

neutron-lan

SDN study environnement @ home

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Last update: May 29th, 2014

Background and Motivation

- Too many SDN definitions
 - I have been confused a lot.
 - OpenFlow, OVSD, Netconf, BGP extensions such as FlowSpec...
 - The latest addition: OpFlex (DevOps-like)
- What's the real SDN?
 - Let's develop SDN by myself and examine every definition.
- But, wait! I need a SDN study environment at home.
 - I am a poor guy, so I cannot buy expensive SDN-capable switches from Cisco, Juniper...

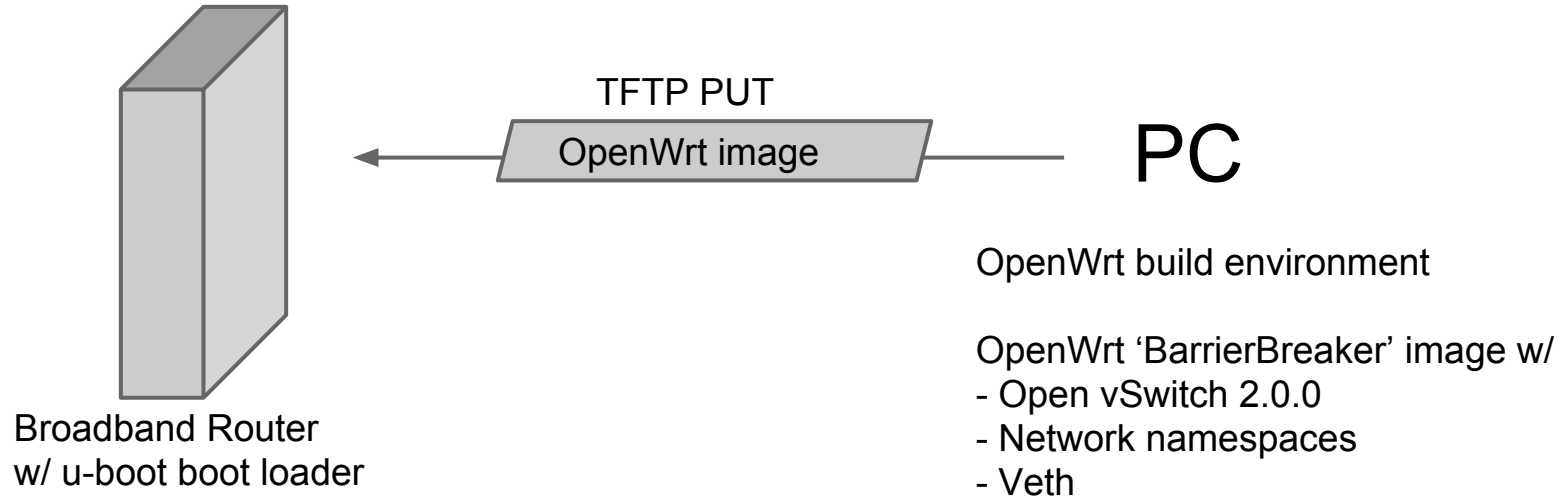
Strategy

- My budget is less than \$200.
- Switches/routers I purchased in Akihabara, Tokyo
 - Three \$40 broadband routers and one \$40 Raspberry Pi
- And I develop all the SDN software from scratch
 - But reuse existing networking software as much as possible, such as Open vSwitch
- Base knowledge/skills
 - SDN in the past: SIP and IP-PBX
 - OpenFlow, OpenStack neutron and SaltStack
 - Java and Python
 - HTML5 and CSS (a little)
- Let's develop neutron-like SDN for my home network ⇒ let's call it 'neutron-lan'

Project 'neutron-lan' characteristics

- Cheap routers as 'Baremetal Switch'
 - OpenWrt routers and Raspberry Pi
 - u-boot for installing new firmware
- OpenWrt kernel/kernel modules rebuilt(compiled) for supporting additional features
 - Open vSwitch 2.0.0, network namespaces(netns), veth and LXC.
- Home-made DevOps tool 'NLAN' for small routers w/ small memory/storage footprints
 - 100% Python implementation
 - YAML-based state rendering (Python's OrderedDict internally)
 - Model-driven service abstraction
 - Both imperative and declarative state definitions
 - OVSDB as a general-purpose config database
 - RFC7047 client library
 - With NLAN-specific OVSDB schema and schema extensions
 - MIME Multipart messages to cover various kinds of info
 - CRUD/RPC Transaction outputs
 - Exceptions
 - Logging info
 - RFC7047 JSON-RPC transactions
- VXLAN-based edge-overlay for network virtualization
 - Broadcast tree per VNI
 - Distributed Virtual Routing topology as well as hub & spoke topology
- LXC for Network Functions Virtualization

Cheap routers as 'Baremetal Switch'



Test bed (cont'd)

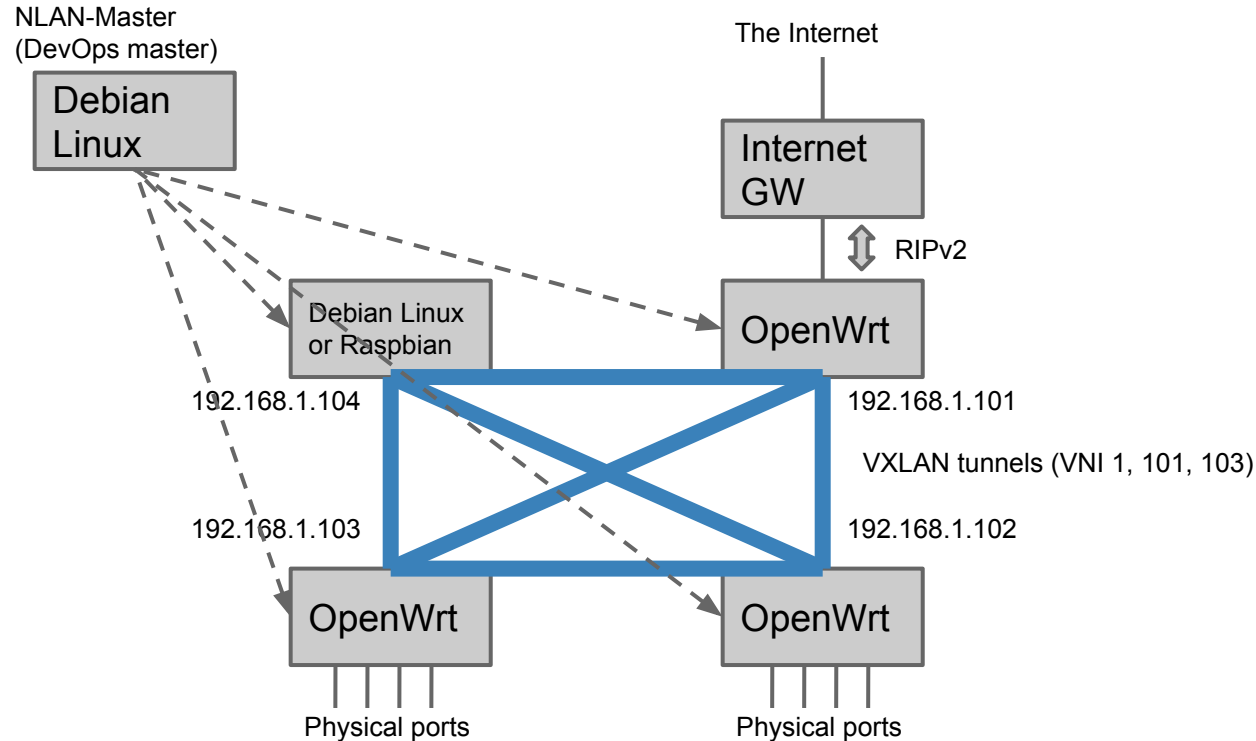


OpenWrt routers
(and Home Gateway)

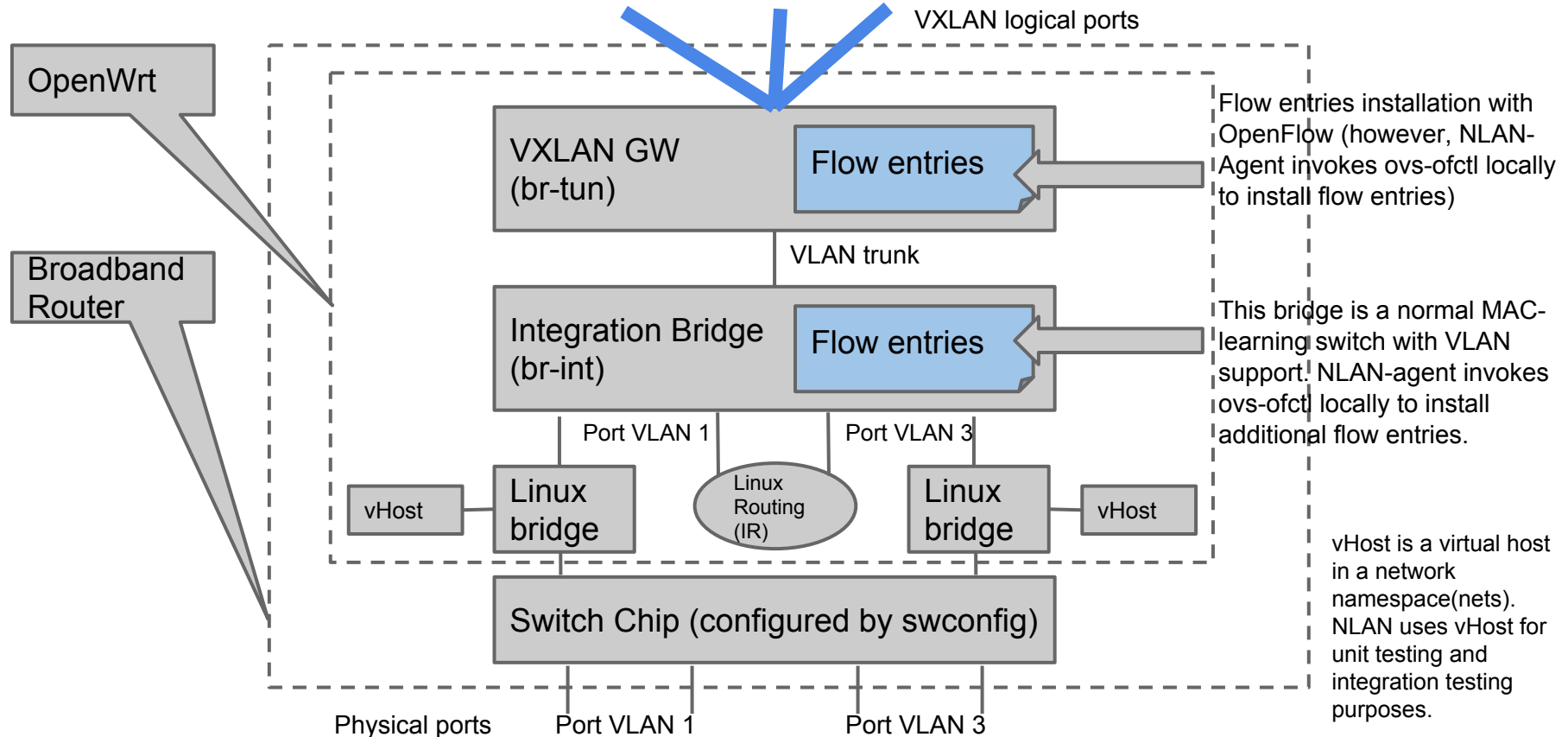


Raspberry Pi

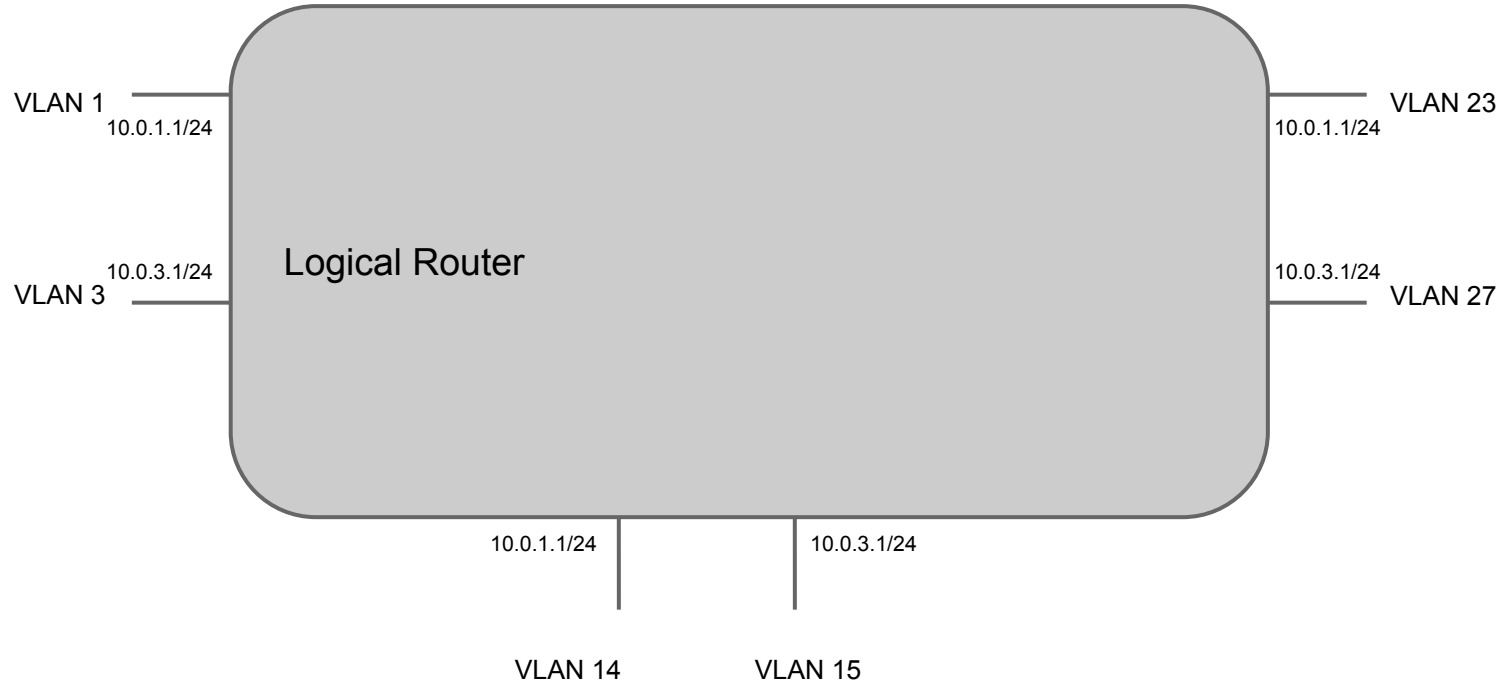
Test bed



OpenStack-neutron-like bridge configuration



Distributed Virtual Router (Logical view)



Virtual network topologies

NLAN node operation mode	Virtual Network Topology
dvr	Distributed Virtual Router
hub	Hub & Spoke
spoke	Hub & Spoke
spoke_dvr	Mixture of DVR and Hub & Spoke

NLAN “subnets” state and its parameters in YAML

subnets:

- vid: 1

vni: 1001

ip_dvr:

addr: '10.0.1.1/24'

mode: **hub**  mode can be 'dvr', 'hub', 'spoke' or 'spoke_dvr'

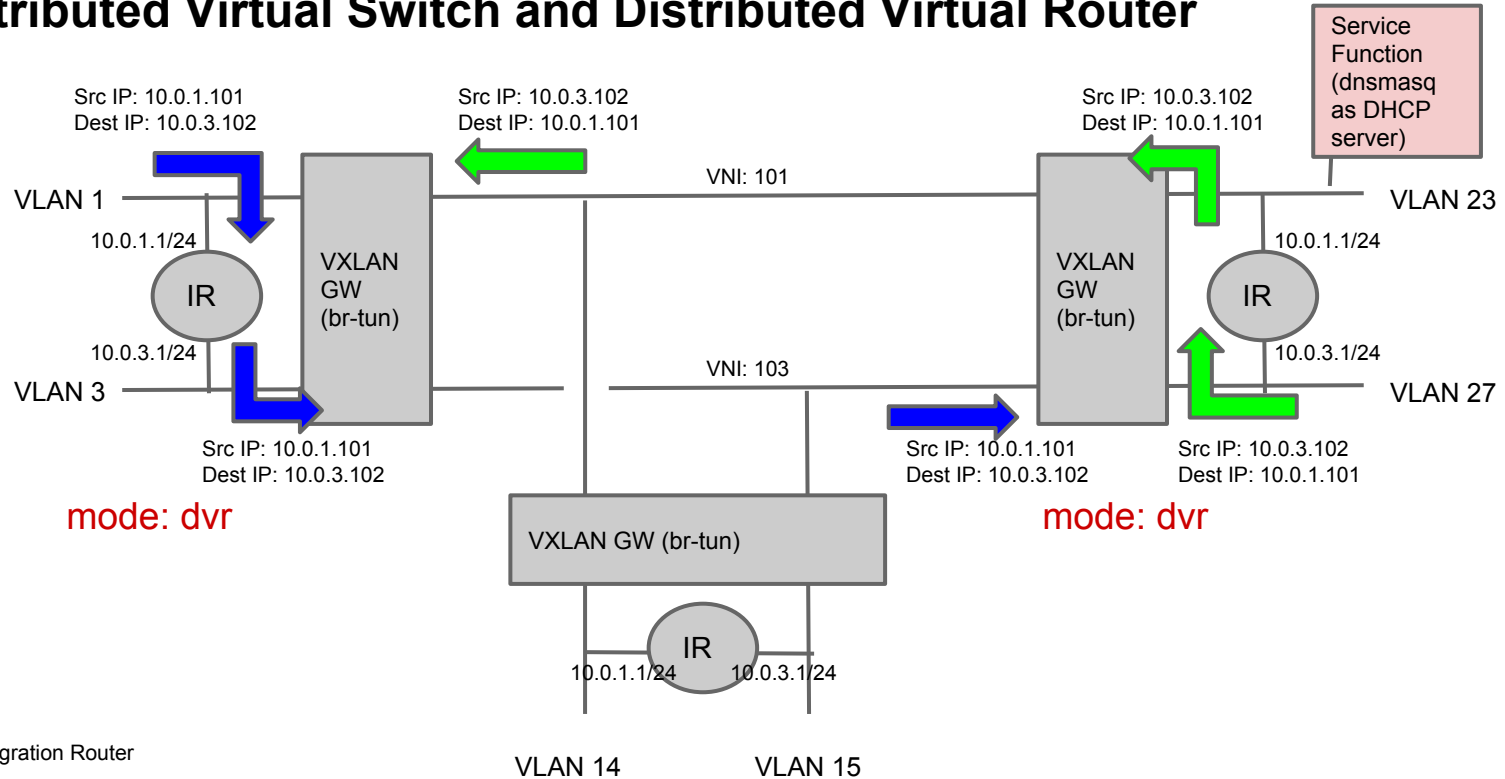
dhcp: **enabled**

ip_vhost: '10.0.1.101/24'

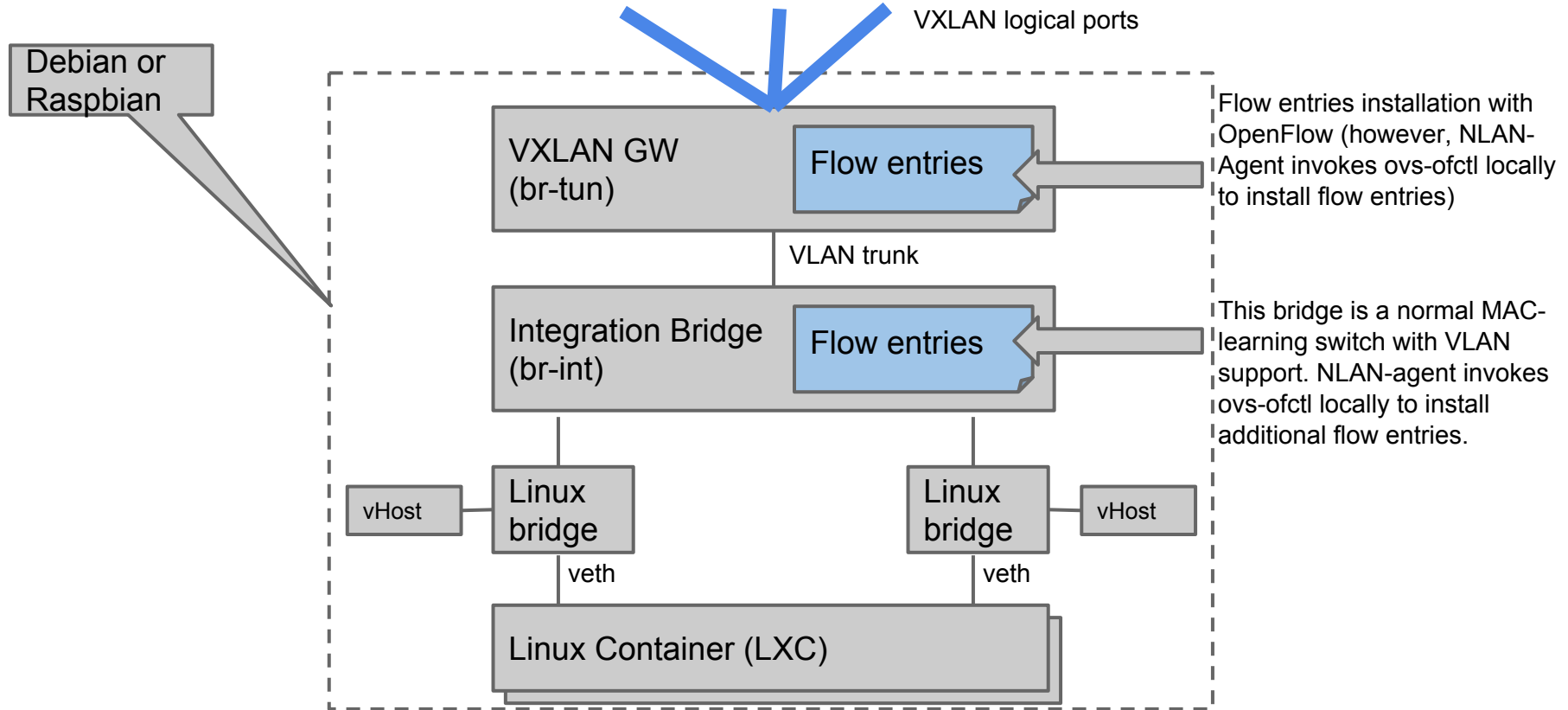
ports: [eth0.1]

peers: <peers>

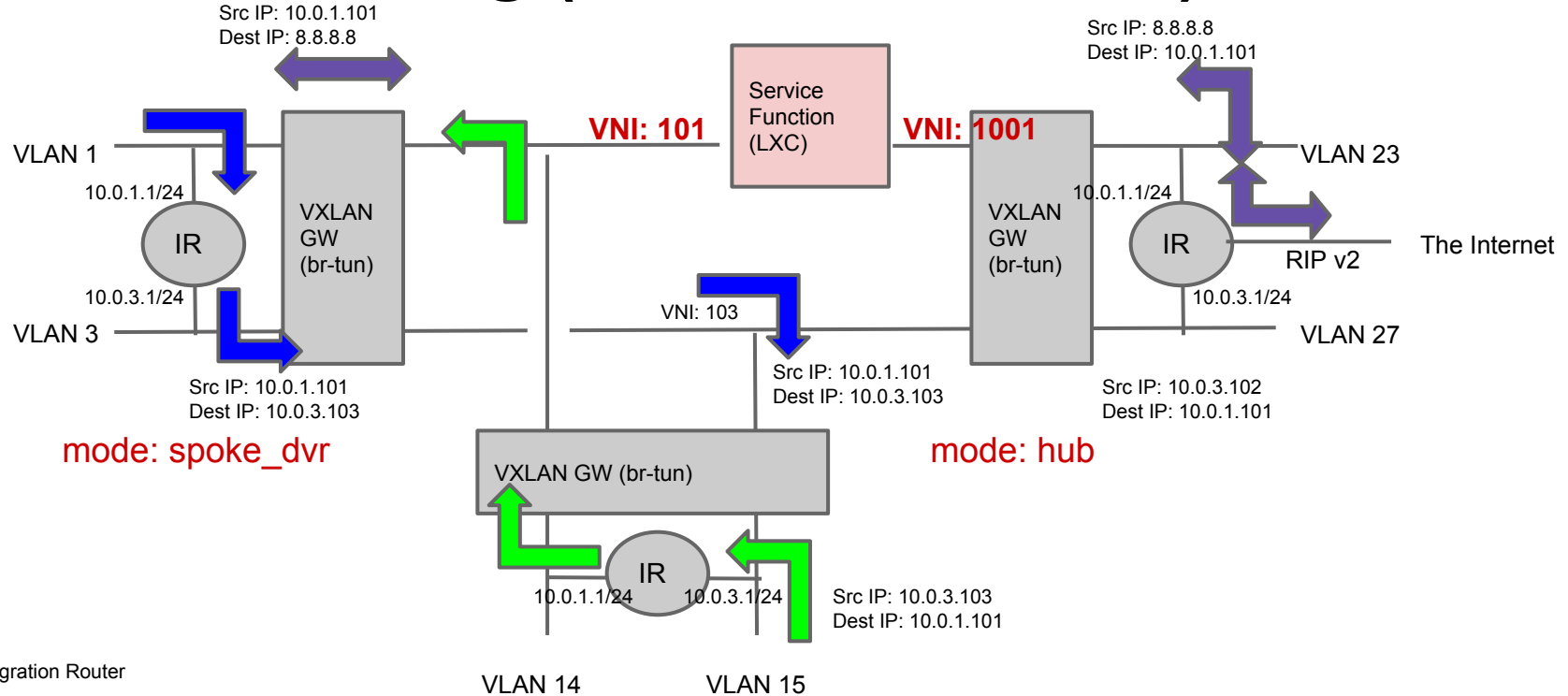
Distributed Virtual Switch and Distributed Virtual Router



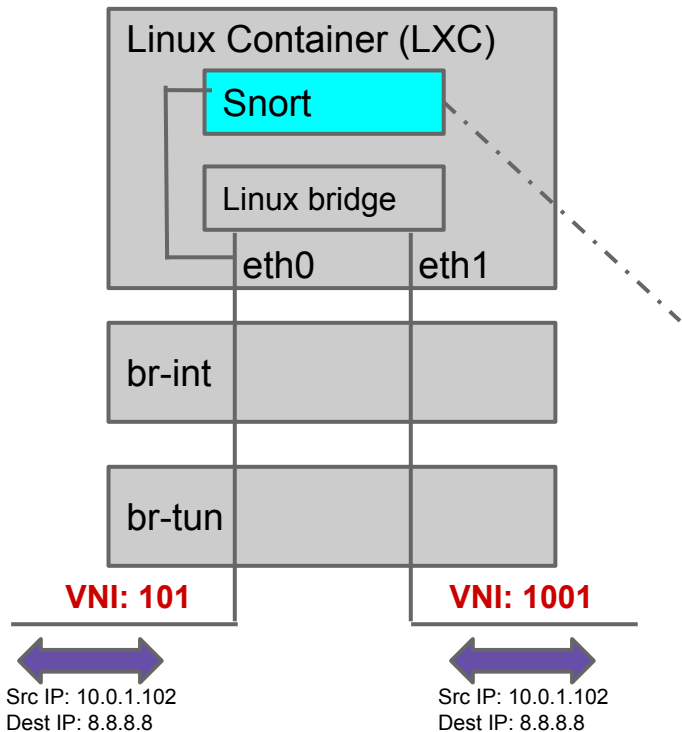
Service Function in Linux Container



Service Chaining (Service Insertion)



Example: Snort (in IPS mode) as Service Function



```
04/13-23:16:32.859385 10.0.1.102 -> 8.8.8.8  
ICMP TTL:64 TOS:0x0 ID:11745 IpLen:20 DgmLen:84 DF  
Type:8 Code:0 ID:49496 Seq:25 ECHO  
==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+
```

```
04/13-23:16:32.861970 8.8.8.8 -> 10.0.1.102  
ICMP TTL:63 TOS:0x0 ID:38077 IpLen:20 DgmLen:84  
Type:0 Code:0 ID:49496 Seq:25 ECHO REPLY
```

```
==+=+=====+
```

```
04/13-23:16:33.861151 10.0.1.102 -> 8.8.8.8
ICMP TTL:64 TOS:0x0 ID:11746 IpLen:20 DgmLen:84 DF
Type:8 Code:0 ID:49496 Seq:26 ECHO
=====
```

```
04/13-23:16:33.862906 8.8.8.8 -> 10.0.1.102  
ICMP TTL:63 TOS:0x0 ID:38078 IpLen:20 DgmLen:84  
Type:0 Code:0 ID:49496 Seq:26 ECHO REPLY  
==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+==+=+
```

Snort is a free and open source IPS/IDS software.

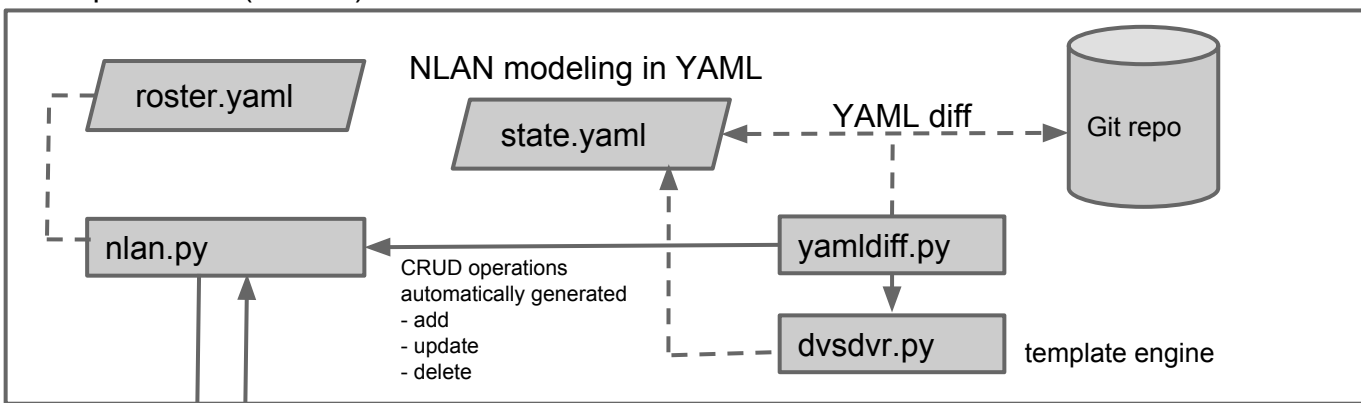
Home-made DevOps tool 'NLAN'

- 100% Python implementation
- Borrowed a lot of ideas from SaltStack
 - Model-driven approach
 - YAML-based state rendering w/ a simple template engine
 - Imperative/declarative state rendering
- Works with OpenWrt with minimal Python
 - opkg install python-mini
 - opkg install python-json
 - sshd
- OVSDb as a local config mgmt database
- State schema defined in YAML
 - merged with OVSDb schema in JSON

NLAN architecture (w/ config modules)

It's a bit like Salt State Modules...

DevOps master (Debian)

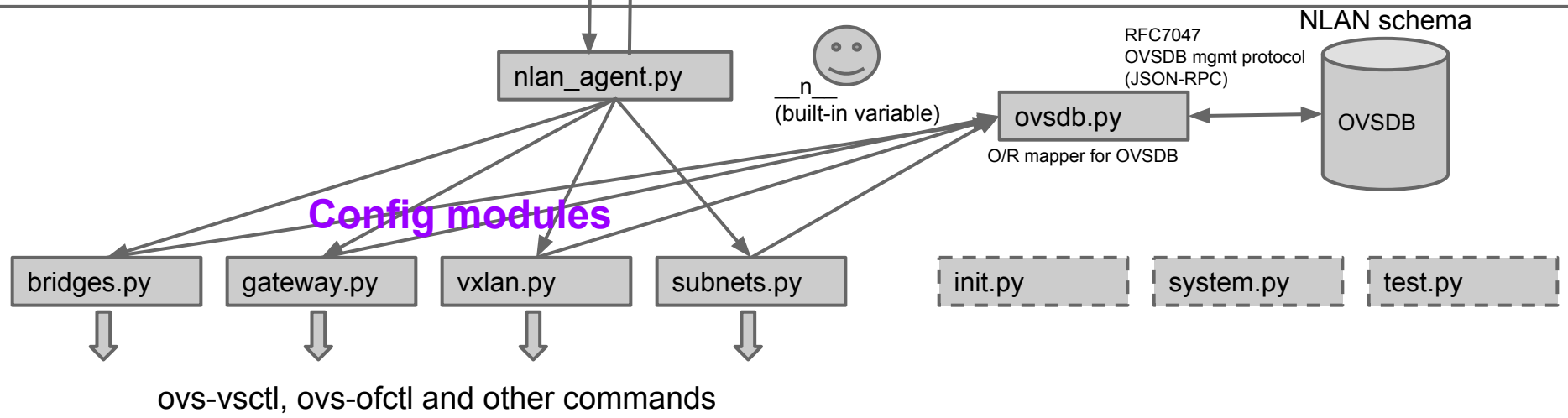


Python OrderedDict object
via STDIN

Command output
via STDOUT

SSH

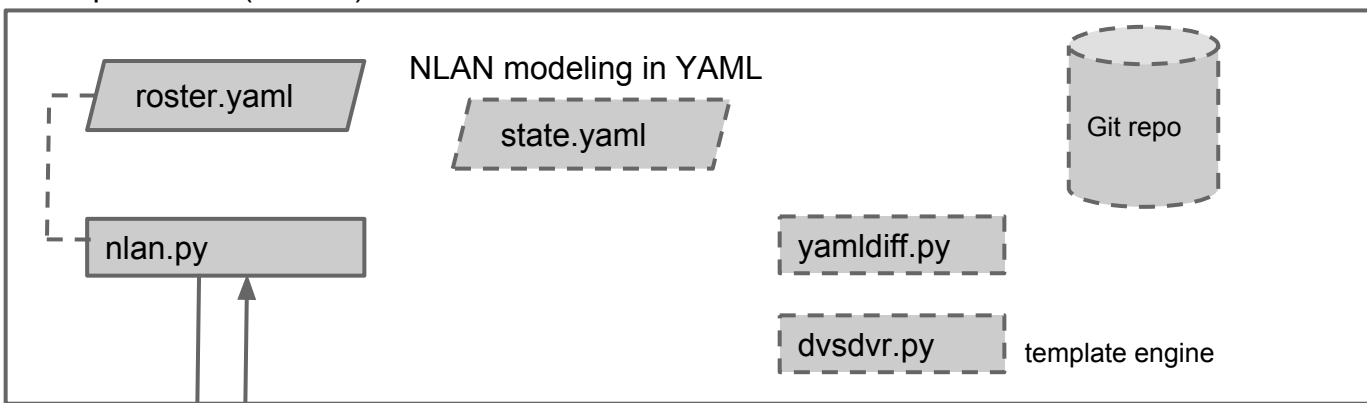
Router (OpenWrt or Raspbian)



NLAN architecture (w/ rpc modules)

It's a bit like Salt Execution Modules...

DevOps master (Debian)

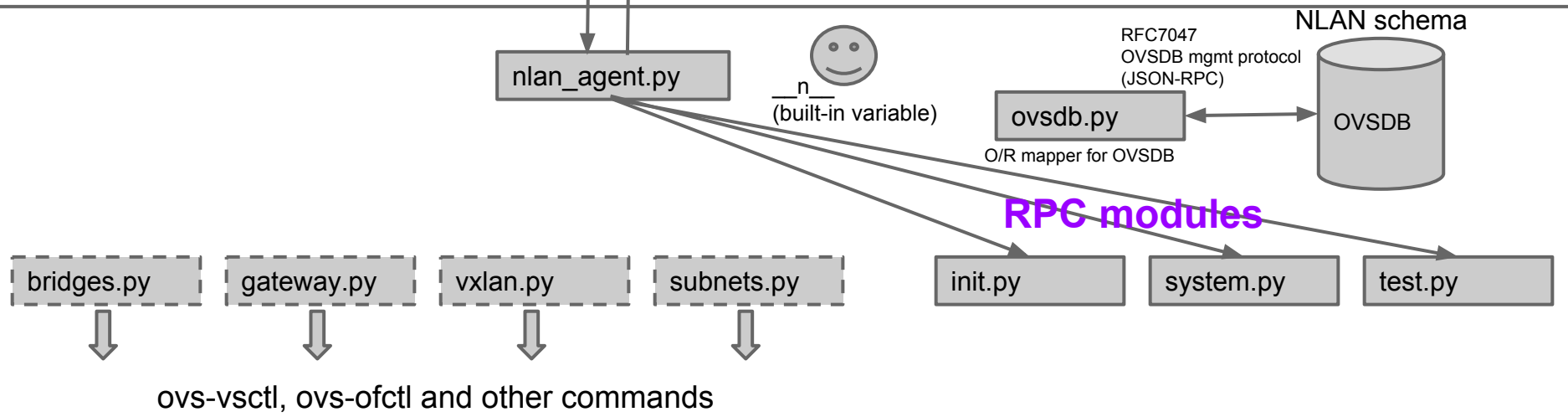


Python OrderedDict object
via STDIN

Command output
via STDOUT

SSH

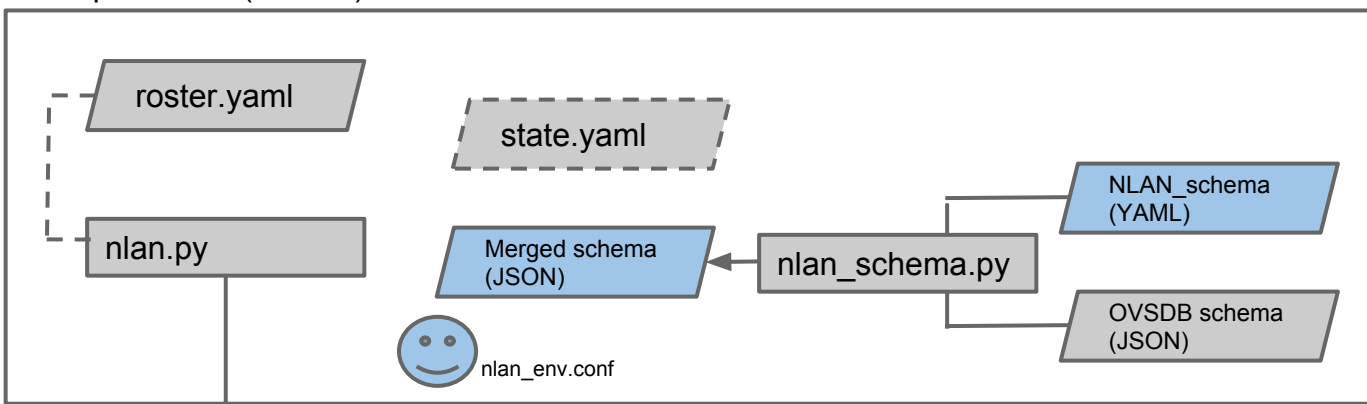
Router (OpenWrt or Raspbian)



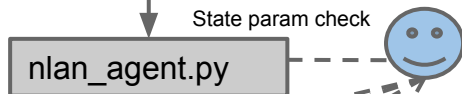
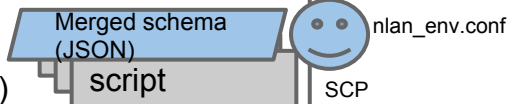
NLAN architecture (OvFlex)

Flexible OVSDb schemas (not so rigid)

DevOps master (Debian)



Router (OpenWrt or Raspbian)

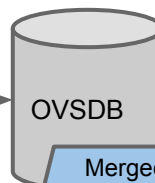


NLAN-specific schema

RFC7047
OVSDb mgmt protocol
(JSON-RPC)

NLAN schema

ovsdb.py
O/R mapper for OVSDb



NLAN-specific environment variables



ovs-vsctl, ovs-ofctl and other commands

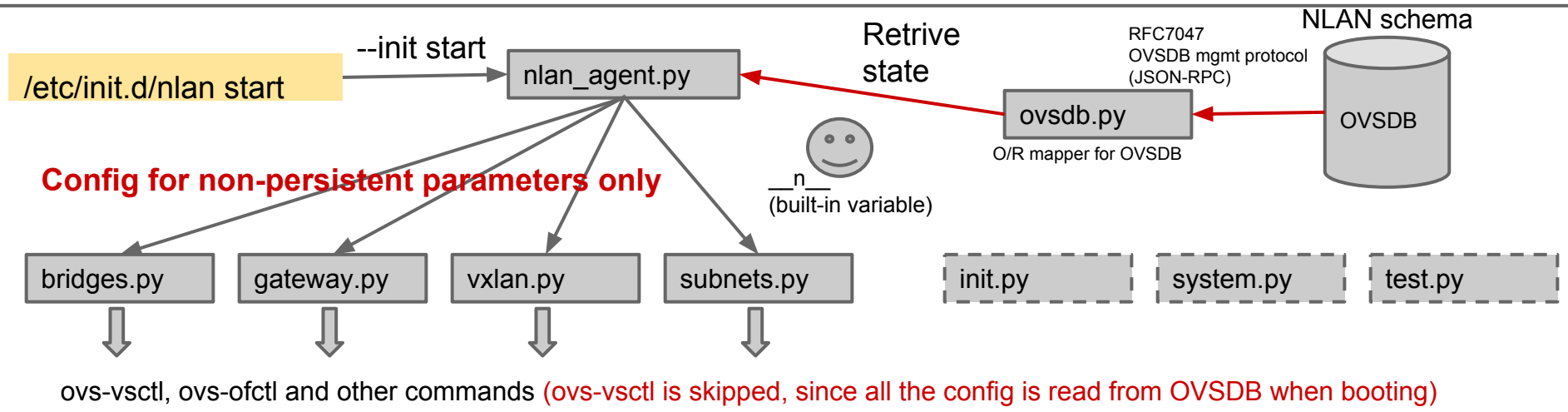
NLAN architecture

(System reboot)

DevOps master (Debian)

(All the routers are independent from the master)

Router (OpenWrt or Raspbian)



NLAN architecture

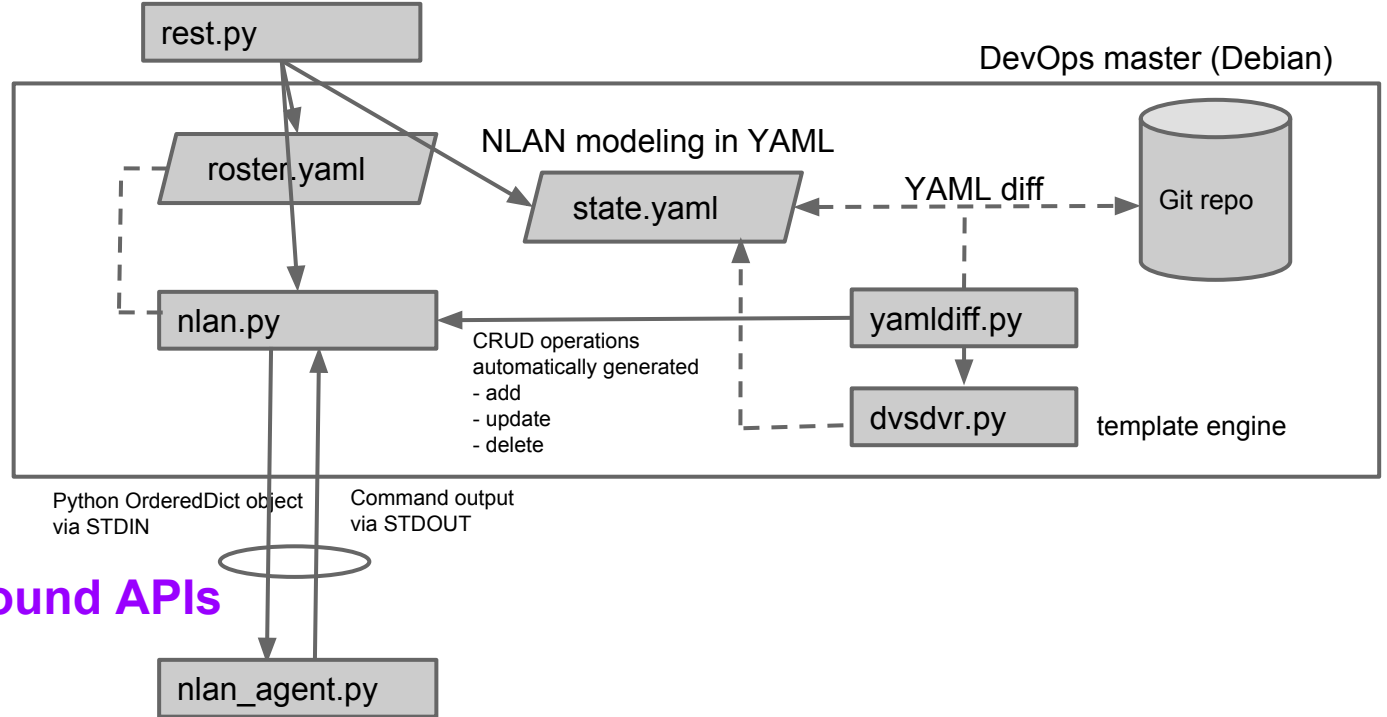
(REST APIs)

Northbound APIs

It's a bit like RESTCONF...



HTTP GET/POST/PUT/DELETE/OPTIONS w/ query parameters



Southbound APIs

OpFlex -- Flexible OVSDB schemas

OpFlex:

<http://www.cisco.com/c/en/us/solutions/collateral/data-center-virtualization/application-centric-infrastructure/white-paper-c11-731302.html>

OpFlex:

“It uses dynamic, flexible schemas for interaction with devices, effectively increasing the network to a higher common denominator feature set. The Open vSwitch Database (OVSDB) management protocol allows configuration of high-level abstract data models as well as basic primitives such as ports and bridges, and can support SDN geeks’ innovations”

OVSDB schema (Open_vSwitch database)

NLAN schema in YAML

```
      :
NLAN_Subnet:
  columns:
    vni:
      type:
        key: {type: integer, minInteger: 0, maxInteger: 16777215}
        min: 1
        max: 1
        _description: "Virtual network identifier"
    vid:
      type:
        key: {type: integer, minInteger: 0, maxInteger: 4095}
        min: 0
        max: 1
        _description: "VLAN ID"
    ip_dvr:
      type:
        key: {type: string, enum: [set, [addr, mode, dhcp]]}
        value: {type: string, _pattern: {addr: ipv4_prefix, mode: dvr_mode, dhcp:
string}}
    min: 0
    max: 3
    _description: "Distributed Virtual Router setting"
    ip_vhost:
      type:
        key: {type: string, _pattern: ipv4_prefix}
        min: 0
        max: 1
        _description: "Virtual host in a linux network namespace"
    default_gw:
      type:
        key: {type: string, _pattern: ipv4_address}
        min: 0
        max: 1
        _description: "Default GW address for this subnet"
      :
```

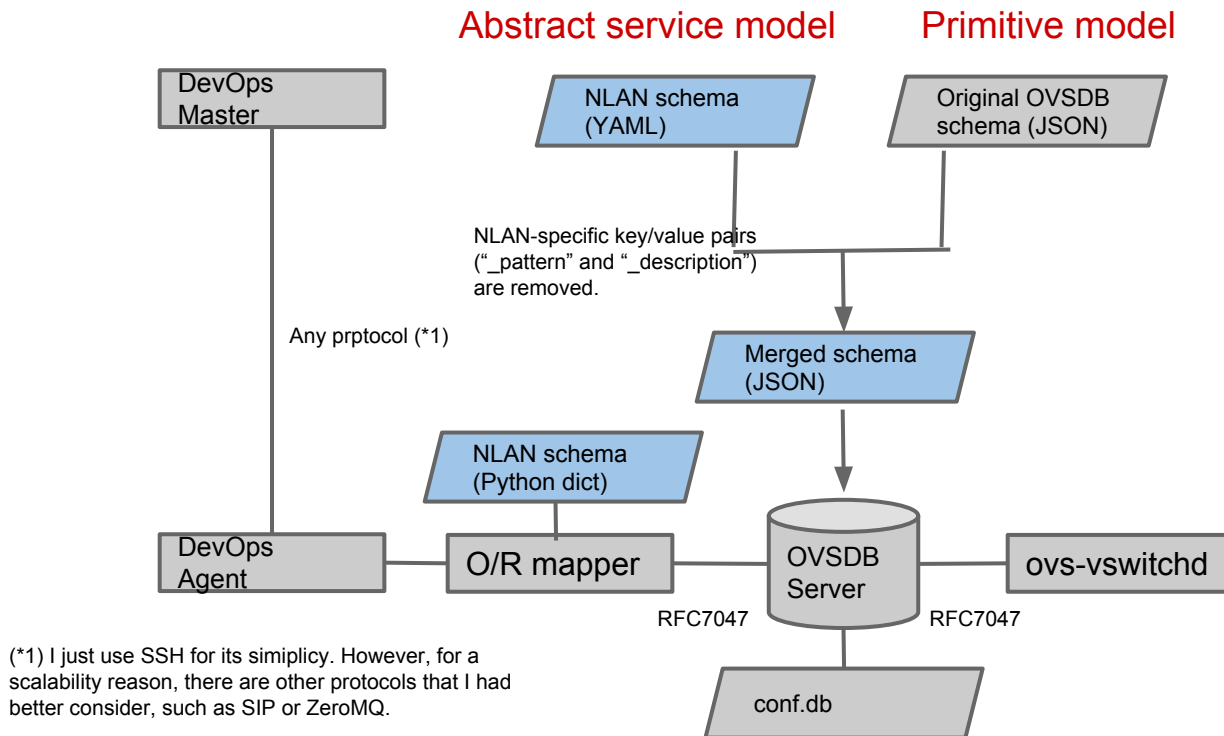
Note: `_pattern` and `_description` are NLAN-specific OVSDB schema extensions

Original OVSDB schema in JSON

```
{
  "name": "Open_vSwitch",
  "version": "7.4.2",
  "cksum": "951746691 20389",
  "tables": {
    "NLAN": {
      "columns": {
        "bridges": {
          "type": {
            "key": {
              "type": "uuid",
              "refTable": "NLAN_Bridges",
              "min": 0, "max": 1
            }
          }
        },
        "services": {
          "type": {
            "key": {
              "type": "uuid",
              "refTable": "NLAN_Service",
              "min": 0, "max": "unlimited"
            }
          }
        },
        "gateway": {
          "type": {
            "key": {
              "type": "uuid",
              "refTable": "NLAN_Gateway",
              "min": 0, "max": 1
            }
          }
        },
        "vxlan": {
          "type": {
            "key": {
              "type": "uuid",
              "refTable": "NLAN_VXLAN",
              "min": 0, "max": 1
            }
          }
        },
        "subnets": {
          "type": {
            "key": {
              "type": "uuid",
              "refTable": "NLAN_Subnet",
              "min": 0, "max": "unlimited"
            }
          }
        }
      },
      "isRoot": true,
      "maxRows": 1
    }
  }
}
```

Merging schemas

OVSDB schema can also express more abstract data models.



NLAN states in OVSDDB

(ovsdb-client dump Open_vSwitch)

```
NLAN table
_uuid          bridges          gateway          services  subnets
              vxlan

-----
0fc74b76-a3cb-40d7-9de5-26ea5d93e908 ae90946b-b00c-4e39-9ef0-2eda7ed89d66 dd3a47e2-b22c-45c6-a9f2-59f70f01eab7 [] [0ealcaea-57ab-4c29-913a-b916e903231
8, 6a607cd4-d0d0-4c7b-9b02-bf26c2acd343, abeeafb2-bedf-41f6-bf03-acclab773574] 4b0a1be2-1149-4665-943e-76088c20f271

NLAN_Bridges table
_uuid          controller ovs_bridges
-----
ae90946b-b00c-4e39-9ef0-2eda7ed89d66 [] enabled

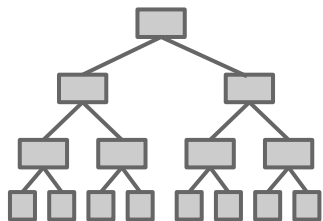
NLAN_Gateway table
_uuid          network rip
-----
dd3a47e2-b22c-45c6-a9f2-59f70f01eab7 "eth2" enabled

NLAN_Service table
_uuid chain name
-----

NLAN_Subnet table
_uuid          default_gw ip_dvr          ip_vhost          peers          ports v id vni
-----
0ealcaea-57ab-4c29-913a-b916e9032318 [] {addr="192.168.100.1/24", mode=dvr} "192.168.100.101/24" ["192.168.1.102", "192.168.1.103"] [] 2 1
abeeafb2-bedf-41f6-bf03-acclab773574 [] {addr="10.0.1.1/24", dhcp=enabled, mode=hub} "10.0.1.101/24" ["192.168.1.104"] [] 1 1001
6a607cd4-d0d0-4c7b-9b02-bf26c2acd343 [] {addr="10.0.3.1/24", dhcp=enabled, mode=dvr} "10.0.3.101/24" ["192.168.1.102", "192.168.1.103"] [] 3 103

NLAN_VXLAN table
_uuid          local_ip          remote_ips
-----
4b0a1be2-1149-4665-943e-76088c20f271 "192.168.1.101" ["192.168.1.102", "192.168.1.103", "192.168.1.104"]
```

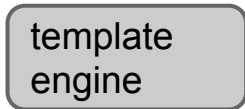

Model-driven service abstraction (cont'd)



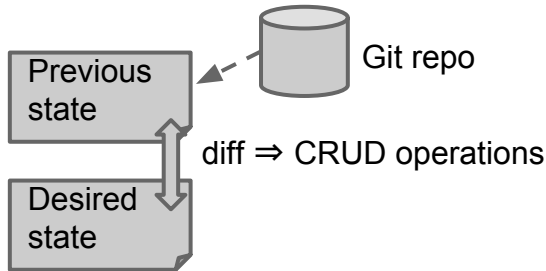
Step1: define network service model



Step2: write the mode as "desired state" in YAML format w/ some placeholders for a template engine

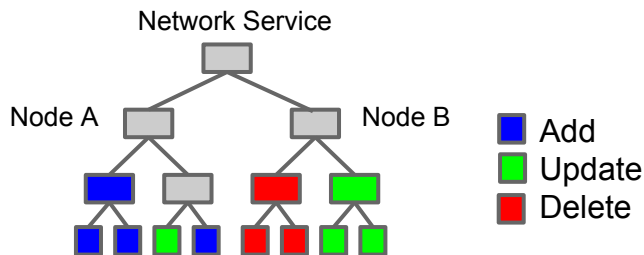


Step3: write a template engine to fill out the placeholders automatically.



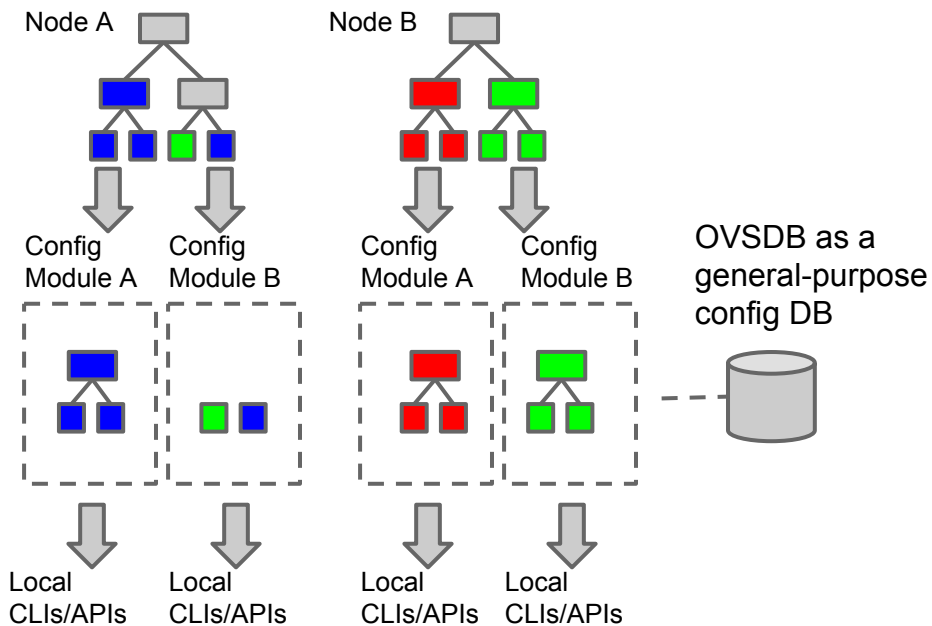
Step4: NLAN-Master (nlan.py and yamldiff.py) generates CRUD operations comparing the desired state with the previous state

Model-driven service abstraction



Step5: Now CRUD-operations (= diff between the previous and the desired states) are in the form of Python OrderedDict object

Step6: NLAN-Agent (nlan_agent.py) routes the CRUD operations to corresponding nodes/modules



Template and placeholders example

`#!/template.dvsvdvr`

`openwrt1:`

`:`

`vxlan:`

`local_ip: <local_ip>`

`remote_ips: <remote_ips>`

`subnets:`

`- vid: 1`

`vni: 101`

`ip_dvr: {addr: '10.0.1.1/24', mode: dvr}`

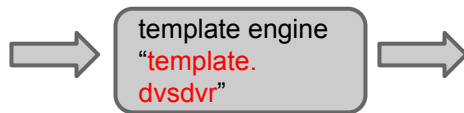
`ip_vhost: '10.0.1.101/24'`

`ports:`

`- eth0.1`

`peers: <peers>`

`:`



- generates a local ip address
- generates VXLAN remote ip addresses
- generates broadcast tree per VNI
- automatically resolves dependencies among parameters

`openwrt1:`

`:`

`vxlan:`

`local_ip: '192.168.1.101'`

`remote_ips: ['192.168.1.102', '192.168.1.103', '192.168.1.104']`

`subnets:`

`- vid: 1`

`vni: 101`

`ip_dvr: {addr: '10.0.1.1/24', mode: dvr}`

`ip_vhost: '10.0.1.101/24'`

`ports:`

`- eth0.1`

`peers: ['192.168.1.102', '192.168.1.104']`

`:`

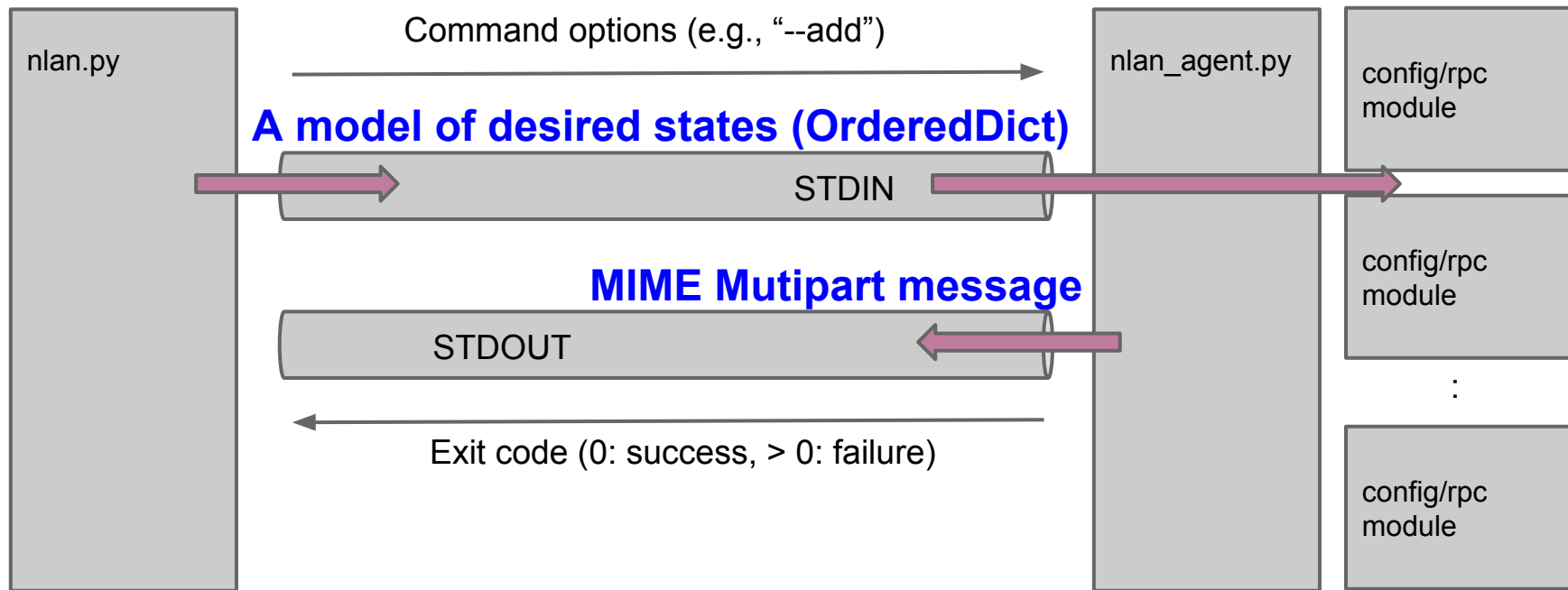
Model of desired state

- NLAN-Master sends Python OrderedDict to NLAN-Agent via ssh STDIN.
- To be exact, string form of an OrderedDict object (sort of object serialization).

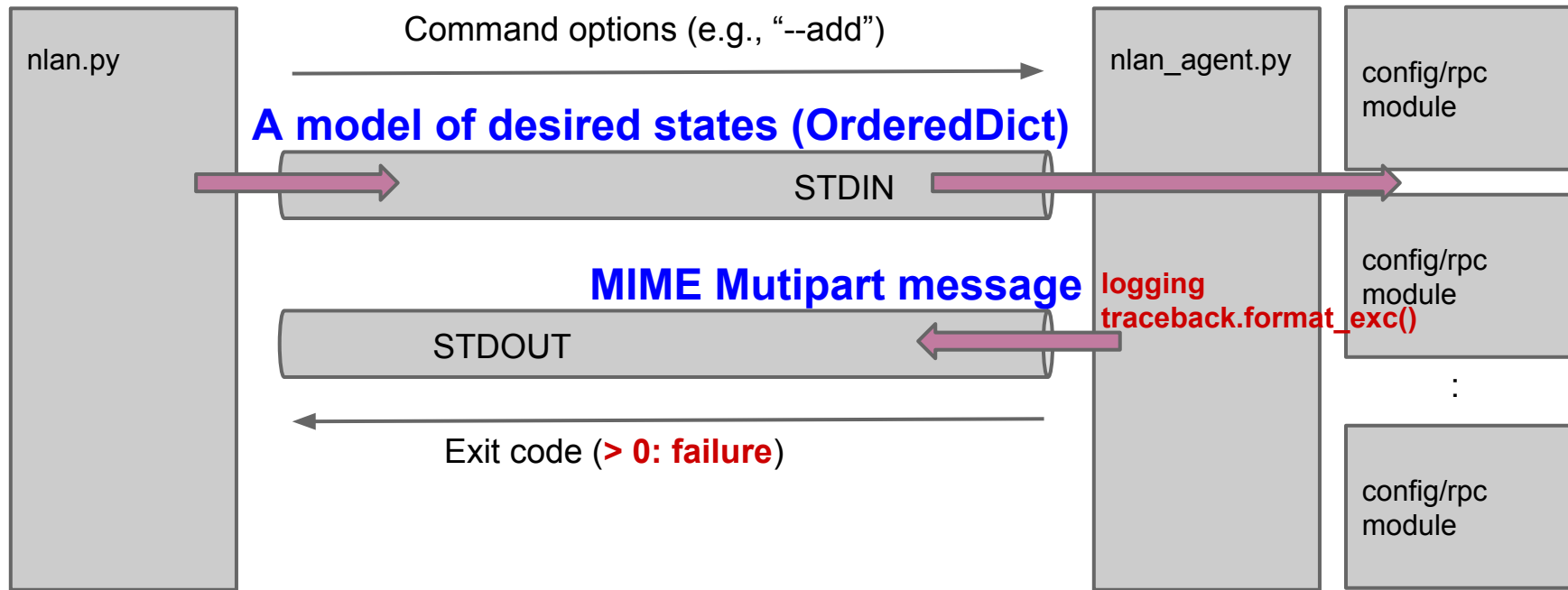
```
"OrderedDict([('bridges', {'ovs_bridges': 'enabled'}), ('gateway', {'network': 'eth2', 'rip':  
'enabled'}), ('vxlan', {'remote_ips': ['192.168.1.103', '192.168.1.102', '192.168.1.104'], 'local_ip':  
'192.168.1.101'}), ('subnets', [{'peers': ['192.168.1.102', '192.168.1.103'], 'vid': 2, '_index': ['vni', 1],  
'ip_vhost': '192.168.100.101/24', 'vni': 1, 'ip_dvr': OrderedDict([('addr', '192.168.100.1/24'),  
('mode', 'dvr')])}], {'peers': ['192.168.1.102', '192.168.1.103'], 'vid': 3, '_index': ['vni', 103],  
'ip_vhost': '10.0.3.101/24', 'vni': 103, 'ip_dvr': OrderedDict([('addr', '10.0.3.1/24'), ('mode', 'dvr')])}],  
{'peers': ['192.168.1.104'], 'vid': 1, '_index': ['vni', 1001], 'ip_vhost': '10.0.1.101/24', 'vni': 1001,  
'ip_dvr': OrderedDict([('addr', '10.0.1.1/24'), ('mode', 'hub')])}]))"
```

- Imperative/declarative state representation.
- I don't use JSON, since NLAN is 100% Python implementation.

NLAN Request/Response over SSH



Exception handling and debugging



Trouble shooting becomes much easier by sending `traceback.format_exc()` and raw command outputs (test/plain) to `nlan.py`.

MIME Multipart example

```
root@debian:~# nlan -t openwrt1 --get bridges ovs_bridges -M
*** Response from router:openwrt1,platform:openwrt
From nobody Thu May 29 03:16:42 2014
MIME-Version: 1.0
Content-Type: multipart/mixed;boundary="NKwDX7NAzowkZDZymawAVVwY3TcnvS1D"
```

```
--NKwDX7NAzowkZDZymawAVVwY3TcnvS1D
Content-Type: test/plain
Content-Description: Default out
X-NLAN-Type: default_out
```

```
--NKwDX7NAzowkZDZymawAVVwY3TcnvS1D
Content-Type: application/x-nlan
Content-Description: CRUD get
X-NLAN-Type: crud_response
```

```
OrderedDict([('bridges', {'ovs_bridges': 'enabled'})])
```

```
--NKwDX7NAzowkZDZymawAVVwY3TcnvS1D
Content-Type: application/x-nlan
Content-Description: NLAN Response
X-NLAN-Type: nlan_response
```

```
OrderedDict([('message', 'Execution completed'), ('exit', 0)])
```

```
--NKwDX7NAzowkZDZymawAVVwY3TcnvS1D--
```

Just use Python's "email" package for parsing the message.

Showing exception from remote routers

```
root@debian:~# nlan -t openwrt1 --add bridges ovs_bridges=enabled
*** Response from router:openwrt1,platform:openwrt
exception: CmdError
message: Command execution error
traceback: Traceback (most recent call last):
  File "/opt/nlan/nlan_agent.py", line 158, in _route
    call()
  File "/opt/nlan/config/bridges.py", line 35, in add
    cmdp('ovs-vsctl add-br br-int')
  File "/opt/nlan/cmdutil.py", line 115, in check_cmdp
    return _cmd('check_call', True, *args)
  File "/opt/nlan/cmdutil.py", line 20, in _cmd
    return _cmd2(check=check, persist=persist, args=cmd_args)
  File "/opt/nlan/cmdutil.py", line 62, in _cmd2
    raise CmdError(argstring, e.returncode, out)
CmdError: Command execution error

command: ovs-vsctl add-br br-int
stdout: None
exit: 1
operation: add
progress: [('bridges', False)]
```



traceback.format_exc()

Showing debug information from remote routers

```
--37axII0rq4QKTU6Ll2jpcwxt3HC3Vm2
```

```
Content-Type: text/plain
```

```
Content-Description: [DEBUG] 2014-05-29 10:23:50, 057 module:cmdutil,  
function:log, router:openwrt3
```

```
X-NLAN-Type: logger
```

```
cmd: ip netns exec ns1 ip route add default via 192.168.100.3 dev eth0
```

```
--37axII0rq4QKTU6Ll2jpcwxt3HC3Vm2
```

```
Content-Type: text/plain
```

```
Content-Description: [DEBUG] 2014-05-29 10:23:50, 060 module:cmdutil,  
function:log, router:openwrt3
```

```
X-NLAN-Type: logger
```

```
cmd: ip addr add dev int_dvr1 192.168.100.3/24
```

```
--37axII0rq4QKTU6Ll2jpcwxt3HC3Vm2
```

```
Content-Type: text/plain
```

```
Content-Description: [DEBUG] 2014-05-29 10:23:50, 065 module:cmdutil,  
function:log, router:openwrt3
```

```
X-NLAN-Type: logger
```

```
cmd: route
```

```
Kernel IP routing table
```

Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
10.0.2.0	*	255.255.255.0	U	0	0	0	eth0
192.168.1.0	*	255.255.255.0	U	0	0	0	eth2
192.168.56.0	*	255.255.255.0	U	0	0	0	eth1
192.168.100.0	*	255.255.255.0	U	0	0	0	int_dvr1

```
--37axII0rq4QKTU6Ll2jpcwxt3HC3Vm2
```

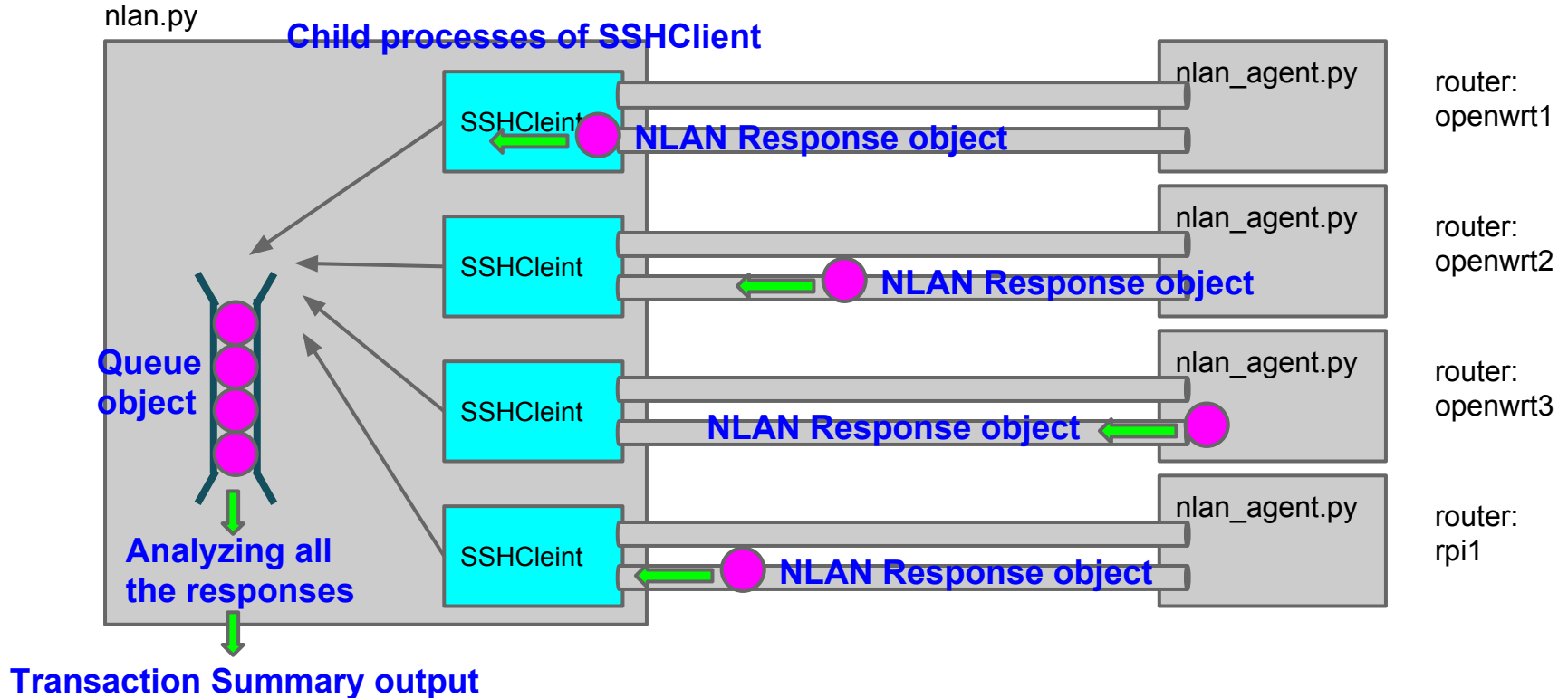
NLAN's logger can print every command executed at remote routers.

Showing transactions with OVSDb at remote routers

```
[DEBUG] 2014-05-29 03:45:53,322 module:ovsdb,function:crud,router:rp11
CRUD operation (add): {'peers': ['192.168.1.102', '192.168.1.103'], 'ports': ['mz.101'], 'vni': 101, 'vid': 1}
[DEBUG] 2014-05-29 03:45:53,323 module:ovsdb,function:_send,router:rp11
request:
  id: 89846
  method: transact
  params:
    - Open_vSwitch
    - op: insert
      row:
        peers:
          - set
          - - 192.168.1.102
          - 192.168.1.103
        ports:
          - set
          - - mz.101
        vid: 1
        vni: 101
        table: NLAN_Subnet
        uuid-name: temp_515801
    - mutations:
        - - subnets
        - insert
        - - set
        - - - named-uuid
        - temp_515801
        op: mutate
        table: NLAN
        where: []
response:
  error: null
  id: 89846
  result:
    - uuid:
        - uuid
        - cb6bc9a6-0a86-415f-a82c-19f6a5e841d0
    - count: 1
```

NLAN can show RFC7047 JSON-RPC transactions in the form of YAML.

Parallel SSH sessions



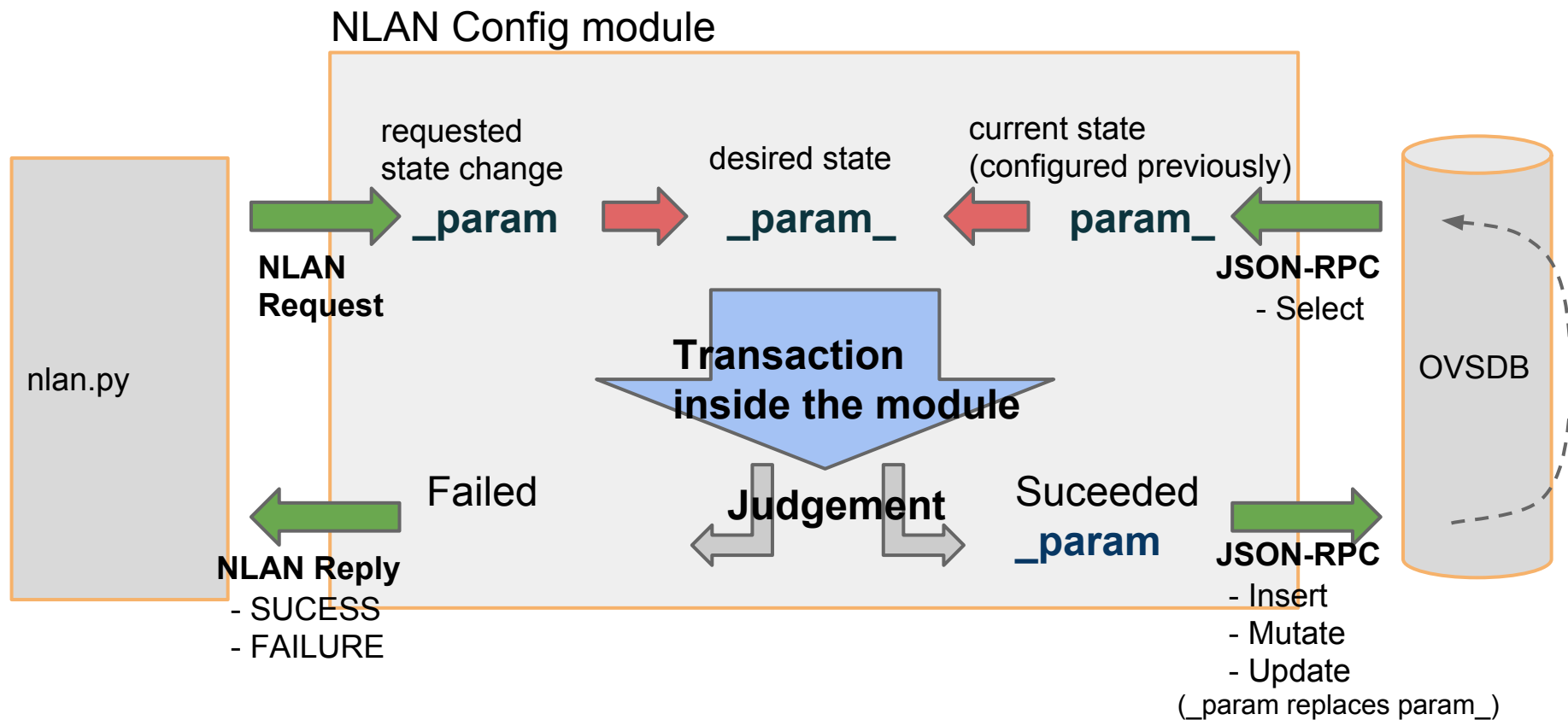
Transaction Summary output

Transaction Summary

```
Start Time: 2014-04-22 20:48:31.835552
```

Router	Result	Elapsed Time
openwrt1	:-)	2.88(sec)
openwrt3	:-)	2.99(sec)
openwrt2	:-)	3.00(sec)
rpil	:-)	3.08(sec)

CRUD operations inside NLAN config modules



Global variables (__dict__) generated by CRUD.params()

model

```
state +- param a
|
+- param b
|
+- param c
|
+- param d
```

State parameters (for add/update operations)

			Global variables generated by Model.params()			
State params	Requested by Master	OVSDB	_param (Requested change)	_param_ (Desired state)	param_ (Current state in OVSDB)	Operation
a	1	None	_a=1	_a_=1	a_=None	add
b	2	1	_b=2	_b_=2	b_=1	update
c	None	1	_c=None	_c_=1	c_=1	
d	None	None	_d=None	_d_=None	d_=None	

State parameters (for delete operations)

			Global variables generated by Model.params()			
State params	Requested by Master	OVSDB	_param (Requested change)	_param_ (Desired state)	param_ (Current state in OVSDB)	Operation
a	1	None	_a=1	_a_=***	a_=None	(Never exists)
b	1	1	_b=1	_b_=None	b_=1	delete
c	None	1	_c=None	_c_=1	c_=1	
d	None	None	_d=None	_d_=None	d_=None	

Python coding in NLAN Config modules

nlan_agent.py

```
with oputil.CRUD(...):  
    module.add()
```



module.py

```
def add():  
    if _param1:  
        (execute local commands w/ _param1 and other  
         _param_(s) as arguments)  
    if _param2:  
        (execute local commands w/ _param2 and other  
         _param_(s) as arguments)  
    if _param3:  
        (execute local commands w/ _param3 and other  
         _param_(s) as arguments)
```

```
with oputil.CRUD(...):  
    module.delete()
```



```
def delete():
```

: Every NLAN config
module MUST implement
add(), delete() and
update() functions.

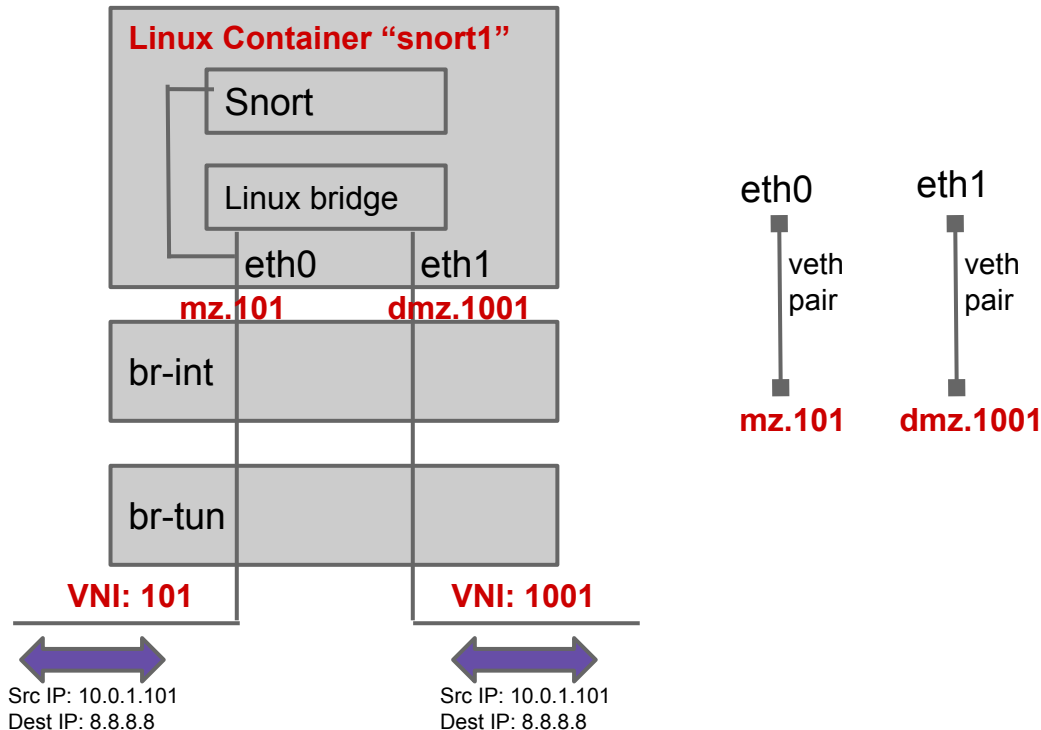
```
with oputil.CRUD(...):  
    module.update()
```



```
def update():
```

Service Function Chaining in YAML

```
rpi1:
  bridges:
    ovs_bridges: enabled
  services: # Service Functions
    - name: snort1
      chain: [mz.101, dmz.1001]
  vxlan:
    local_ip: <local_ip>
    remote_ips: <remote_ips>
  subnets:
    - vid: 111
      vni: 1001
      peers: <peers>
      ports: <sfports>
    - vid: 1
      vni: 101
      peers: <peers>
      ports: <sfports>
```



NLAN command usage (nlan.py)

Copy NLAN-agent-side modules to all the target routers (incl. NLAN/OVSDB schema and Linux init.d scripts):

```
$ nlan.py --scpmmod
```

Initialize states at all the target routers:

```
$ nlan.py init.run
```

Ask all the target routers to transit to the desired states

```
$ nlan.py -G deploy
```

Rollback to the previous config

```
$ nlan.py init.run
```

```
$ nlan.py -R deploy
```

Command line CRUD (add/get/update/delete) operations

```
$ nlan.py -t openwrt1 --add subnets _index=101 vid=1 ip_dvr=mode:dvr,addr:10.0.1.1/24 ip_vhost=10.0.1.101/24
```

```
$ nlan.py -t openwrt1 --update subnets _index=101 ip_vhost=10.0.1.109/24
```

```
$ nlan.py -t openwrt1 --delete subnets _index=101 ip_vhost=10.0.1.109/24
```

```
$ nlan.py -t openwrt1 --get subnets _index=101 vid ip_dvr
```

Reboot all the target routers:

```
$ nlan.py system.reboot
```

NLAN command usage (nlan_agent.py)

Initialize states:

```
$ nlan_agent.py init.run
```

Command line CRUD (add/get/update/delete) operations

```
$ nlan_agent.py --add subnets _index=101 vid=1 ip_dvr=mode:dvr,addr:10.0.1.1/24 ip_vhost=10.0.1.101/24
```

```
$ nlan_agent.py --update subnets _index=101 ip_vhost=10.0.1.109/24
```

```
$ nlan_agent.py --delete subnets _index=101 ip_vhost=10.0.1.109/24
```

```
$ nlan_agent.py --get subnets _index=101 vid ip_dvr
```

Reboot all the target routers:

```
$ nlan.py system.reboot
```

REST APIs

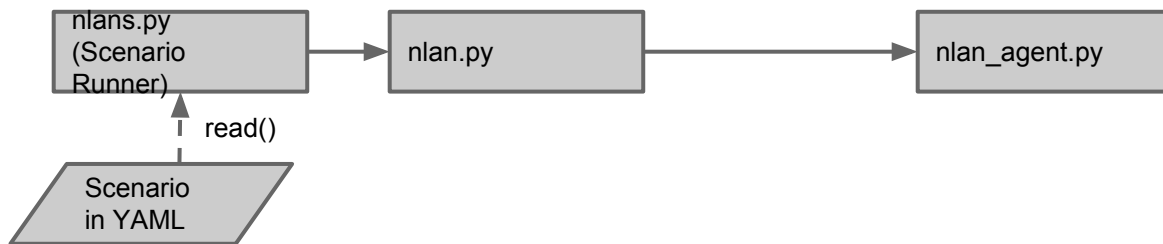
HTTP Method	NLAN CRUD operations	NLAN RPC operations
GET	CRUD: get URL: /<router>/ config /<module>/<_index>	URL: /<router>/ rpc /<module>/<func>
POST	CRUD: add URL: /<router>/ config /<module>/<_index>	-
PUT	CRUD: update URL: /<router>/ config /<module>/<_index>	-
DELETE	CRUD: delete URL: /<router>/ config /<module>/<_index>	-
OPTIONS	Get NLAN schemas URL: none	-

REST APIs example

HTTP Method	URL	Query parameters
POST	/_ALL/rpc/test/echo	params=Hello!
OPTIONS	(none)	params=subnets
POST	/openwrt1/rpc/init/run	(none)
POST	/openwrt1/config/bridges	ovs_bridges=enabled
POST	/openwrt1/config/vxlan	local_ip=192.168.1.101&remote_ips=192.168.1.102,192.168.56.103
PUT	/openwrt1/config/vxlan	remote_ips=192.168.1.102,192.168.56.104
GET	/openwrt1/config/vxlan	params=remote_ips
POST	/openwrt1/config/subnets/101	vni=101&vid=1&ip_dvr=addr:10.0.1.1/24,mode:dvr
DELETE	/openwrt1/config/subnets/101	params=ip_dvr
POST	/openwrt1/rpc/db/state	(none)

Scenario Runner

- nlans.py -- reads test scenarios and executes each test
- Test scenarios written in YAML
- Automatic test result confirmation
 - Inspired by Python's "unittest"
 - "assert"
 - "asserRaises"
 - ("assertOutputs" to be supported)



Simple RPC library

```
import rpc
```

```
# calls test.kwargs_test(...) at router 'openwrt1'
```

```
rpc = rpc.RPC(module='test', func='kwargs_test', target='openwrt1')
```

```
result = rpc(1, b='Hello', d='World!')
```

```
print result
```

```
# calls test.echo(*args) at all routers on the roster
```

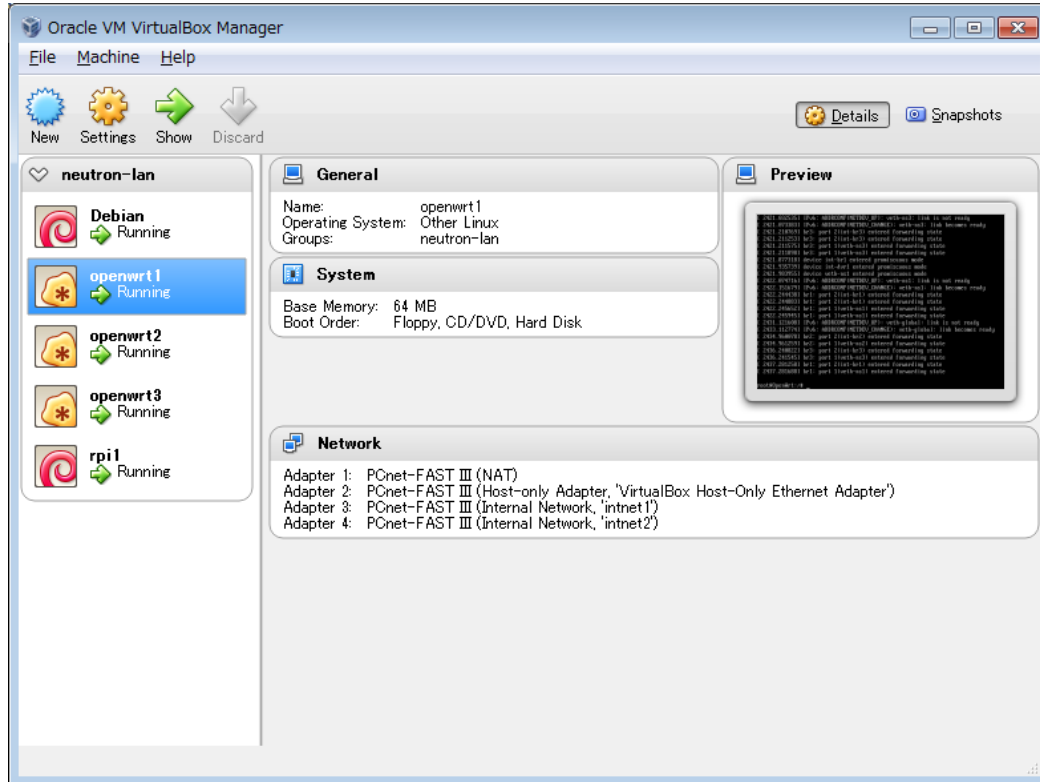
```
rpc = rpc.RPC(module='test', func='echo')
```

```
results = rpc('Hello World!')
```

```
for l in results:
```

```
    print l['router'], l['stdout']
```

NLAN Software Development environment on VirtualBox

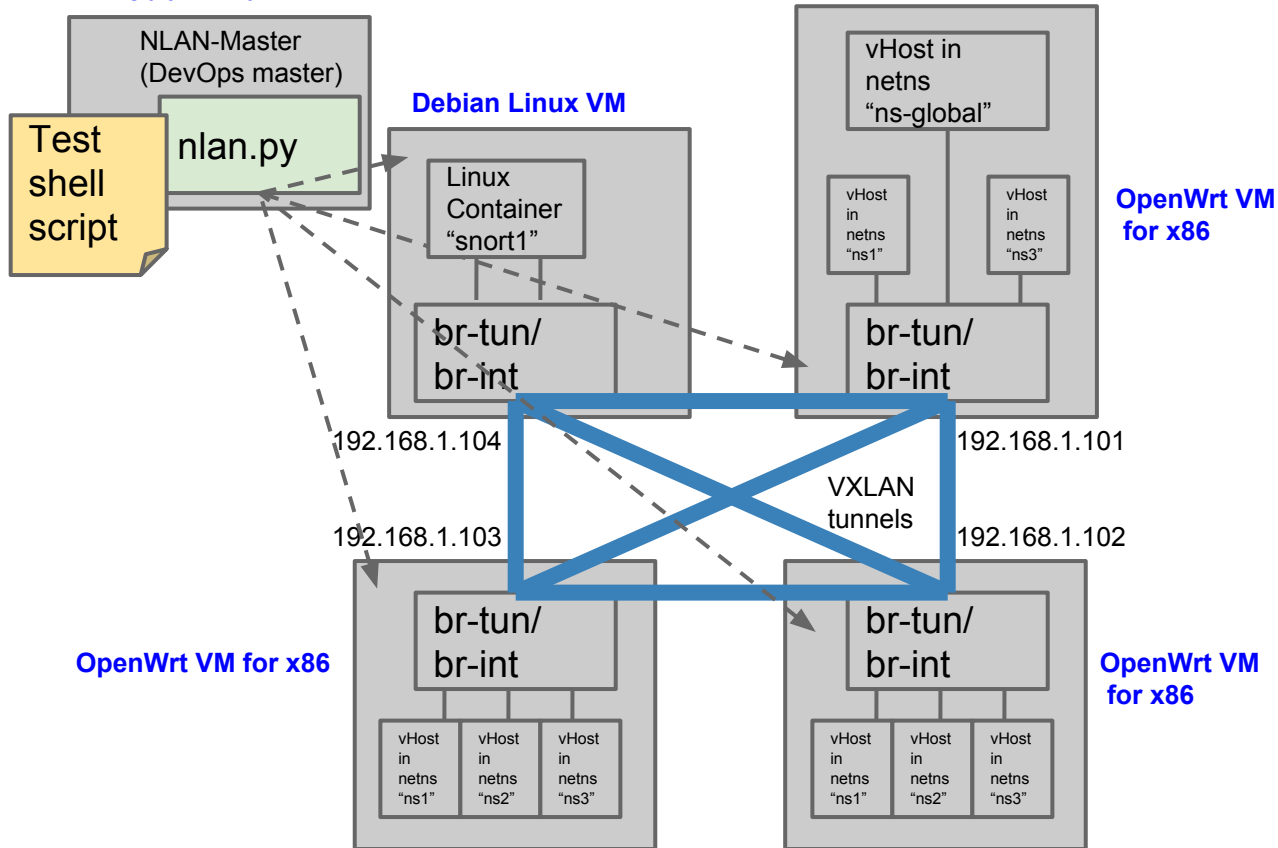


- Five VMs running on one Win7 PC.
 - Two Debian VMs
 - Three OpenWrt VMs
- OpenWrt image for x86
 - I built the kernel with Open vSwitch 2.0.0 and netns/veth/LXC support
 - Very light-weight Linux supporting Open vSwitch 2.0.0 ⇒ An alternative to mininet 2.0.0
- Network adapters setting
 - Internet access: "NAT"
 - Management: "Host-Only"
 - NLAN underlay: "Internal"

Integration Test environment on VirtualBox

(running the test script every day)

Debian Linux VM



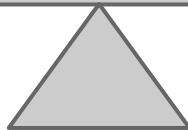
- Open vSwitch-based network more realistic than mininet 2.0
 - Every vSwitch with full-fledged(?) Linux
 - netns-based virtual hosts
- Mimics "Beremetal Switch"
- Integration Test script running on Debian Linux VM
 - Makes use of "nlan.py"

Future work

- NLAN enhancements
 - NLAN Agent in a Linux container (lxc-execute)
 - Multi-generation config rollback
 - Full-automatic integration testing
- Studying NETCONF and OpenDaylight
 - I have understood that modeling is the core part of SDN and DevOps, and NETCONF supposed to be a perfect language for modeling network.
 - I want to see if it is really 'an idealized SDN controller' as O'Reilly "SDN" book tells me.

Man-power for developing and testing SDN

CAPEX/OPEX reduction



Balance