Programmable data planes, P4, and Trellis

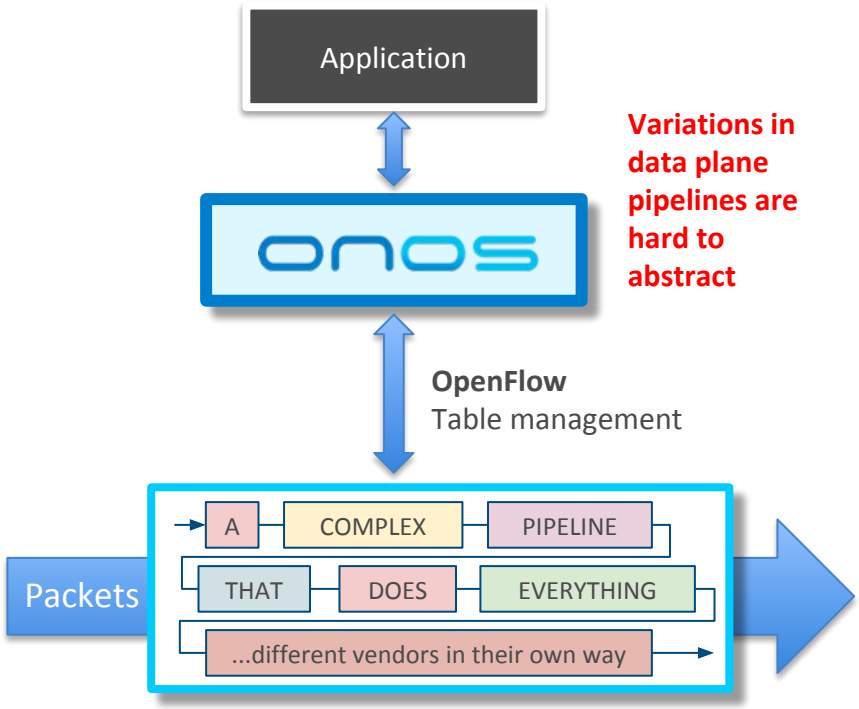
Carmelo Cascone
MTS, P4 Brigade Leader
Open Networking Foundation

Outline

- Introduction to P4 and P4 Runtime
- P4 support in ONOS
- Future plans for Trellis

P4 and P4 Runtime Overview

Fixed-function data plane pipeline

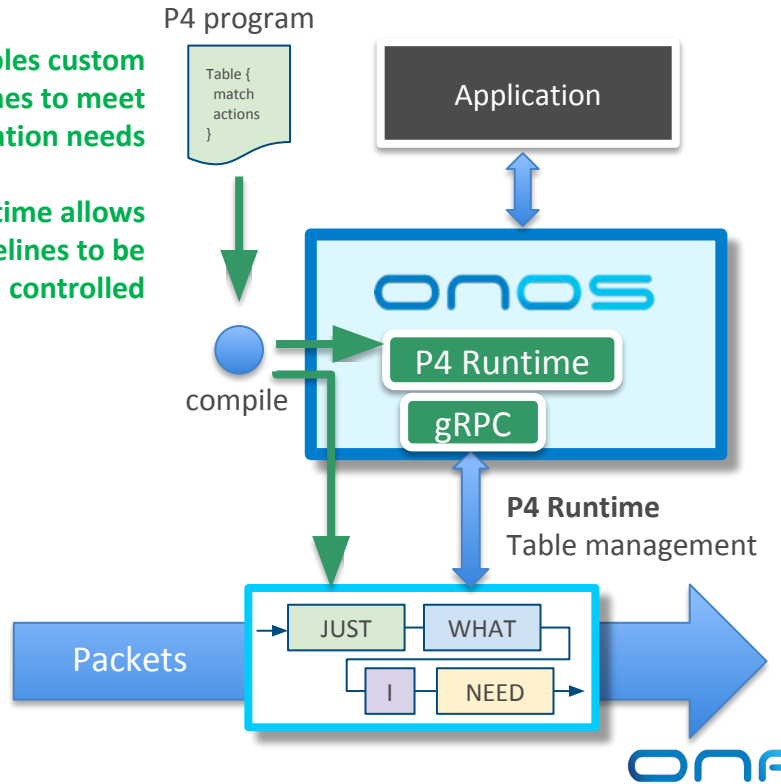


Variations in data plane pipelines are hard to abstract

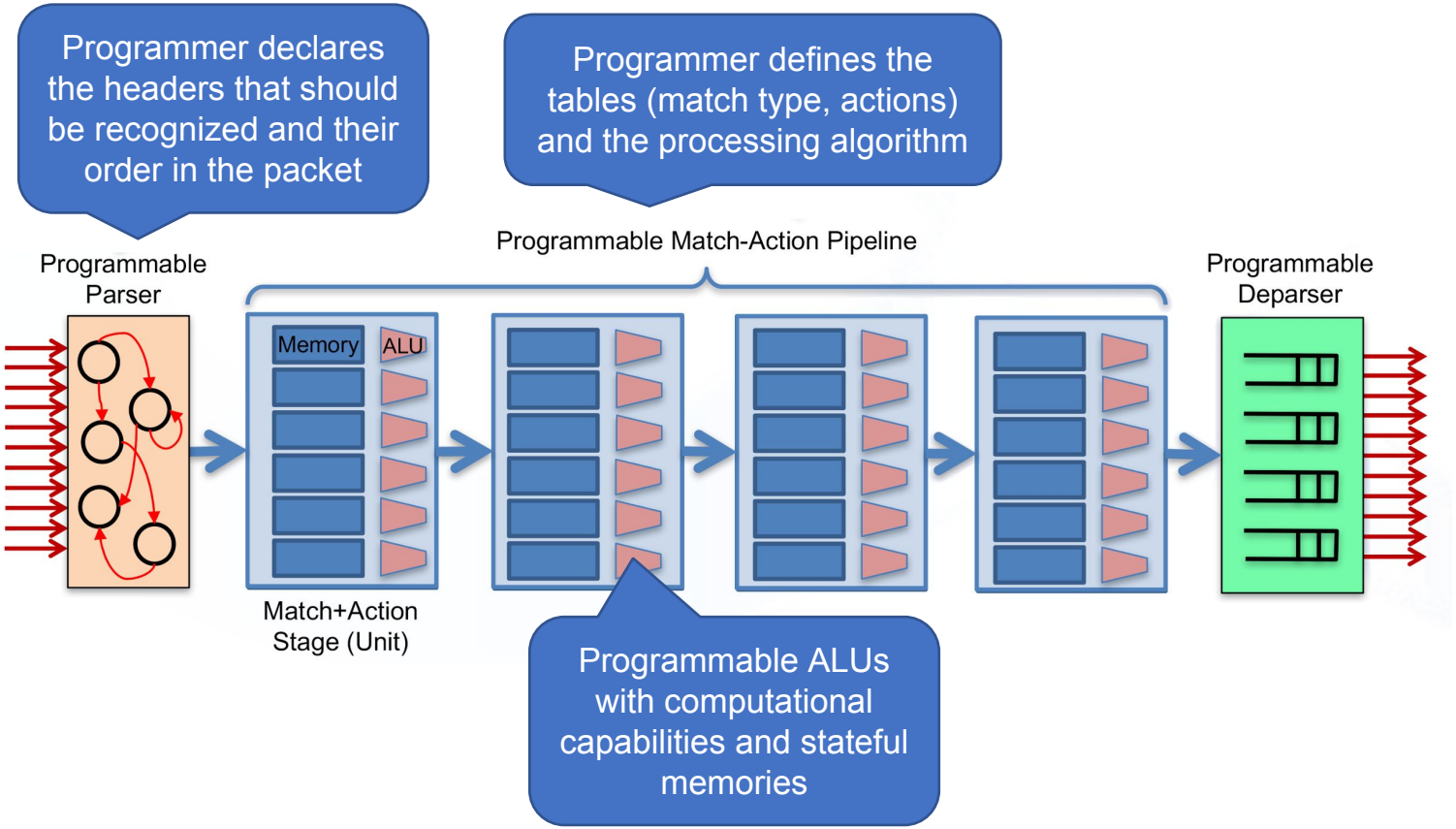
Programmable (or fixed) data plane pipeline

P4 enables custom pipelines to meet application needs

P4 Runtime allows custom pipelines to be loaded and controlled



Programmable Switch Architecture



Slide courtesy: p4.org

P4 Packet Processing Language

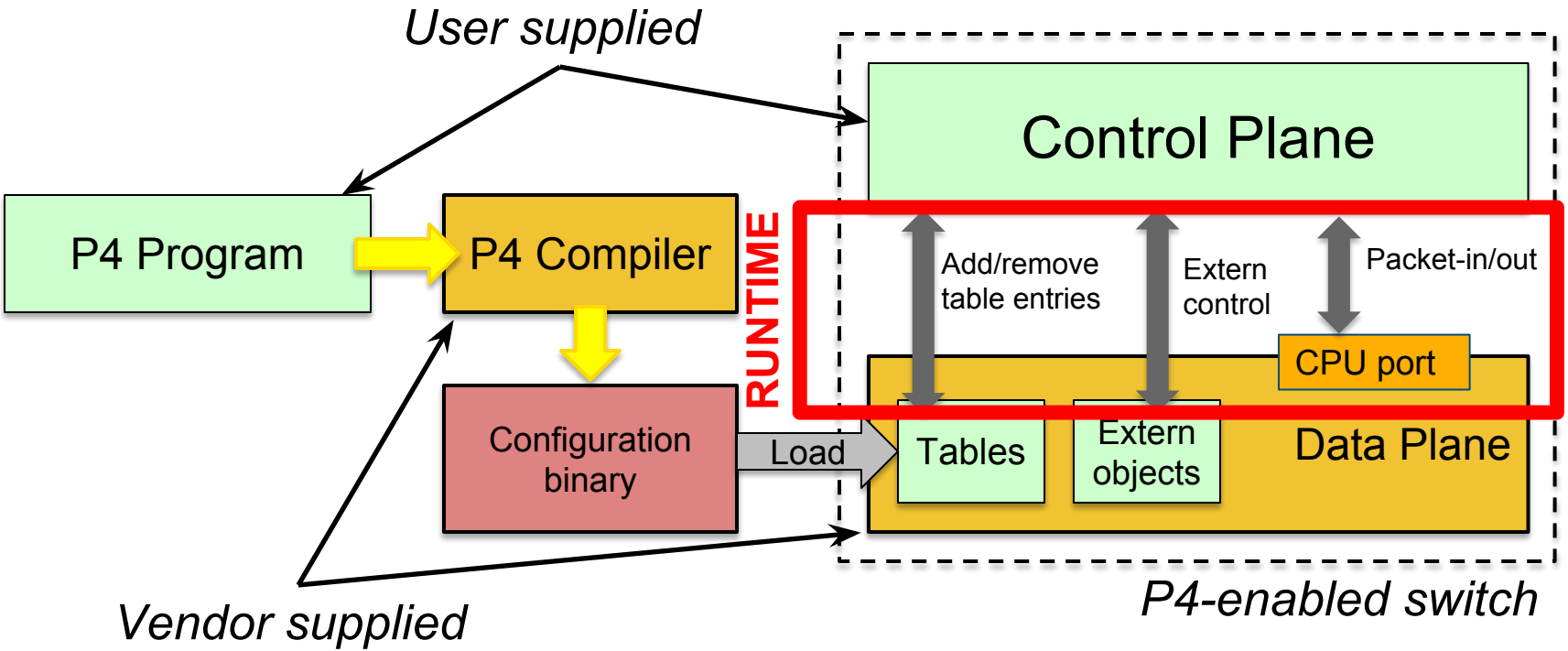
- Domain-specific language to specify packet forwarding behaviours
- Open source consortium: P4.org
- Hardware agnostic, can be compiled to programmable ASICs, FPGAs, NPUs, etc.
- Value as a description language for fixed-function devices

Example P4 code

```
header ethernet_t {
   bit<48> dst_addr;
   bit<48> src_addr;
...
header ipv4_t {
   bit<4>  version;
   bit<4>  ihl;
   bit<8>  diffserv;
...
parser parser_impl(packet_in pkt, out headers_t hdr)
{ /* Parser state machine */ }
```

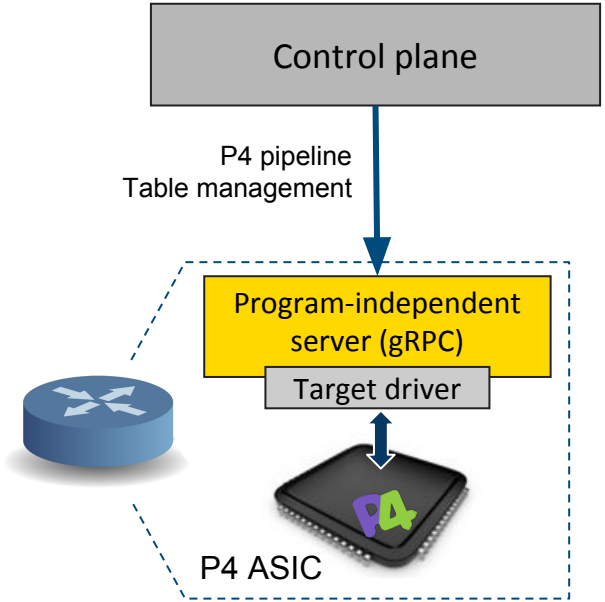
```
action set_next_hop(bit<48> dst_addr) {
   ethernet.dst_addr = dst_addr;
   ipv4.ttl = ipv4.ttl - 1;
}
...
table ip_table {
  key = { ipv4.dst_addr : LPM; }
  actions = { set_next_hop();
              drop(); send_to_ctrl(); }
  size = 4096;
}
```

P4 Workflow


User supplied
Control Plane
P4 Program
P4 Compiler
RUNTIME
Add/remove
table entries
Extern
control
Packet-in/out
CPU port
Configuration
binary
Load
Tables
Extern
objects
Data Plane
Vendor supplied
P4-enabled switch

P4 Runtime

- **Framework for runtime control of P4 targets**
  - Open-source API + server implementation
    - https://github.com/p4lang/PI
  - Initial contribution by Google and Barefoot Networks
- **Work-in-progress by the p4.org API WG**
- **Protobuf-based API + gRPC client/server impl.**
  - Many RPC features for free (e.g. authentication)
- **P4 program-independent**
  - API doesn't change with the P4 program
- **Enables field-reconfigurability**
  - Ability to push new P4 program once switches have been deployed



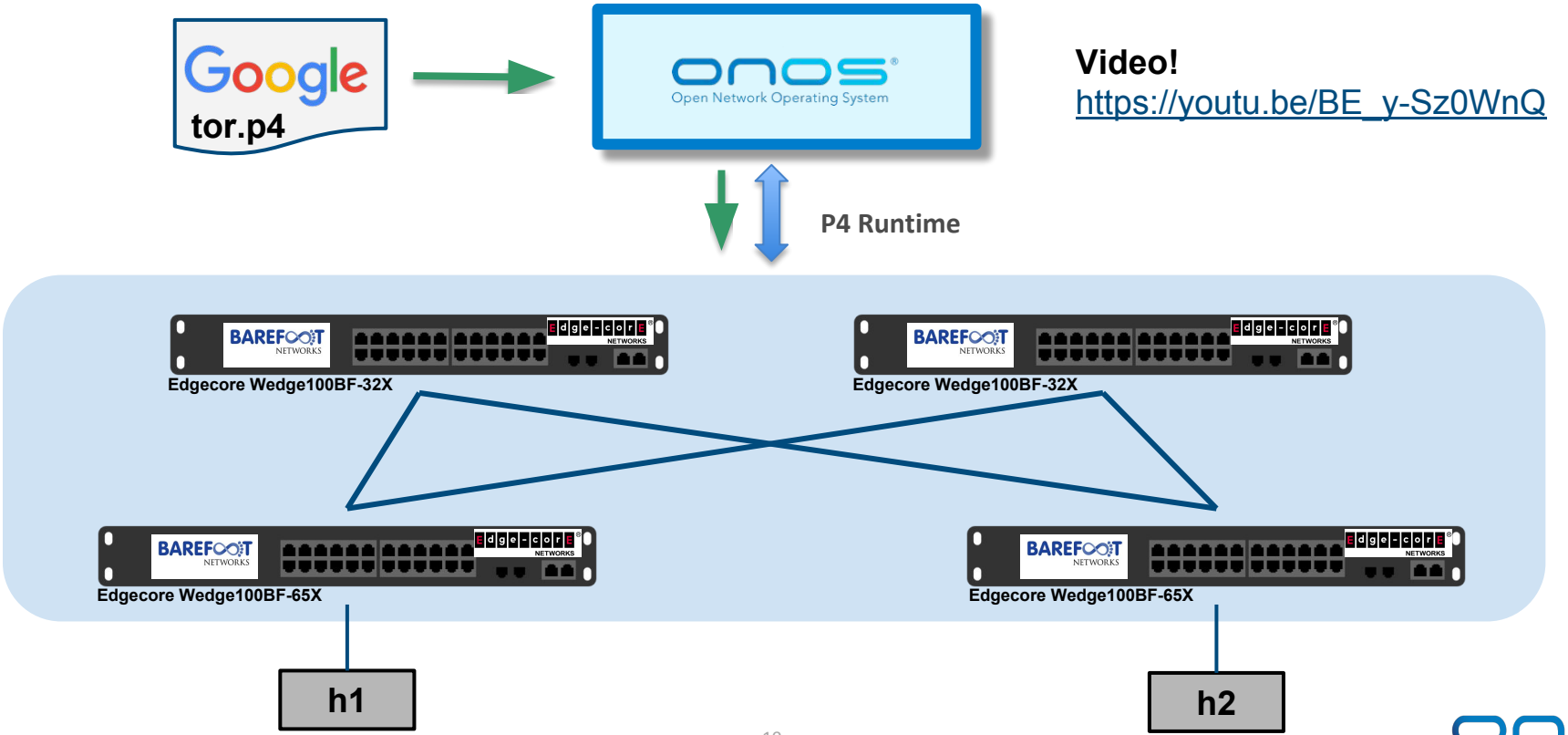
P4 on ONOS

P4 on ONOS Today

- **Applications can bring their own P4 pipelines**
- **Northbound API to control any P4 program**
  - Ways to map existing protocol-dependent ONOS APIs to P4 pipelines
  - New pipeline-agnostic ONOS API to control custom pipelines
- **New P4 device drivers**
  - Barefoot Tofino-based switches
  - BMv2 software switch (great for prototyping)
- **P4 Runtime southbound interface**
  - Protocol support for P4 Runtime and gRPC

P4 on ONOS Demo

L123 SDN NFV World Congress 2017



Video!
https://youtu.be/BE_y-Sz0WnQ

Takeaways so far

- **P4 offers a formal contract between controller and switch**
  - Controller's view of the pipeline (P4 program) is implemented by the switch
  - P4 Runtime API allows to control any pipeline → silicon independence!
    - No need to extend the API
    - API is pipeline-agnostic by definition

- **P4 Runtime offers value for fixed-function devices**
  - Provided that their behavior can be expressed in P4
  - Or, provided a compiler to map the P4 logical pipeline to the physical one

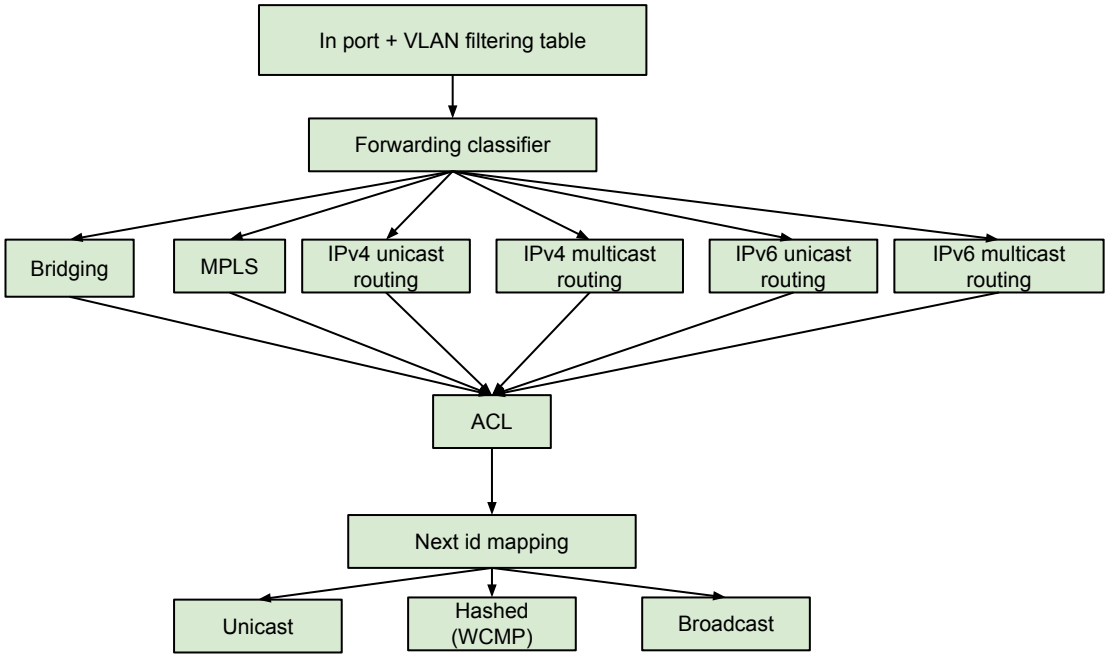
What’s next for CORD: fabric.p4

fabric.p4: P4-based CORD Fabric

- **Goal: bring more heterogeneity in the CORD fabric with P4 silicon**
  - e.g. Barefoot Tofino, or any other vendor that offers a P4 compiler
- **Short-term scope - P4-based underlay (Spring 2018)**
  - Design a P4 pipeline (fabric.p4) that is equivalent to the OF-DPA one
  - Use fabric.p4 as a drop-in replacement for the current Trellis underlay
    - Do not change the ONOS application programming the pipeline
- **Long-term - offload x86 processing to fabric**
  - P4-based overlay, i.e. move VXLAN handling from OVS to the ASIC
  - CORD VNFs offloading (will come to this later)

fabric.p4: where we are today

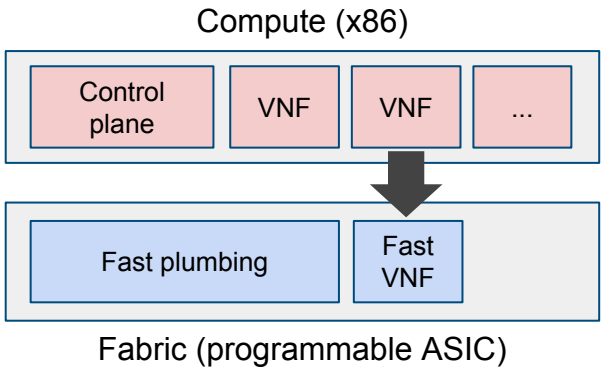
- Prototype P4 code and ONOS driver for fabric.p4 (Pipeliner)
  - Under `onos/pipelines/fabric`



VNF offloading

- **Programmable data planes offer great degree of flexibility beyond plumbing**

Progr. ASIC capabilities	VNF building blocks
Arbitrary header parsing/deparsing	Domain specific encap/decap (e.g. PPPoE termination, GTP, etc.)
Stateful memories	TCP connection tracking (L4 load balancing, NAT, firewall, etc.)
Computational capabilities	Billing



- **Benefits**
  - Scalability - VNFs executed at wire speed
  - Low latency and jitter - avoid non-determinism of x86 processing

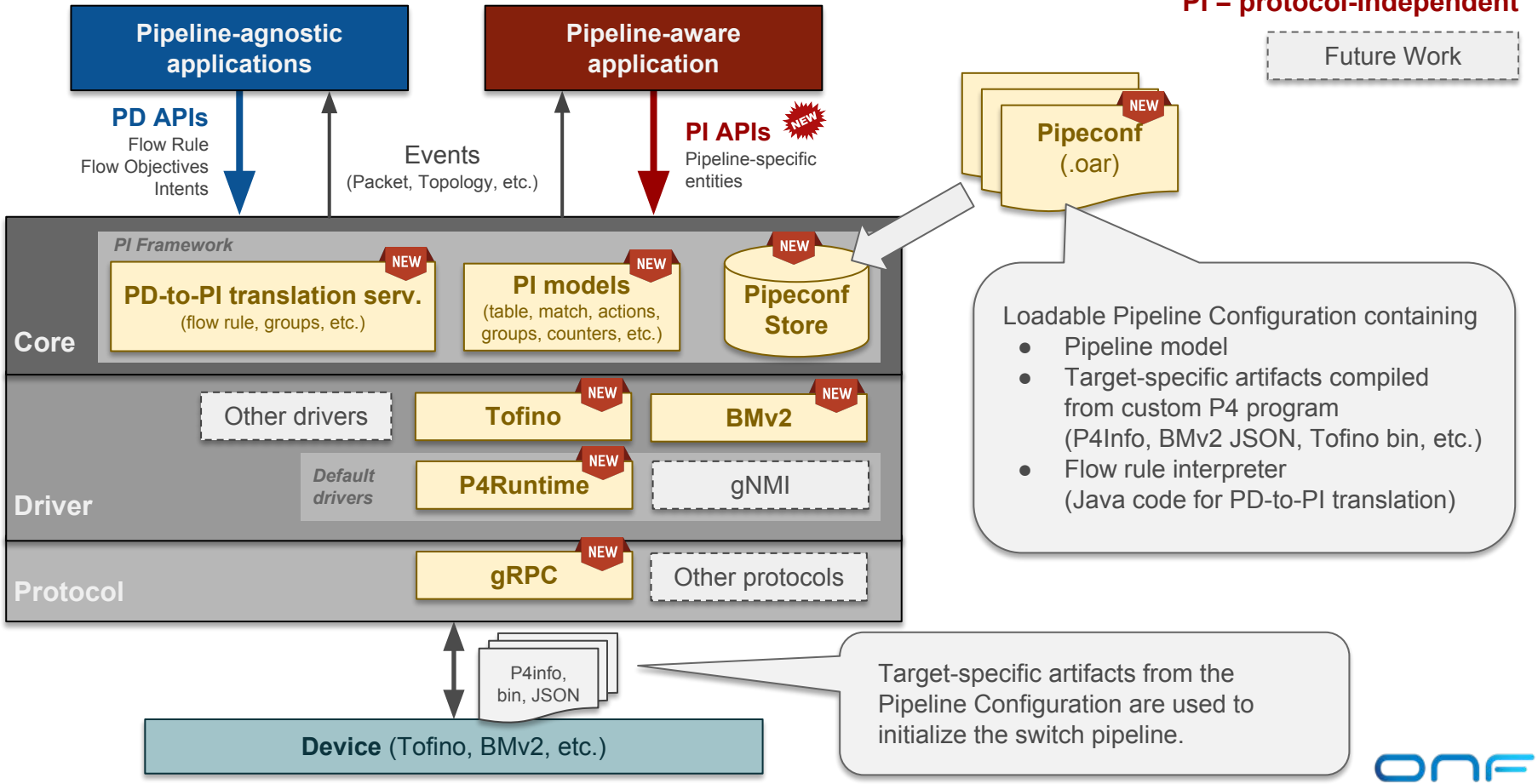
Thanks!

Join the P4 Brigade!
http://bit.ly/onos-p4-brigade

P4 support in ONOS

PD = protocol-dependent
PI = protocol-independent

Future Work



Loadable Pipeline Configuration containing

- Pipeline model
- Target-specific artifacts compiled from custom P4 program (P4Info, BMv2 JSON, Tofino bin, etc.)
- Flow rule interpreter (Java code for PD-to-PI translation)

Target-specific artifacts from the Pipeline Configuration are used to initialize the switch pipeline.

P4Runtime API

p4runtime.proto simplified excerpts:

```
message TableEntry {
  uint32 table_id;
  repeated FieldMatch match;
  Action action;
  int32 priority;
  ...
}
```

```
message Action {
  uint32 action_id;
  message Param {
    uint32 param_id;
    bytes value;
  }
  repeated Param params;
}
```

```
message FieldMatch {
  uint32 field_id;
  message Exact {
    bytes value;
  }
  message Ternary {
    bytes value;
    bytes mask;
  }
  ...
  oneof field_match_type {
    Exact exact;
    Ternary ternary;
    ...
  }
}
```

To add a table entry, the control plane needs to know:

- **IDs of P4 entities**
  - Tables, field matches, actions, params, etc.
- **Which field matches are defined in which table**
  - The match type, bitwidth, etc.
- **Which parameters are required by which actions**
- **Other P4 program attributes**

Full protobuf definition:
https://github.com/p4lang/PI/blob/master/proto/p4/p4runtime.proto