Using an Open Source SDN Controller to Deploy a Multi-Terabit/s Production Network

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Introduction to faucet

- Lightweight Open Source SDN controller
- OpenFlow v1.3
- Supports Layer 2 and Layer 3
- Policy driven approach to extensibility
A little bit of history

● Started with a set of goals:
  ○ Robust software
  ○ Reliable hardware
  ○ Extensive production testing
  ○ Operators comfortable using it
  ○ Interoperate with existing tools

● Born out of collaborative effort of SDN community in New Zealand
  ○ REANNZ, Google, University of Waikato, Victoria University of Wellington, etc…

● Now up to 47 contributors from around the world
● Our code base just turned 5 years old
Why use faucet?

- Low system resource requirements
- Uses multi-table OpenFlow pipeline
- Multi-vendor without drivers
- Well tested, production quality
- High Availability through idempotency
- Controller is not in the forwarding path
Throw out the kitchen sink

- FAUCET is intentionally small
  - ~10,000 lines of code
  - ~5,000 lines of tests
- Implement useful primitives in FAUCET that can be built on top of
  - Forwarding, VLANs, ACLs, L3 FIB
- Implement some additional protocols for interop
  - BGP, Stacking, LACP, ARP & IPv6 ND
- Leave protocols modular so they are only turned on when configured
Faucet

Gauge

faucet.yaml

Prometheus

Grafana

External System

Events

Instrumentation

Flow Rules & Port Statistics

External Router

Faucet

faucet.yaml

Gauge

gauge.yaml

External System

SDN Switch
Faucet configuration

- YAML configuration file
- Represents topology & features of network
- Faucet is idempotent
  - Give 2 controllers same configuration and they will configure the network the same

```yaml
vlans:
  office:
    vid: 100
    description: "office network"
  faucet_vips: ['10.0.100.254/24']

dps:
  sw1:
    dp_id: 0x1
    hardware: "Open vSwitch"
    interfaces:
      1:
        description: "host1"
        native_vlan: office
      2:
        description: "host2"
        native_vlan: office
```
Faucet pipeline

1. Apply custom policy to port
2. Ensure packet has correct VLAN tag applied
3. Apply custom policy to VLAN
4. Determine if packet is forwarded or routed. Learn from unknown MAC
5. Perform routing & neighborhood discovery
6. For known MAC, output packet on correct port
7. Flood packet for unknown MAC inside VLAN
Faucet policy

- Can modify behaviour without changing code by adding ACLs
- ACL has a match an action
  - Matches on anything OpenFlow can
  - Action can be DROP, ALLOW, OUTPUT, MODIFY
Policy use cases

- **Port-based ACLs**
  - DHCP and DHCPv6 spoofing protection
  - IPv6 Router Advertisement Guard
  - NFV offload, output 802.1x EAPOL frames to NAC

- **VLAN-based ACLs**
  - Drop anything other than IPv6 ethertype on IPv6-only network

- **Inter-VLAN Routing ACLs**
  - Limit traffic between VLANs
  - Implement Policy Based Routing
Example faucet policy

- IPv6 Router Advertisement Guard

```yaml
acls:
  ipv6_ra_guard:
    - rule:
      dl_type: 0x86dd # ipv6
      nw_proto: 58    # icmpv6
      icmpv6_type: 134 # router advertisement
      actions:
        allow: 0       # drop
```
Faucet test suite

- Unit test coverage (>90%)
- Integration test suite (>180 scenarios)
- Run both against every PR
  - Avoid regressions
  - Allows us to refactor frequently
- Integration tests can be run against hardware too
  - Easy to qualify devices for faucet support
  - Vendors can use as part of QA for new firmwares
Push on green

- Leverage integration tests as part of deploy process
  - Implement test cases that cover deployment
- Only deploy new faucet code/configuration when tests pass
- This allows for frequent (automated) deploys
  - I deploy on my faucet network at work once a week
SC18

- Annual SuperCompute Conference in the US
- 30th anniversary was November 2018 in Dallas, Texas
- “SCinet” network built each year to power conference
  - One of the world’s fastest temporary networks
- Faucet was deployed on SCinet for SC18
SCinet 2018

- 4.02 terabit/s connectivity
- $52 million in hardware
- 4.25 tons of equipment
- 225 volunteers
Let’s take a step back

- How did we get involved?
- Approached conference committee April 2018
- Proposed a mutually beneficial faucet deployment
- Our proposal was accepted and work begun...
Phase 1: Planning

- Months of video conferences from NZ to USA/Europe
- Faucet SCinet team distributed between
  - Hamilton, New Zealand
  - Wellington, New Zealand
  - Berkeley, California, USA
  - Champaign, Illinois, USA
  - Dallas, Texas, USA
Scope for faucet deployment

- Faucet will run in parallel with regular network
- Peer with regular SCinet core and advertise/receive routes
- Will provide percentage of booths on show floor Internet access
- Each booth has separate VLAN and subnet
- Booth can be connected at 1GbE, 10GbE or 100GbE
- Customer information comes from Django web app
Initial design

- Faucet needs physical presence in
  - Core layer (NOC)
  - Access layer (DNOC)
Phase 2: Source hardware

- Approach hardware vendors and ask nicely for hardware
- Thanks Allied-Telesis, Cisco and NoviFlow!
  - 2 devices each
- Coordinate shipping to test lab in Berkeley, California
Iterate on network design

Port counts:
- 75x 100GbE
- 146x 10GbE
- 48x 1GbE

9.008 Terabit per second
Network functions

Faucet will provide:
- VLANs
- IPv6 Router Advertisements
- Inter-VLAN Routing
- Network Security Policy

NFV Services:
- DHCP
- BGP
Brief introduction to P4

- **Control plane**
  - Runtime API
  - P4 Runtime
  - Control signals

- **Data plane**
  - Tables
  - Memory

- **P4 program**
- **P4 architecture model**
- **P4 compiler**
- **Load API**
- **Load dataplane runtime**
Combining P4 and OpenFlow

1. Write OpenFlow as P4 application
2. Compile application with Barefoot’s P4 compiler to run on Tofino ASIC
3. Faucet uses OpenFlow as runtime API (instead of P4 Runtime) to push rules to P4 ASIC

Feature written by NoviFlow and available in their NoviWare Network OS
Development

- Make sure required features work by adding integration tests
- Built a scale model back in New Zealand
- Started work on automation
Automation

- Define a set of tasks once, can then repeat tasks at no cost
- Applies perfectly for network service definitions
- Faucet SCinet deployment heavily used ansible
## Automation

<table>
<thead>
<tr>
<th>SCinet Customer DB</th>
<th>Python</th>
<th>Ansible</th>
<th>Configuration</th>
</tr>
</thead>
</table>
| Source of truth for network | Use django models to dump all customer connections into YAML | Take YAML and use jinja2 templates to output configuration | • Faucet  
• DHCP  
• BGP  
• Linux Interfaces |

- 290 lines of YAML  
- 260 lines of jinja2 templates  
- 180 lines of ansible  
- 1200 lines of config
Available on GitHub

- Ansible code
  - https://github.com/wandsdn/sc18-ansible

- Generated faucet configuration
  - https://github.com/wandsdn/sc18-faucet-configs
Delivered
Friday 8/10/2018 at 9:02 am

TO
BERKELEY, CA US
Phase 3: Testing

- Use ansible to deploy configurations
- Throw a lot of traffic at it
- Network namespaces are great!
  - Can easily spin up thousands of network namespaces on a single machine
  - Use a network namespace to represent fake booth
- Write some bash scripts to manage
  - Test reachability (`onall.sh pingall.sh`)
  - Test throughput (`randomiperf.sh`)
Ship network off to conference venue

Delivered
Friday 10/19/2018 at 10:02 am

TO
DALLAS, TX US
Phase 4: Staging

- SCinet equipment is staged away from show floor
- Network is turned on for the first time
- Interop testing and diagnosing problems
Faucet staging team photo after network booted up without issue
Phase 5: Show Setup
Phase 5: Show Setup

- Customer database is finalised
- Trigger automation to deploy configuration
- Work with booths as they are built to ensure access works
Load test

- Borrow some linux boxes full of 100G interfaces to load test network
Phase 6: Show Time

- Look for issues
  - Watch tickets queue
  - Watch monitoring
- Fix issues
  - Deploy light meters
  - Swap optics
  - Rolling fibres
Phase 6: Cleanup

- 7 months of planning
- 3 weeks of testing
- 3 weeks setup
- 1 day of tear down
What did we learn?

- Automating the network services that 90% of customers use helped operators have more time to spend working on the interesting 10% of customers.
- Faucet allowed us to effectively ignore the underlying network equipment.
- Proved 10,000 lines of python can easily handle many terabit/s.
Want to try faucet out yourself?

- Complete the tutorial series on our website
- In an hour you will be able to:
  - Install faucet in virtual environment
  - Configure policy/ACLs
  - Configure VLANs
  - Configure Routing
  - Configure NFV

https://docs.faucet.nz/en/latest/tutorials/
Questions?

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