipng.ch] for 18 years
  - Incorporated [ipng.ch] in Switzerland in 2021

Intro: IPng Networks - AS8298

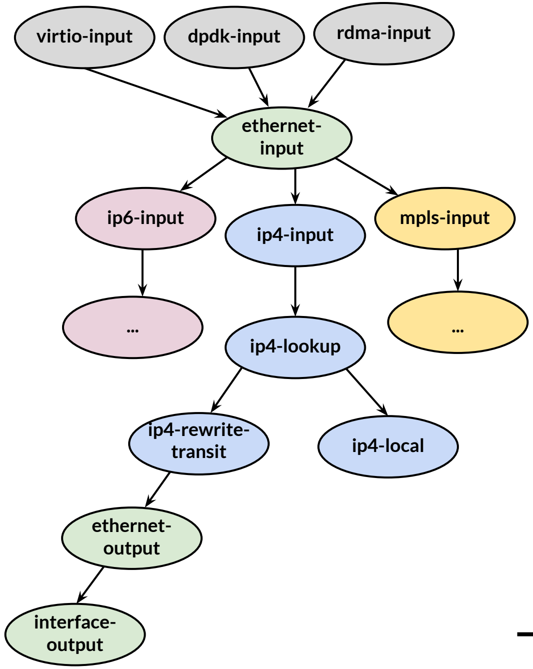




- Developer of Software Routers - DPDK and VPP [ref]
- Tiny operator from Brüttisellen (ZH), Switzerland [ref]

- Thirteen VPP/Bird2 routers [ref] (UN/LOCODE names)
- European ring: *peering on the FLAP** [ref] ~2’150 adjacencies
- Acquired AS8298 from SixXS [ref]

Intro: Vector Packet Processing



FD.io VPP [ref] is an open source dataplane that:

- runs in userspace,
- provides *very* fast networking,
- using DPDK, RDMA, VirtIO, VMXNet3, AVF, …
- easily exceeds 100Mpps+ and 100Gbps+
- on commodity x86_64 / amd64 hardware!

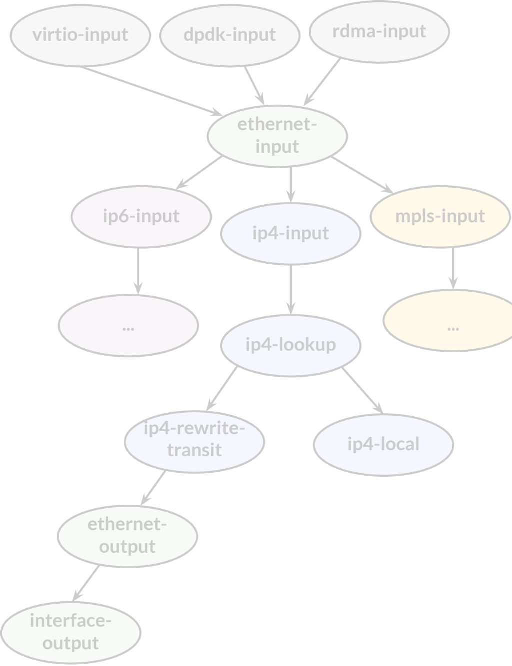
See FOSDEM'22 [video] or GRNOG #16 [video]

- Contributed* to **Linux Control Plane** plugin [GitHub]
- LinuxCP adds BGP/OSPF/VRRP/etc to VPP

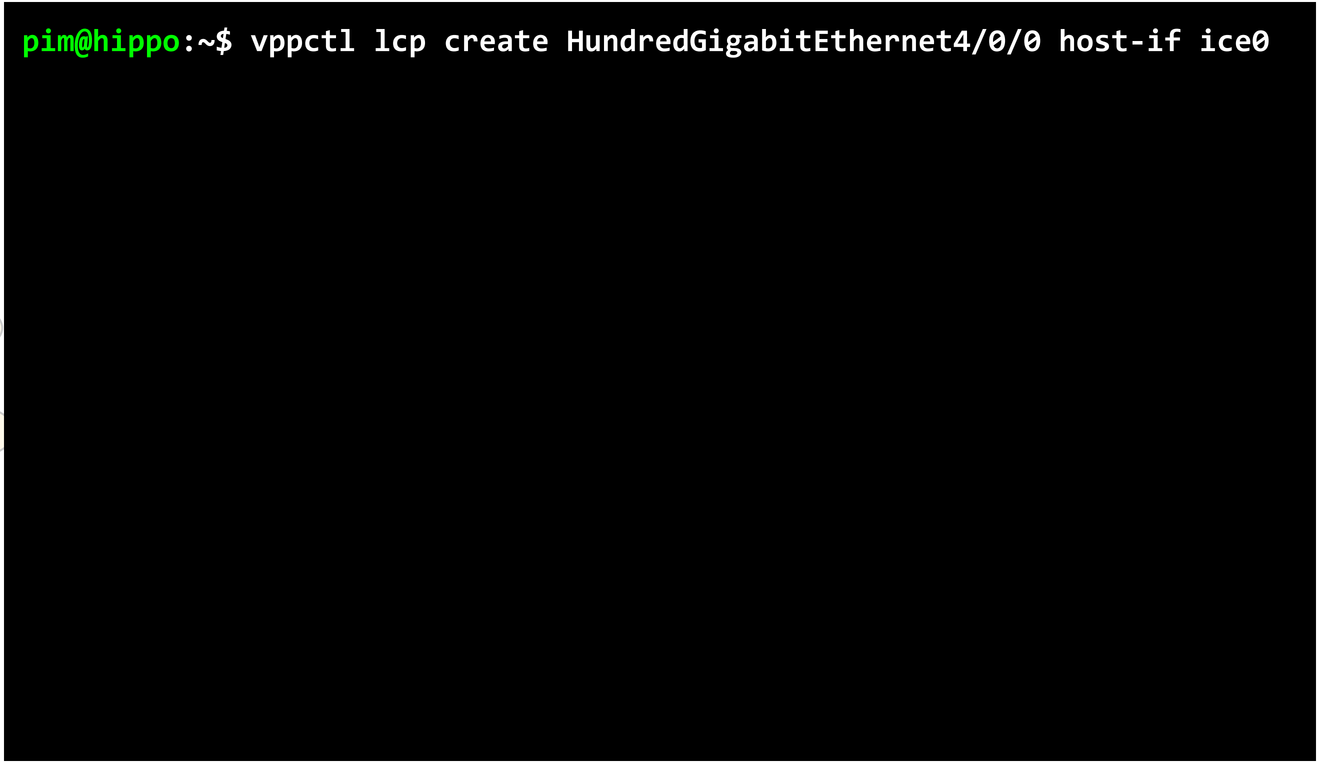
This talk: **ARP/ND/Unnumbered in VPP** and **OSPFv3+ in Bird2.**

*) *Thanks to Pierre Pfister, Neale Ranns, Matt Smith and Jon Loeliger for the [collaboration]!*

Intro: VPP LinuxCP

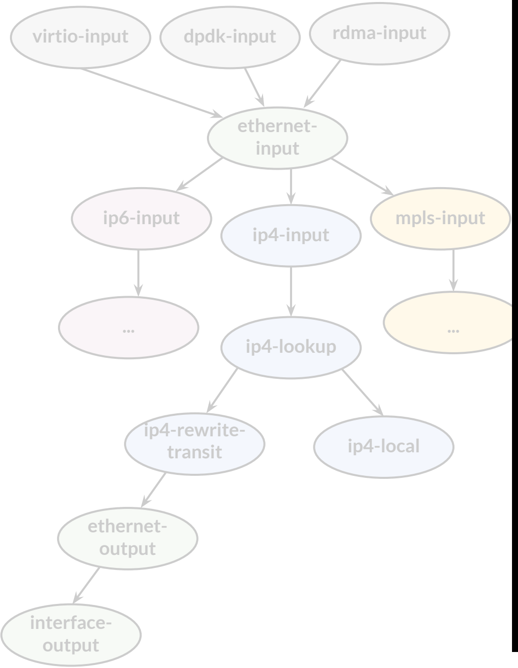


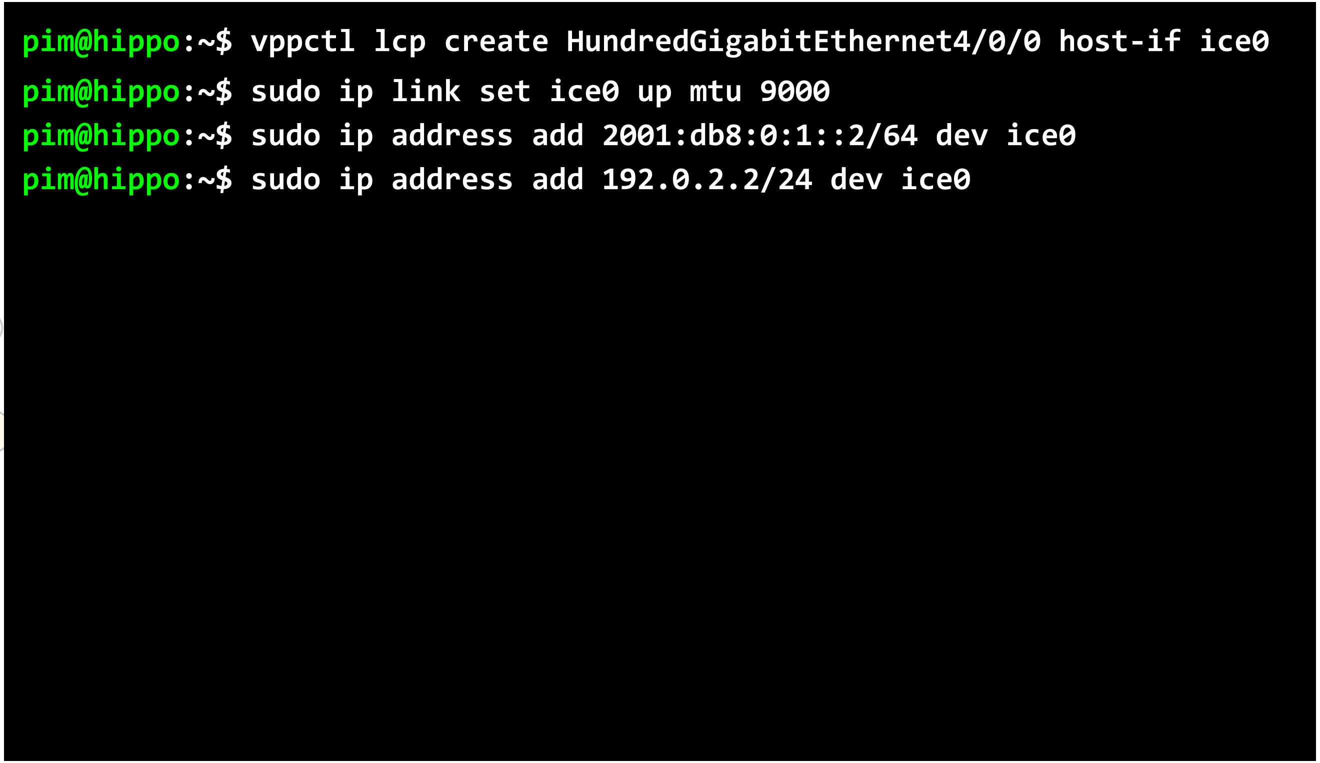
virtio-input
dpdk-input
rdma-input
ethernet-input
ip6-input
ip4-input
mpls-input
...
ip4-lookup
...
ip4-rewrite-transit
ip4-local
ethernet-output
interface-output



```
pim@hippo:~$ vppctl lcp create HundredGigabitEthernet4/0/0 host-if ice0
```

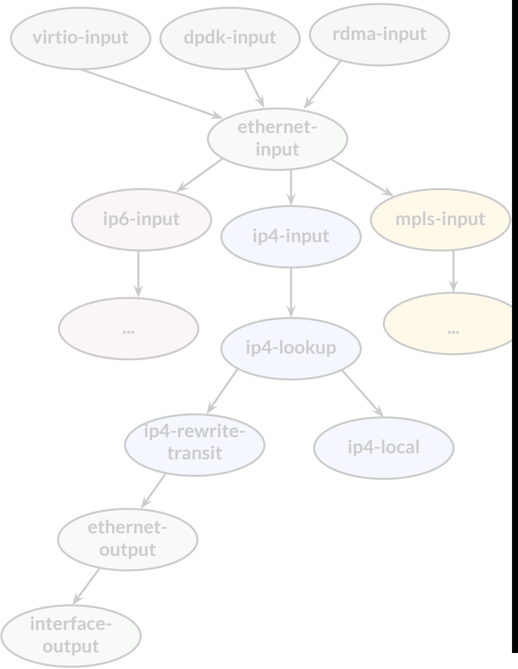
Intro: VPP LinuxCP

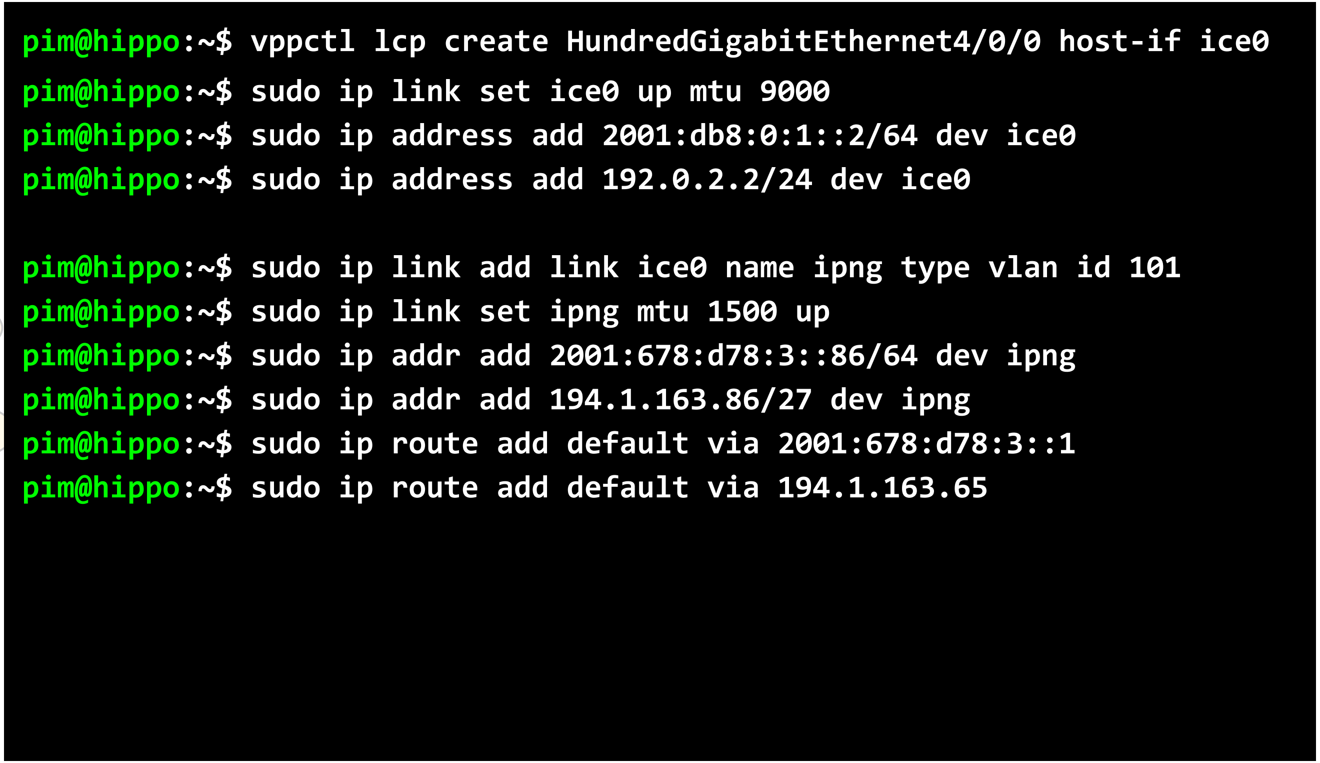




```
pim@hippo:~$ vppctl lcp create HundredGigabitEthernet4/0/0 host-if ice0
pim@hippo:~$ sudo ip link set ice0 up mtu 9000
pim@hippo:~$ sudo ip address add 2001:db8:0:1::2/64 dev ice0
pim@hippo:~$ sudo ip address add 192.0.2.2/24 dev ice0
```

Intro: VPP LinuxCP





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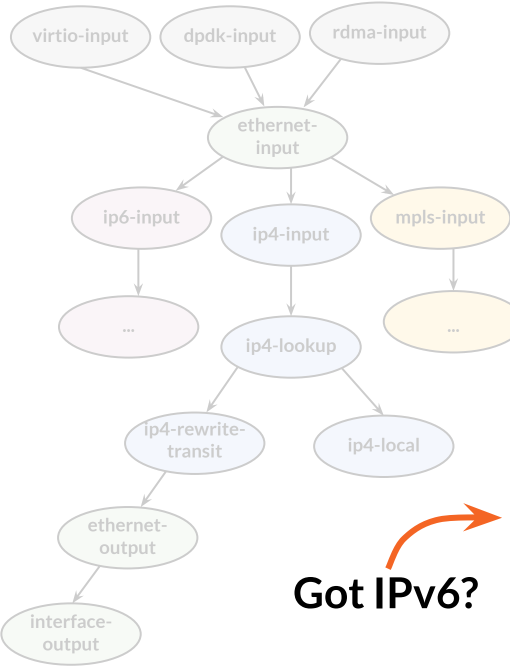
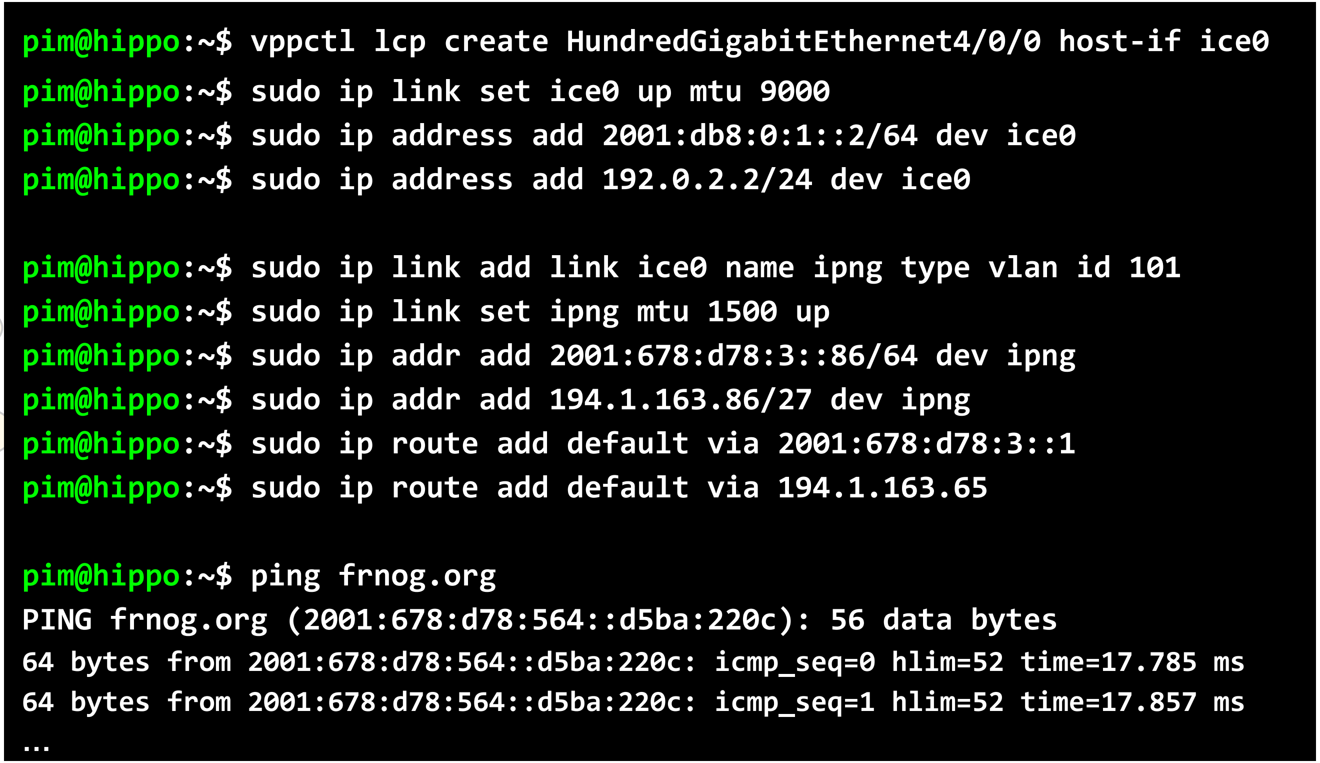
pim@hippo:~$ sudo ip address add 192.0.2.2/24 dev ice0

pim@hippo:~$ sudo ip link add link ice0 name ipng type vlan id 101
pim@hippo:~$ sudo ip link set ipng mtu 1500 up
pim@hippo:~$ sudo ip addr add 2001:678:d78:3::86/64 dev ipng
pim@hippo:~$ sudo ip addr add 194.1.163.86/27 dev ipng
pim@hippo:~$ sudo ip route add default via 2001:678:d78:3::1
pim@hippo:~$ sudo ip route add default via 194.1.163.65
```

Intro: VPP LinuxCP

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pim@hippo:~$ vppctl lcp create HundredGigabitEthernet4/0/0 host-if ice0
pim@hippo:~$ sudo ip link set ice0 up mtu 9000
pim@hippo:~$ sudo ip address add 2001:db8:0:1::2/64 dev ice0
pim@hippo:~$ sudo ip address add 192.0.2.2/24 dev ice0

pim@hippo:~$ sudo ip link add link ice0 name ipng type vlan id 101
pim@hippo:~$ sudo ip link set ipng mtu 1500 up
pim@hippo:~$ sudo ip addr add 2001:678:d78:3::86/64 dev ipng
pim@hippo:~$ sudo ip addr add 194.1.163.86/27 dev ipng
pim@hippo:~$ sudo ip route add default via 2001:678:d78:3::1
pim@hippo:~$ sudo ip route add default via 194.1.163.65

pim@hippo:~$ ping frnog.org
PING frnog.org (2001:678:d78:564::d5ba:220c): 56 data bytes
64 bytes from 2001:678:d78:564::d5ba:220c: icmp_seq=0 hlim=52 time=17.785 ms
64 bytes from 2001:678:d78:564::d5ba:220c: icmp_seq=1 hlim=52 time=17.857 ms
…
```

Got IPv6?

Act 1: IPv4 OSPFv3 with VPP

OSPFv3: Enter a gross hack

[RFC 5838]: support multiple address families in OSPFv3

Although IPv6 link local addresses could be used as next hops for IPv4 …
… it is desirable to have IPv4 next-hop addresses
... IPv4 will be advertised in the “link local address” field in Link-LSA
… address is placed in the first 32 bits of the “link local address” field
… and the remaining bits MUST be set to zero.

This approach fundamentally breaks IPv6 next-hops!

🤦 `s/could be used/`**`cannot ever be used`**`/`

OSPFv3: Unnumbered

Clever solution by santiago@ in [commit] to Bird2:

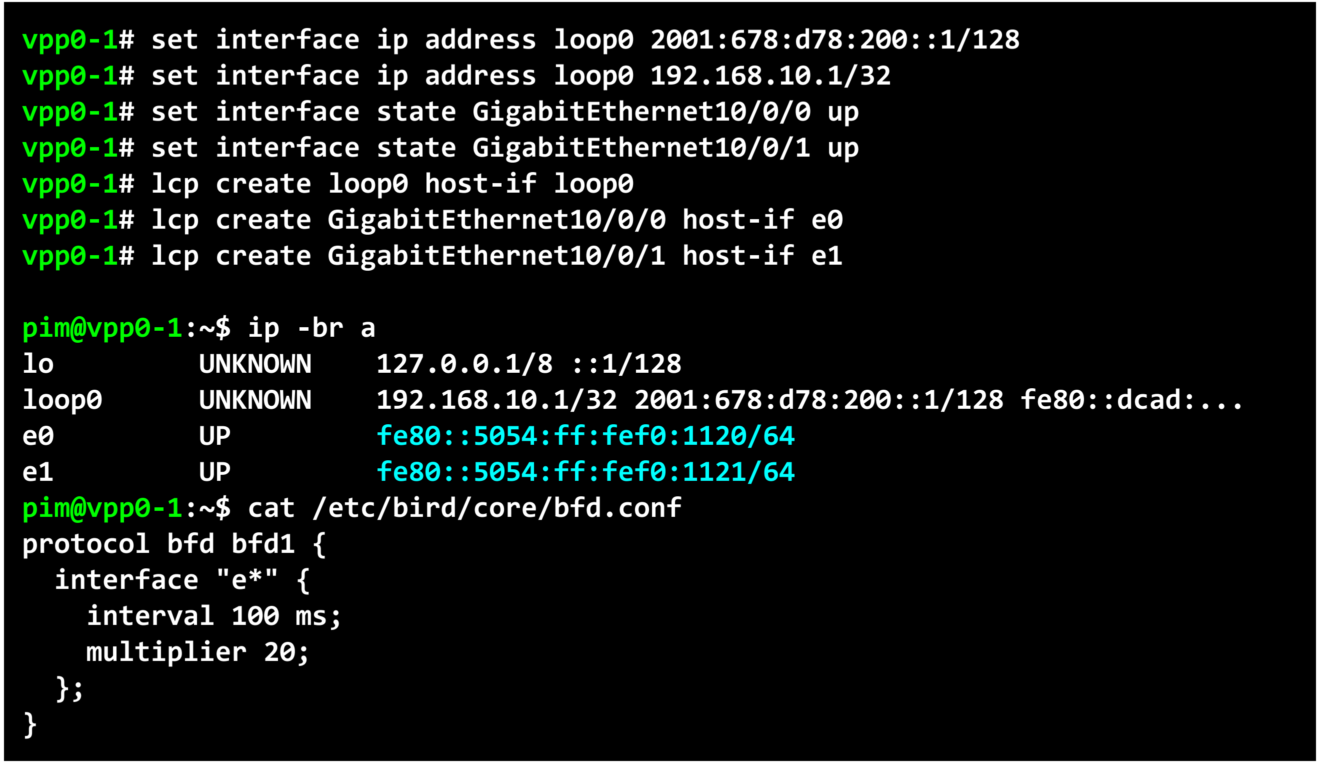
Add `update_loopback_addr()` to scan *all* IPv4 interfaces

1. prefer *host* (/32) addresses
2. else use *OSPF stub* addresses
3. else just any old IPv4 address

No interface IPv4 address?

- Find one for the (RFC5838) Link-LSA
- Learn routes as `RNF_ONLINK` from /32 neighbors

VPP: Unnumbered with OSPFv3



```
vpp0-1# set interface ip address loop0 2001:678:d78:200::1/128
vpp0-1# set interface ip address loop0 192.168.10.1/32
vpp0-1# set interface state GigabitEthernet10/0/0 up
vpp0-1# set interface state GigabitEthernet10/0/1 up
vpp0-1# lcp create loop0 host-if loop0
vpp0-1# lcp create GigabitEthernet10/0/0 host-if e0
vpp0-1# lcp create GigabitEthernet10/0/1 host-if e1

pim@vpp0-1:~$ ip -br a
lo          UNKNOWN    127.0.0.1/8 ::1/128
loop0       UNKNOWN    192.168.10.1/32 2001:678:d78:200::1/128 fe80::dcad:...
e0          UP         fe80::5054:ff:fef0:1120/64
e1          UP         fe80::5054:ff:fef0:1121/64
pim@vpp0-1:~$ cat /etc/bird/core/bfd.conf
protocol bfd bfd1 {
  interface "e*" {
    interval 100 ms;
    multiplier 20;
  };
}
```

Status

✓ VPP+BFD: Config

OSPFv3: Config

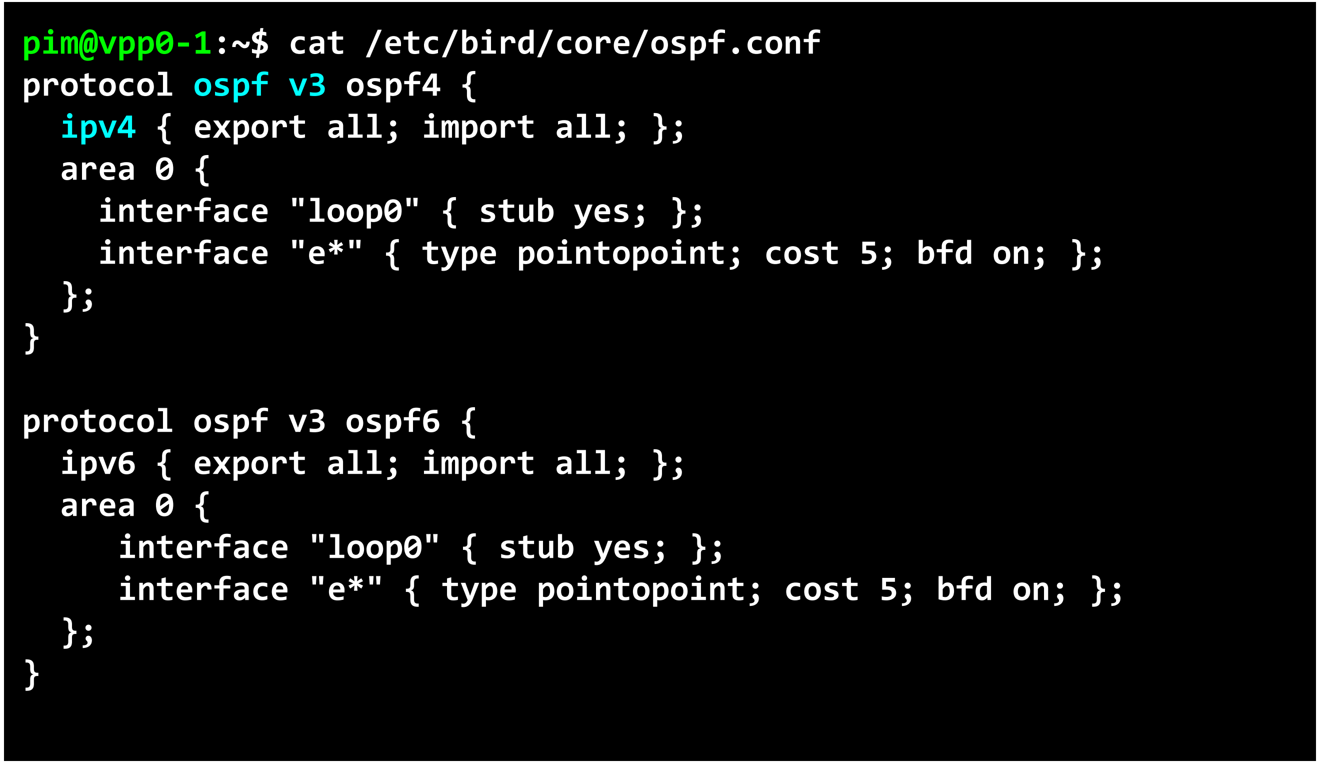
BFD+OSPFv3: Adjacency

OSPFv3: Learning

VPP: Forwarding

VPP: ICMPv4

VPP: Unnumbered with OSPFv3



```
pim@vpp0-1:~$ cat /etc/bird/core/ospf.conf
protocol ospf v3 ospf4 {
  ipv4 { export all; import all; };
  area 0 {
    interface "loop0" { stub yes; };
    interface "e*" { type pointopoint; cost 5; bfd on; };
  };
}

protocol ospf v3 ospf6 {
  ipv6 { export all; import all; };
  area 0 {
     interface "loop0" { stub yes; };
     interface "e*" { type pointopoint; cost 5; bfd on; };
  };
}
```

Status

✓ VPP+BFD: Config

✓ OSPFv3: Config

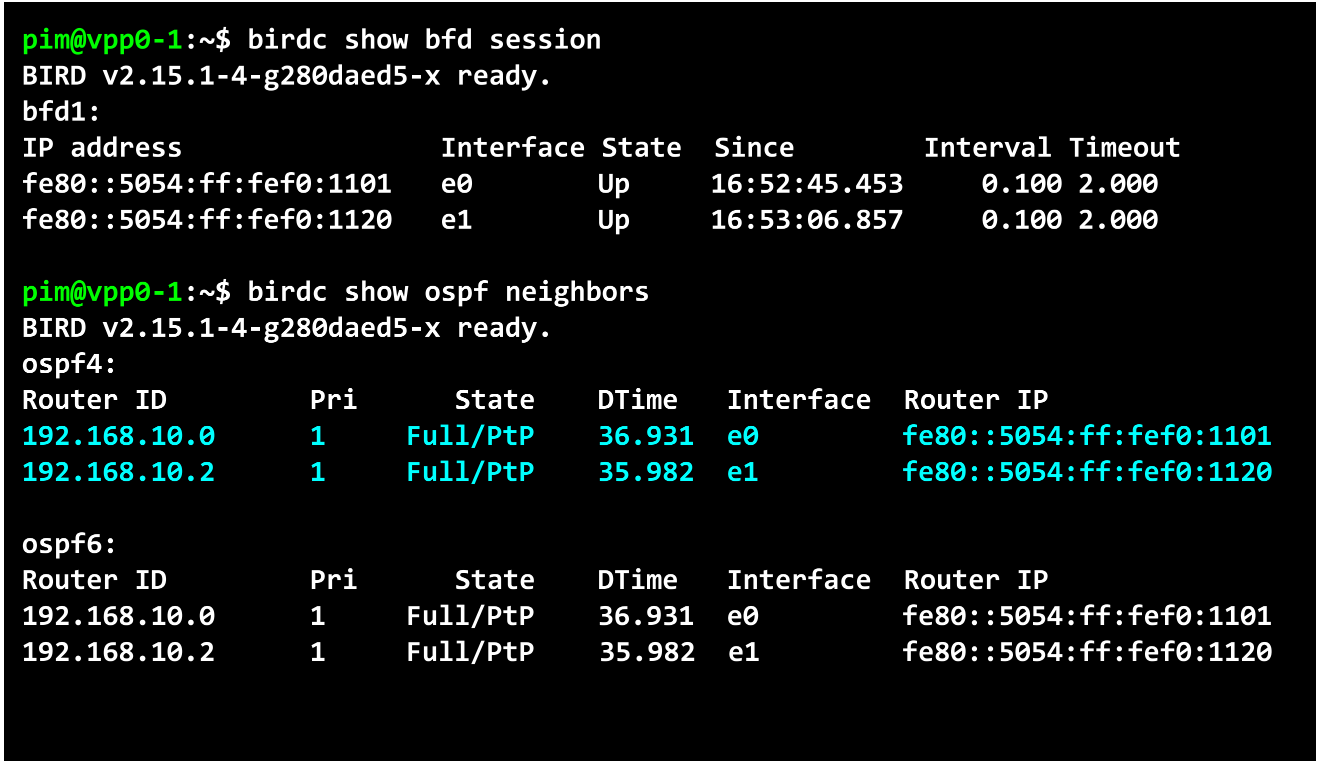
BFD+OSPFv3: Adjacency

OSPFv3: Learning

VPP: Forwarding

VPP: ICMPv4

VPP: Adjacencies with OSPFv3



```
pim@vpp0-1:~$ birdc show bfd session
BIRD v2.15.1-4-g280daed5-x ready.
bfd1:
IP address                Interface State  Since        Interval Timeout
fe80::5054:ff:fef0:1101   e0        Up     16:52:45.453     0.100 2.000
fe80::5054:ff:fef0:1120   e1        Up     16:53:06.857     0.100 2.000

pim@vpp0-1:~$ birdc show ospf neighbors
BIRD v2.15.1-4-g280daed5-x ready.
ospf4:
Router ID         Pri      State    DTime   Interface  Router IP
192.168.10.0      1     Full/PtP    36.931  e0         fe80::5054:ff:fef0:1101
192.168.10.2      1     Full/PtP    35.982  e1         fe80::5054:ff:fef0:1120

ospf6:
Router ID         Pri      State    DTime   Interface  Router IP
192.168.10.0      1     Full/PtP    36.931  e0         fe80::5054:ff:fef0:1101
192.168.10.2      1     Full/PtP    35.982  e1         fe80::5054:ff:fef0:1120
```

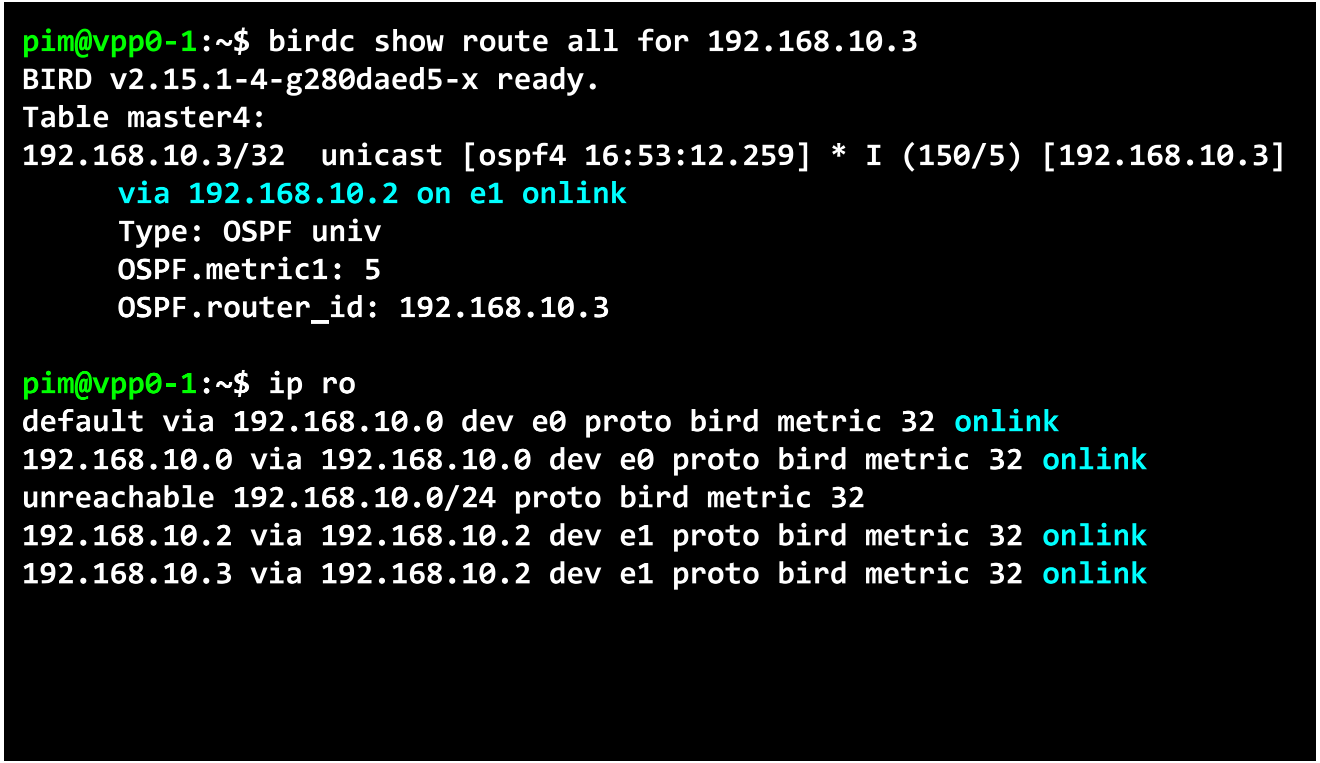
Status

✓ VPP+BFD: Config
✓ OSPFv3: Config
✓ BFD+OSPFv3: Adjacency
OSPFv3: Learning
VPP: Forwarding
VPP: ICMPv4

VPP: Learning IPv4 prefixes with OSPFv3

Status

- ✓ VPP+BFD: Config
- ✓ OSPFv3: Config
- ✓ BFD+OSPFv3: Adjacency
- ✓ OSPFv3: Learning
- VPP: Forwarding
- VPP: ICMPv4

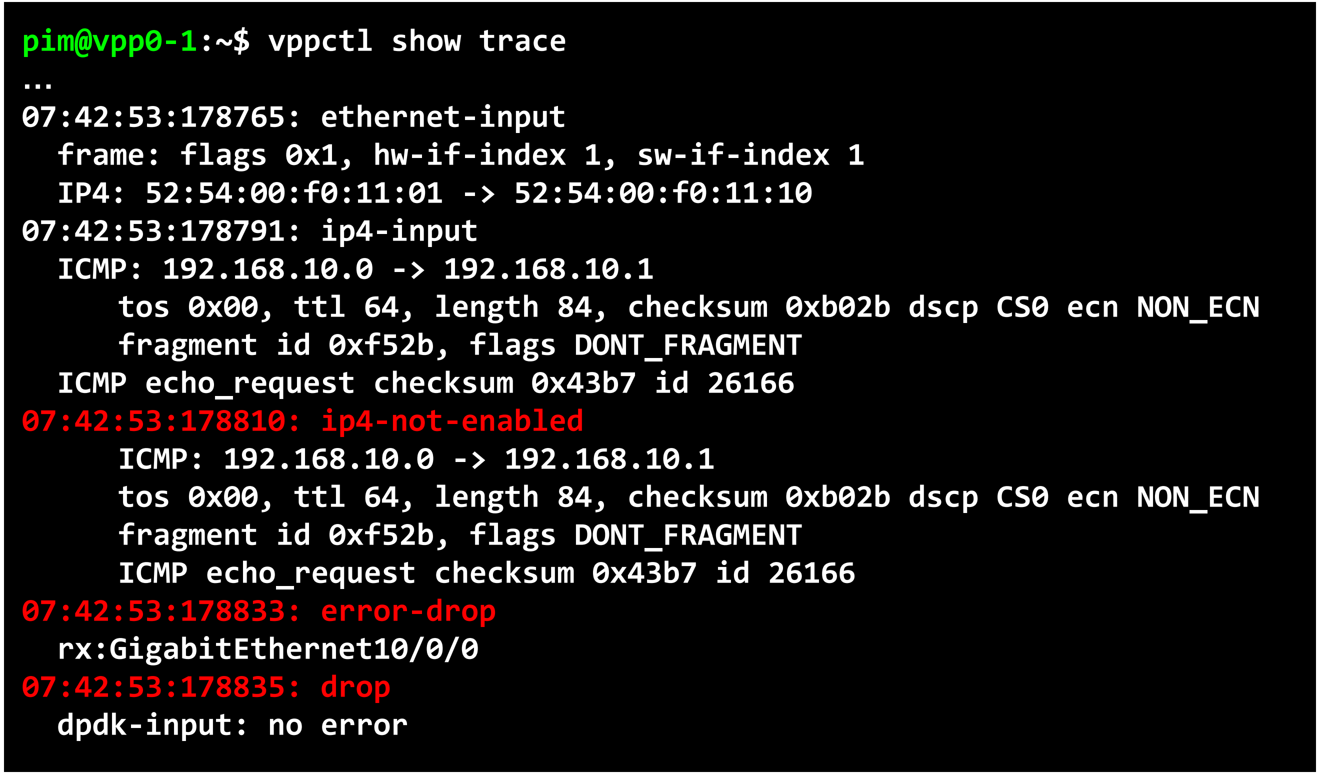


```
pim@vpp0-1:~$ birdc show route all for 192.168.10.3
BIRD v2.15.1-4-g280daed5-x ready.
Table master4:
192.168.10.3/32  unicast [ospf4 16:53:12.259] * I (150/5) [192.168.10.3]
     via 192.168.10.2 on e1 onlink
     Type: OSPF univ
     OSPF.metric1: 5
     OSPF.router_id: 192.168.10.3

pim@vpp0-1:~$ ip ro
default via 192.168.10.0 dev e0 proto bird metric 32 onlink
192.168.10.0 via 192.168.10.0 dev e0 proto bird metric 32 onlink
unreachable 192.168.10.0/24 proto bird metric 32
192.168.10.2 via 192.168.10.2 dev e1 proto bird metric 32 onlink
192.168.10.3 via 192.168.10.2 dev e1 proto bird metric 32 onlink
```

VPP: Forwarding IPv4 on non-ip4 interface

Status

- ✓ VPP+BFD: Config
- ✓ OSPFv3: Config
- ✓ BFD+OSPFv3: Adjacency
- ✓ OSPFv3: Learning
- ❌ VPP: Forwarding
- VPP: ICMPv4

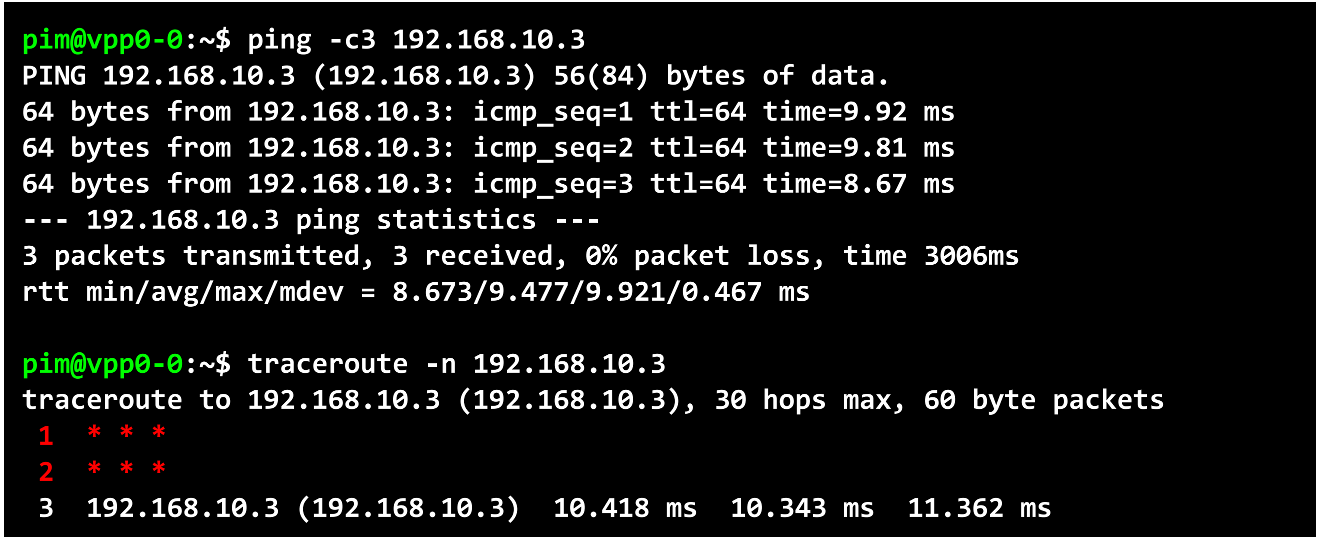


```
pim@vpp0-1:~$ vppctl show trace
...
07:42:53:178765: ethernet-input
  frame: flags 0x1, hw-if-index 1, sw-if-index 1
  IP4: 52:54:00:f0:11:01 -> 52:54:00:f0:11:10
07:42:53:178791: ip4-input
  ICMP: 192.168.10.0 -> 192.168.10.1
     tos 0x00, ttl 64, length 84, checksum 0xb02b dscp CS0 ecn NON_ECN
     fragment id 0xf52b, flags DONT_FRAGMENT
  ICMP echo_request checksum 0x43b7 id 26166
07:42:53:178810: ip4-not-enabled
     ICMP: 192.168.10.0 -> 192.168.10.1
     tos 0x00, ttl 64, length 84, checksum 0xb02b dscp CS0 ecn NON_ECN
     fragment id 0xf52b, flags DONT_FRAGMENT
     ICMP echo_request checksum 0x43b7 id 26166
07:42:53:178833: error-drop
  rx:GigabitEthernet10/0/0
07:42:53:178835: drop
  dpdk-input: no error
```

VPP: ICMPv4 on non-ip4 interface

Attempt 1: `ip4_sw_interface_enable_disable()` in Linux CP

- Forwarding works …
- … but breaks ICMPv4 (eg. Path MTU)



```
pim@vpp0-0:~$ ping -c3 192.168.10.3
PING 192.168.10.3 (192.168.10.3) 56(84) bytes of data.
64 bytes from 192.168.10.3: icmp_seq=1 ttl=64 time=9.92 ms
64 bytes from 192.168.10.3: icmp_seq=2 ttl=64 time=9.81 ms
64 bytes from 192.168.10.3: icmp_seq=3 ttl=64 time=8.67 ms
--- 192.168.10.3 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 3006ms
rtt min/avg/max/mdev = 8.673/9.477/9.921/0.467 ms

pim@vpp0-0:~$ traceroute -n 192.168.10.3
traceroute to 192.168.10.3 (192.168.10.3), 30 hops max, 60 byte packets
 1  * * *
 2  * * *
 3  192.168.10.3 (192.168.10.3)  10.418 ms  10.343 ms  11.362 ms
```

Status

✓ VPP+BFD: Config

✓ OSPFv3: Config

✓ BFD+OSPFv3: Adjacency

✓ OSPFv3: Learning

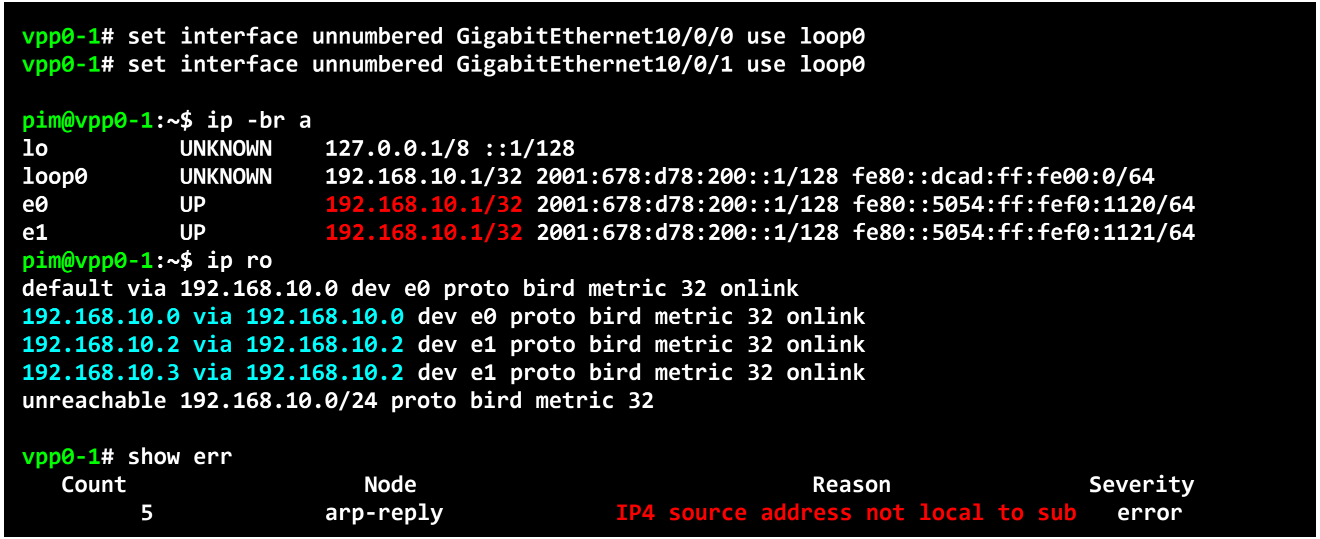
✓ VPP: Forwarding

❌ VPP: ICMPv4

VPP: ARP for *on-link* IPv4 nexthop

Attempt 2: `set interface unnumbered` in VPP

- ICMPv4 works …
- … but forwarding breaks, VPP drops *on-link* ARP req



```
vpp0-1# set interface unnumbered GigabitEthernet10/0/0 use loop0
vpp0-1# set interface unnumbered GigabitEthernet10/0/1 use loop0

pim@vpp0-1:~$ ip -br a
lo           UNKNOWN    127.0.0.1/8 ::1/128
loop0        UNKNOWN    192.168.10.1/32 2001:678:d78:200::1/128 fe80::dcad:ff:fe00:0/64
e0           UP         192.168.10.1/32 2001:678:d78:200::1/128 fe80::5054:ff:fef0:1120/64
e1           UP         192.168.10.1/32 2001:678:d78:200::1/128 fe80::5054:ff:fef0:1121/64
pim@vpp0-1:~$ ip ro
default via 192.168.10.0 dev e0 proto bird metric 32 onlink
192.168.10.0 via 192.168.10.0 dev e0 proto bird metric 32 onlink
192.168.10.2 via 192.168.10.2 dev e1 proto bird metric 32 onlink
192.168.10.3 via 192.168.10.2 dev e1 proto bird metric 32 onlink
unreachable 192.168.10.0/24 proto bird metric 32

vpp0-1# show err
   Count                  Node                              Reason                    Severity
         5              arp-reply                 IP4 source address not local to sub    error
```

Status

- ✓ VPP+BFD: Config
- ✓ OSPFv3: Config
- ✓ BFD+OSPFv3: Adjacency
- ✓ OSPFv3: Learning
- ❌ VPP: Forwarding
- ✓ VPP: ICMPv4

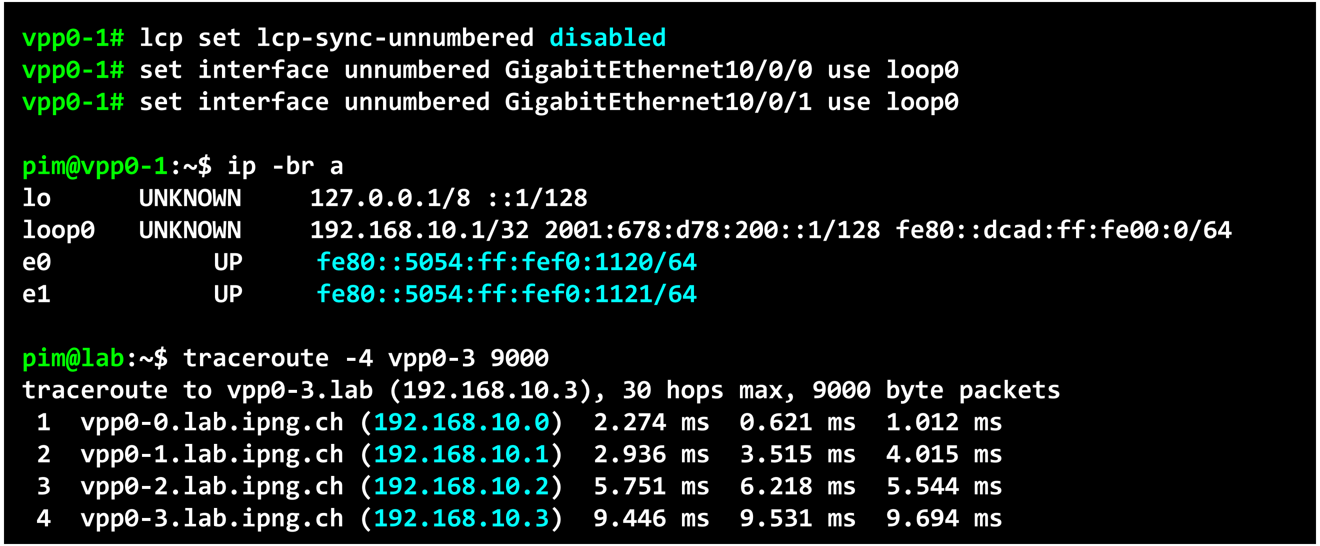
VPP: OSPFv3 and Unnumbered IPv4

Attempt 3: `set interface unnumbered` in VPP, inhibit Linux CP

- ARP issue fixed by pim@ in Gerrit [40482]
- Linux CP: inhibit sync of *unnumbered* to Linux [GitHub]

Status

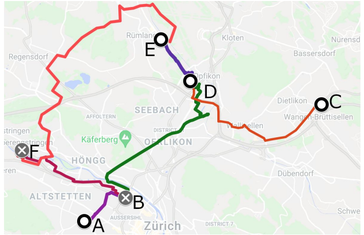
✓ VPP+BFD: Config
✓ OSPFv3: Config
✓ BFD+OSPFv3: Adjacency
✓ OSPFv3: Learning
✓ VPP: Forwarding
✓ VPP: ICMPv4

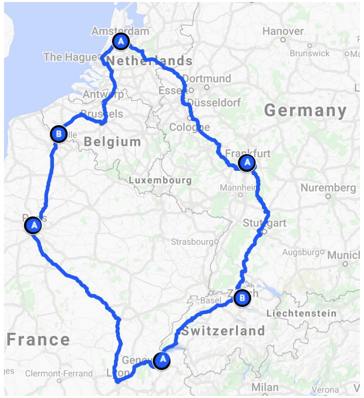


```
vpp0-1# lcp set lcp-sync-unnumbered disabled
vpp0-1# set interface unnumbered GigabitEthernet10/0/0 use loop0
vpp0-1# set interface unnumbered GigabitEthernet10/0/1 use loop0

pim@vpp0-1:~$ ip -br a
lo       UNKNOWN    127.0.0.1/8 ::1/128
loop0    UNKNOWN    192.168.10.1/32 2001:678:d78:200::1/128 fe80::dcad:ff:fe00:0/64
e0            UP     fe80::5054:ff:fef0:1120/64
e1            UP     fe80::5054:ff:fef0:1121/64

pim@lab:~$ traceroute -4 vpp0-3 9000
traceroute to vpp0-3.lab (192.168.10.3), 30 hops max, 9000 byte packets
 1  vpp0-0.lab.ipng.ch (192.168.10.0)  2.274 ms  0.621 ms  1.012 ms
 2  vpp0-1.lab.ipng.ch (192.168.10.1)  2.936 ms  3.515 ms  4.015 ms
 3  vpp0-2.lab.ipng.ch (192.168.10.2)  5.751 ms  6.218 ms  5.544 ms
 4  vpp0-3.lab.ipng.ch (192.168.10.3)  9.446 ms  9.531 ms  9.694 ms
```

Act 3: Rollout in AS8298

AS8298: Removing IP4/IP6 PtP addresses





Start situation:

- Each router has an IPv4 /32 and IPv6 /128 `loop0`
- IPv4 OSPF with /31 PtP, IPv6 OSPFv3 with /112 PtP

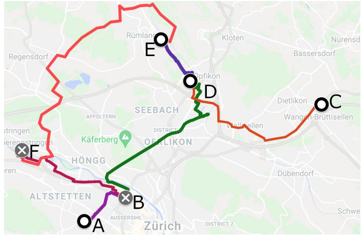
Game plan:

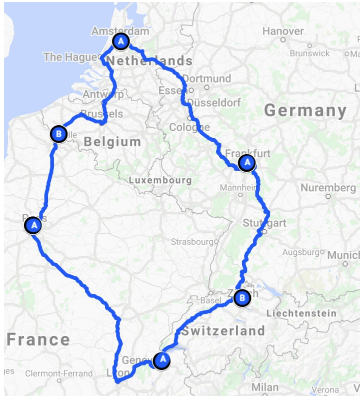
- Upgrade bird2, upgrade VPP dataplane:
  - rename ‘ospf4’ to ‘ospf4_old’ (which is OSPFv2)
  - add an empty ‘ospf4’ (which is OSPFv3)
- Then, move all interfaces from ‘ospf4_old’ to ‘ospf4’
- Finally, delete ‘ospf4_old’

End situation:

- Each router has *only one* IPv4 /32 and IPv6 /128 `loop0`
- ~~IPv4 OSPF with /31 PtP, IPv6 OSPFv3 with /112 PtP~~

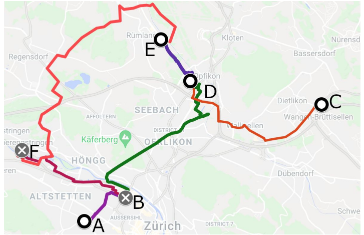
Step 1: Upgrade software

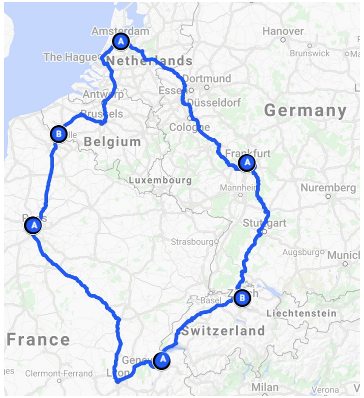


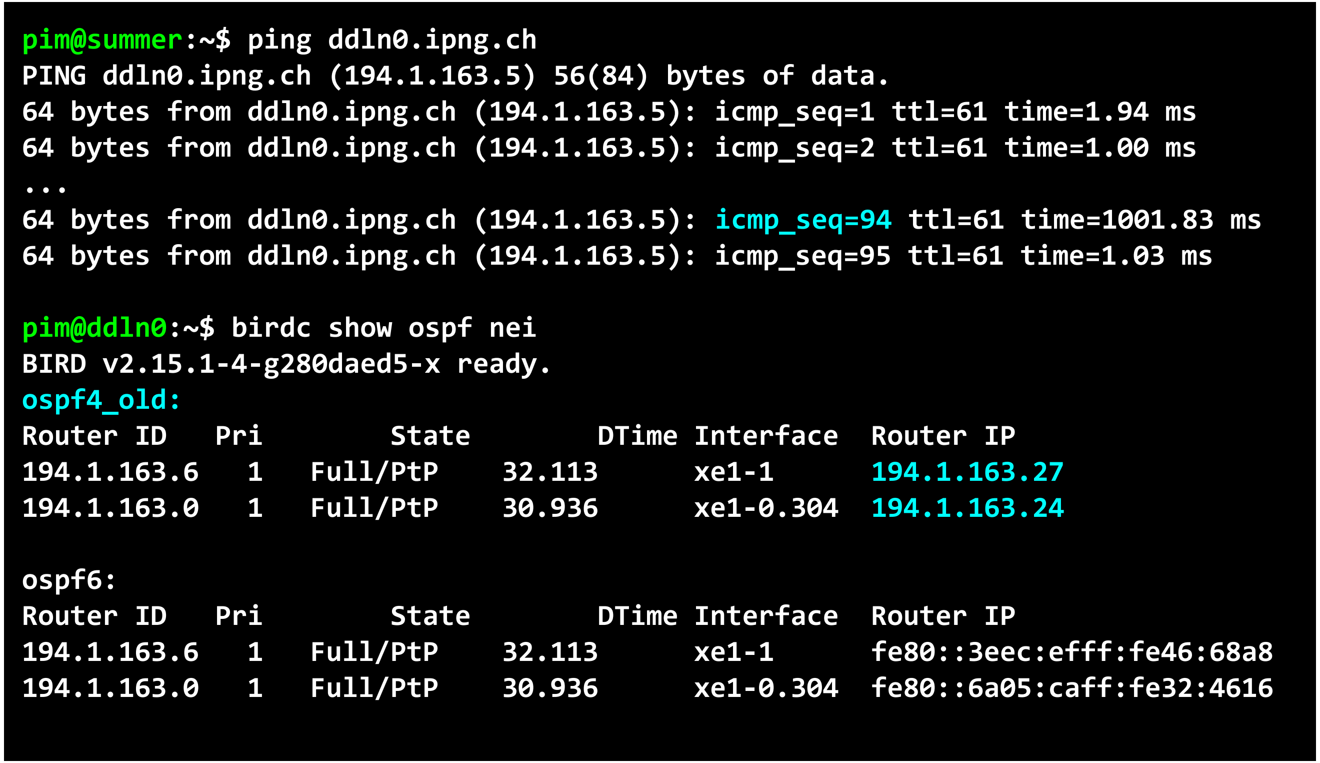


```
pim@ddln0:~$ sed -rn ‘s,cost (.+),cost 10\1,’ /etc/bird/core/ospf.conf
pim@ddln0:~$ birdc configure

pim@ddln0:~$ sed -i ‘s,protocol.*ospf4,$1_old,’ /etc/bird/core/ospf.conf
pim@ddln0:~$ scp bookworm-builder:bird2_2.15.1_amd64.deb .
pim@ddln0:~$ wget -m --no-parent \
            https://ipng.ch/media/vpp/bookworm/24.06-rc0~183-gb0d433978/

pim@ddln0:~$ sudo nsenter --net=/var/run/netns/dataplane

root@ddln0:~# pkill -9 vpp && systemctl stop vpp bird-dataplane
root@ddln0:~# dpkg -i ~pim/ipng.ch/media/vpp/bookworm/*/*.deb
root@ddln0:~# dpkg -i ~pim/bird2_2.15.1_amd64.deb
root@ddln0:~# systemctl start bird-dataplane
root@ddln0:~# systemctl restart vpp-snmp-agent-dataplane
root@ddln0:~# systemctl restart vpp-exporter-dataplane
```

Step 1: Upgrade software

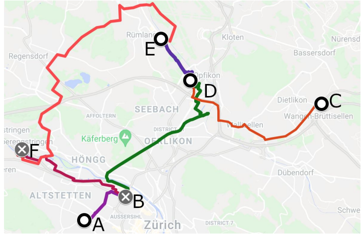


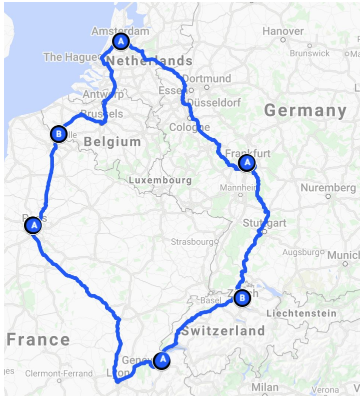


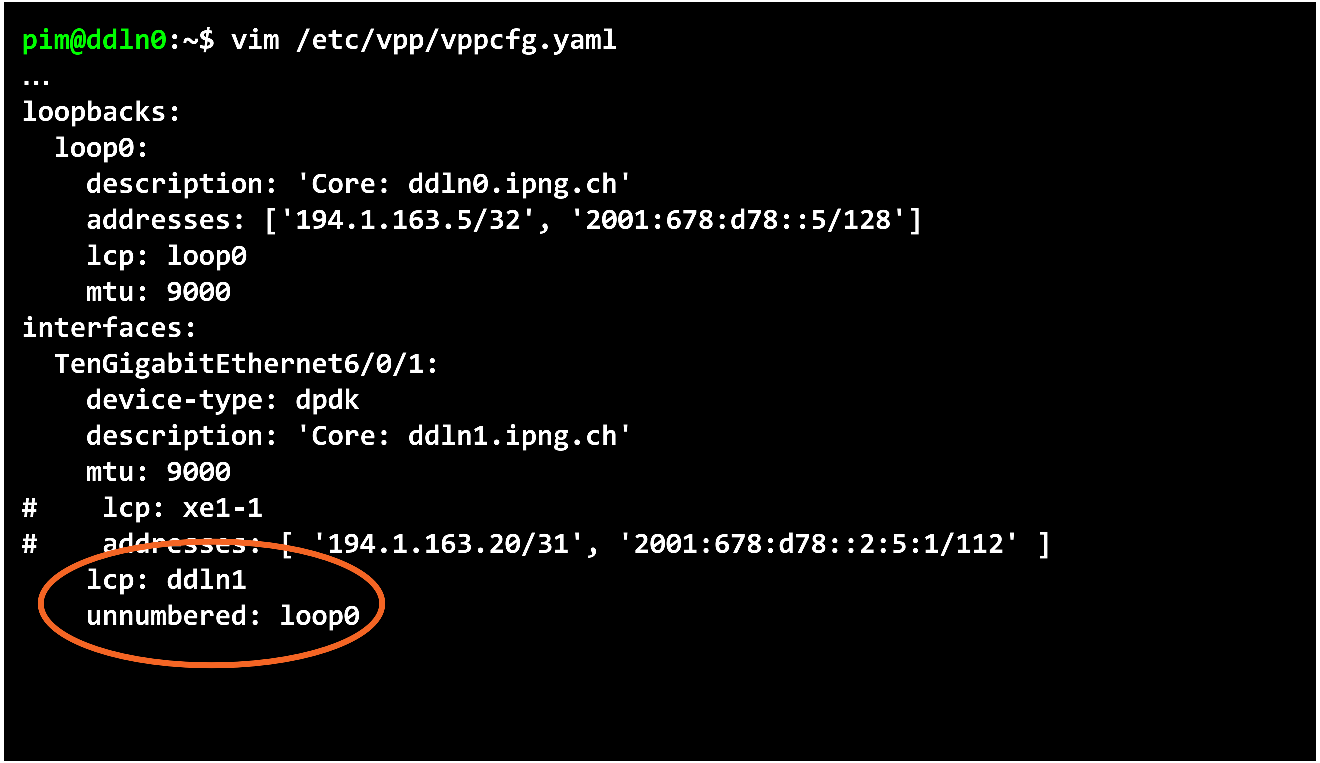


```
pim@summer:~$ ping ddln0.ipng.ch
PING ddln0.ipng.ch (194.1.163.5) 56(84) bytes of data.
64 bytes from ddln0.ipng.ch (194.1.163.5): icmp_seq=1 ttl=61 time=1.94 ms
64 bytes from ddln0.ipng.ch (194.1.163.5): icmp_seq=2 ttl=61 time=1.00 ms
...
64 bytes from ddln0.ipng.ch (194.1.163.5): icmp_seq=94 ttl=61 time=1001.83 ms
64 bytes from ddln0.ipng.ch (194.1.163.5): icmp_seq=95 ttl=61 time=1.03 ms

pim@ddln0:~$ birdc show ospf nei
BIRD v2.15.1-4-g280daed5-x ready.
ospf4_old:
Router ID    Pri          State          DTime Interface  Router IP
194.1.163.6    1    Full/PtP     32.113       xe1-1      194.1.163.27
194.1.163.0    1    Full/PtP     30.936       xe1-0.304  194.1.163.24

ospf6:
Router ID    Pri          State          DTime Interface  Router IP
194.1.163.6    1    Full/PtP     32.113       xe1-1      fe80::3eec:efff:fe46:68a8
194.1.163.0    1    Full/PtP     30.936       xe1-0.304  fe80::6a05:caff:fe32:4616
```

Step 2: Reconfigure VPP

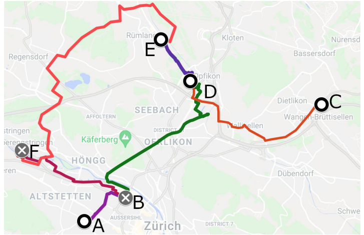


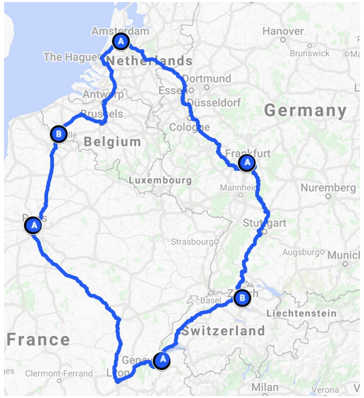


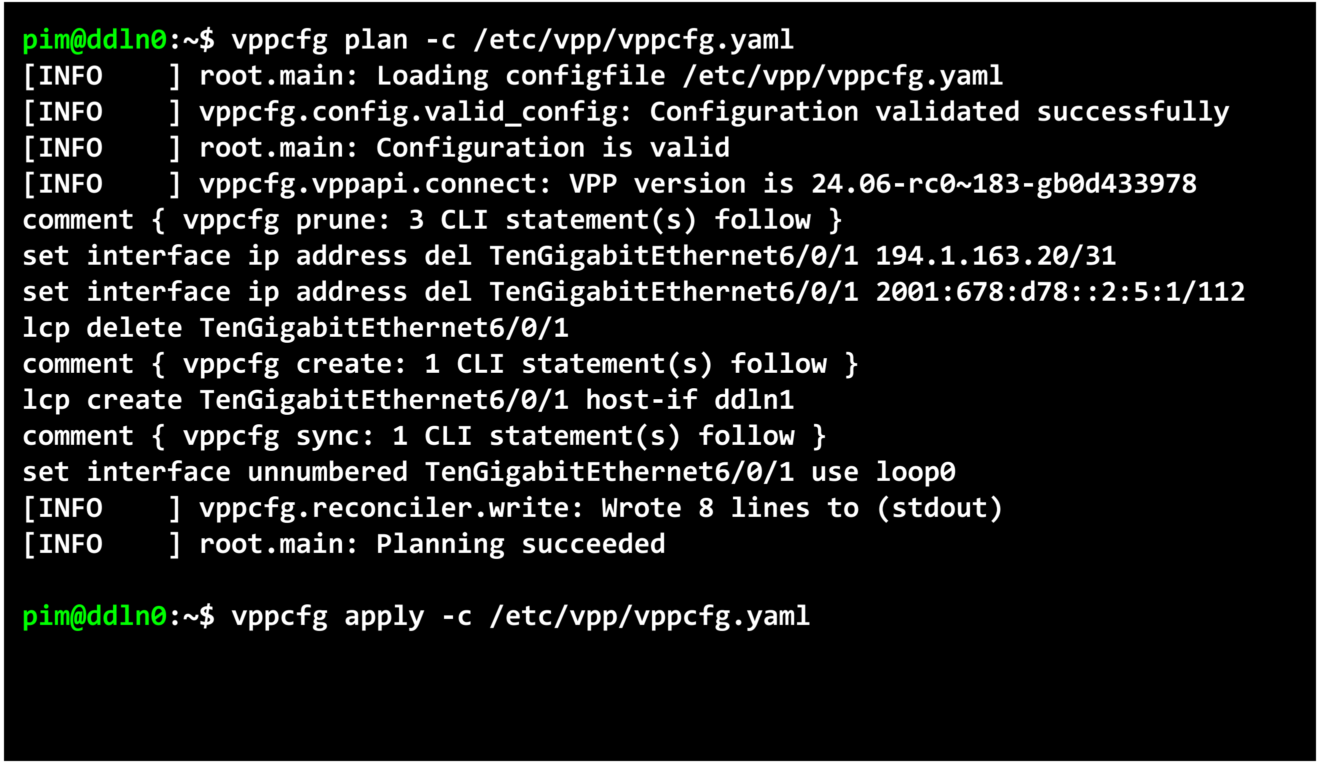


```
pim@ddln0:~$ vim /etc/vpp/vppcfg.yaml
…
loopbacks:
  loop0:
    description: 'Core: ddln0.ipng.ch'
    addresses: ['194.1.163.5/32', '2001:678:d78::5/128']
    lcp: loop0
    mtu: 9000
interfaces:
  TenGigabitEthernet6/0/1:
    device-type: dpdk
    description: 'Core: ddln1.ipng.ch'
    mtu: 9000
#     lcp: xe1-1
#     addresses: [ '194.1.163.20/31', '2001:678:d78::2:5:1/112' ]
    lcp: ddln1
    unnumbered: loop0
```

Step 2: Reconfigure VPP

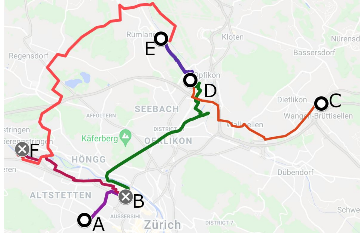


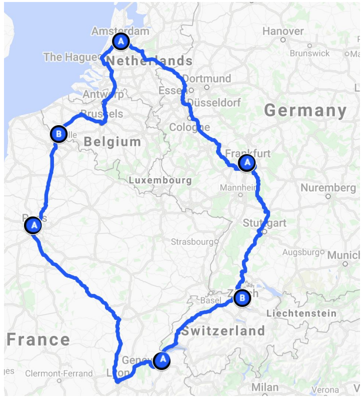


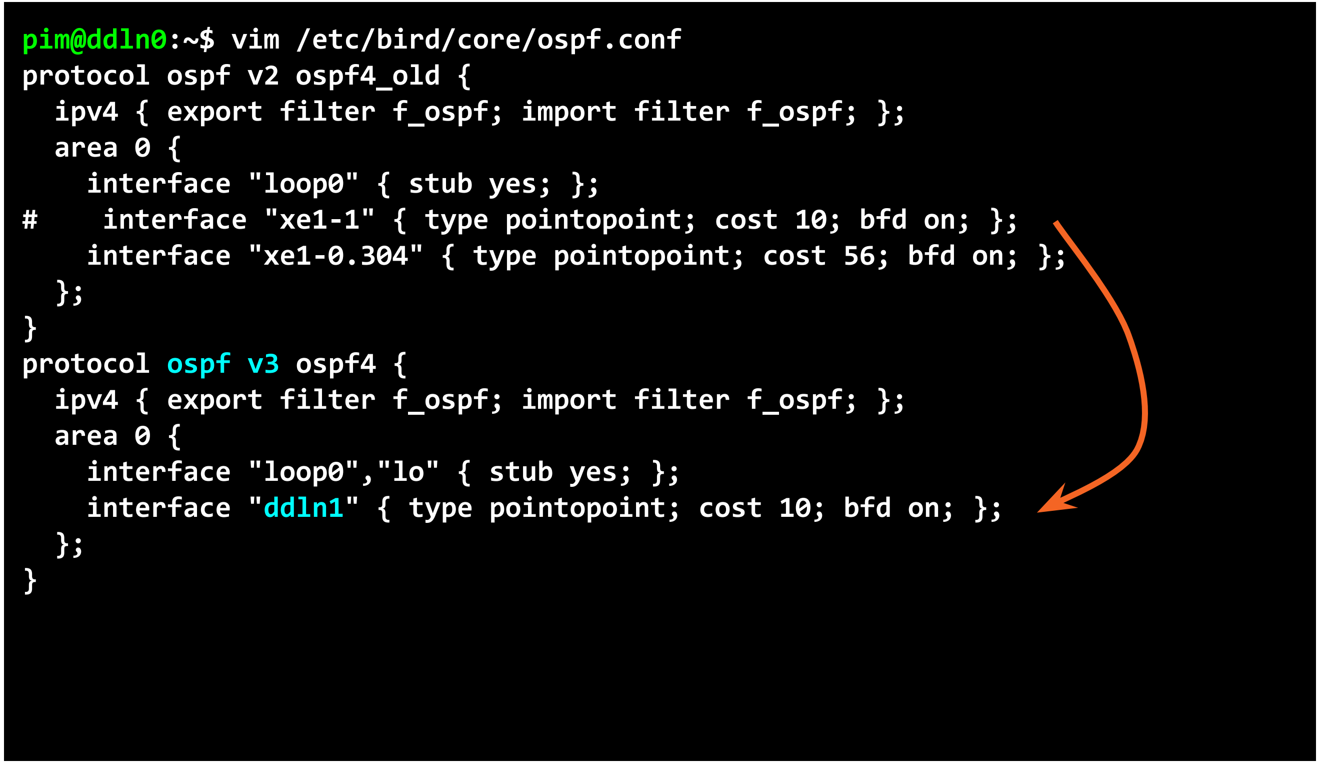


```
pim@ddln0:~$ vppcfg plan -c /etc/vpp/vppcfg.yaml
[INFO    ] root.main: Loading configfile /etc/vpp/vppcfg.yaml
[INFO    ] vppcfg.config.valid_config: Configuration validated successfully
[INFO    ] root.main: Configuration is valid
[INFO    ] vppcfg.vppapi.connect: VPP version is 24.06-rc0~183-gb0d433978
comment { vppcfg prune: 3 CLI statement(s) follow }
set interface ip address del TenGigabitEthernet6/0/1 194.1.163.20/31
set interface ip address del TenGigabitEthernet6/0/1 2001:678:d78::2:5:1/112
lcp delete TenGigabitEthernet6/0/1
comment { vppcfg create: 1 CLI statement(s) follow }
lcp create TenGigabitEthernet6/0/1 host-if ddln1
comment { vppcfg sync: 1 CLI statement(s) follow }
set interface unnumbered TenGigabitEthernet6/0/1 use loop0
[INFO    ] vppcfg.reconciler.write: Wrote 8 lines to (stdout)
[INFO    ] root.main: Planning succeeded

pim@ddln0:~$ vppcfg apply -c /etc/vpp/vppcfg.yaml
```

Step 3: Move interface to OSPFv3

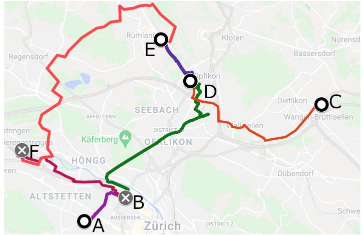


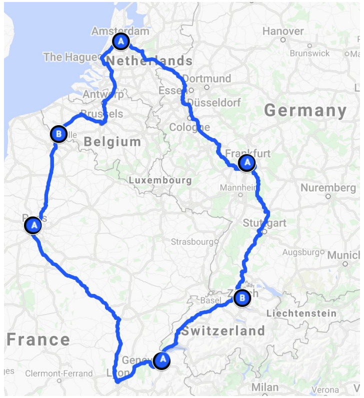


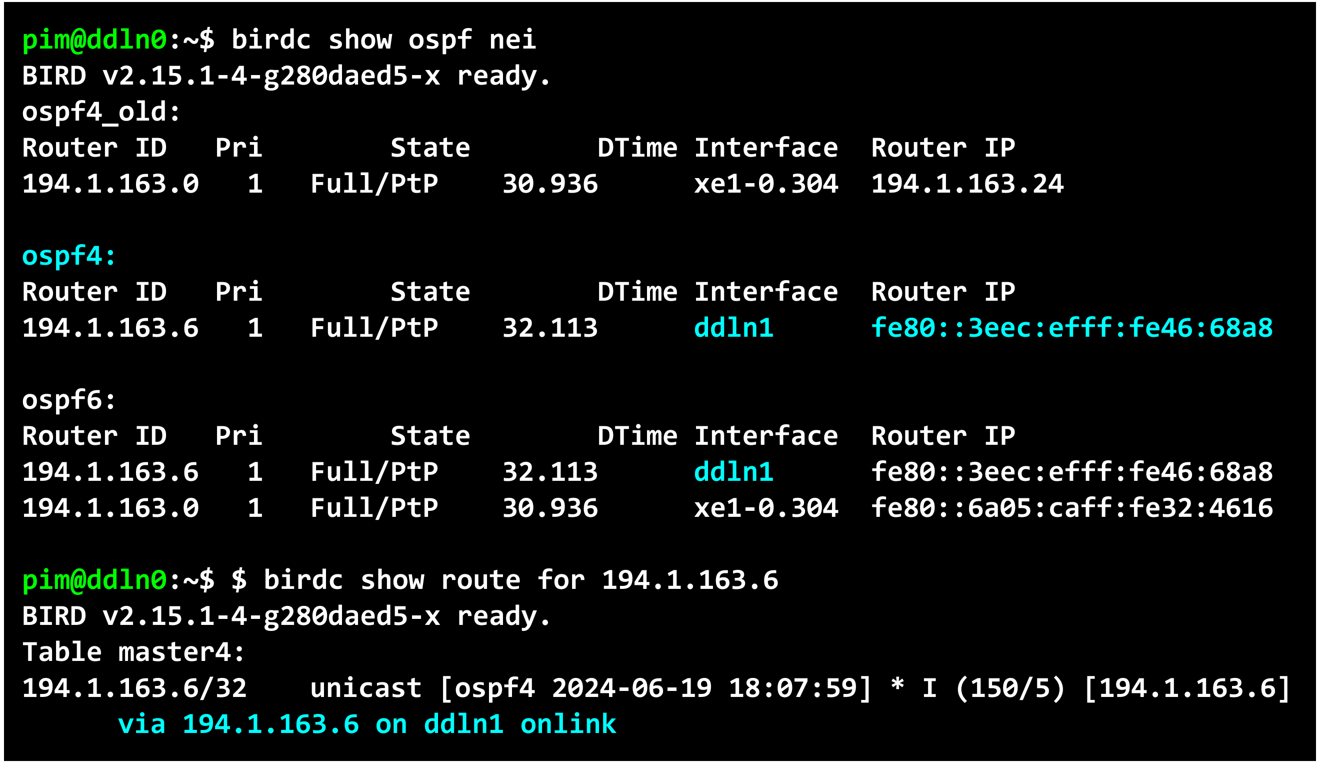


```
pim@ddln0:~$ vim /etc/bird/core/ospf.conf
protocol ospf v2 ospf4_old {
  ipv4 { export filter f_ospf; import filter f_ospf; };
  area 0 {
    interface "loop0" { stub yes; };
#    interface "xe1-1" { type pointopoint; cost 10; bfd on; };
    interface "xe1-0.304" { type pointopoint; cost 56; bfd on; };
  };
}
protocol ospf v3 ospf4 {
  ipv4 { export filter f_ospf; import filter f_ospf; };
  area 0 {
    interface "loop0","lo" { stub yes; };
    interface "ddln1" { type pointopoint; cost 10; bfd on; };
  };
}
```

Step 3: Move interface to OSPFv3





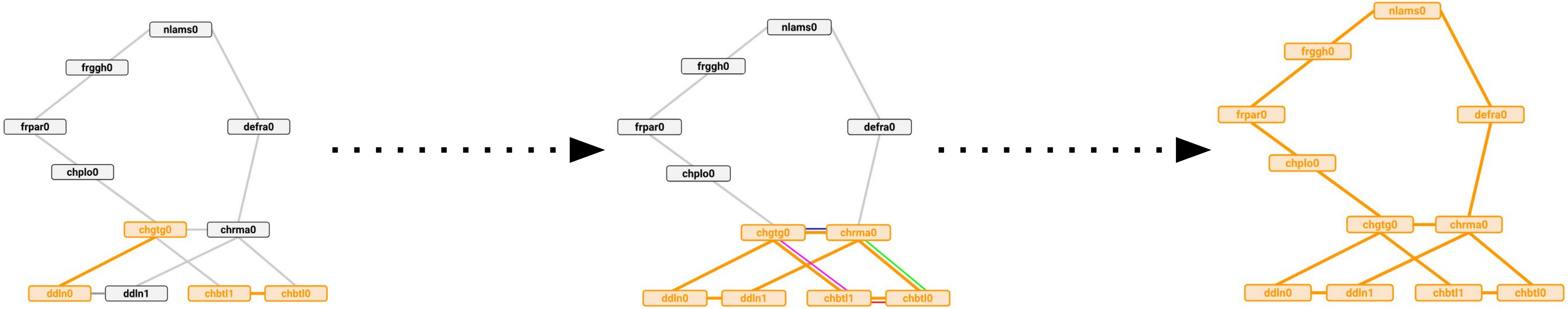


```
pim@ddln0:~$ birdc show ospf nei
BIRD v2.15.1-4-g280daed5-x ready.
ospf4_old:
Router ID    Pri          State         DTime Interface   Router IP
194.1.163.0    1    Full/PtP     30.936       xe1-0.304   194.1.163.24

ospf4:
Router ID    Pri          State         DTime Interface   Router IP
194.1.163.6    1    Full/PtP     32.113       ddln1       fe80::3eec:efff:fe46:68a8

ospf6:
Router ID    Pri          State         DTime Interface   Router IP
194.1.163.6    1    Full/PtP     32.113       ddln1       fe80::3eec:efff:fe46:68a8
194.1.163.0    1    Full/PtP     30.936       xe1-0.304   fe80::6a05:caff:fe32:4616

pim@ddln0:~$ $ birdc show route for 194.1.163.6
BIRD v2.15.1-4-g280daed5-x ready.
Table master4:
194.1.163.6/32    unicast [ospf4 2024-06-19 18:07:59] * I (150/5) [194.1.163.6]
      via 194.1.163.6 on ddln1 onlink
```

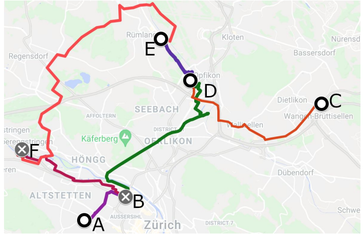
Step 4: Rinse, Repeat

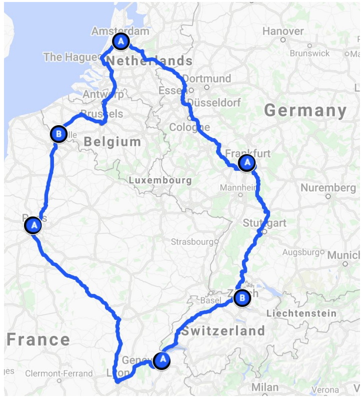
OSPFv3 and OSPF can coexist peacefully

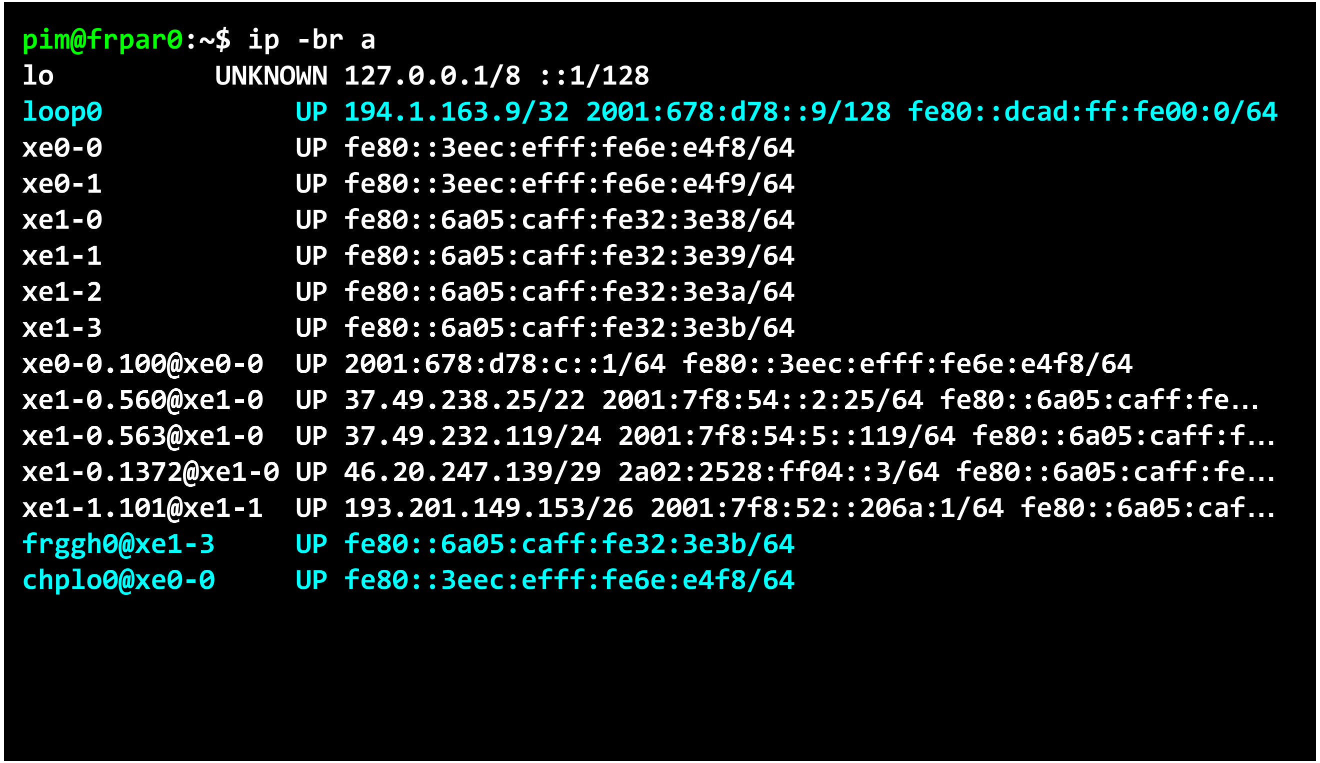
- Bird will learn routes twice, and they will be Ext-E1 within proto and Ext-E2 between proto
- Costs will be inconsistent, E1 always preferred
- No kittens were harmed!



Results

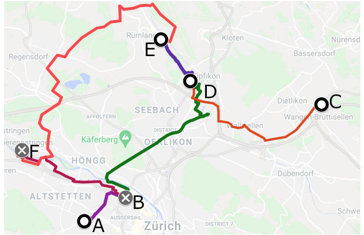


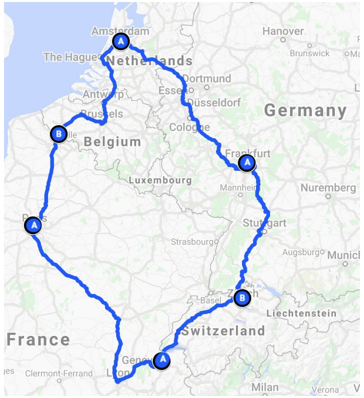


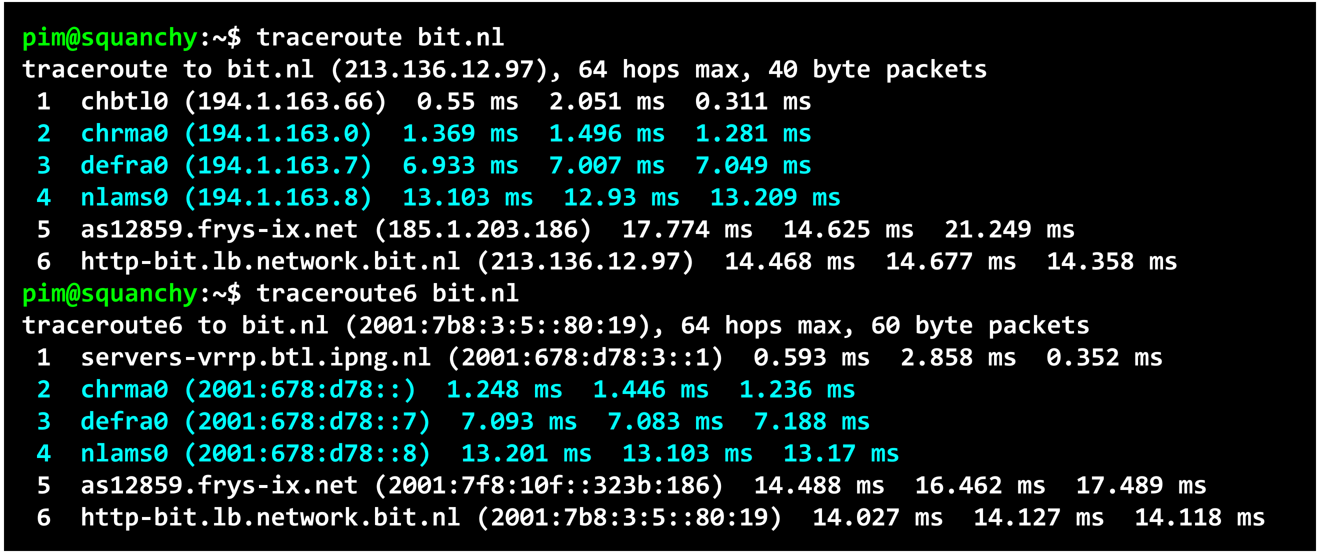


```
pim@frpar0:~$ ip -br a
lo              UNKNOWN 127.0.0.1/8 ::1/128
loop0                UP 194.1.163.9/32 2001:678:d78::9/128 fe80::dcad:ff:fe00:0/64
xe0-0                UP fe80::3eec:efff:fe6e:e4f8/64
xe0-1                UP fe80::3eec:efff:fe6e:e4f9/64
xe1-0                UP fe80::6a05:caff:fe32:3e38/64
xe1-1                UP fe80::6a05:caff:fe32:3e39/64
xe1-2                UP fe80::6a05:caff:fe32:3e3a/64
xe1-3                UP fe80::6a05:caff:fe32:3e3b/64
xe0-0.100@xe0-0      UP 2001:678:d78:c::1/64 fe80::3eec:efff:fe6e:e4f8/64
xe1-0.560@xe1-0      UP 37.49.238.25/22 2001:7f8:54::2:25/64 fe80::6a05:caff:fe...
xe1-0.563@xe1-0      UP 37.49.232.119/24 2001:7f8:54:5::119/64 fe80::6a05:caff:f...
xe1-0.1372@xe1-0     UP 46.20.247.139/29 2a02:2528:ff04::3/64 fe80::6a05:caff:fe...
xe1-1.101@xe1-1      UP 193.201.149.153/26 2001:7f8:52::206a:1/64 fe80::6a05:caf...
frggh0@xe1-3         UP fe80::6a05:caff:fe32:3e3b/64
chplo0@xe0-0         UP fe80::3eec:efff:fe6e:e4f8/64
```

Results







```
pim@squanchy:~$ traceroute bit.nl
traceroute to bit.nl (213.136.12.97), 64 hops max, 40 byte packets
 1  chbtl0 (194.1.163.66)  0.55 ms  2.051 ms  0.311 ms
 2  chrma0 (194.1.163.0)  1.369 ms  1.496 ms  1.281 ms
 3  defra0 (194.1.163.7)  6.933 ms  7.007 ms  7.049 ms
 4  nlams0 (194.1.163.8)  13.103 ms  12.93 ms  13.209 ms
 5  as12859.frys-ix.net (185.1.203.186)  17.774 ms  14.625 ms  21.249 ms
 6  http-bit.lb.network.bit.nl (213.136.12.97)  14.468 ms  14.677 ms  14.358 ms
pim@squanchy:~$ traceroute6 bit.nl
traceroute6 to bit.nl (2001:7b8:3:5::80:19), 64 hops max, 60 byte packets
 1  servers-vrrp.btl.ipng.nl (2001:678:d78:3::1)  0.593 ms  2.858 ms  0.352 ms
 2  chrma0 (2001:678:d78::)  1.248 ms  1.446 ms  1.236 ms
 3  defra0 (2001:678:d78::7)  7.093 ms  7.083 ms  7.188 ms
 4  nlams0 (2001:678:d78::8)  13.201 ms  13.103 ms  13.17 ms
 5  as12859.frys-ix.net (2001:7f8:10f::323b:186)  14.488 ms  16.462 ms  17.489 ms
 6  http-bit.lb.network.bit.nl (2001:7b8:3:5::80:19)  14.027 ms  14.127 ms  14.118 ms
```

AS8298 returned:

- 27x IPv4 /31s and IPv6 /112s in total.

Act 3: Performance of VPP

Dell R730
(2016)

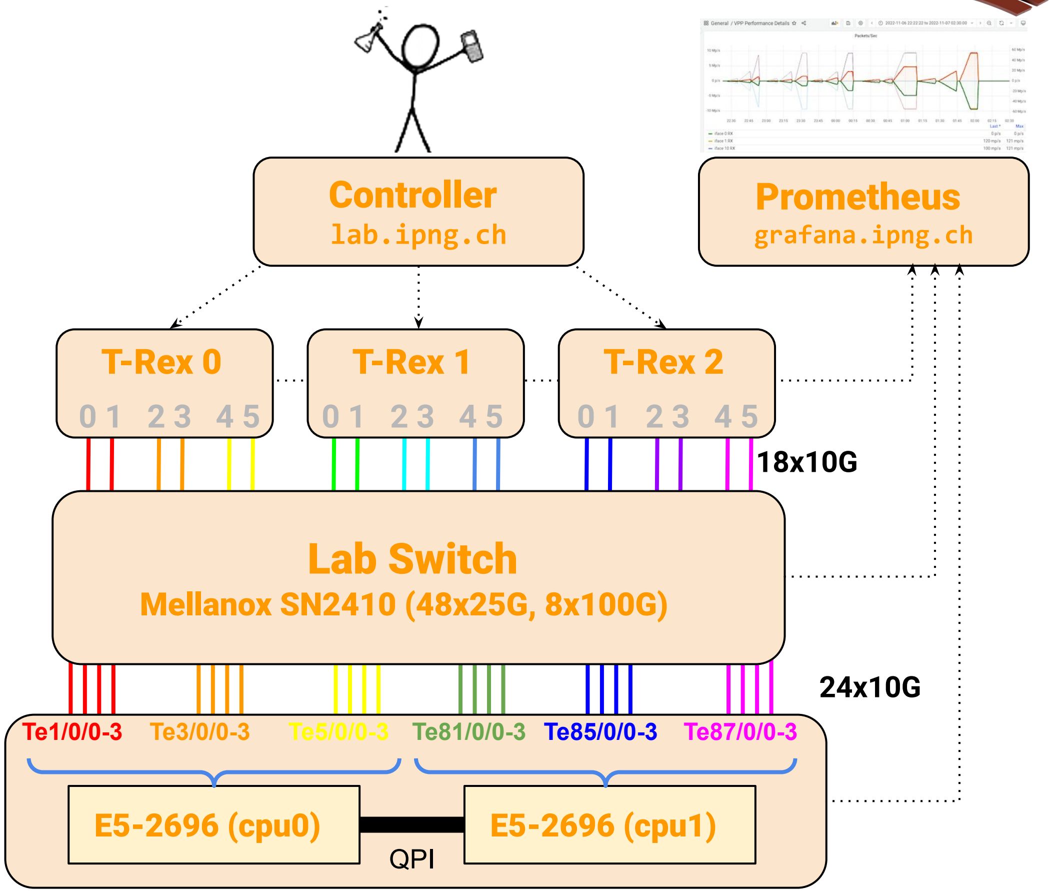
Lab Setup

Load Generator Machines

- 3x Dell R720 (E5-2620, 2.00GHz)
- 9x Dual Intel 82599ES (18x10G)
- Debian Bookworm, T-Rex v3.04
  - 4 CPUs per 10G interface pair

Device Under Test

- Dell R730 (E5-2696 v4 @ 2.20GHz)
  - 2x(22C/44T), 64GB DDR4 2.4GT/s
  - 2x40 PCIe v3.0 Lanes
- 6x Intel X710-DA4 (24x10G)
  - 12x10G on cpu0, 12x10G on cpu1
- Debian Bookworm (Linux 6.1.0-25)
- VPP v24.10-rc0~204-ge9bc33201



Controller
lab.ipng.ch

Prometheus
grafana.ipng.ch

T-Rex 0
0 1 2 3 4 5

T-Rex 1
0 1 2 3 4 5

T-Rex 2
0 1 2 3 4 5

18x10G

Lab Switch
Mellanox SN2410 (48x25G, 8x100G)

24x10G

Te1/0/0-3 Te3/0/0-3 Te5/0/0-3 Te81/0/0-3 Te85/0/0-3 Te87/0/0-3

E5-2696 (cpu0) QPI E5-2696 (cpu1)

Load Testing Methodology

Method 1: VPP has one worker thread, one Rx/Tx queue

- Send *unidirectional* traffic
- Measure cycles/packet for 1kpps, 1Mpps, 10Mpps, ...

  ⇒ Report max packets/sec for one CPU thread

Method 2: VPP has n-1 worker threads with [1, 2, 3, ...] Rx queues

- Send *unidirectional*, or *bidirectional* (!) traffic
  - Warmup at 1kpps (30sec)
  - Ramp up to 100% line rate (in 600sec)
  - Keep at 100% (30sec)
- Measure point at which packet forwarding loss > 0.1%

  ⇒ Report bits/sec, packets/sec and % of line rate.

Method 1 - Single Thread Saturation

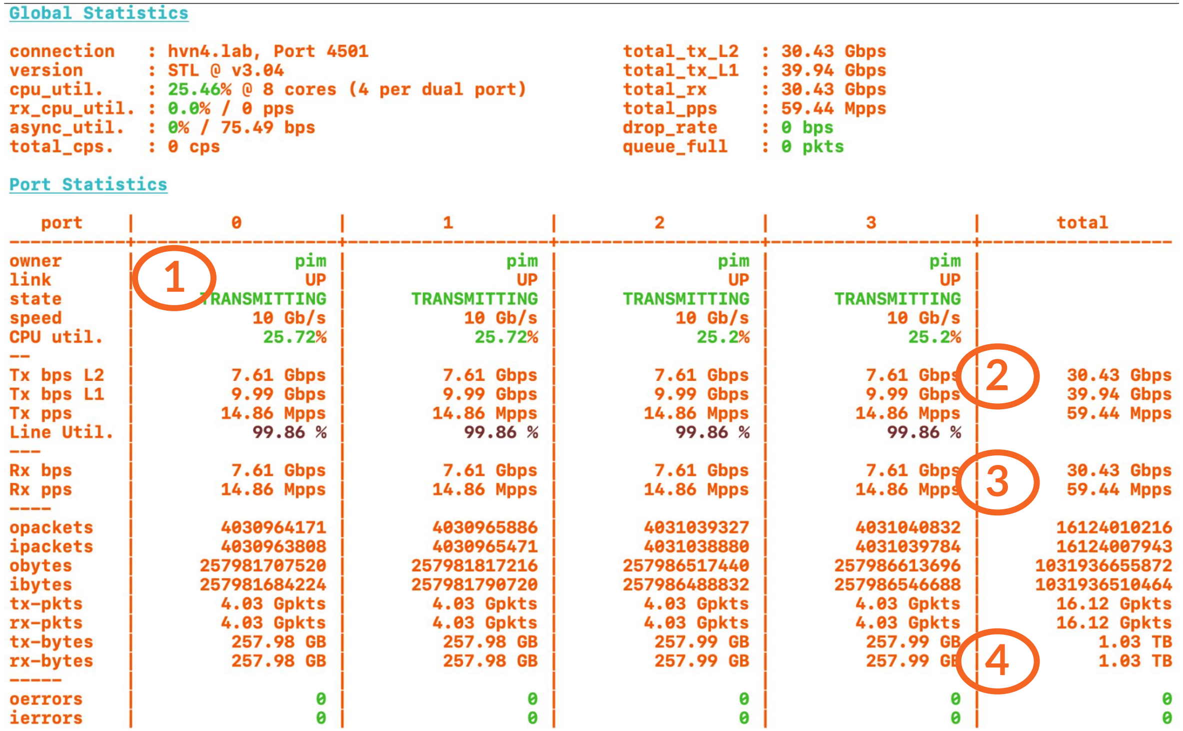
Legend

1. NIC Info, T-Rex CPU utilization
2. Sent traffic (L1, L2, packets/sec)
3. Received traffic (L2, packets/sec)
4. Detailed packet/byte counters

Shown here: 4x10G @64b

- Tx: 59.44Mpps, 39.94Gbps
- Rx: 59.44Mpps, 39.94Gbps

⇒ L2 XC is (at least) 14.88Mpps per core!



```
Global Statistics

connection   : hvn4.lab, Port 4501                      total_tx_L2  : 30.43 Gbps
version      : STL @ v3.04                              total_tx_L1  : 39.94 Gbps
cpu_util.    : 25.46% @ 8 cores (4 per dual port)       total_rx     : 30.43 Gbps
rx_cpu_util. : 0.0% / 0 pps                             total_pps    : 59.44 Mpps
async_util.  : 0% / 75.49 bps                           drop_rate    : 0 bps
total_cps.   : 0 cps                                    queue_full   : 0 pkts

Port Statistics

   port    |         0         |         1         |         2         |         3         |       total
-----------+-------------------+-------------------+-------------------+-------------------+------------------
owner      |               pim |               pim |               pim |               pim |
link       |                UP |                UP |                UP |                UP |
state      |      TRANSMITTING |      TRANSMITTING |      TRANSMITTING |      TRANSMITTING |
speed      |          10 Gb/s |          10 Gb/s |          10 Gb/s |          10 Gb/s |
CPU util.  |            25.72% |            25.72% |             25.2% |             25.2% |
--         |                   |                   |                   |                   |
Tx bps L2  |         7.61 Gbps |         7.61 Gbps |         7.61 Gbps |         7.61 Gbps |        30.43 Gbps
Tx bps L1  |         9.99 Gbps |         9.99 Gbps |         9.99 Gbps |         9.99 Gbps |        39.94 Gbps
Tx pps     |        14.86 Mpps |        14.86 Mpps |        14.86 Mpps |        14.86 Mpps |        59.44 Mpps
Line Util. |           99.86 % |           99.86 % |           99.86 % |           99.86 % |
---        |                   |                   |                   |                   |
Rx bps     |         7.61 Gbps |         7.61 Gbps |         7.61 Gbps |         7.61 Gbps |        30.43 Gbps
Rx pps     |        14.86 Mpps |        14.86 Mpps |        14.86 Mpps |        14.86 Mpps |        59.44 Mpps
----       |                   |                   |                   |                   |
opackets   |        4030964171 |        4030965886 |        4031039327 |        4031040832 |       16124010216
ipackets   |        4030963808 |        4030965471 |        4031038880 |        4031039784 |       16124007943
obytes     |      257981707520 |      257981817216 |      257986517440 |      257986613696 |     1031936655872
ibytes     |      257981684224 |      257981790720 |      257986488832 |      257986546688 |     1031936510464
tx-pkts    |       4.03 Gpkts |       4.03 Gpkts |       4.03 Gpkts |       4.03 Gpkts |       16.12 Gpkts
rx-pkts    |       4.03 Gpkts |       4.03 Gpkts |       4.03 Gpkts |       4.03 Gpkts |       16.12 Gpkts
tx-bytes   |         257.98 GB |         257.98 GB |         257.99 GB |         257.99 GB |           1.03 TB
rx-bytes   |         257.98 GB |         257.98 GB |         257.99 GB |         257.99 GB |           1.03 TB
-----      |                   |                   |                   |                   |
oerrors    |                 0 |                 0 |                 0 |                 0 |                 0
ierrors    |                 0 |                 0 |                 0 |                 0 |                 0
```

```
vpp v24.10-rc0~204-ge9bc33201 built by pim on hvn6-lab at 2024-09-20T08:50:50
```

Method 1: Results (E5-2696 v4)

	clocks/packet @ 1kpps	clocks/packet @ 1Mpps	clocks/packet @ 10Mpps	packets/sec per core
L2 xconnect	991	199	140	15.34Mpps
MPLS	1465	274	172	10.35Mpps
L3 IPv4	1596	299	156	11.08Mpps
L3 IPv6	1941	347	178	9.72Mpps

- CPU cycles/packet: lower is better
- Max PPS per core: higher is better

```
vpp v24.10-rc0~204-ge9bc33201 built by pim on hvn6-lab at 2024-09-20T08:50:50
```

Method 2: VPP can forward 100Gbit

Bidirectional (18 ports, 18 VPP threads):

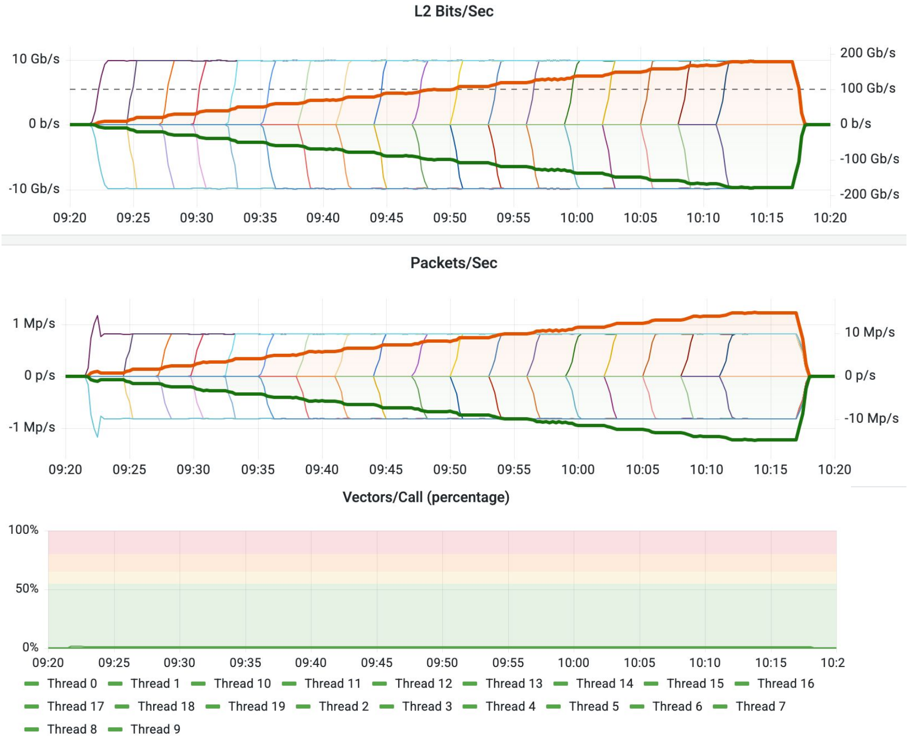
1) 09:22 - Incremental colored traces
T-Rex ports turned on one by one,
3 minutes apart, sending 1514b

2) 09:50 100Gbps achieved

3) 10:12180Gbps achieved
14.7Mpps @1514b

Note: 24 CPU threads unused; 6 NICs unused.

⇒ Proof that VPP (easily) forwards 100Gbps



Method 2: VPP can forward 100Mpps

Bidirectional (18 ports, 18 VPP threads):

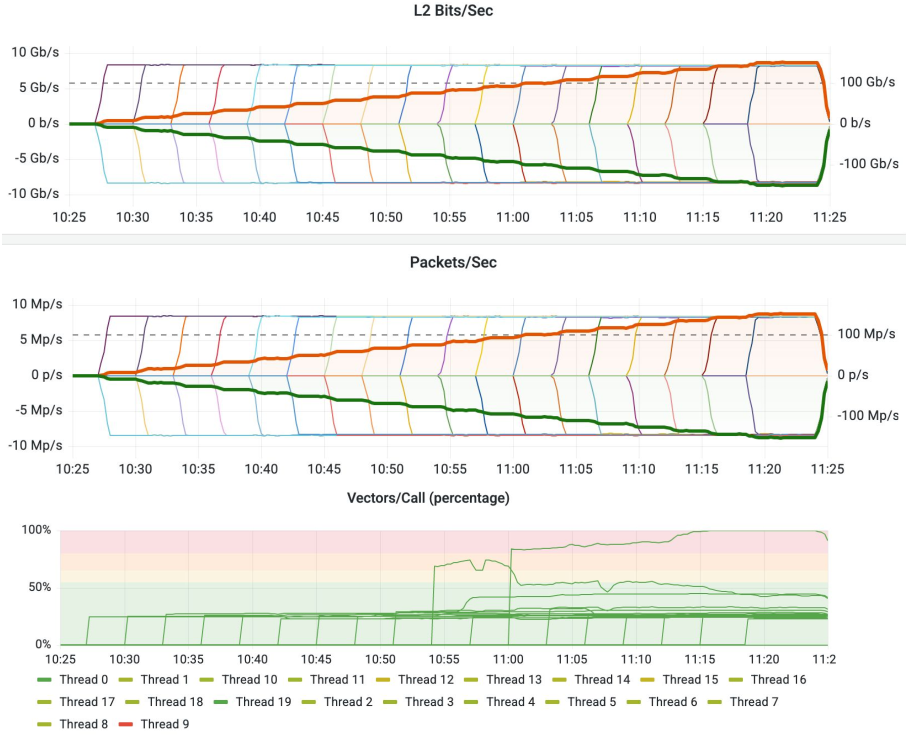
1) 10:26 - Incremental colored traces
T-Rex ports turned on one by one,
3 minutes apart, sending 128b.

2) 11:02 100Mpps achieved

3) 11:19165Mpps achieved
149Gbps @128b

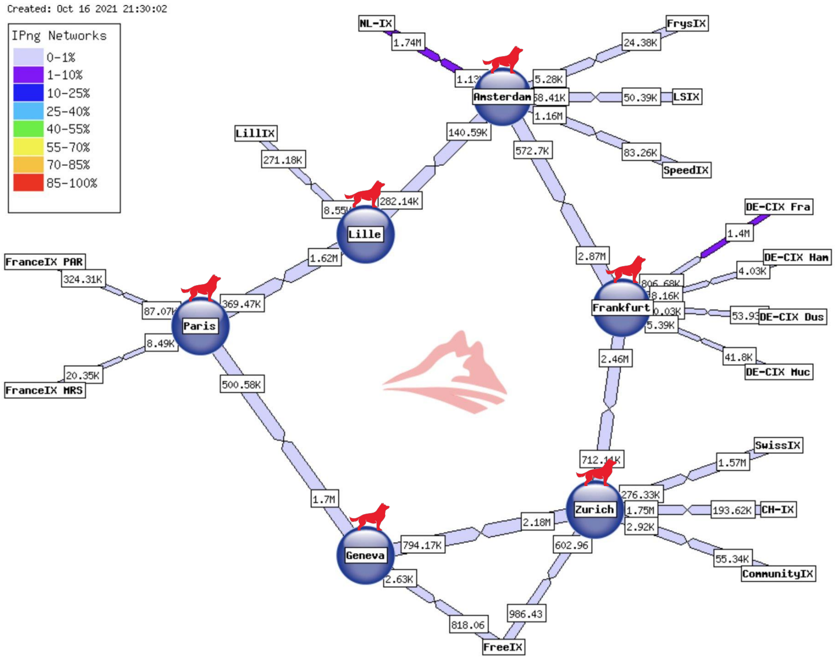
Note: 24 CPU threads unused; 6 NICs unused.

⇒ **Proof that VPP (easily) forwards 100Mpps**



```
vpp v24.10-rc0~204-ge9bc33201 built by pim on hvn6-lab at 2024-09-20T08:50:50
```

Questions, Discussion



If you peer with IPng Networks, thanks!

If you don't: please peer with AS8298

<peering@ipng.ch>

Useful Resources

- VPP Mailinglist [vpp-dev@lists.fd.io]
- VPP Linux CP [GitHub]
- Articles [ipng.ch]
- Mastodon [@IPngNetworks]

Also: thanks for listening!