ONF Connect 2019

Next-Gen SDN Tutorial

September 10, 2019

These slides:
`http://bit.ly/ngsdn-tutorial-slides`

Exercises and VM:
`http://bit.ly/ngsdn-tutorial-lab`

NG-SDN Tutorial - Before we start...

- **Get USB keys with VM from instructors**
  - Or download: http://bit.ly/ngsdn-tutorial-lab
  - Option to use Docker instead of VM
- **Copy and import VM into VirtualBox**
  - User: `sdn` - Password: `rocks`
- **If VirtualBox complains about a missing network adapter, remove that in the VM configuration (adapter 2)**
- **Update deps inside VM (requires Internet access)**
  - `cd ~/ngsdn-tutorial`
  - `git pull origin master`
  - `make pull-deps`

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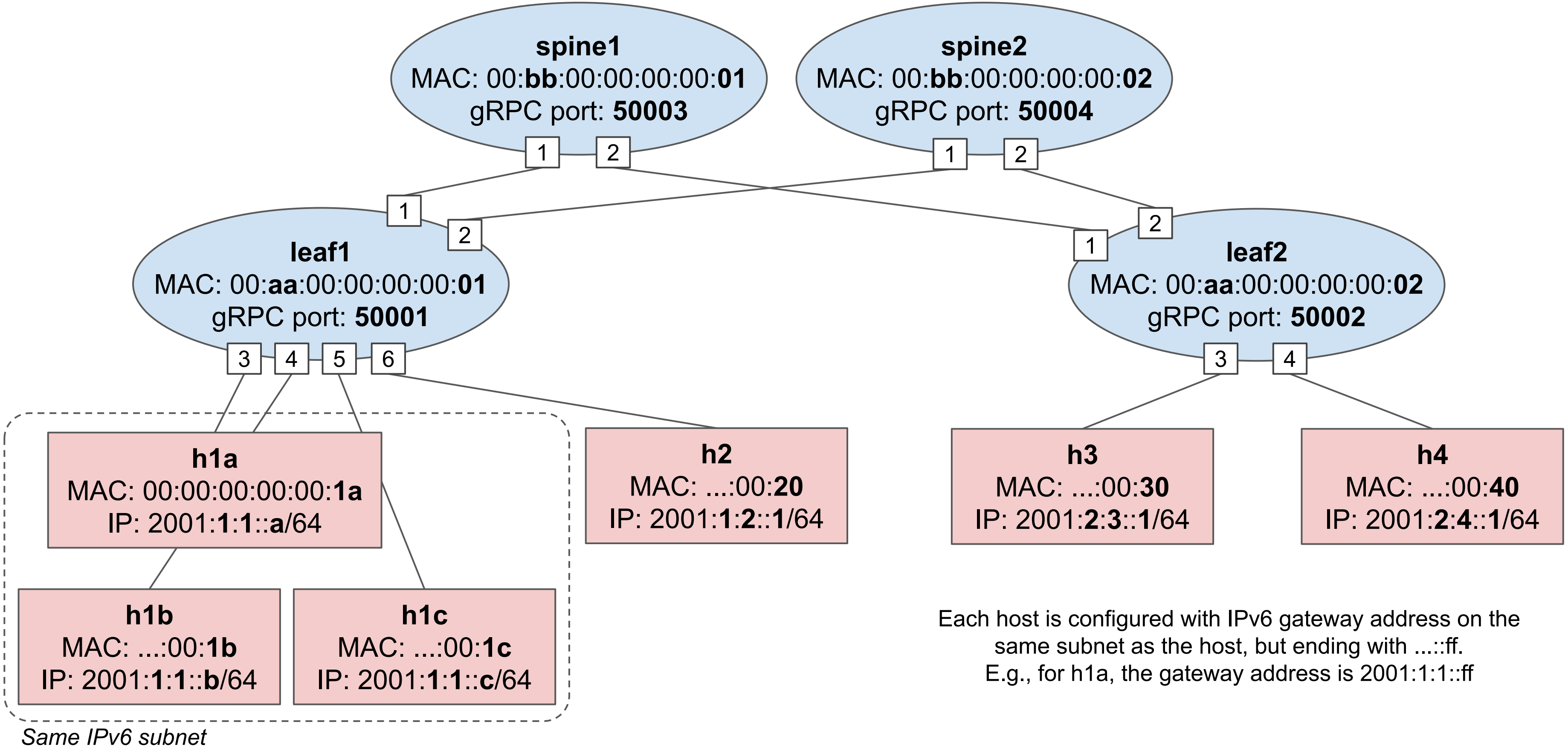
Mininet topology for hands-on exercises



Each host is configured with IPv6 gateway address on the same subnet as the host, but ending with ...::ff.
E.g., for h1a, the gateway address is 2001:1:1::ff

Instructors

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ONF

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ONF

Schedule

8.00am-9.00am registration / breakfast / technical set up for hands-on lab

9.00am-9:20am - NG-SDN overview

9.20am-10.45 - P4 and P4Runtime basics (with hands-on lab)

10.45am-11.15am - break

11.15am-12.30pm - YANG, gNMI and OpenConfig basics (with hands-on lab)

12.30pm-1.30pm- lunch

1.30pm-3.00pm - Using ONOS as the control plane (with hands-on lab)

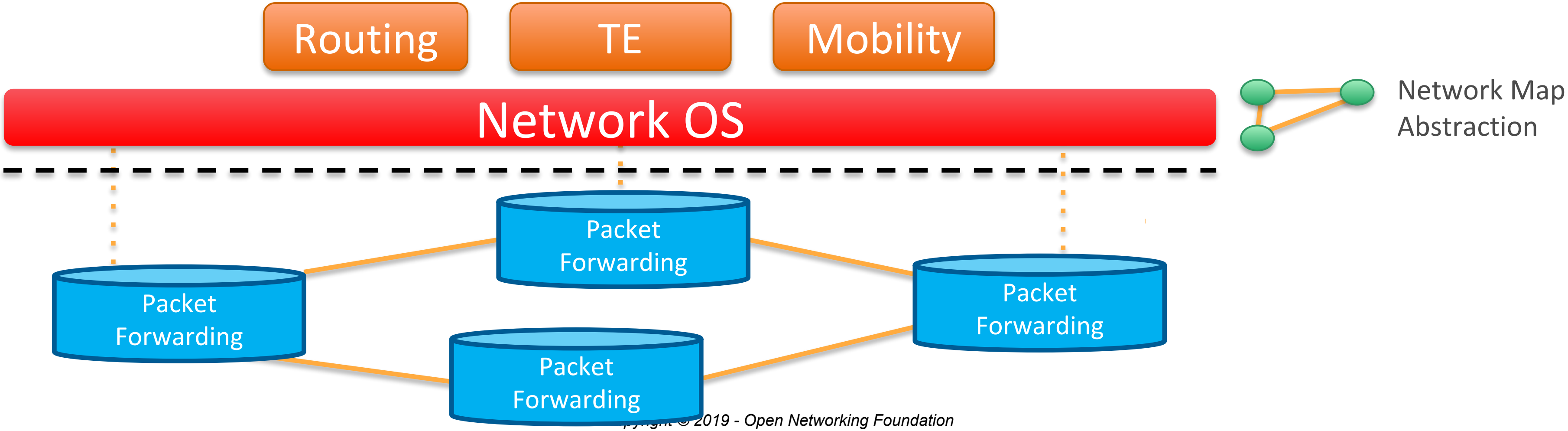
3.00pm-3.30pm - break

3.30pm-5.00pm - Use cases (with hands-on lab)

NG-SDN Overview

Software Defined Networking (SDN) v1

- **Introduction of Programmatic Network Interfaces**
  - Data Plane programming: OpenFlow
  - Configuration and Management: NETCONF and YANG
- **Promise: Enable separation of data plane and control plane**
  - Unlock control and data plane for independent innovation

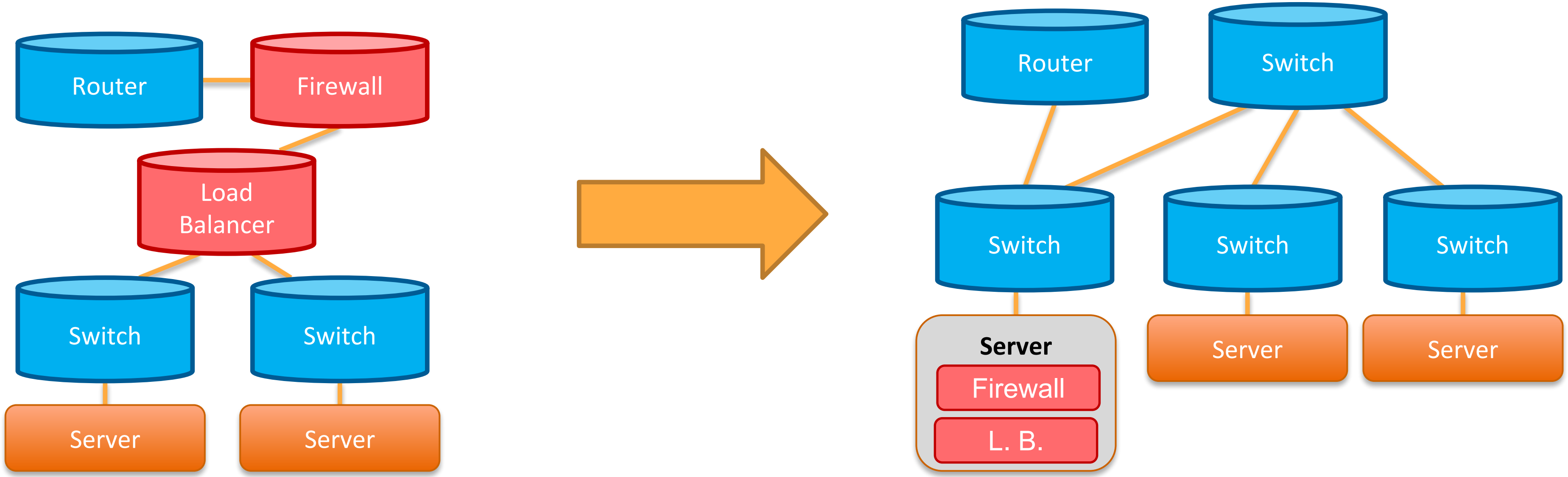


SDN v1 Problems

- **Programmatic Network Interfaces are Inconsistent**
  - OpenFlow provided no data plane pipeline specification; every vendor's pipeline is different
  - Every vendor provides their own models for configuration or management
  - Differences in protocol implementations require custom handling in the control plane
- **Reality: Control planes are written and tested against specific hardware**
  - Some control planes have worked around this by building their own abstractions to handle these differences, but new abstractions are either **least common denominator** (e.g. SAI) or **underspecified** (e.g. FlowObjectives)
  - Other control planes have exploited specific APIs are essentially locked in to specific vendors

Network Function Virtualization (NFV) v1

- Migrate specialized networking hardware (e.g. firewall, load balancer) to commodity servers
- Virtualized network functions (VNFs) are packaged and distributed as VMs or containers, which are easier to deploy



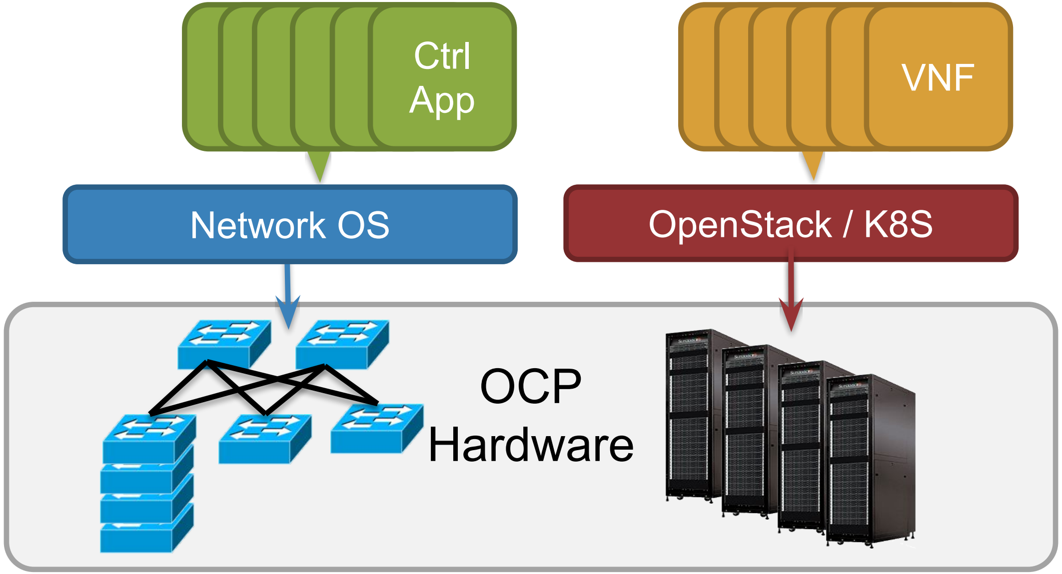
NFV v1 Problems

- **CPUs are not the right hardware for many network functions**
  - Latency and jitter are higher than alternatives
  - Higher cost per packet and increased power consumption
- **NFV data plane topologies are inefficient**
  - Additional switching hops required to implement sequences of VNFs (service chains), especially when placement algorithms are not optimized

Combining SDN and NFV

- **SDN (fabric) and NFV (overlay) are managed separately**
  - Increased operational complexity / opex
  - Difficult to optimize across different stacks
  - Lack of visibility for troubleshoot and end-to-end optimization
  - Separate resource pools

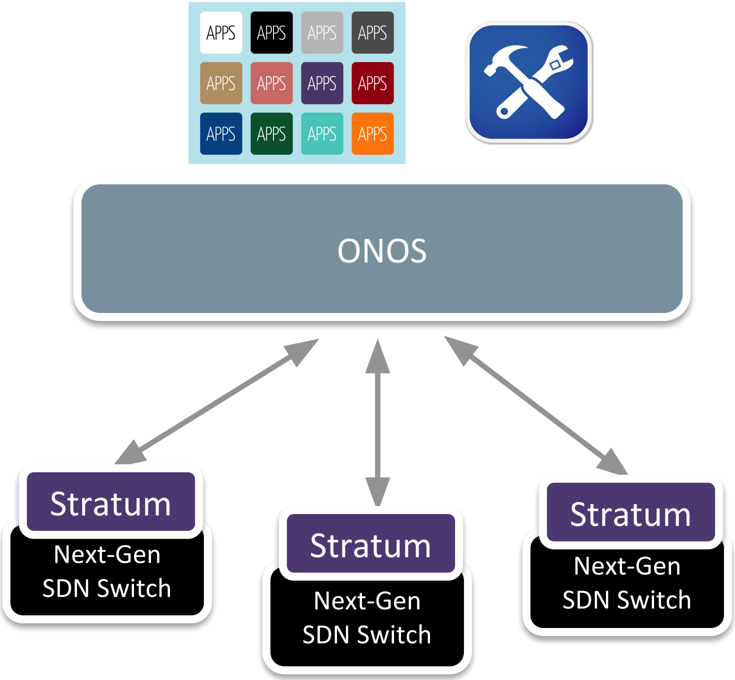
Overall, the benefits of SDN/NFV using 1st generation architectures are not without their costs.



Questions

- Can we get the benefits of SDN and NFV without paying these costs?
- Can we incorporate lessons learned from production deployments of SDN v1 and NFV v1?
- Can we take advantage of new networking hardware efficiently and rapidly?

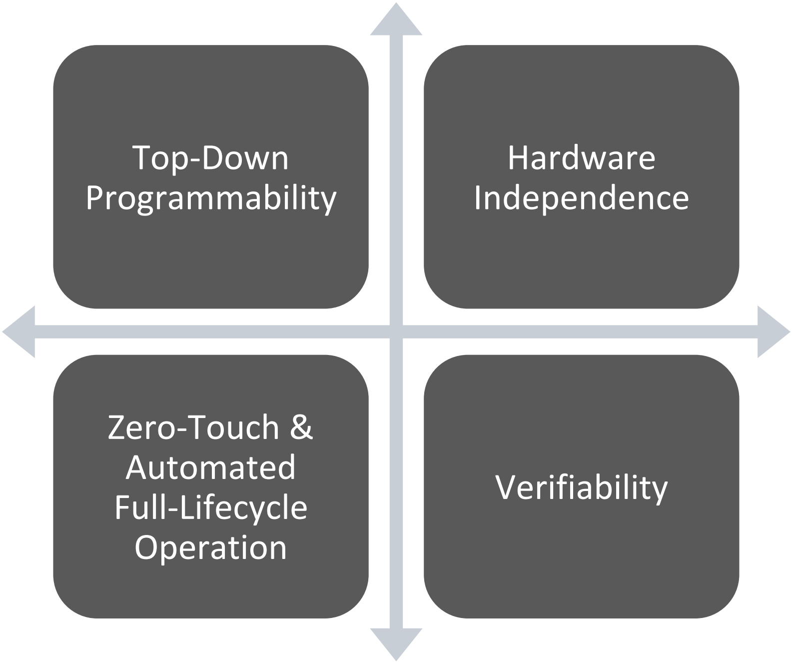
Next-Gen Software Stack Components



- ONOS
  - Supports Next-Gen SDN interfaces (P4Runtime, gNMI, gNOI)
  - Cloud-native: microservices, Kubernetes, gRPC, etc.
  - Enable apps to take advantage of the new capabilities
- Stratum
  - Thin switch OS
  - Supports Next-Gen SDN interfaces (P4Runtime, gNMI, gNOI)
  - Supports OpenConfig YANG models
- Forwarding devices
  - Supports programmable forwarding (P4)
  - Also supported fixed function and partially programmable devices
    - Enables smooth migration and diversity of silicon options

NG-SDN Big Picture

Revolutionary New Capabilities

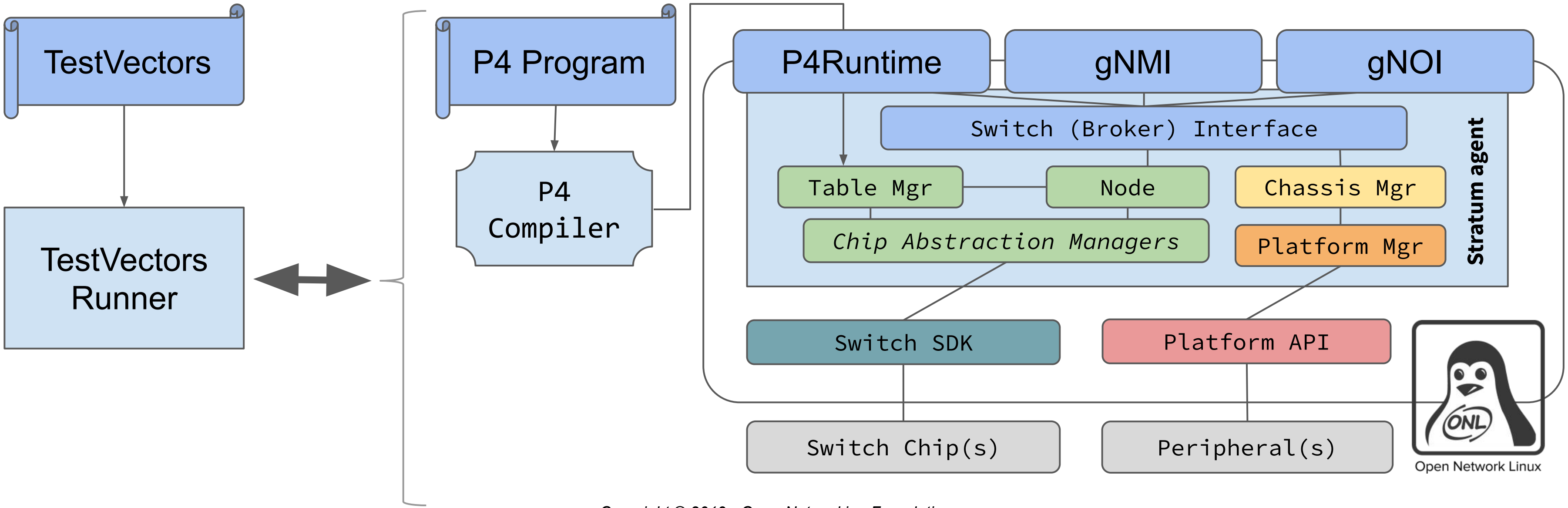


Evolutionary Roadmap

- **Next-Gen SDN Interfaces are defined**
  - P4, P4Runtime, OpenConfig, gNMI, gNOI
- **Stratum now released to Open Source**
- **ONOS 2.2 supports NG APIs**
  - µONOS will provide new configuration subsystem that will be compatible
- **Cloud native tool chains established**
  - Kubernetes
- **Ready to embark on Verification**

What is Stratum?

Open source, production targeted, thin switch OS that implements NG-SDN interfaces and models



Stratum = implementation of 3 APIs

- **Control – P4Runtime with P4-defined pipelines**
  - Manage match-action table entries and other forwarding pipeline state

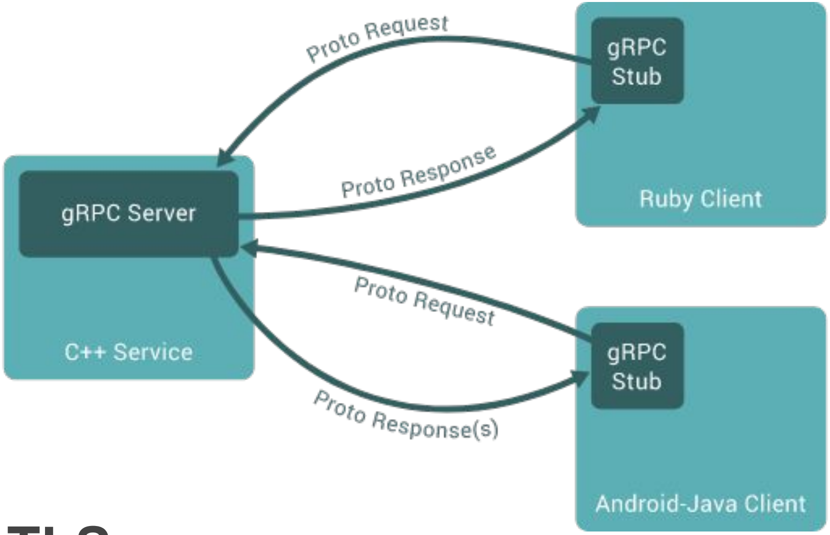
- **Configuration – gNMI with OpenConfig models**
  - Configure everything else that is not the forwarding pipeline.
    e.g. set port speed, read port counters, manage fans, etc.

- **Operations – gNOI**
  - Execute operational commands on device.
    e.g, reboot, push SSL certificates, etc.

All of Stratum's APIs are defined gRPC / Protobuf

Aside: gRPC (gRPC Remote Procedure Call)

- **Use Protocol Buffers to define service API and messages**
- **Automatically generate client/server stubs in:**
  - C / C++
  - C#
  - Dart
  - Go
  - Java
  - Node.js
  - PHP
  - Python
  - Ruby



- **Transport over HTTP/2.0 and TLS**
  - Efficient single TCP connection implementation that supports bidirectional streaming

An Aside: Protocol Buffers

- Google's Lingua Franca for serializing data: RPCs and storage
- Binary data representation
- Structures can be extended and maintain backward compatibility
- Code generators for many languages
- Strongly typed
- Not required for gRPC, but very handy

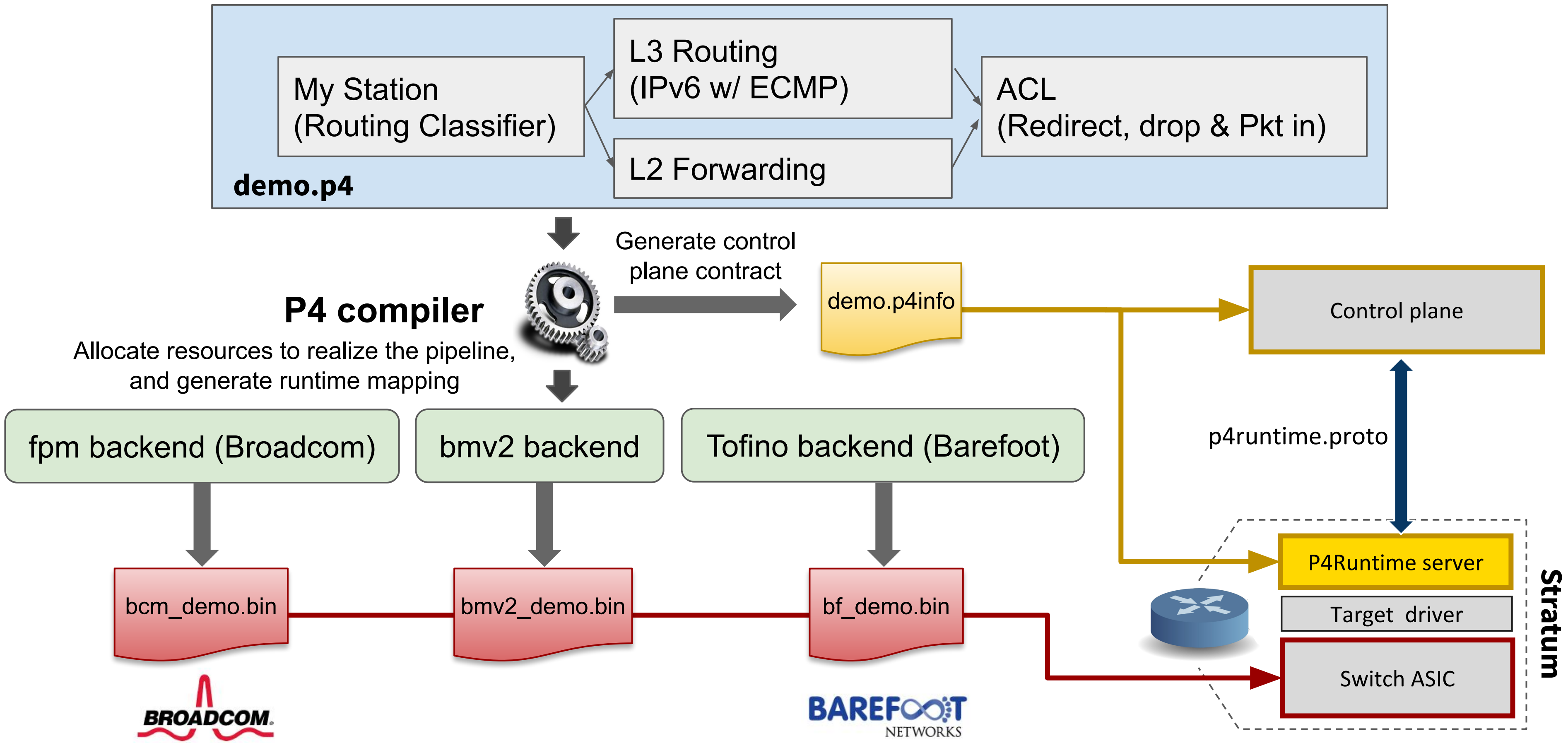
```
syntax = "proto3";

message Person {
  string name = 1;
  int32 id = 2;
  string email = 3;

  enum PhoneType {
    MOBILE = 0;
    HOME = 1;
    WORK = 2;
  }

  message PhoneNumber {
    string number = 1;
    PhoneType type = 2;
  }

  repeated PhoneNumber phone = 4;
}
```

gRPC Service Example

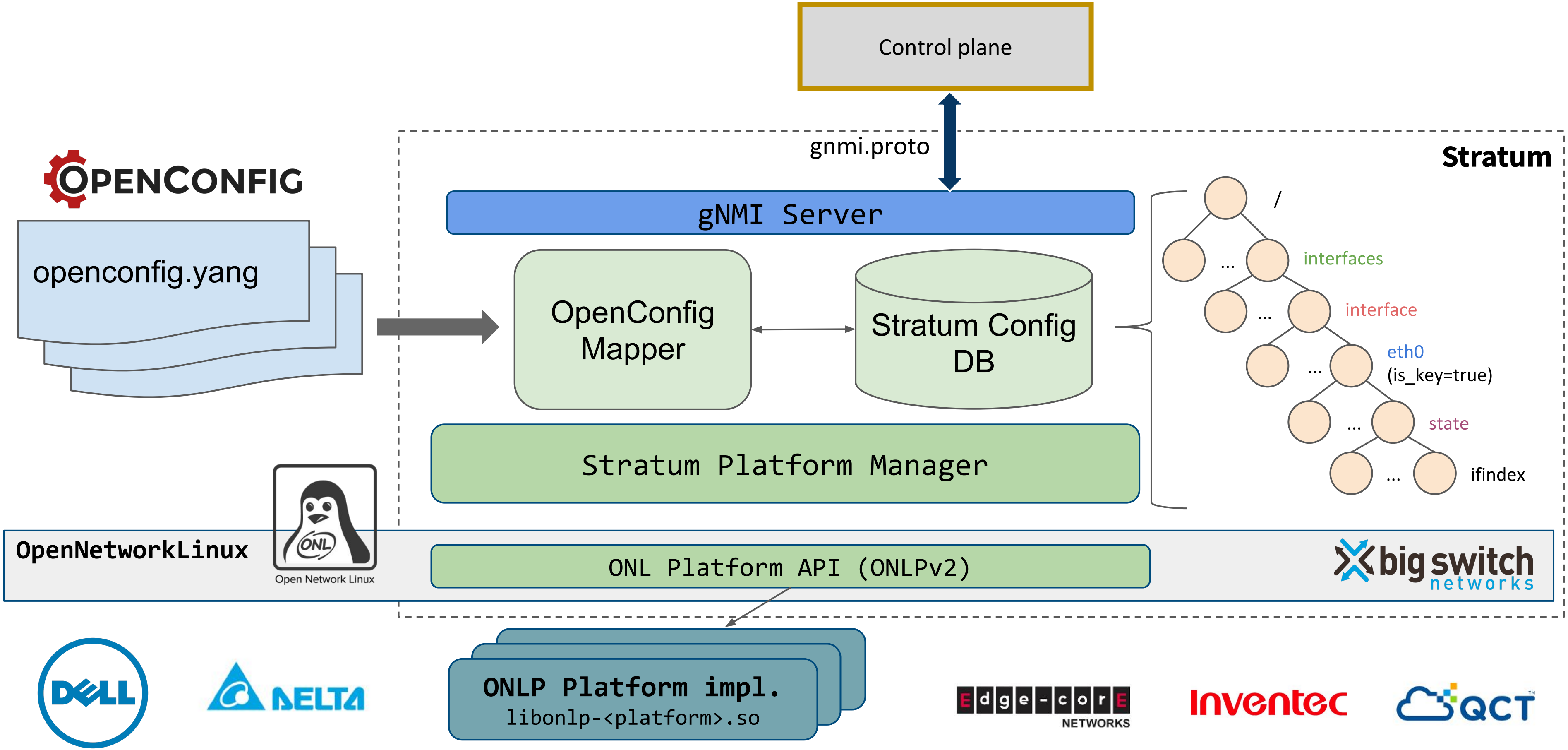
```
// The greeter service definition.
service Greeter {
  // Sends a greeting
  rpc SayHello (HelloRequest) returns (HelloReply) {}
}

// The request message containing the user's name.
message HelloRequest {
  string name = 1;
}

// The response message containing the greetings
message HelloReply {
  string message = 1;
}
```

More details here: https://grpc.io/docs/guides/

Achieving ASIC Independence



Achieving Platform Independence



Stratum Switch Support Today

Switch Vendor / *Switching ASIC*	DELL	DELTA	Edge-corE NETWORKS	Inventec	QCT	STORDIS
BAREFOOT NETWORKS **Tofino** *Up to 6.5 Tbps*		**AG9064v1** *64 x 100 Gbps*	**Wedge100BF-32X** *32 x 100 Gbps* **Wedge100BF-65X** *65 x 100 Gbps*	**D5054** *32 x 100 Gbps + 48 x 25 Gbps*		**BF6064X** *64 x 100 Gbps*
BROADCOM. **Tomahawk** *Up to 3.2 Tbps*	**Z9100** *32 x 100 Gbps*		**AS7712** *32 x 100 Gbps*	**D7032** *32 x 100 Gbps*	**T7032-IX1** *32 x 100 Gbps*	

\+ 2 software switches: **bmv2** (functional software switch) & **dummy switch** (used for API testing)

Near-term future platforms:

- Additional platforms for existing targets
  - Existing vendors + Asterfusion, ...
- Mellanox SN2700 (Spectrum)
- Datacom platforms (PowerPC-based)

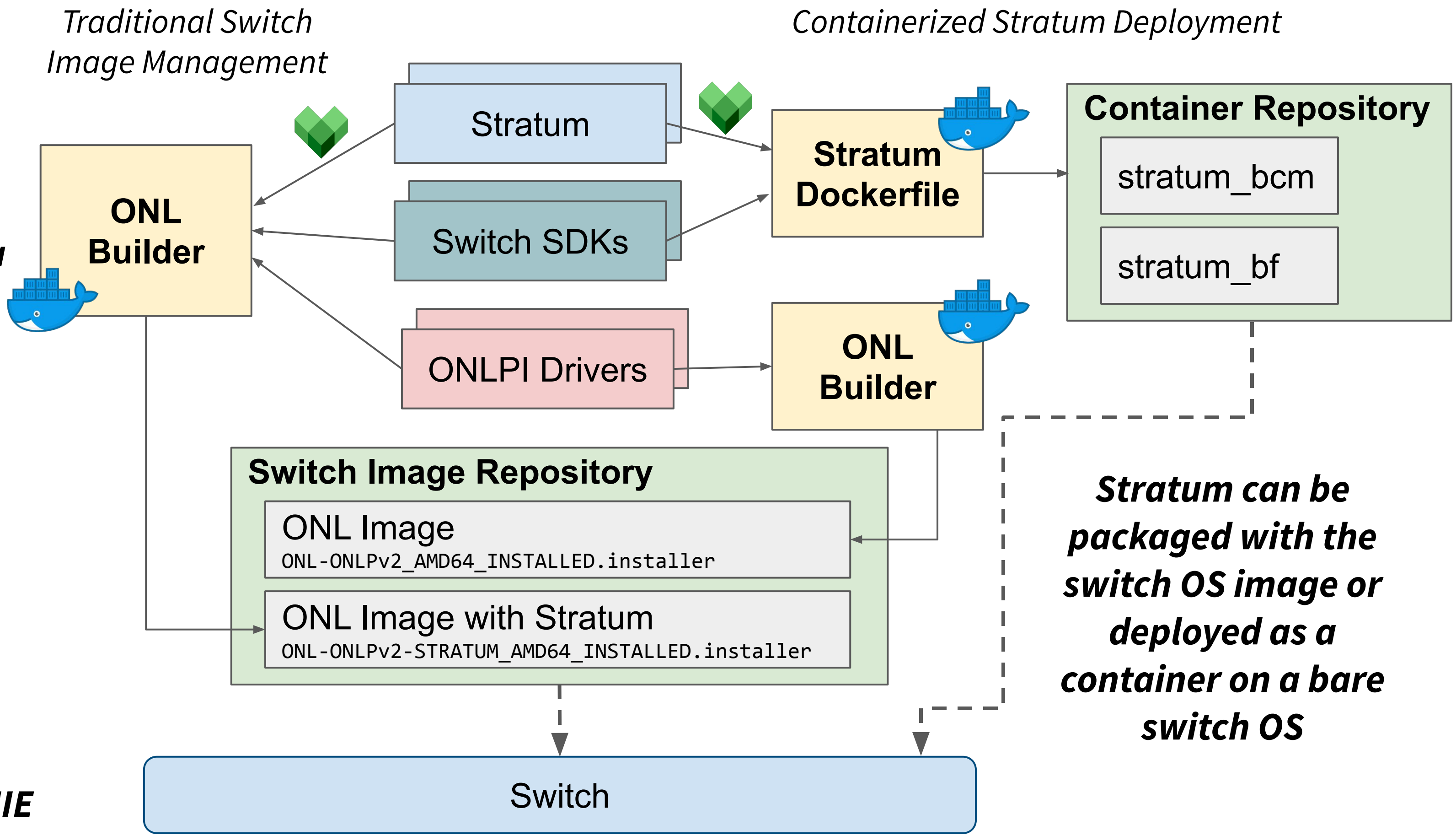
Asterfusion

Mellanox TECHNOLOGIES

DATACOM

Building and Installing Stratum

Step 1: Build ONL image offline (or download a pre-built one)



Stratum can be packaged with the switch OS image or deployed as a container on a bare switch OS

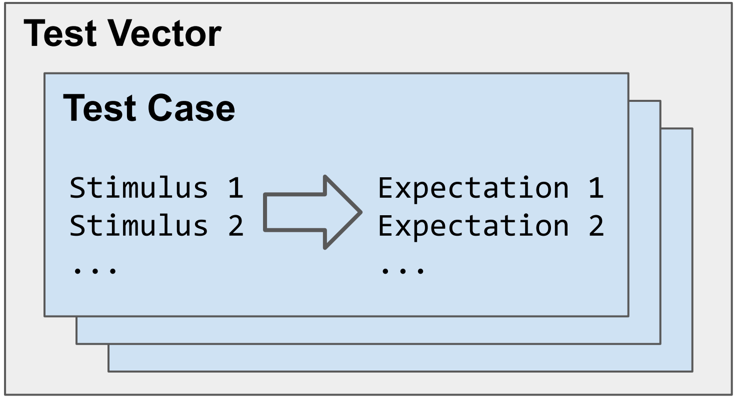
Step 2: Install ONL on boot via ONIE

Testing Stratum Devices

Test Vectors serve as compliance tests for Stratum-based devices

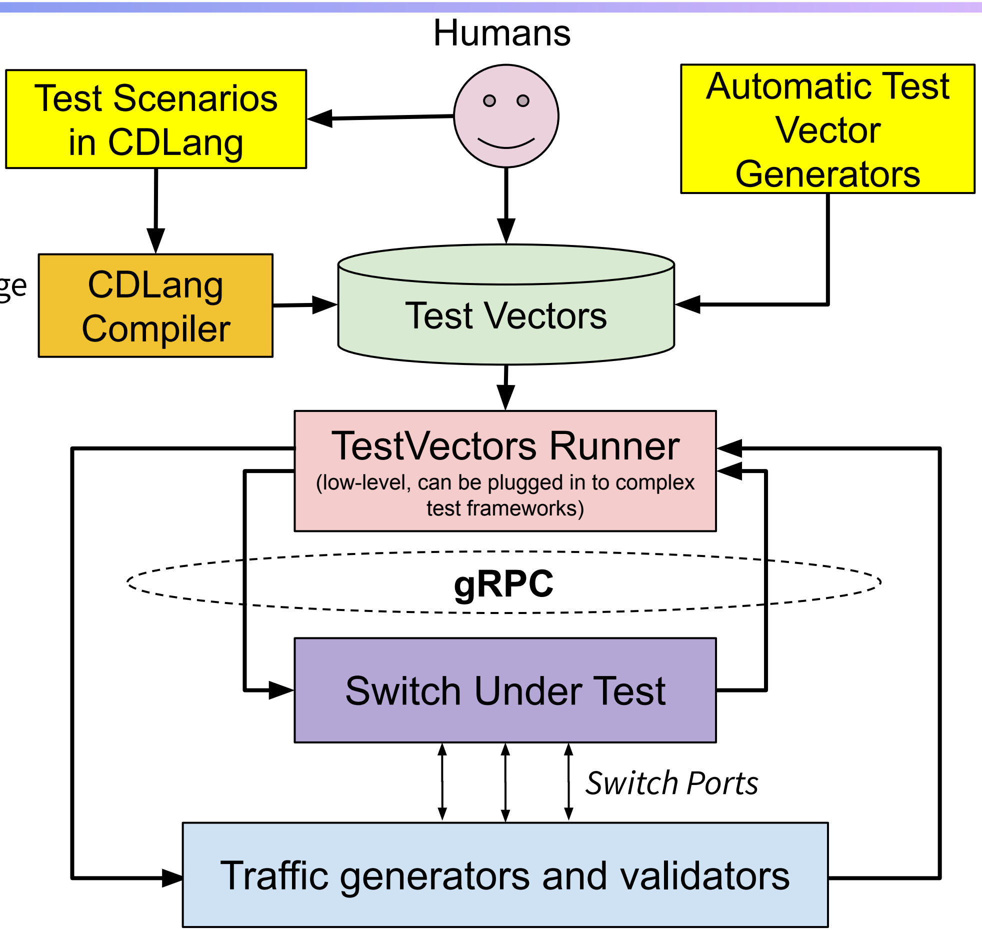
They can be written **manually** or **generated automatically**

- Stratum comes with a Contract Definition language (cdlang) for generating test vectors



TestVectors Runner is a data-driven framework that enables users to execute TestVectors

- Reference impl. in **golang**; supports **P4RT/gNMI**



Tutorial Goals

- Learn how to work with P4 and YANG code
- Understand P4Runtime and gNMI and use CLI utilities to communicate with Stratum devices
- Gain experience running ONOS and Stratum
- Modify a simple Control Plane application that interacts with a P4-defined pipeline

Hands-on overview

Goal: Build IPv6-based leaf-spine fabric with P4, Stratum and ONOS

Getting there step-by-step:

- **Exercise 1 - P4 and P4Runtime basics**
- **Exercise 2 - Yang, OpenConfig, and gNMI basics**
- **Exercise 3 - Using ONOS as the control plane for Stratum**
- **Exercise 4 - Modify P4 program and ONOS app to enable IP routing**