OpenStack: OVS Deep Dive

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Overview

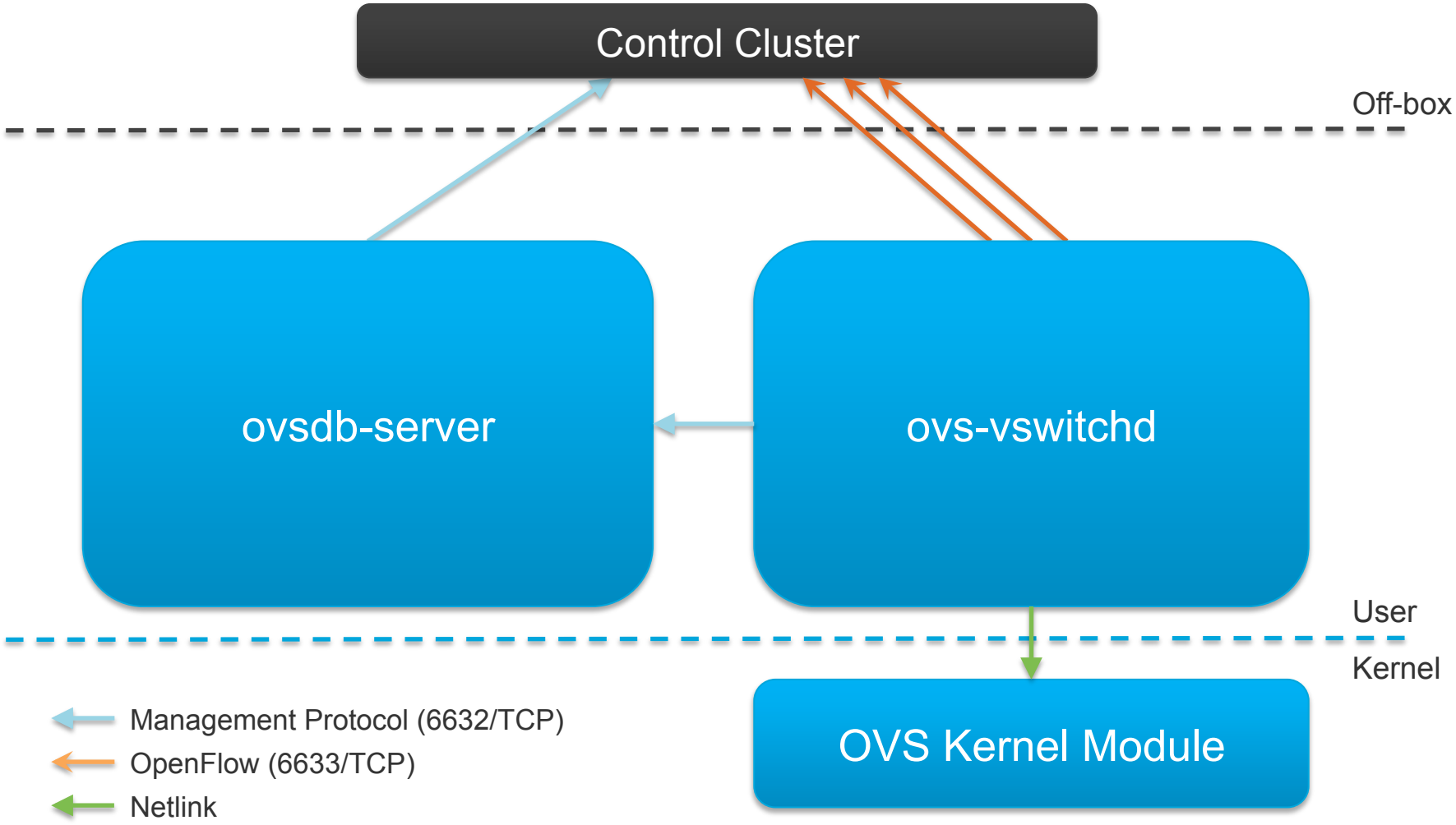
- **Visibility (NetFlow, IPFIX, sFlow, SPAN/RSPAN)**
- **Fine-grained ACLs and QoS policies**
- **Centralized control through OpenFlow and OVSDB**
- **Port bonding, LACP, tunneling**
- **Works on FreeBSD and Linux-based hypervisors**
  - Xen, XenServer, KVM, VirtualBox
- **Open source, commercial-friendly Apache 2 license**
- **Multiple ports to physical switches**

Visibility

- **Number of subscribers to mailing lists:**
  - discuss: 1371
  - announce: 716
  - dev: 651
  - git: 158
- **OpenStack Summit User Survey showed 48% of deployments use Open vSwitch for their networking solution**

(Partial) List of Contributors

Main Components



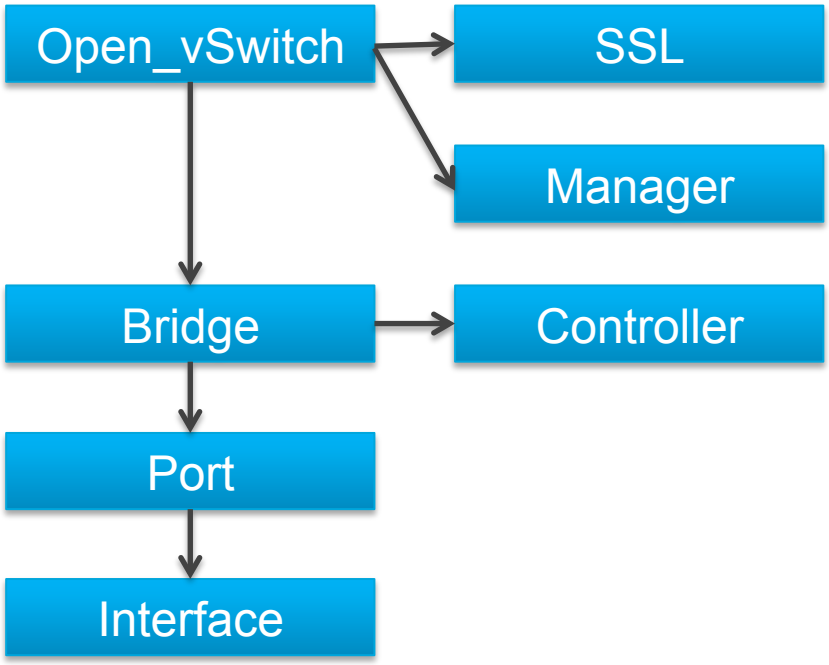
CONFIGURATION DATABASE

ovsdb-server

- **Database that holds switch-level configuration**
  - Bridge, interface, tunnel definitions
  - OVSDB and OpenFlow controller addresses
- **Configuration is stored on disk and survives a reboot**
- **Custom database with nice properties:**
  - Value constraints
  - Weak references
  - Garbage collection
- **Log-based (fantastic for debugging!)**
- **Speaks OVSDB protocol to manager and ovs-vswitchd**
- **The OVSDB protocol is in the process of becoming an Informational RFC**

Tools: ovs-vsctl, ovsdb-tool, ovsdb-client, ovs-appctl

Core Tables



“Open_vSwitch” is the root table and there is always only a single row. The tables here are the ones most commonly used; a full entity-relationship diagram is available in the ovs-vswitchd.conf.db man page.

Debugging the Database

- **ovs-vsctl: Configures ovs-vswitchd, but really a high-level interface for database**
  - ovs-vsctl add-br <bridge>
  - ovs-vsctl list-br
  - ovs-vsctl add-port <bridge> <port>
  - ovs-vsctl list-ports <bridge>
  - ovs-vsctl get-manager <bridge>
  - ovs-vsctl get-controller <bridge>
  - ovs-vsctl list <table>
- **ovsdb-tool: Command-line tool for managing database file**
  - ovsdb-tool show-log [-mmm] <file>

ovsdb-tool show-log

Record number

Time of Change

Caller's comment

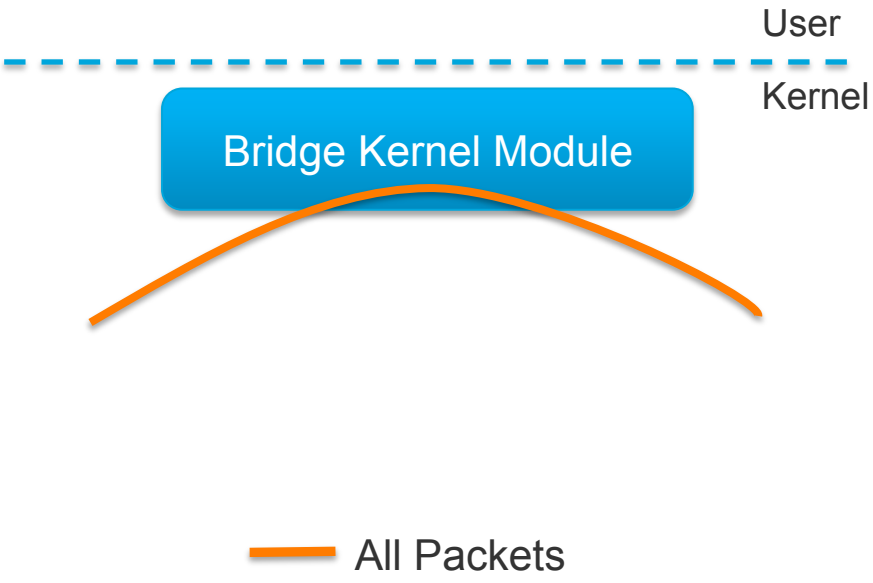
```
root@vm-vswitch:~# ovsdb-tool show-log -m
...
record 3: 2011-04-13 16:03:52 "ovs-vsctl: /usr/bin/ovs-vsctl --timeout=20 --
--with-iface --if-exists del-port eth0 -- --may-exist add-br xenbr0 -- --
may-exist add-port xenbr0 eth0 -- set Bridge xenbr0 "other-config:hwaddr=
\"00:0c:29:ab:f1:e9\"" -- set Bridge xenbr0 fail_mode=standalone -- remove
Bridge xenbr0 other_config disable-in-band -- br-set-external-id xenbr0 xs-
network-uuids 9ae8bc91-cfb8-b873-1947-b9c4098e4f4b"
    table Port insert row "xenbr0":
    table Port insert row "eth0":
    table Interface insert row "eth0":
    table Interface insert row "xenbr0":
    table Open_vSwitch row a1863ada:
    table Bridge insert row "xenbr0":
...
```

Database changes

FORWARDING PATH

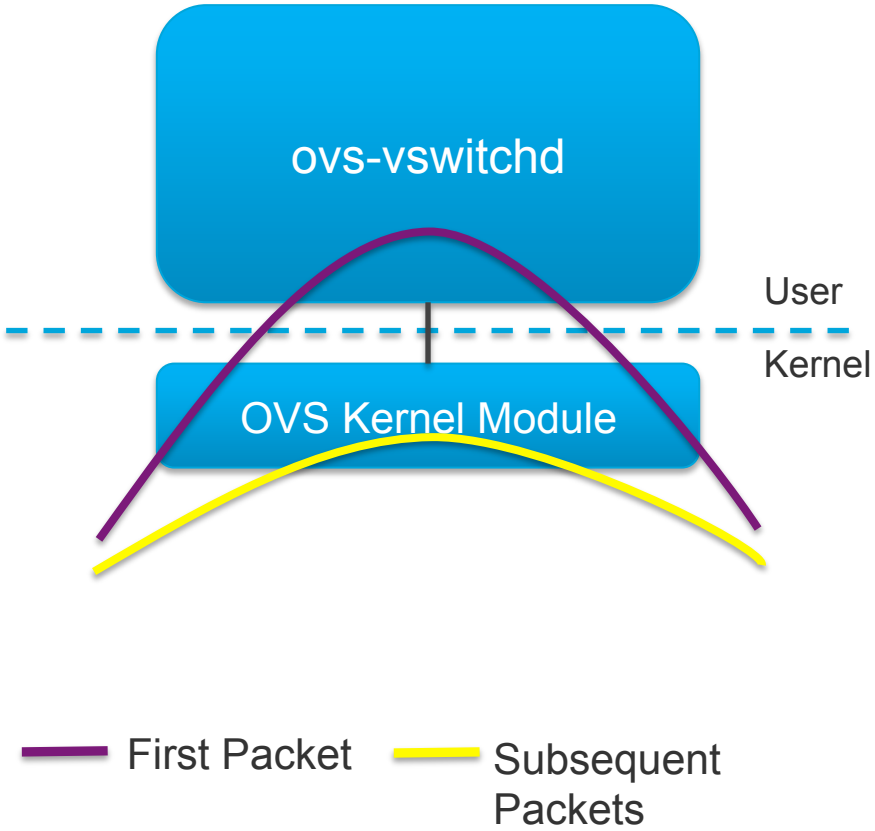
Linux Bridge Design

- Simple forwarding
- Matches destination MAC address and forwards
- Packet never leaves kernel



Open vSwitch Design

- Decision about how to process packet made in userspace
- First packet of new flow goes to ovs-vswitchd, following packets hit cached entry in kernel



ovs-vswitchd

- **Core component in the system:**
  - Communicates with outside world using OpenFlow
  - Communicates with ovsdb-server using OVSDB protocol
  - Communicates with kernel module over netlink
  - Communicates with the system through netdev abstract interface
- **Supports multiple independent datapaths (bridges)**
- **Packet classifier supports efficient flow lookup with wildcards and "explodes" these (possibly) wildcard rules for fast processing by the datapath**
- **Implements mirroring, bonding, and VLANs through modifications of the same flow table exposed through OpenFlow**
- **Checks datapath flow counters to handle flow expiration and stats requests**

Tools: ovs-ofctl, ovs-appctl

OVS Kernel Module

- **Kernel module that handles switching and tunneling**
- **Fast cache of non-overlapping flows**
- **Designed to be fast and simple**
  - Packet comes in, if found, associated actions executed and counters updated. Otherwise, sent to userspace
  - Does no flow expiration
  - Knows nothing of OpenFlow
- **Implements tunnels**

Tools: ovs-dpctl

Userspace Processing

- Packet received from kernel
- Given to the classifier to look for matching flows accumulates actions
- If “normal” action included, accumulates actions from “normal” processing, such as L2 forwarding and bonding
- Actions accumulated from configured modules, such as mirroring
- Prior to 1.11, an exact match flow is generated with the accumulated actions and pushed down to the kernel module (along with the packet)

Kernel Processing

- Packet arrives and header fields extracted
- Header fields are hashed and used as an index into a set of large hash tables
- If entry found, actions applied to packet and counters are updated
- If entry is not found, packet sent to userspace and miss counter incremented

Megaflows

- **Version 1.11 added support for wildcarding in the datapath**
- **ovs-vswitchd dynamically determines how much wildcarding can be done:**
  - Flow table
  - Actions from matching flow
  - General switch configuration (e.g., bonding)
- **With megaflows, “normal” performance close to Linux bridge**

Tunnels

- **Tunnels in OVS are just virtual ports with own OpenFlow port number**
- **Keys set statically at creation time or dynamically through OpenFlow action**
- **Types:**
  - GRE
  - VXLAN
  - LISP
- **Visible in kernel datapath:**
  - ovs-dpctl show

UTILITIES

OpenFlow

- **ovs-ofctl speaks to OpenFlow module**
  - ovs-ofctl show <bridge>
  - ovs-ofctl dump-flows <bridge>
  - ovs-ofctl add-flow <bridge> <flow>
  - ovs-ofctl del-flows <bridge> [flow]
  - ovs-ofctl snoop <bridge>
- **OpenFlow plus extensions**
  - Resubmit Action: Simulate multiple tables in a single table
  - NXM: Extensible match
  - Registers: Eight 32-bit metadata registers
  - Fine-grained control over multiple controllers
- **See “hidden” flows (in-band, fail-open, etc):**
  - ovs-appctl bridge/dump-flows <bridge>

ovs-ofctl show

```
root@vm-vswitch:~# ovs-ofctl show br0
OFPT_FEATURES_REPLY (xid=0x2): dpid:0000505400000005
n_tables:254, n_buffers:256
capabilities: FLOW_STATS TABLE_STATS PORT_STATS QUEUE_STATS ARP_MATCH_IP
actions: OUTPUT SET_VLAN_VID SET_VLAN_PCP STRIP_VLAN SET_DL_SRC SET_DL_DST SET_NW_SRC
SET_NW_DST SET_NW_TOS SET_TP_SRC SET_TP_DST ENQUEUE
 1(eth0): addr:50:54:00:00:00:05
     config:     0
     state:      0
     current:    1GB-FD COPPER AUTO_NEG
     advertised: 10MB-HD 10MB-FD 100MB-HD 100MB-FD 1GB-FD COPPER AUTO_NEG
     supported:  10MB-HD 10MB-FD 100MB-HD 100MB-FD 1GB-FD COPPER AUTO_NEG
     speed: 1000 Mbps now, 1000 Mbps max
 2(eth1): addr:50:54:00:00:00:06
     config:     0
     state:      0
     current:    1GB-FD COPPER AUTO_NEG
     advertised: 10MB-HD 10MB-FD 100MB-HD 100MB-FD 1GB-FD COPPER AUTO_NEG
     supported:  10MB-HD 10MB-FD 100MB-HD 100MB-FD 1GB-FD COPPER AUTO_NEG
     speed: 1000 Mbps now, 1000 Mbps max
 LOCAL(br0): addr:50:54:00:00:00:05
     config:     0
     state:      0
     speed: 0 Mbps now, 0 Mbps max
OFPT_GET_CONFIG_REPLY (xid=0x4): frags=normal miss_send_len=0
```

OpenFlow port number

Interface name

ovs-ofctl dump-flows

- **The default flow table includes a single entry that does "normal" processing:**

```
root@vm-vswitch:~# ovs-ofctl dump-flows br0
NXST_FLOW reply (xid=0x4):
 cookie=0x0, duration=4.05s, table=0, n_packets=8, n_bytes=784,
idle_age=0, priority=0 actions=NORMAL
```

Hidden Flows

- **There are flows that OVS uses for its own purpose that are higher priority than can be configured from outside**
- **Types**
  - In-band control (priority >= 180000): Allow control traffic to pass regardless of configured flows
  - Fail-open (priority = 0xf0f0f0): Allow all traffic to pass when a connection to the controller fails
- **They are hidden from controllers and commands like "ovs-ofctl dump-flows" due to being higher priority than OpenFlow allows (>65535)**
- **Only visible with "ovs-appctl bridge/dump-flows <bridge>"**

Kernel Datapath

- **ovs-dpctl speaks to kernel module**
- **See datapaths and their attached interfaces:**
  - ovs-dpctl show
- **See flows cached in datapath:**
  - ovs-dpctl dump-flows

ovs-dpctl show

hit: Packets hit existing entry

missed: Packets sent to userspace

lost: Dropped before getting to userspace

```
root@vm-vswitch:~# ovs-dpctl show
system@ovs-system:
        lookups: hit:188056 missed:7722 lost:0
        flows: 2
        masks: hit:199268 total:1 hit/pkt:1.02
        port 0: ovs-system (internal)
        port 1: br0 (internal)
        port 2: eth0
        port 3: eth1
```

Interface type

Interface name

Datapath port number

ovs-dpctl dump-flows

- **Flows used to be exact-match:**

in_port(2),eth(src=50:54:00:00:00:01,dst=50:54:00:00:00:03),eth_type(0x0800),ipv4(src=192.168.0.1,dst=192.168.0.2,proto=1,tos=0,ttl=64,frag=no),icmp(type=8,code=0), packets:3, bytes:294, used:0.185s, actions:3

in_port(3),eth(src=50:54:00:00:00:03,dst=50:54:00:00:00:01),eth_type(0x0800),ipv4(src=192.168.0.2,dst=192.168.0.1,proto=1,tos=0,ttl=64,frag=no),icmp(type=0,code=0), packets:3, bytes:294, used:0.205s, actions:2

- **Starting in OVS 1.11, may contain wildcards:**

in_port(3),eth(src=50:54:00:00:00:03,dst=50:54:00:00:00:01),eth_type(0x0800),ipv4(src=192.168.0.2/0.0.0.0,dst=192.168.0.1/0.0.0.0,proto=1/0,tos=0/0,ttl=64/0,frag=no/0x2),icmp(type=0/0,code=0/0), packets:95, bytes:9310, used:0.425s, actions:2

in_port(2),eth(src=50:54:00:00:00:01,dst=50:54:00:00:00:03),eth_type(0x0800),ipv4(src=192.168.0.1/0.0.0.0,dst=192.168.0.2/0.0.0.0,proto=1/0,tos=0/0,ttl=64/0,frag=no/0x2),icmp(type=8/0,code=0/0), packets:95, bytes:9310, used:0.525s, actions:3

ovs-appctl

- **Utility to invoke runtime control and query facilities in most OVS daemons**
- **The "-t <target>" option specifies the daemon name (default is ovs-vswitchd)**
- **All daemons support the following commands:**
  - help – Lists the commands supported by the target
  - version – Displays the version and compilation date of the target
  - vlog/list – List the known logging modules and their current levels
  - vlog/set [spec] – Sets logging levels
- **Many interesting features supported, which are defined in the targets' man pages**

Flow Debugging

- **Flow tables can become incredibly complex, but OVS has tools to make it easier to debug**
- **Here is a set of rules to (poorly) implement a firewall (with an unnecessary resubmit) to block all TCP traffic except port 80:**

```
# Move TCP traffic arriving on port 1 to next stage of “pipeline”
priority=100,tcp,in_port=1 actions=resubmit:4000

# Allow port TCP port 80 traffic (and implicitly drop all others)
priority=100,tcp,in_port=4000,tp_dst=80 actions=NORMAL

# Allow all non-TCP traffic arriving on port 1
priority=90,in_port=1 actions=NORMAL

# Allow all traffic arriving on port 2
priority=100,in_port=2 actions=NORMAL
```

Tracing Flow (ICMP Allowed)

```
root@vm-vswitch:~# ovs-appctl ofproto/trace
"skb_priority(0),in_port(2),skb_mark(0),eth(src=50:54:00:00:00:01,dst=50:54
:00:00:00:03),eth_type(0x0800),ipv4(src=192.168.0.1,dst=192.168.0.2,proto=1
,tos=0,ttl=64,frag=no),icmp(type=8,code=0)”
Bridge: br0
Flow:
icmp,metadata=0,in_port=1,vlan_tci=0x0000,dl_src=50:54:00:00:00:01,dl_dst=5
0:54:00:00:00:03,nw_src=192.168.0.1,nw_dst=192.168.0.2,nw_tos=0,nw_ecn=0,nw
_ttl=64,icmp_type=8,icmp_code=0
Rule: table=0 cookie=0 priority=90,in_port=1
OpenFlow actions=NORMAL
forwarding to learned port

Final flow: unchanged
Relevant fields:
skb_priority=0,icmp,in_port=1,vlan_tci=0x0000/0x1fff,dl_src=50:54:00:00:00:
01,dl_dst=50:54:00:00:00:03,nw_frag=no,icmp_code=0
Datapath actions: 3
```

Applied OpenFlow rule

Datapath flow description

Datapath action

Tracing Flow (TCP allowed)

```
root@vm-vswitch:~# ovs-appctl ofproto/trace
"skb_priority(0),in_port(2),skb_mark(0),eth(src=50:54:00:00:00:01,dst=50:5
4:00:00:00:03),eth_type(0x0800),ipv4(src=192.168.0.1,dst=192.168.0.2,proto
=6,tos=0x10,ttl=64,frag=no),tcp(src=56176,dst=80),tcp_flags(0x002)"
Bridge: br0
Flow:
tcp,metadata=0,in_port=1,vlan_tci=0x0000,dl_src=50:54:00:00:00:01,dl_dst=5
0:54:00:00:00:03,nw_src=192.168.0.1,nw_dst=192.168.0.2,nw_tos=16,nw_ecn=0,
nw_ttl=64,tp_src=56176,tp_dst=80,tcp_flags=0x002
Rule: table=0 cookie=0 priority=100,tcp,in_port=1
OpenFlow actions=resubmit:4000

    Resubmitted flow: unchanged
    Resubmitted regs: reg0=0x0 reg1=0x0 reg2=0x0 reg3=0x0 reg4=0x0
reg5=0x0 reg6=0x0 reg7=0x0
    Resubmitted  odp: drop
    Rule: table=0 cookie=0 priority=100,tcp,in_port=4000,tp_dst=80
    OpenFlow actions=NORMAL
    forwarding to learned port

Final flow: unchanged
Relevant fields:
skb_priority=0,tcp,in_port=1,vlan_tci=0x0000/0x1fff,dl_src=50:54:00:00:00:
01,dl_dst=50:54:00:00:00:03,nw_frag=no,tp_dst=80
Datapath actions: 3
```

First applied OpenFlow rule

Second applied OpenFlow rule

Datapath flow description

Datapath action

Tracing Flow (TCP denied)

```
root@vm-vswitch:~# ovs-appctl ofproto/trace
"skb_priority(0),in_port(2),skb_mark(0),eth(src=50:54:00:00:00:01,dst=50:54:00:
00:00:03),eth_type(0x0800),ipv4(src=192.168.0.1,dst=192.168.0.2,proto=6,tos=0x1
0,ttl=64,frag=no),tcp(src=56177,dst=100),tcp_flags(0x002)"
Bridge: br0
Flow:
tcp,metadata=0,in_port=1,vlan_tci=0x0000,dl_src=50:54:00:00:00:01,dl_dst=50:54:
00:00:00:03,nw_src=192.168.0.1,nw_dst=192.168.0.2,nw_tos=16,nw_ecn=0,nw_ttl=64,
tp_src=56177,tp_dst=100,tcp_flags=0x002
Rule: table=0 cookie=0 priority=100,tcp,in_port=1
OpenFlow actions=resubmit:4000

    Resubmitted flow: unchanged
    Resubmitted regs: reg0=0x0 reg1=0x0 reg2=0x0 reg3=0x0 reg4=0x0 reg5=0x0
reg6=0x0 reg7=0x0
    Resubmitted  odp: drop
    No match

Final flow: unchanged
Relevant fields: skb_priority=0,tcp,in_port=1,nw_frag=no,tp_dst=100
Datapath actions: drop
```

First applied OpenFlow Rule

No matching second flow, so implicit drop

Datapath flow description

Datapath action

Logging

- ovs-appctl configures running OVS daemons
- Most common use is to modify logging levels
- By default configures ovs-vswitchd, but “-t” option changes target
- Default level for log files is “info”, only thing lower is “dbg”

```
root@vm-vswitch:~# ovs-appctl vlog/list
                  console    syslog    file
                  -------    ------    ------
bridge             EMER        ERR       INFO
vswitchd           EMER        ERR       INFO
...
root@vm-vswitch:~# ovs-appctl vlog/set ofproto:file:dbg
```

Log Files

- **Open vSwitch logs: /var/log/openvswitch/***
  - ovs-vswitchd.log
  - ovsdb-server.log
- **System: /var/log/messages**
- **Configuration Database: /etc/openvswitch/conf.db**

Questions?

- Try the documentation, we strive to make it thorough and up to date
- Look at the FAQ:
  - http://openvswitch.org/faq/
- Ask questions on the mailing list:
  - discuss@openvswitch.org