Open Networking Foundation

Realizing Next Generation SDN/NFV

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ONCon

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ONF's History

The ONF has a lot of experience building SDN and NFV solutions

OpenFlow

2008

ONOS
Open Network Operating System

2014

CORD

2016

Trellis
(in production with a major operator)

2018

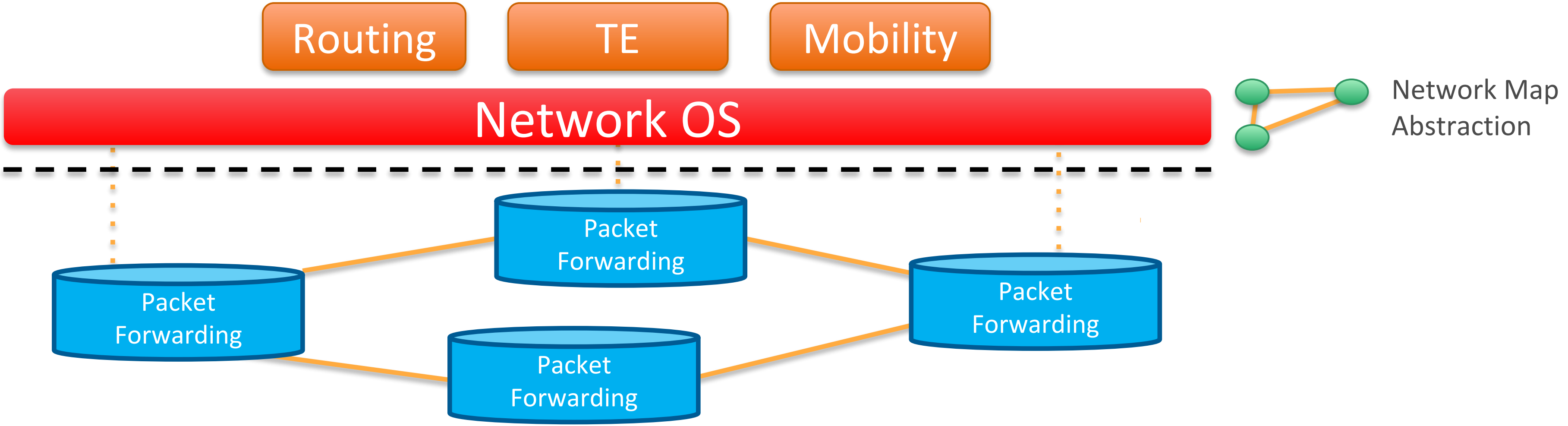
SEBA
(Service Provider Field Trials)

STRATUM

2019

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

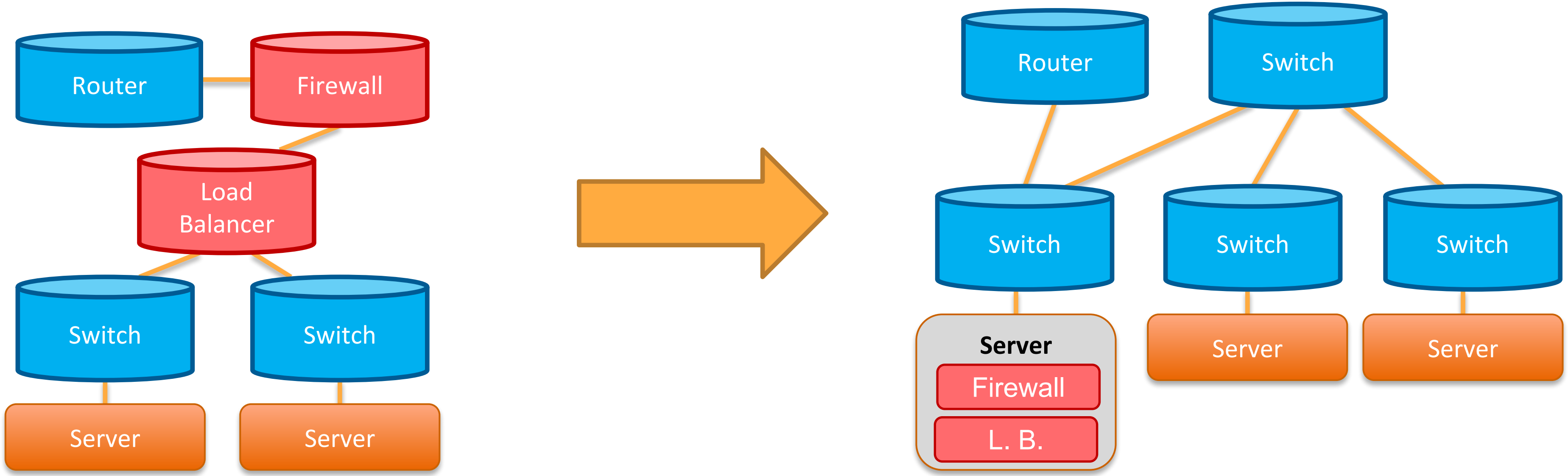


SDN v1 Problems

- 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



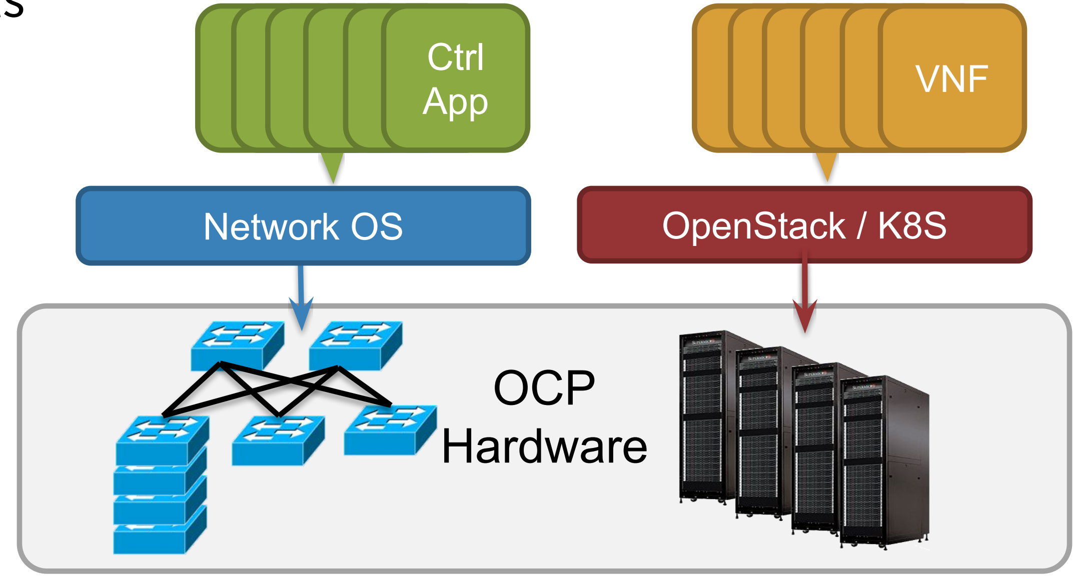
NFV v1 Problems

- CPUs are not the right hardware for many network functions
  - Latency and jitter are higher than alternative targets
  - 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 troubleshooting and end-to-end optimization
  - Separate resource pools

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



Can we get the benefits of SDN and NFV without paying these costs?

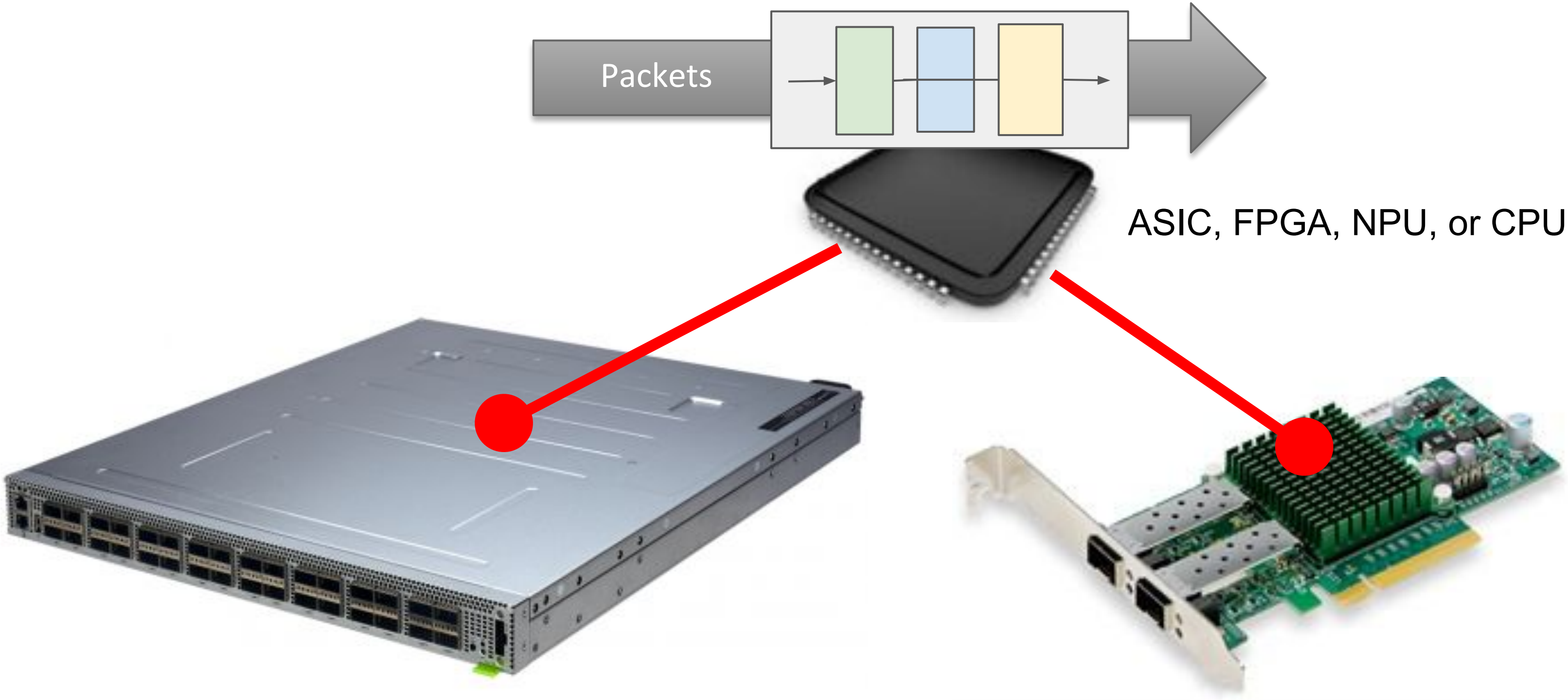
Enabling the Next Generation of SDN

- Development of New Technologies
    - Hardware: Programmable ASICs, FPGAs, Smart NICs
    - Software: P4
- Adopt “cloud mindset” for deployment and management
    - Zero touch operations
    - Containerization
- Leverage Open Source Components
    - Data planes, control planes, networks functions, and apps

#1
Development of New Technologies

Packet Forwarding Pipelines

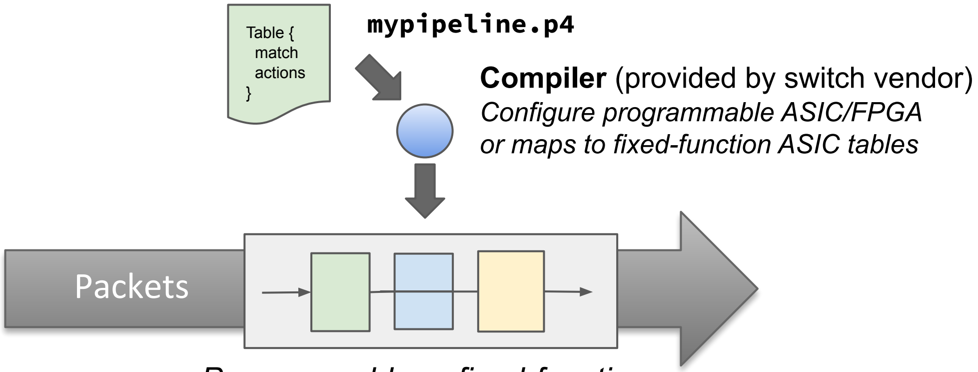
Pipeline of match-action tables



How is this pipeline specified?

P4 Language

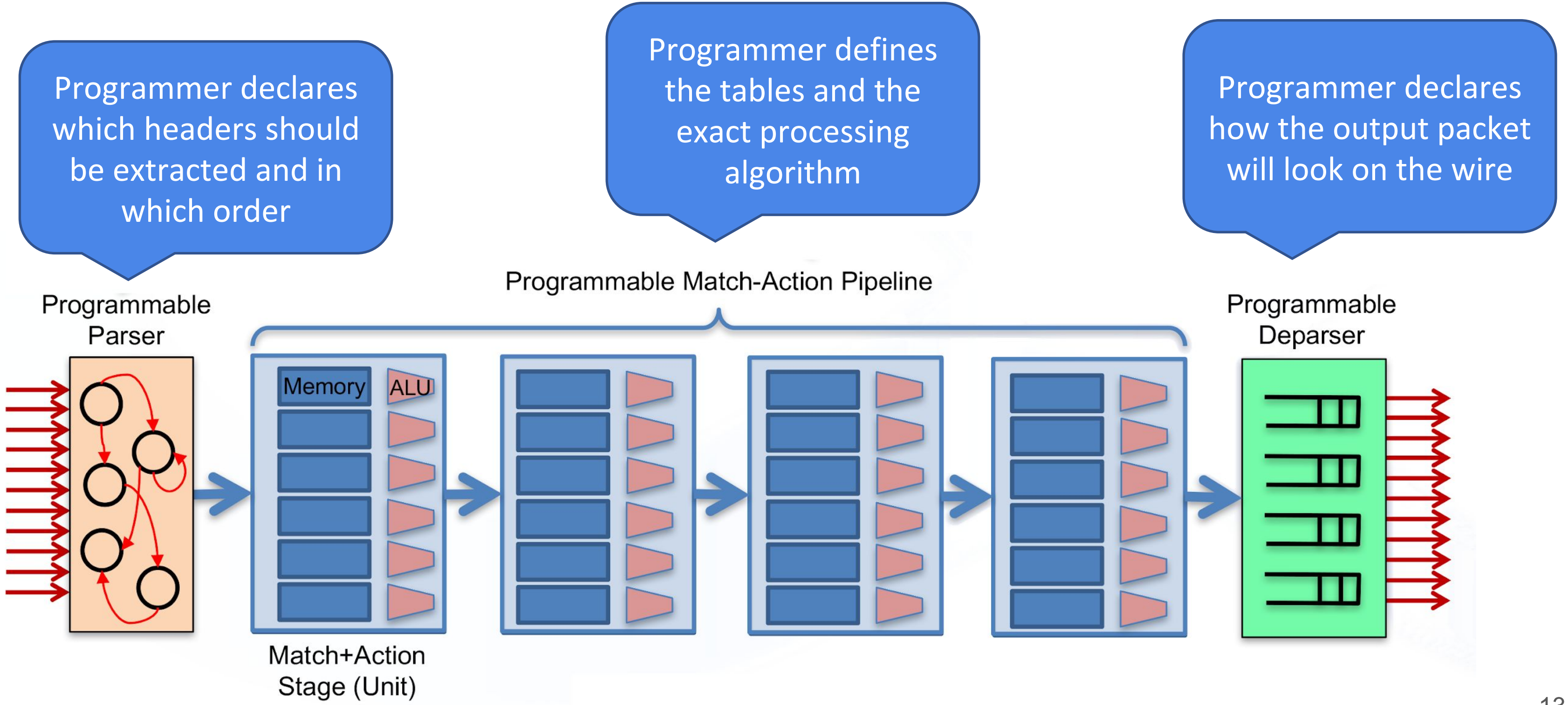
- **Domain-specific language to formally specify a forwarding pipeline**
  - Describe protocol headers, lookup tables, actions, counters, etc.
  - Can describe fast pipelines (e.g ASIC, FPGA) as well as a slower ones (e.g. SW switch)
- **Good for programmable switches, as well as fixed-function ones**
  - *Programmable*: optimize chip resources to application needs, support new protocols
  - *Fixed-function*: defines “contract” with the control plane for runtime control



Programmable or fixed-function pipeline

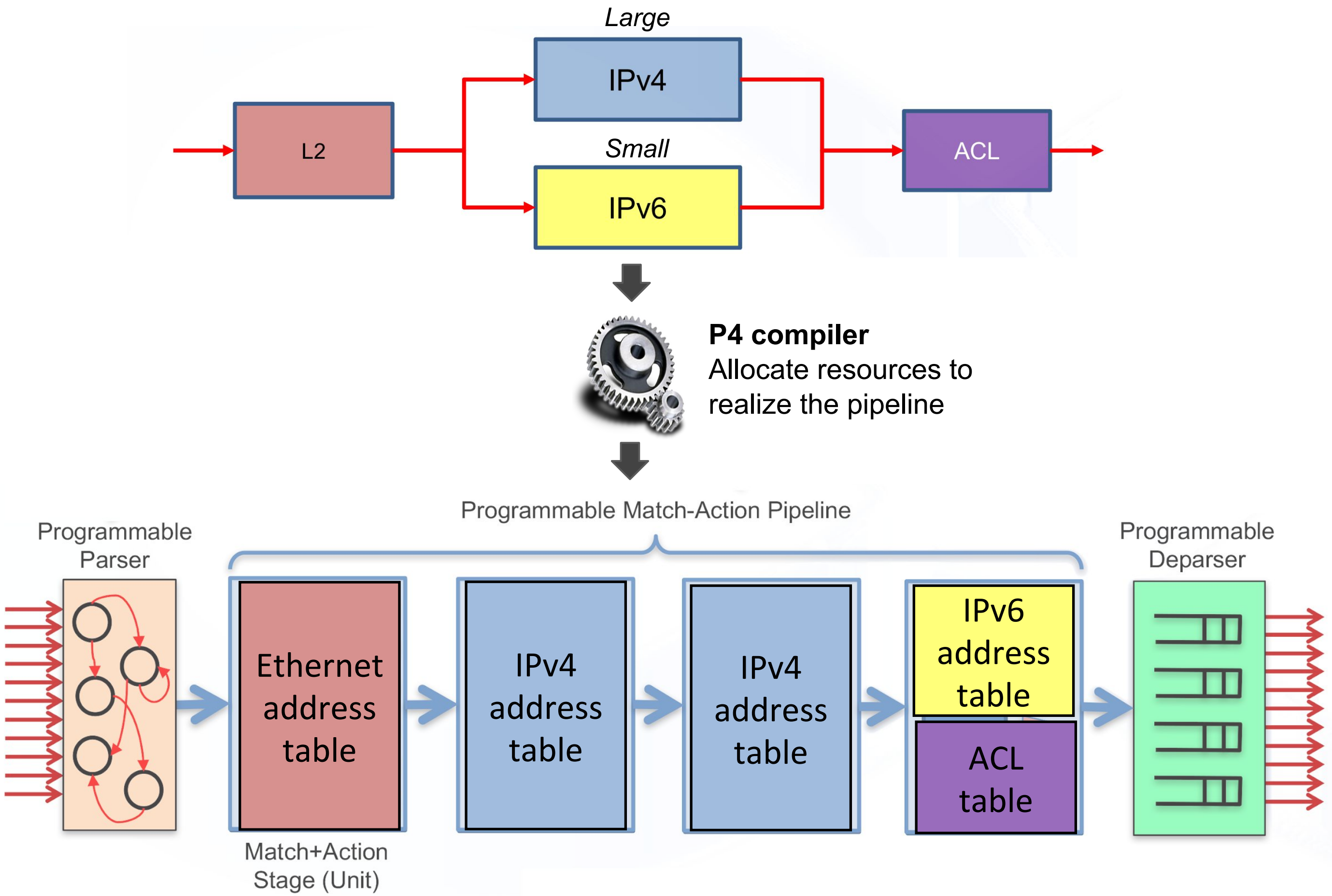
PISA: Protocol-Independent Switch Architecture

Abstract machine model of a high-speed **programmable** switch architecture



Slide courtesy P4.org

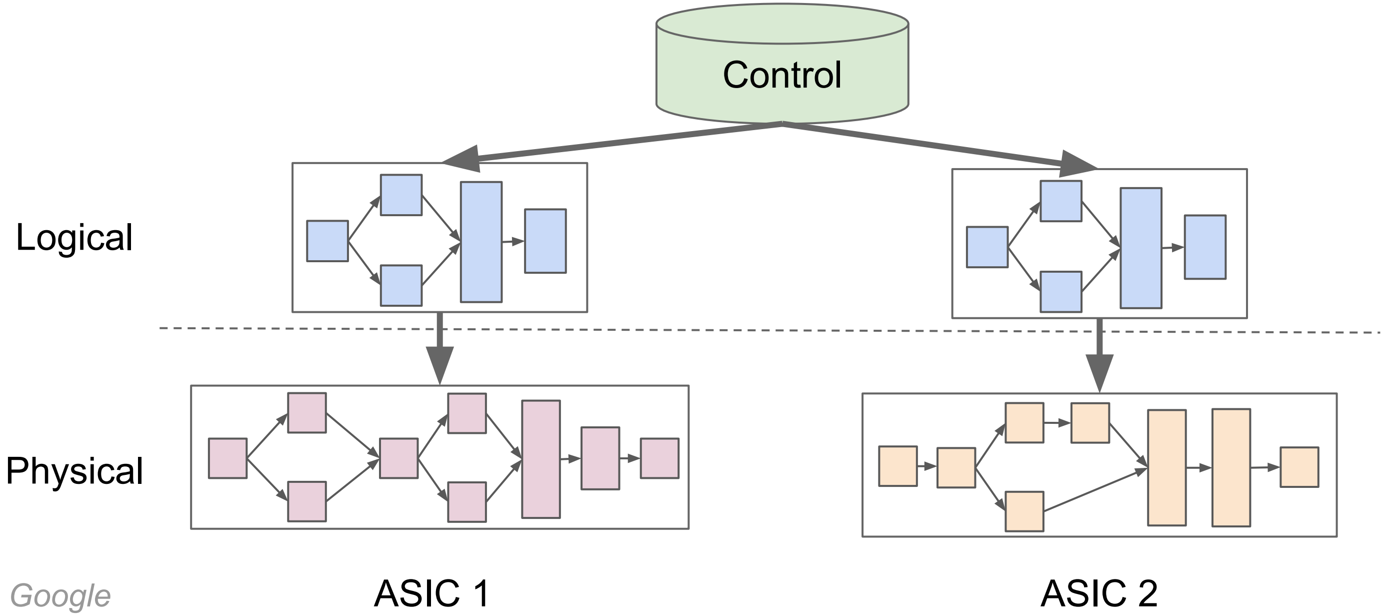
Compiling a simple logical pipeline on PISA



Slide courtesy P4.org

P4 Programs as Fixed-Function Chip Abstraction

- P4 program tailored to apps / role - does not describe the hardware
- Switch maps program to fixed-function ASIC
- Enables portability



Slide from Google

Why should we use P4?

1. Explicit packet and pipeline definition enable deployment to heterogeneous targets
    - Same program can be used for fixed-function and programmable targets from different manufacturers
2. Clear language semantics enable automated verification
    - Generate test inputs and results by analyzing the P4 program

Slides

For insight into automated verification:

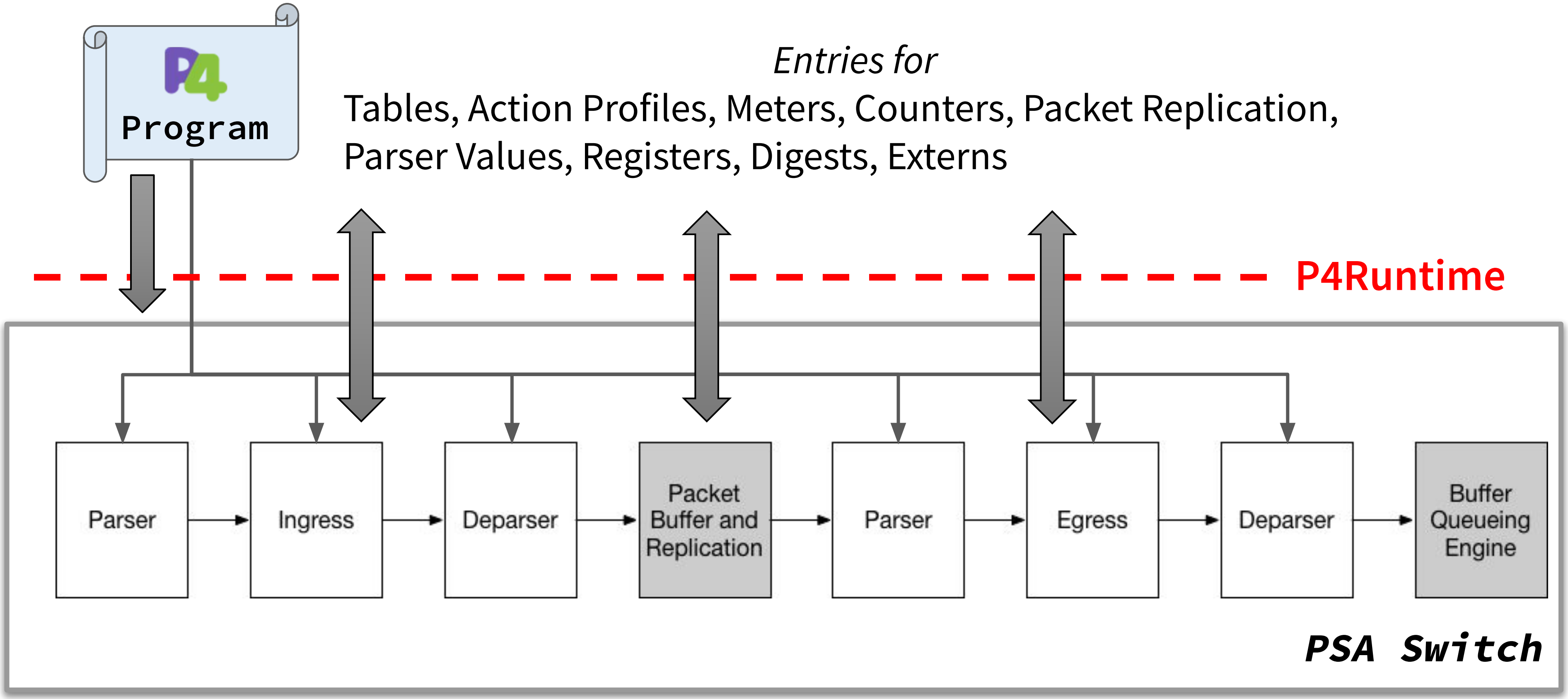
Leveraging P4 for Fixed Function Switches

Speakers: Konstantin Weitz & Stefan Heule (Google)

Links: Slides, Video, or scan the QR codes

Video

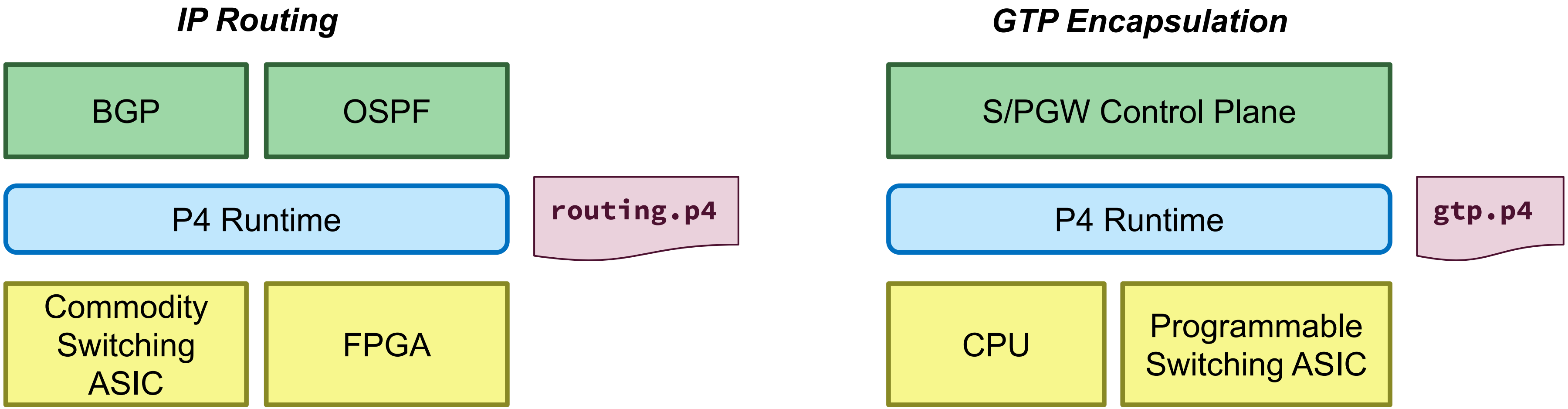
Control Interface: P4Runtime



Slide adapted from P4.org

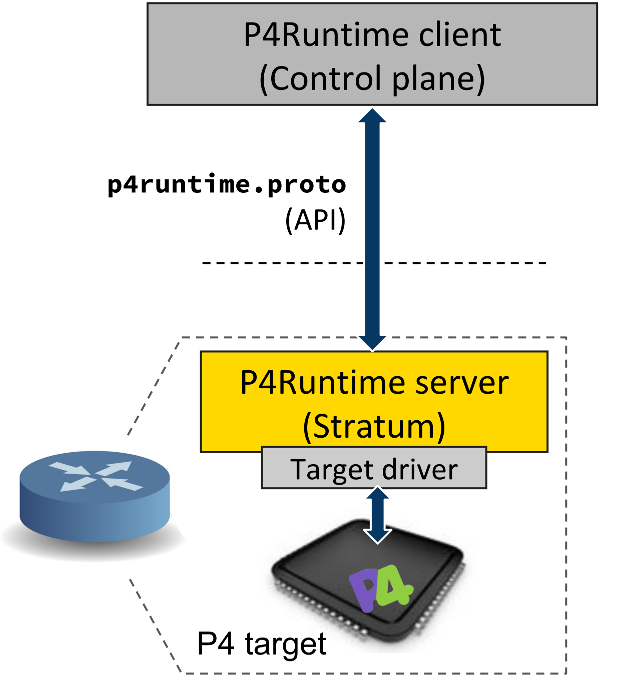
API Consistency for Network Functions

- Provide a consistent interface for network function programming that is independent of hardware or location
- Implement network functions on hardware that meets performance needs



P4Runtime overview

- **API for runtime control of P4-defined switches**
  - Generic RPCs to manage P4-defined table entries and other forwarding state
- **Community-developed (p4.org API WG)**
  - Initial contribution by Google and Barefoot
  - RC of version 1.0 available: https://p4.org/p4-spec/
- **gRPC/protobuf-based API definition**
- **Enables field-reconfigurability**
  - Ability to push new P4 program, i.e. re-configure the switch pipeline, without recompiling the switch software stack
  - E.g. to add new match-action tables, support parsing of new header formats



Slide courtesy P4.org

P4Runtime TableEntry Example

basic_router.p4

```
action ipv4_forward(bit<48> dstAddr,
                    bit<9>  port) {
   /* Action implementation */
}
table ipv4_lpm {
   key = {
       hdr.ipv4.dstAddr: lpm;
   }
   actions = {
       ipv4_forward;
       ...
   }
   ...
}
```

Logical view of table entry

```
hdr.ipv4.dstAddr=10.0.1.1/32
     -> ipv4_forward(00:00:00:00:00:10, 7)
```

Control plane generates

Protobuf TableEntry message

```
table_entry {
  table_id: 33581985
  match {
    field_id: 1
    lpm {
      value: "\n\000\001\001"
      prefix_len: 32
    }
  }
  action {
    action_id: 16786453
    params {
      param_id: 1
      value: "\000\000\000\000\000\n"
    }
    params {
      param_id: 2
      value: "\000\007"
    }
  }
}
```

#2
Next Step: Adopting a Cloud Mindset

Zero Touch Operations

- Humans don’t log into individual boxes to configure them
- Configuration is generated automatically and sent to devices
    - Changes are defined by high-level, network-centric intent
- Management plane listens to telemetry events and applications drive network state towards policy objections
    - Rollback happens automatically in network invariants are violated

Vision: Zero Touch Networking

"70% of network failures happen during management operations, due to the high level of complexity of such operations across a wide variety of network types, devices, and services" - Google

Evolve or Die: High-Availability Design Principles Drawn from Google's Network Infrastructure

Authors: Ramesh Govindan, Ina Minei, et al. (Google)

Links: Paper, Video, or scan the QR codes

Paper

Video

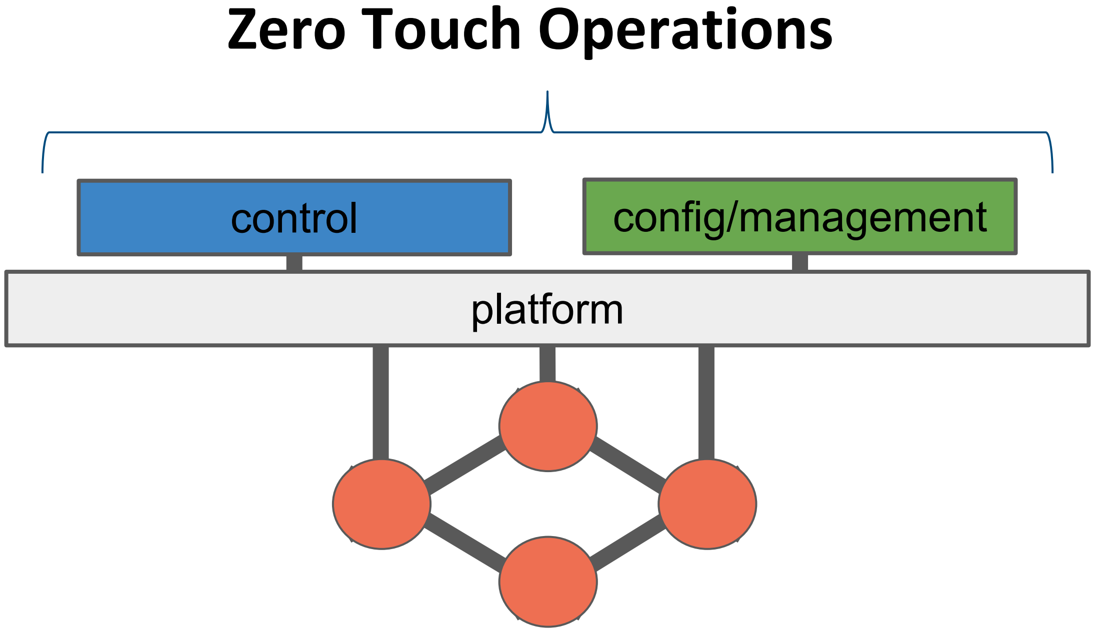
Zero Touch Operations

Availability
Reliability
3, 4 or 5 “9’s”

Velocity
Daily updates

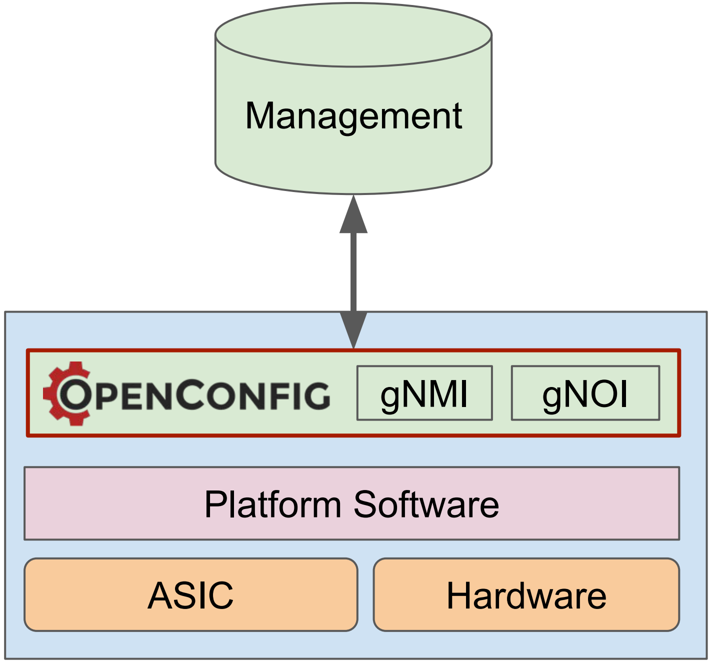
Zero Touch Operations: Control and Config/Management

To achieve a zero touch network a seamless interplay of control and config/management needs to happen. High level network centric policies always need a combination of both elements to be achieved with no impact.



Simplify and Centralize Configuration

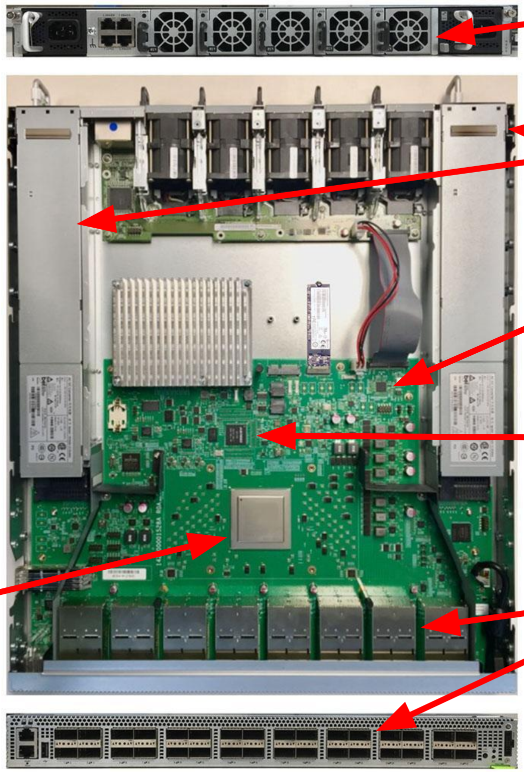
- Leverage vendor-neutral models as much as practical
- Centralize configuration and management to reduce deployment complexity
- This applies to both data plane and control plane components



Slide adapted from Google

OAM Interfaces: gNMI and gNOI

- gNMI for:
  - Configuration
  - Monitoring
  - Telemetry
- gNOI for Operations



Fan Speed

Power supplies

Monitor Sensors
e.g. temperature

Software Deployment and Upgrade

Port State and Mapping
LED Control

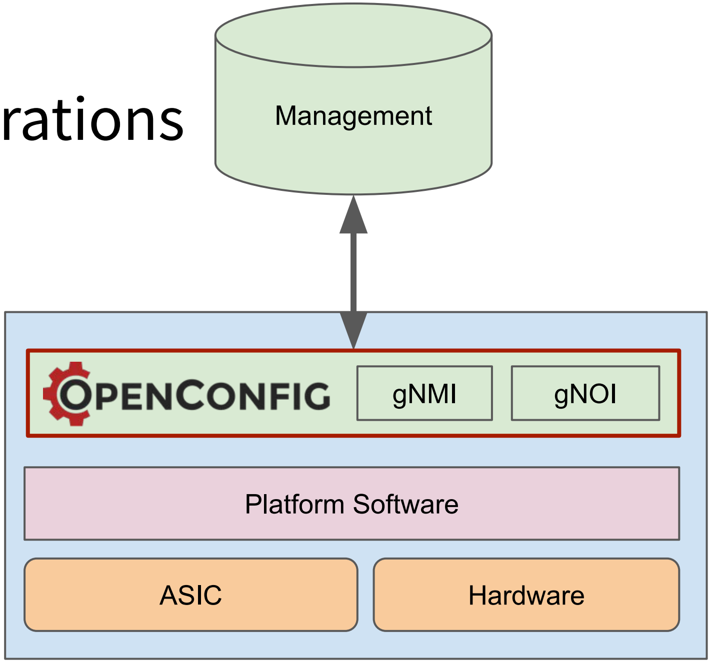
Switch Chip Configuration
QoS Queues and Scheduling
Serialization / Deserialization
Port Channelization

Management Network

… and the list goes on.

Enhanced Configuration

- Configuration and Management
- Declarative configuration
- Streaming telemetry
- Model-driven management and operations
  - gNMI - network management interface
  - gNOI - network operations interface
- Vendor-neutral data models



Slide adapted from Google

OpenConfig Model - An Example

```
module: openconfig-interfaces
  +--rw interfaces
     +--rw interface* [name]
        +--rw config
        |  +--rw name?             string
        |  +--rw type              identityref
        |  +--rw mtu?              uint16
        |  +--rw loopback-mode?    boolean
        |  +--rw description?      string
        |  +--rw enabled?          boolean
        +--ro state
        |  +--ro name?             string
        |  +--ro type              identityref
        |  +--ro mtu?              uint16
        |  +--ro loopback-mode?    boolean
        |  +--ro description?      string
        |  +--ro enabled?          boolean
        |  +--ro ifindex?          uint32
        |  +--ro admin-status      enumeration
        |  +--ro oper-status       enumeration
        |  +--ro last-change?      oc-types:timeticks64
        |  +--ro logical?          boolean
        |  +--ro counters
        |     +--ro in-octets?           oc-yang:counter64
        |     +--ro in-pkts?             oc-yang:counter64
        |  ...
```

```
augment "/oc-if:interfaces/oc-if:interface/oc-if:config" {
    leaf forwarding-viable {
        type boolean;
        default true;
    }
}
```

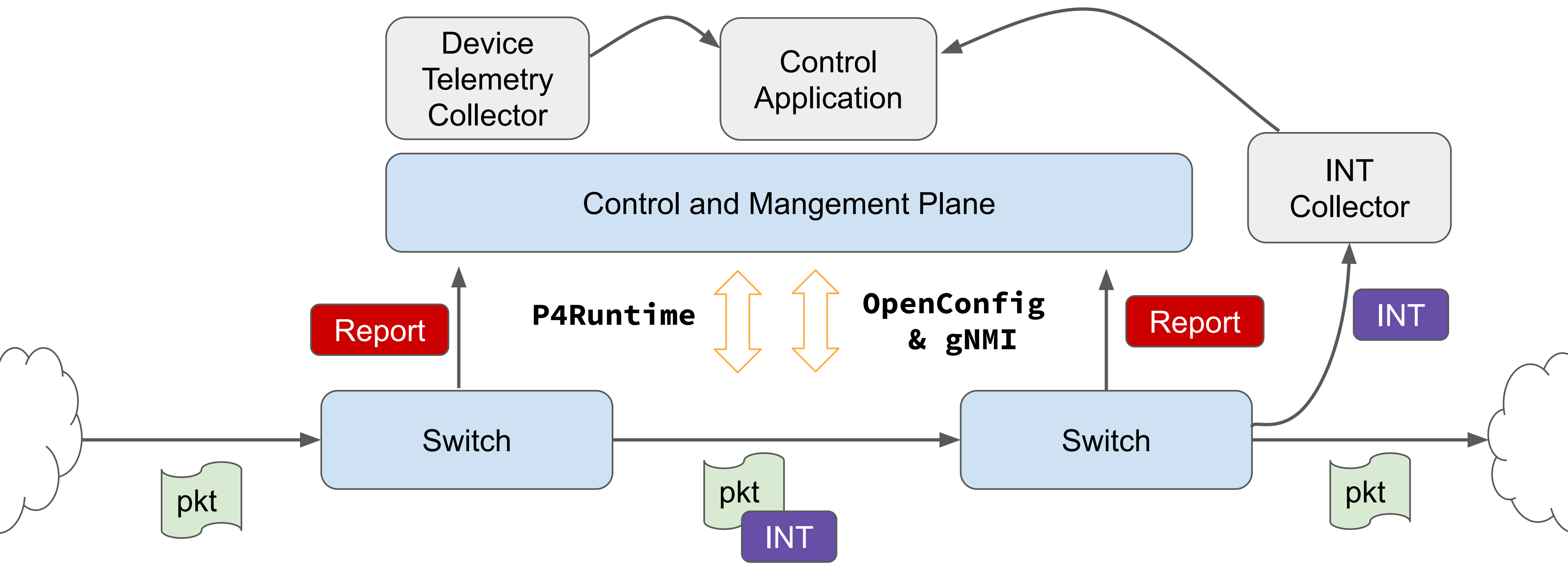
```
+--rw forwarding-viable?    boolean
```

Models are easy to augment, use, and test.

Compile and re-generate topology.

OPENCONFIG

Closed Loop Control Relies on Telemetry



#3
Leverage Open Source Components

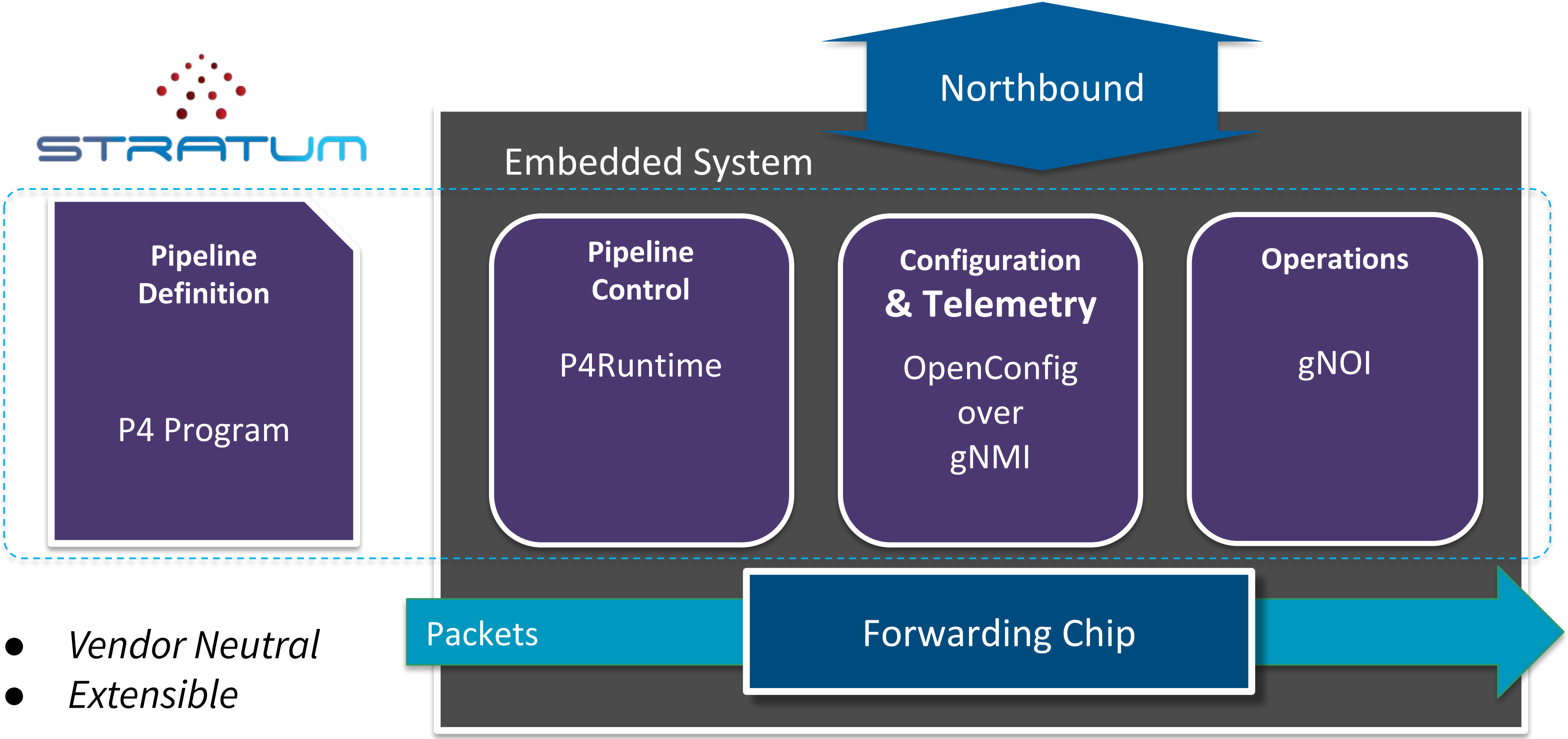
Providing an Implementation

Open Interfaces and Models are necessary, **but not sufficient**, for multi-vender interoperability.

Interfaces are **defined by running code**, so providing an open source implementation helps solidify the interfaces and models. This is not a standards exercise.

If the open source is a fully production ready distribution (ready to run and deploy these interfaces), we can **avoid bugs in different vendor implementations** and improve time to market.

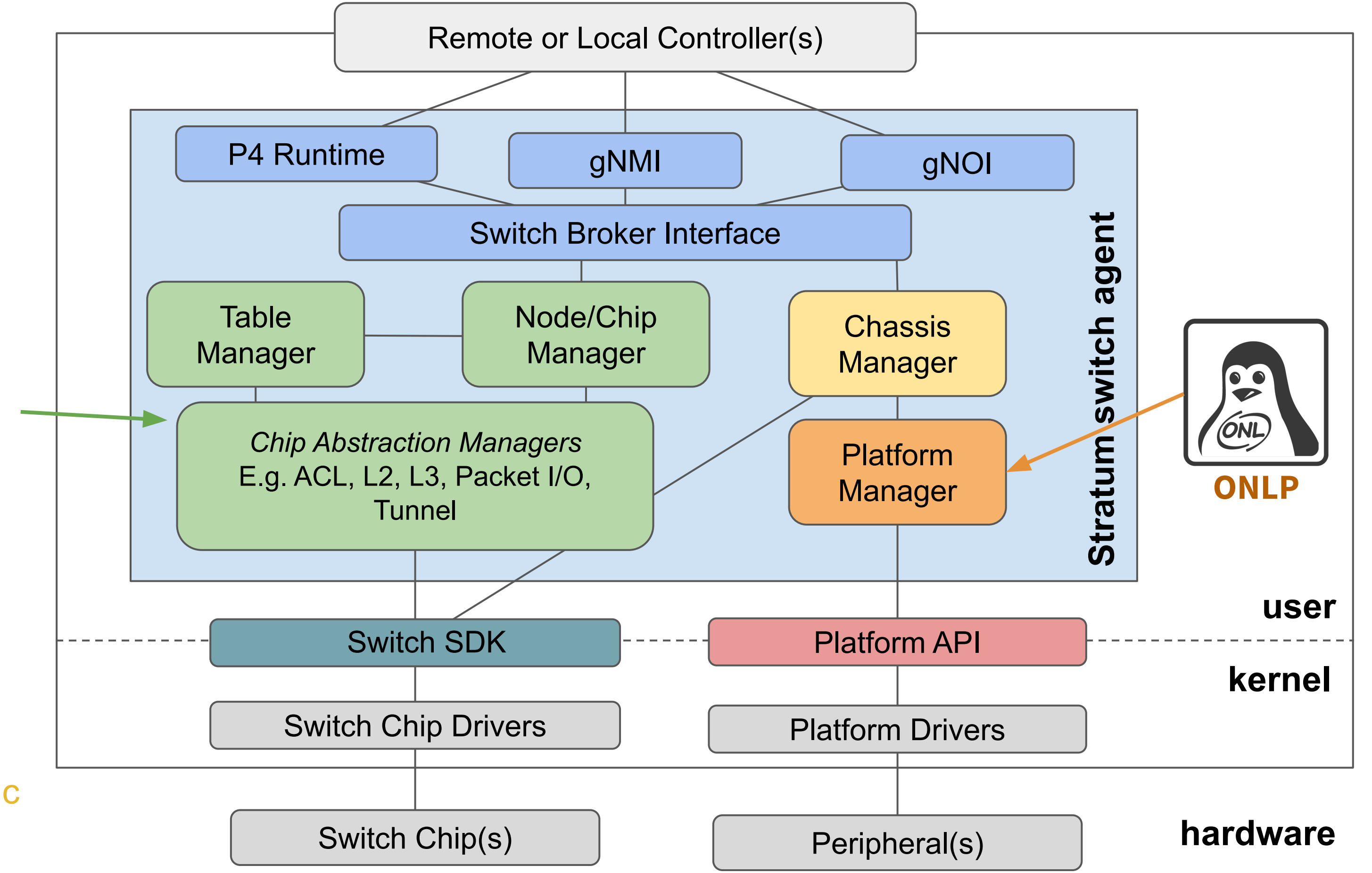
Stratum: Next Generation Data Plane



- *Vendor Neutral*
- *Extensible*

Stratum High-level Architectural Components

PI and **fpm**-based implementations



Common (HW agnostic)
Chip specific
Platform specific
Chip and Platform specific

Stratum Implementation Details

- Implements **P4Runtime**, **gNMI**, and **gNOI** services
- Controlled locally or remotely using **gRPC**
- Written in **C++11**
- Runs as a **Linux** process in user space
- Can be distributed with **ONL**
- Built using **Bazel**

Available to the public end of August 2019!

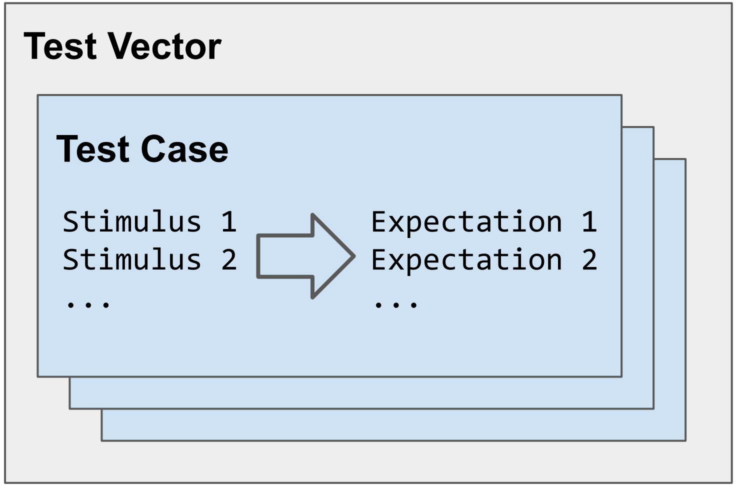
Comprehensive Test Framework

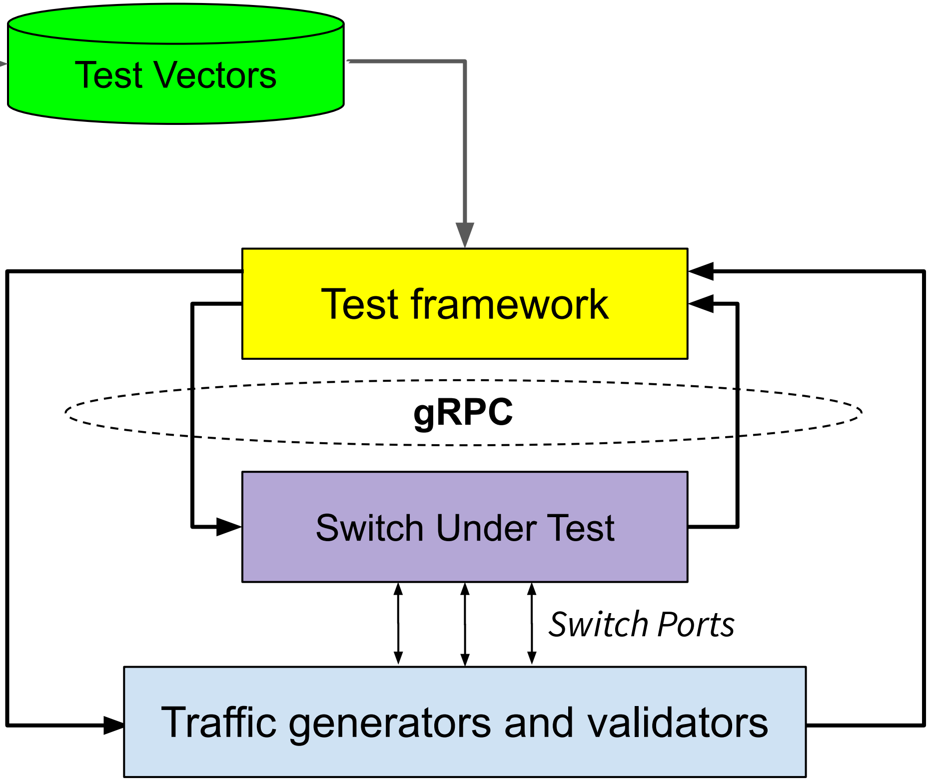
Is an open-source implementation enough for interop?
How to we prevent implementation discrepancies?

There will be other implementations, and they need to be qualified. We also need to make sure that vendor-specific pieces are implemented as expected.

Solution: Provide a **vendor-agnostic, "black box" test framework** for any target that complies with Stratum open APIs (P4Runtime, gNMI, gNOI) along with a **repository of tests.**

Writing Test Vectors



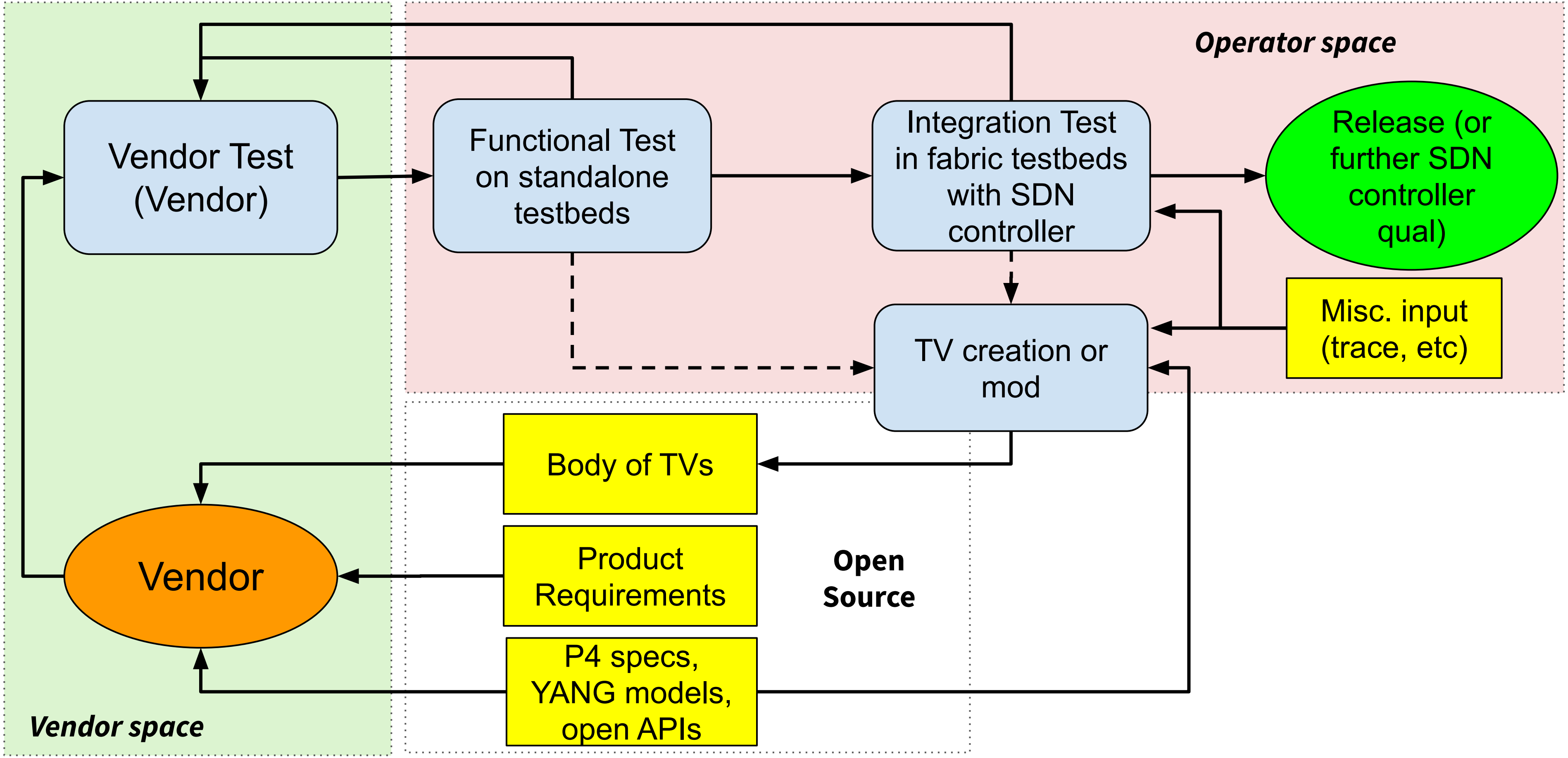


Test Vectors serve as compliance tests for Stratum-based devices.

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

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

Black Box Qualification

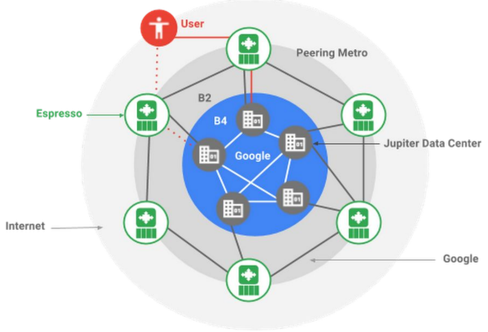


Slide courtesy of Google

Project Genesis

Seed Code

and Community

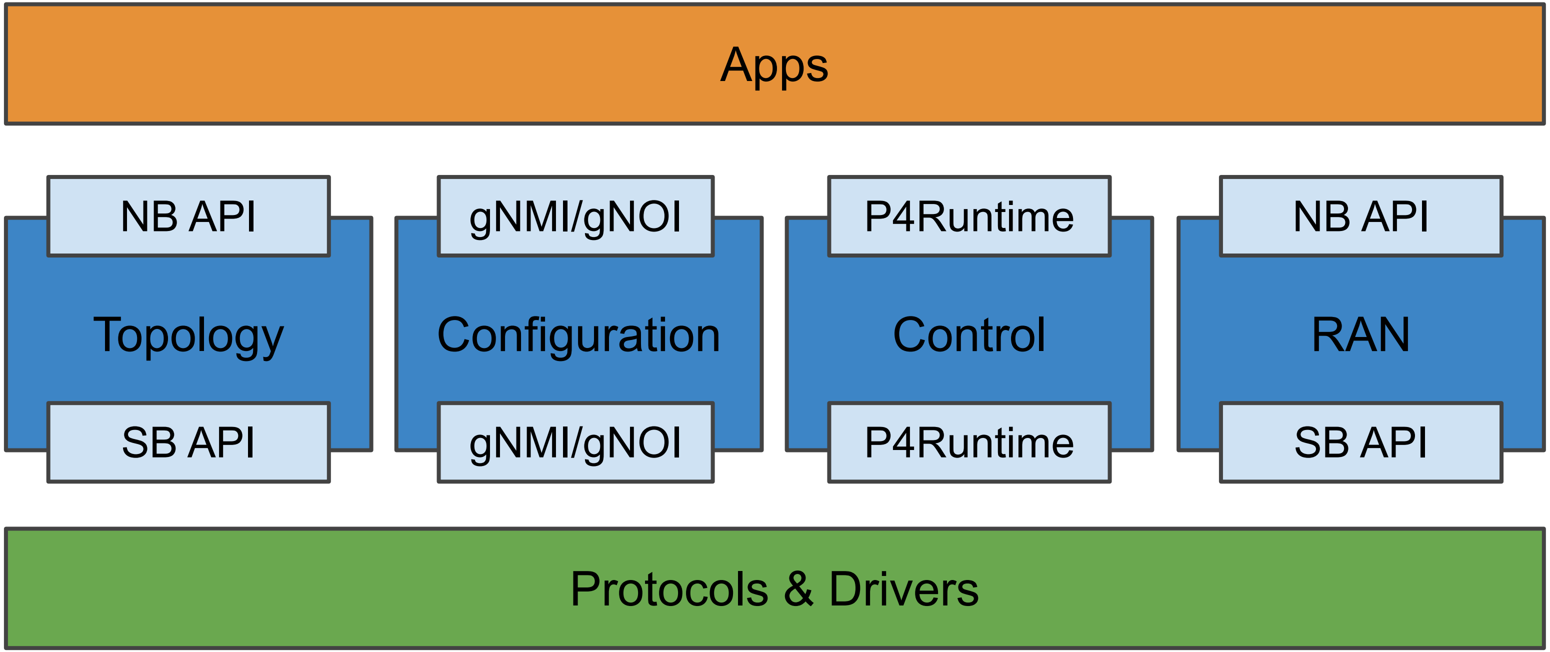


...

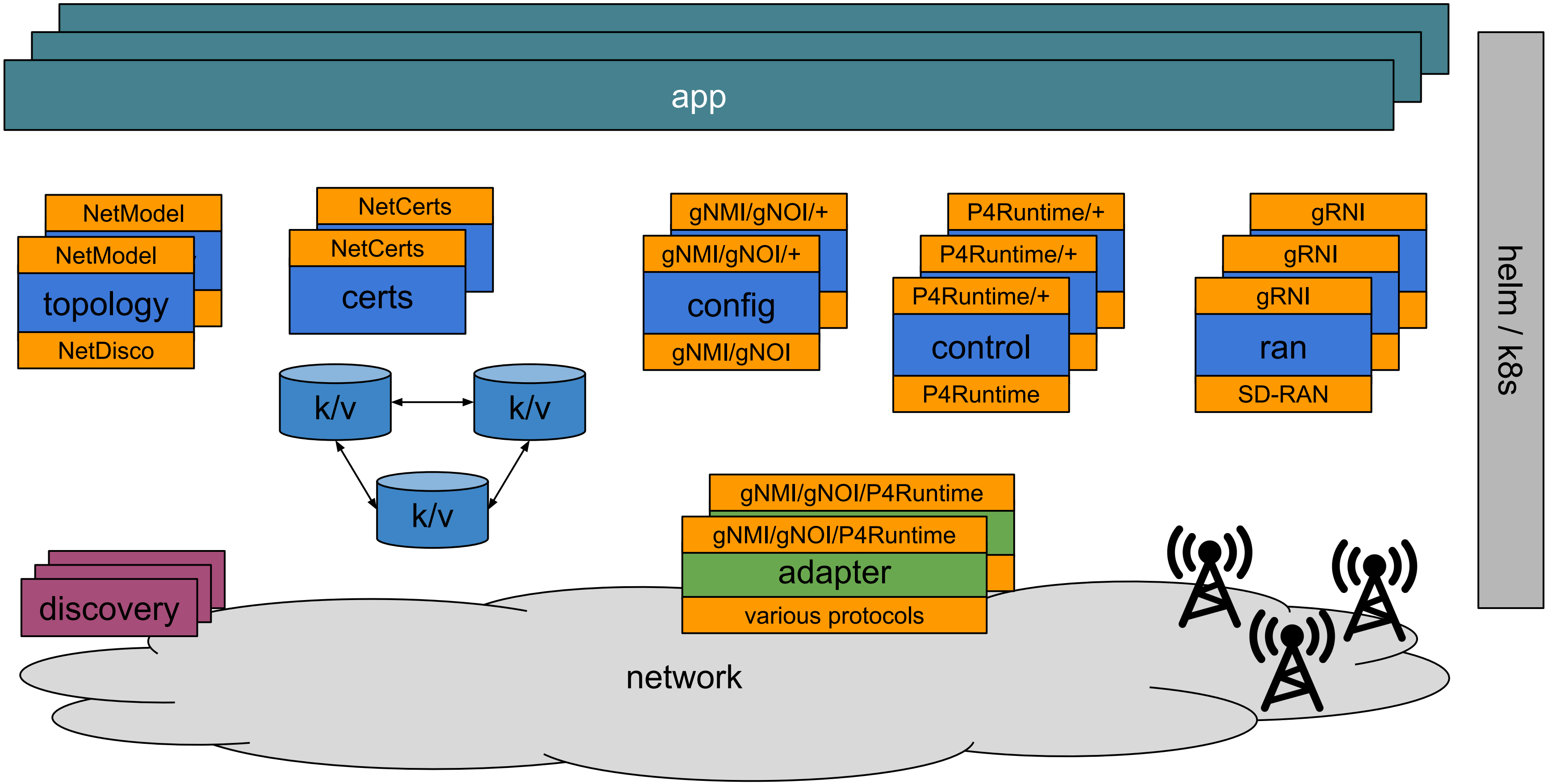
µONOS

rationale & tenets for next-gen SDN controller

NG SDN Controller Architecture



NG SDN Controller Architecture



Configuration Subsystem

- Work hosted under GitHub in the open
  - http://github.com/onosproject/onos-config
- Primarily staffed by ONF at this point
  - external contributions are wanted and welcome
- Bi-weekly updates and demos given at ONOS TST
  - deployment via Helm/Kubernetes
  - multi-device transactions and rollback
  - integrated validation of data via ygot
  - Atomix 4.x with support for gRPC and Go primitives client libraries
  - currently prepping start work on distributed stores
- Planning ONF Connect demos

Topology Subsystem

- Exploring use of Google's Unified Network Model
  - initiating discussions with Google about using UNM or a derivative
  - UNM was part of Jeff Mogul's presentation at Stanford last year
- Goal is to use UNM-like model as a canonical representation
  - allows to capture design intent and supports schema evolution
  - ability to project to alternate representations, eg.
    - RFC 8345 IETF Network Topology model to exchange topology data and changes to topology state
    - custom graph structures and gRPC streaming for run-time performance

Control & RAN Subsystems

- SB API for the subsystem will be P4Runtime
  - well-defined, low-profile interfaces with support for transactions
  - allows direct use with Stratum-compliant switches
  - adapters can be created for devices that do not support P4Runtime
- NB API will be P4Runtime and admin APIs
  - requires network-wide table mapping, e.g. network-sized chassis
  - design work for amin and diagnostic APIs will start shortly
- Provide abstractions and controls relevant to the RAN domain
  - near real-time requirements, e.g. latency sensitive, predictable

Looking Ahead

- **ONOS 2.x already supports P4Runtime and gNMI**
- With ONOS 2.x being a stable platform for some time to come, now is the time to consider next generation architecture
- With Stratum starting to materialize as UPAN data plane, now is the time to consider UPAN control plane
- Goal is to establish the next generation SDN controller architecture
  - kicked off collaboration at start of 2019
  - completely in the open and with the help of the community at large
- Project is named µONOS and will become ONOS 3.0 when ready
- Continue to curate ONOS 1.x & 2.x maintenance and releases
  - core team to do LTS bug fixes, code reviews and release engineering
  - community to continue new feature and applications development

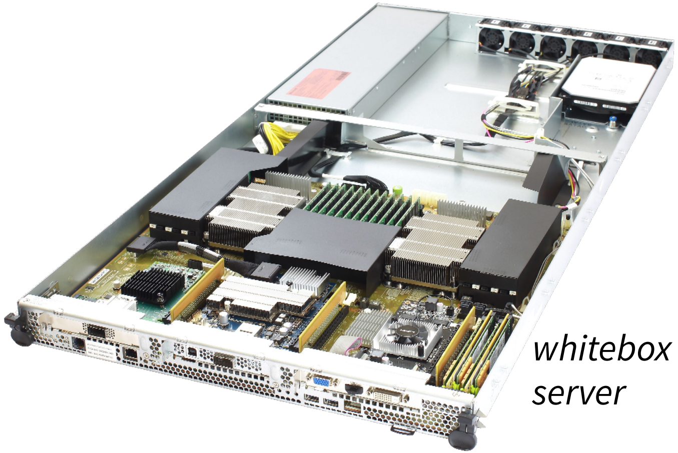
Using Docker to Deploy Applications

Control Plane / SDN App

Shared libraries / runtime

container

Host OS: **Linux**



whitebox server

Stratum Agent / Network Fn.

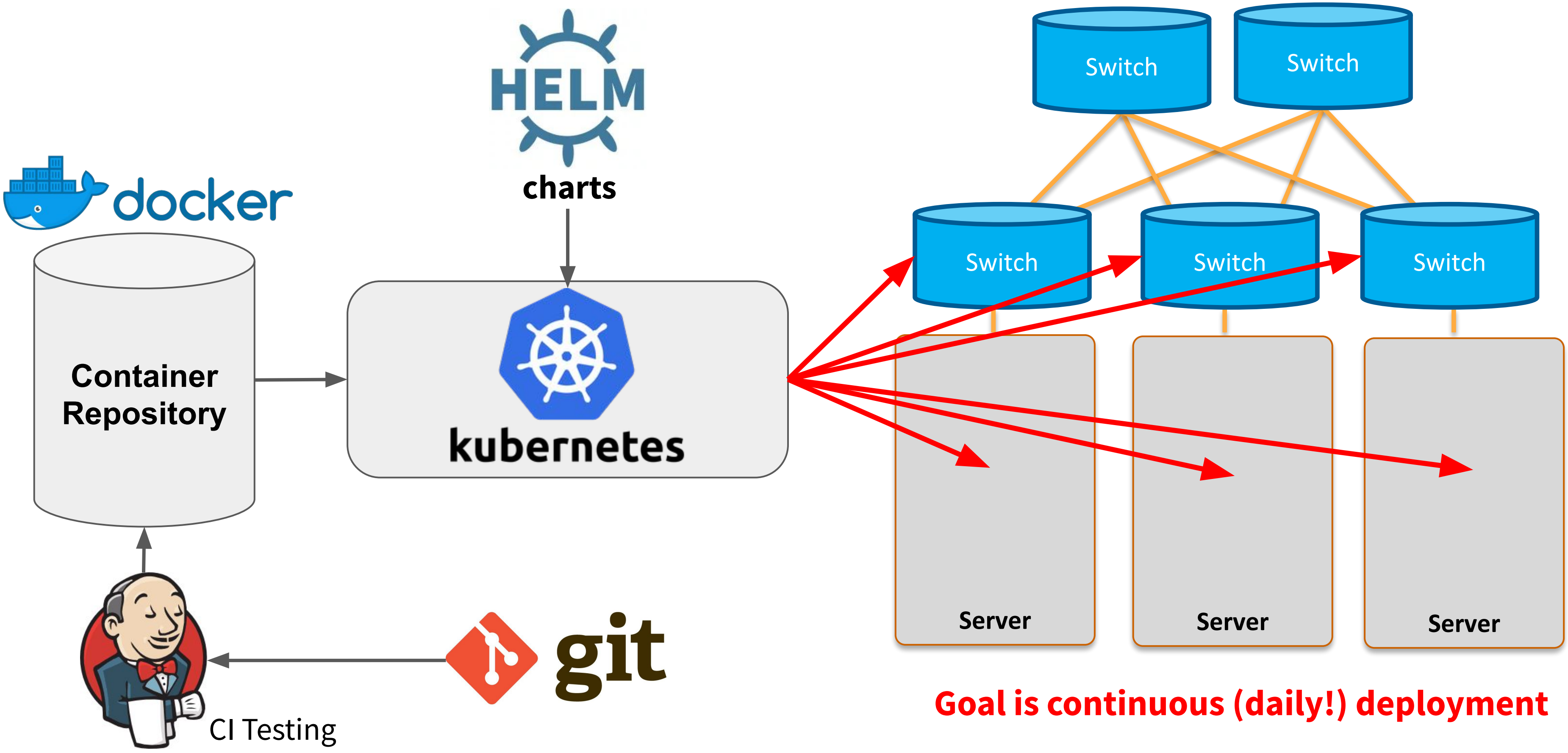
Shared libraries / runtime

container

Host OS: **Linux**

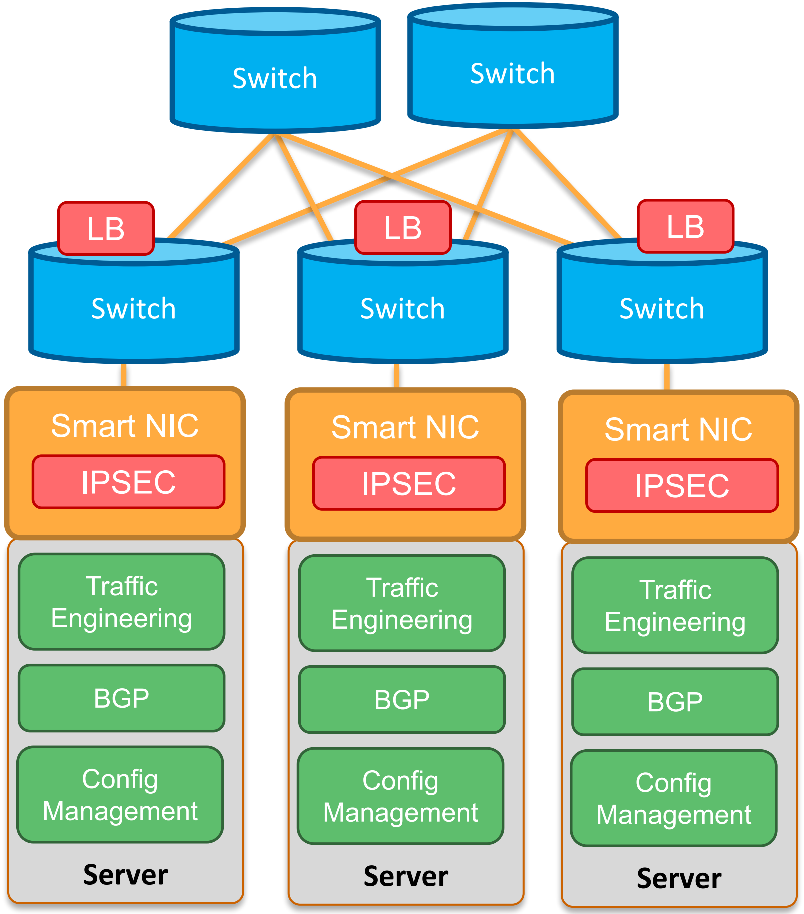
whitebox switch

Using Kubernetes to Deploy to Common Infra



Deploy components on common infrastructure

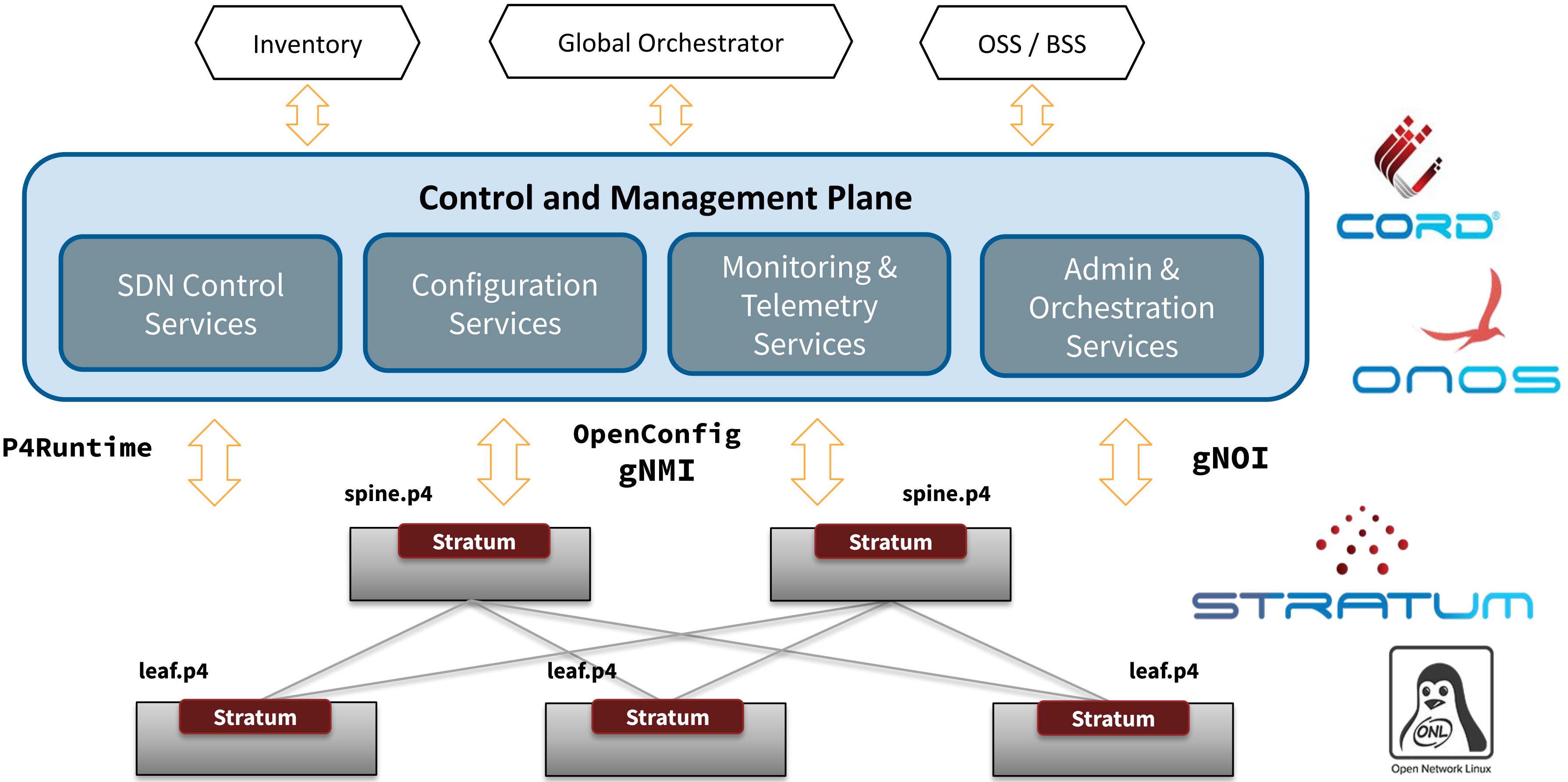
- Deploy control plane and data plane functions on a converged network infrastructure
- Place functions in appropriate locations using an intelligent scheduler
- Deploy functions on hardware that meets performance needs



Network Function

Control Plane Function

Next Generation SDN picture



Enabling the Next Generation of SDN

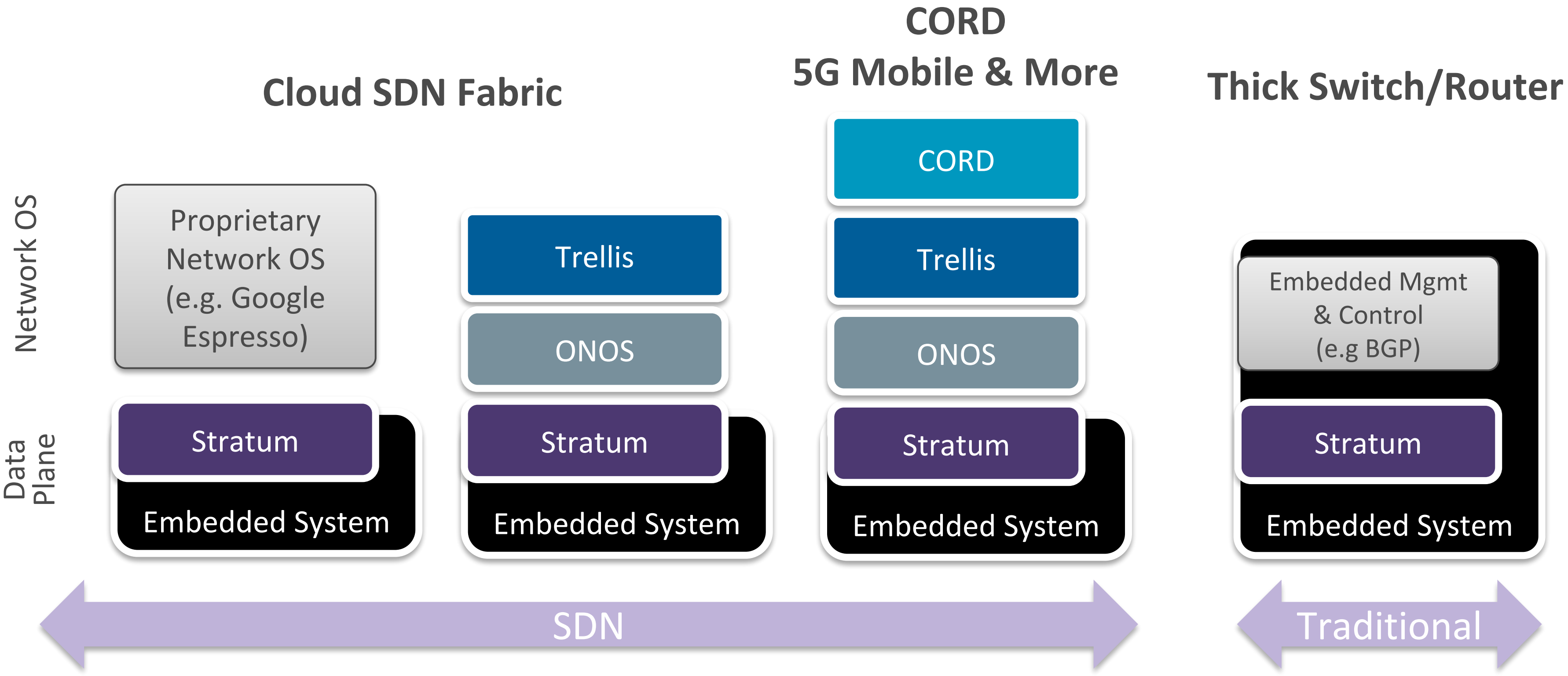
- Development of New Technologies
    - Hardware: Programmable ASICs, FPGAs, Smart NICs
    - Software: P4
- Adopt "cloud mindset" for deployment and management
    - Zero touch operations
    - Containerization
- Leverage Open Source Components
    - Data planes, control planes, networks functions, and apps

If this sounds interesting, please get involved!

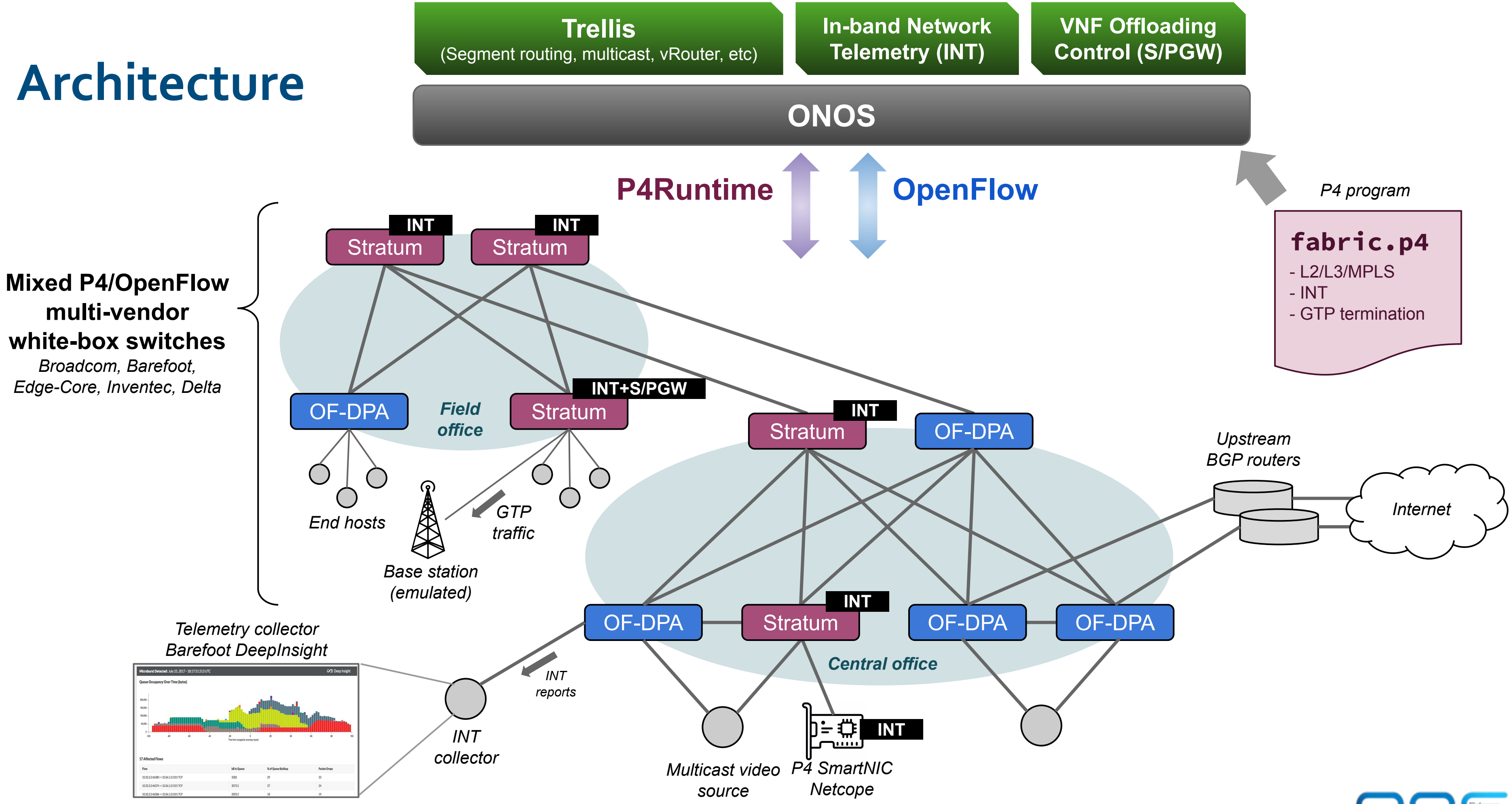
For questions, email brian@opennetworking.org

Backup Slides

Stratum Use Cases

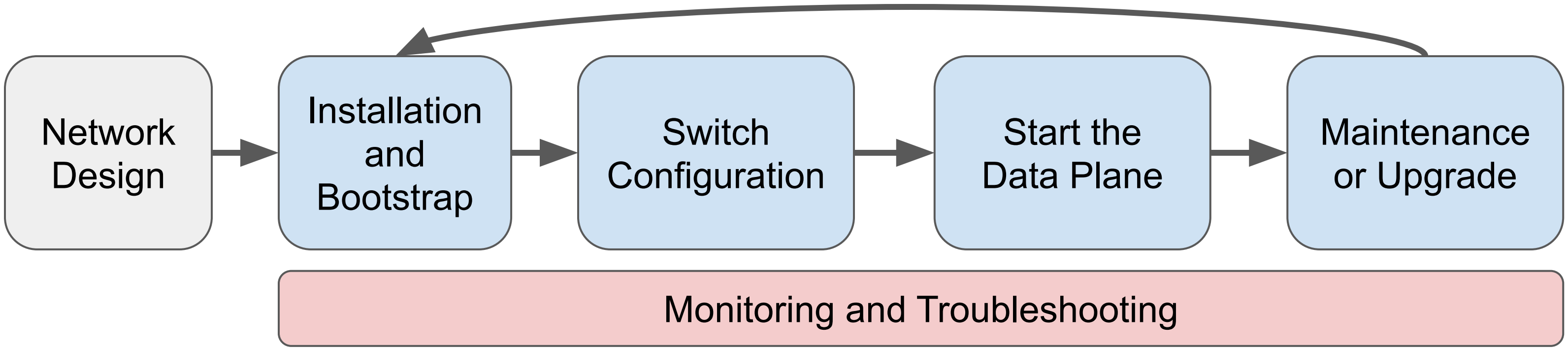


Architecture



Life of a Whitebox Switch: Day 0 to Day N

1. Design
2. Installation & Bootstrap
3. Switch Configuration
4. Start the Data Plane
5. Monitoring & Telemetry
6. Reboot
7. Upgrade

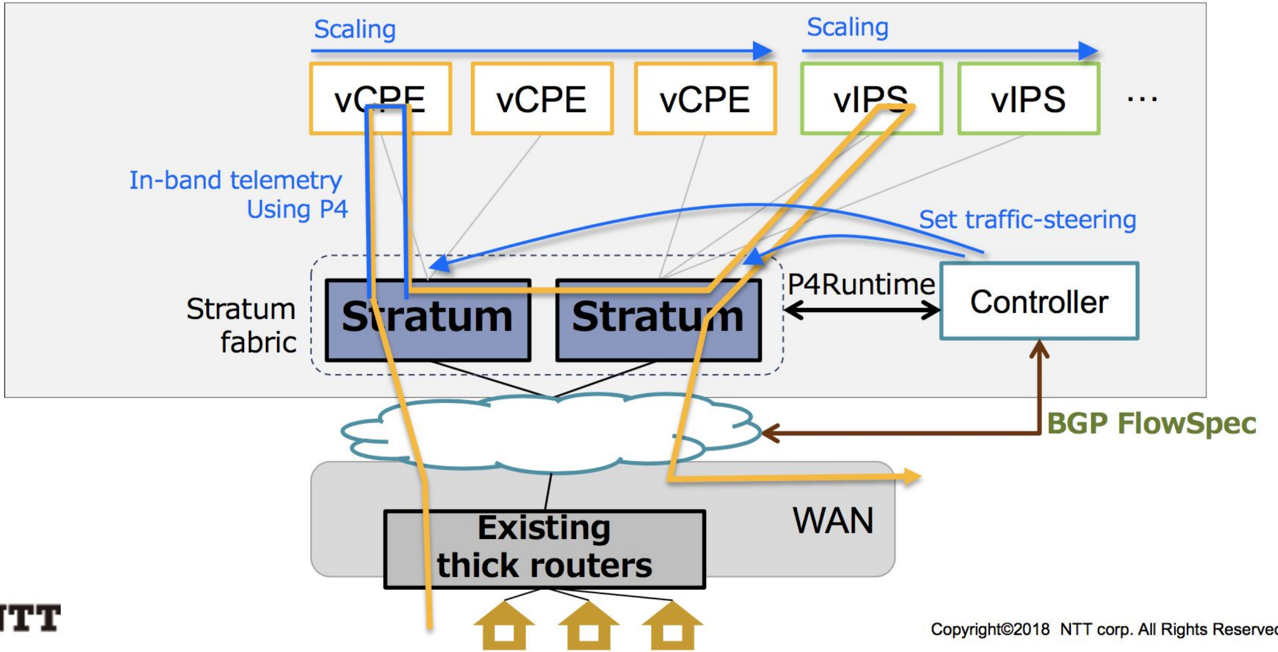


Slide from NTT

Use-case 1

Chaining and Scaling Edge Gateway

- **Flexible traffic chaining with BGP FlowSpec**
- **Auto chaining/scaling**
- **In-band telemetry between VNFs**

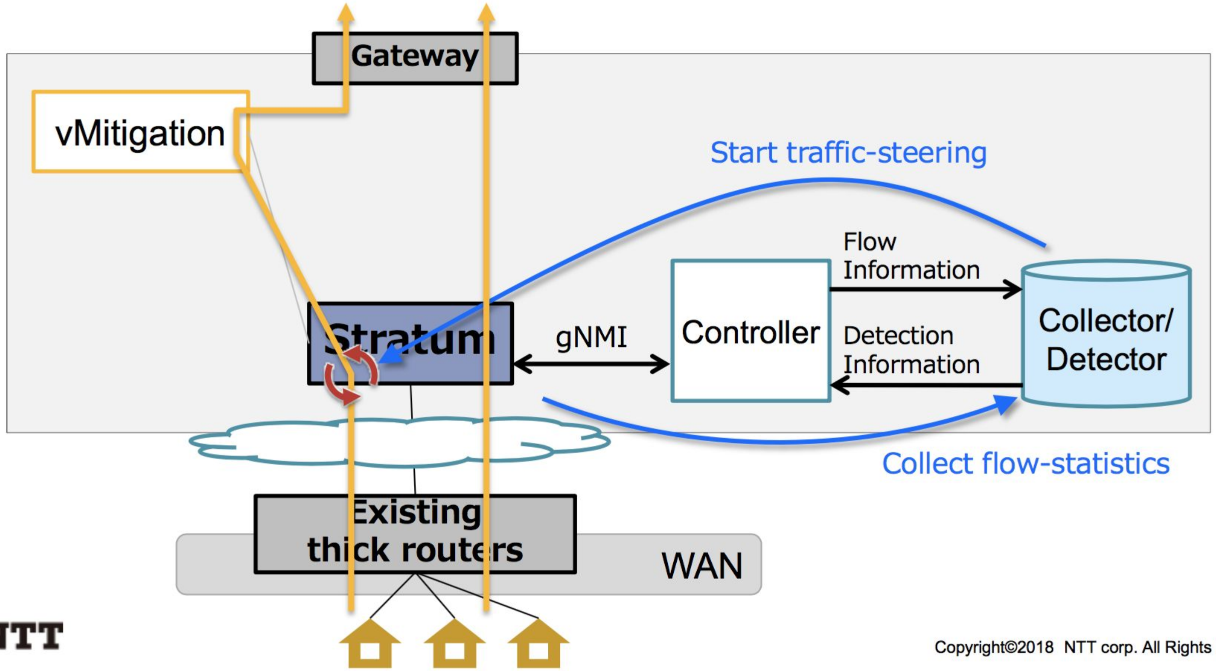


Slide from NTT

[Use-case 2]

DDoS Detection and Steering Function

- **Collect flow-statistics from stratum switches**
- **Steering traffic to mitigation function when collector detects flow burst**

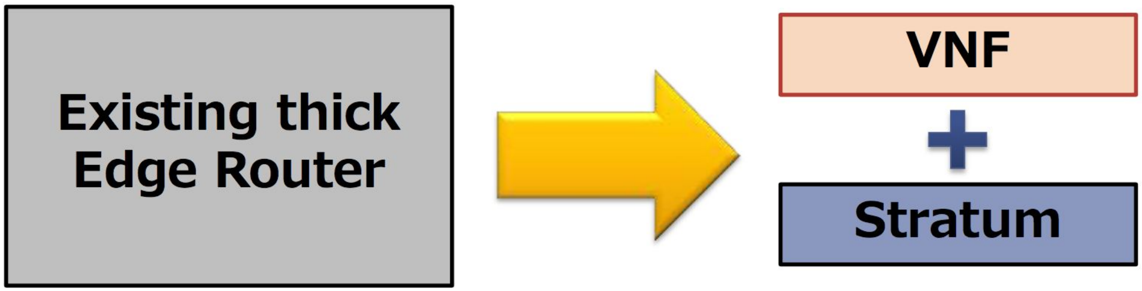


Slide from NTT

Use-case 3

Edge Router on Fixed Networks

- There are thousands of NTT buildings that has the edge-router(s)
- Can edge-routers be replaced by Stratum?

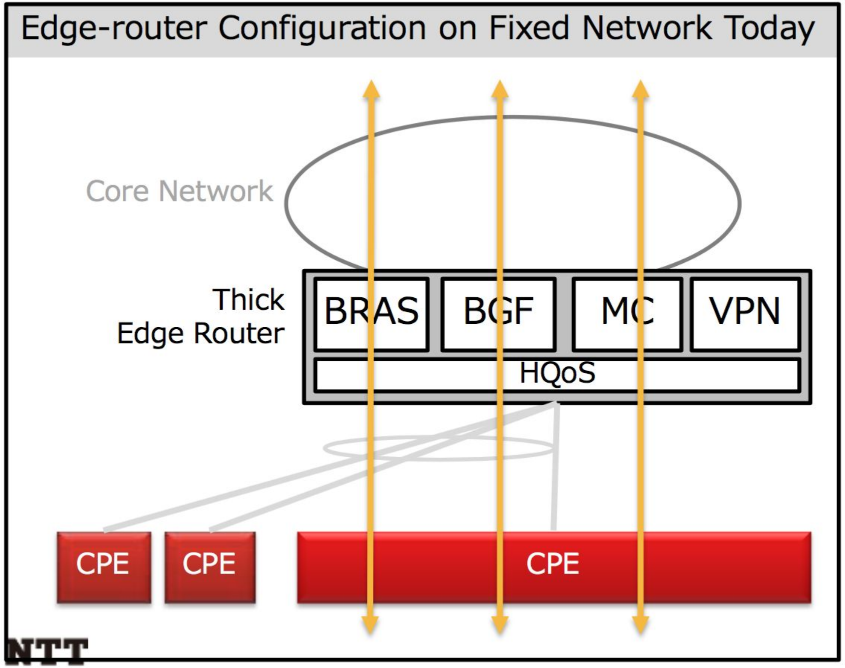


Slide from NTT

Use-case 3 Edge Router on Fixed Networks

Today's Service Edge Router

- **Edge-router contains service functions (BRAS/BGF/Video-Multicast/VPN-GW…) and Hierarchal QoS function**



Service Functions

BRAS:
- PPPoE termination
- AAA(Radius)

BGF:
- NAPT
- Flow-based shaping
- Diffserv

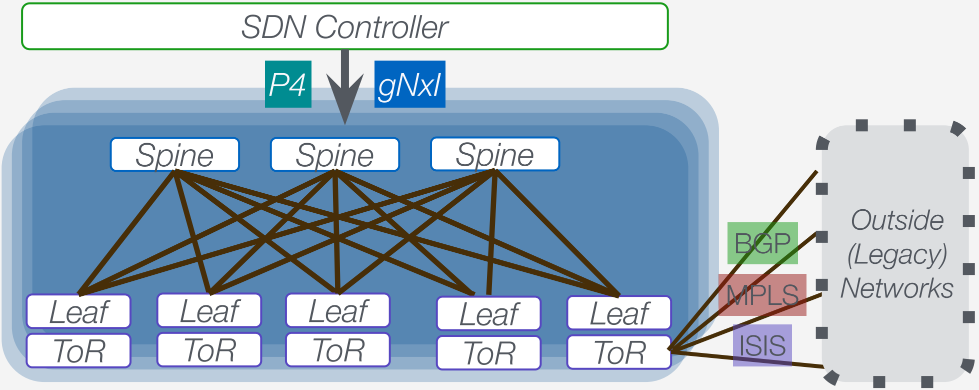
MC(Video Multicast):
- PIM/MLD
- IP Multicast

VPN-GW
- Tunnel termination
- Dynamic routing

Transforming Tencent’s Network: One Datacenter at a Time

- Data center fabric as disaggregated modular switch

Switch OS	→	Data Center SDN Controller
Fabric Cards	→	Spine/Core Switches
Line Cards	→	Leaf/ToR Switches



Data Center Fabric
behaves like one network element

- Centralized control does not mean the entire network must have one controller.
- Rather we opt for a network of controllers, enabled by ONF CORD, Trellis and Stratum.
  - Freedom to use different protocols or RPC at outside controllers.
  - Facilitates integration with legacy networks.