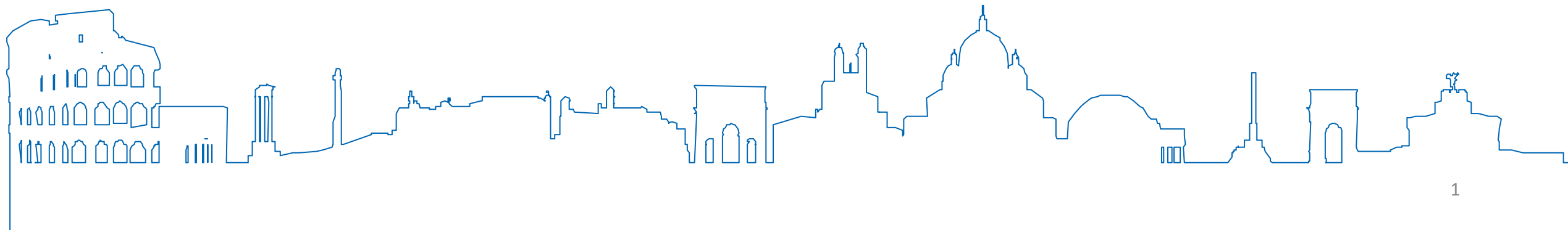


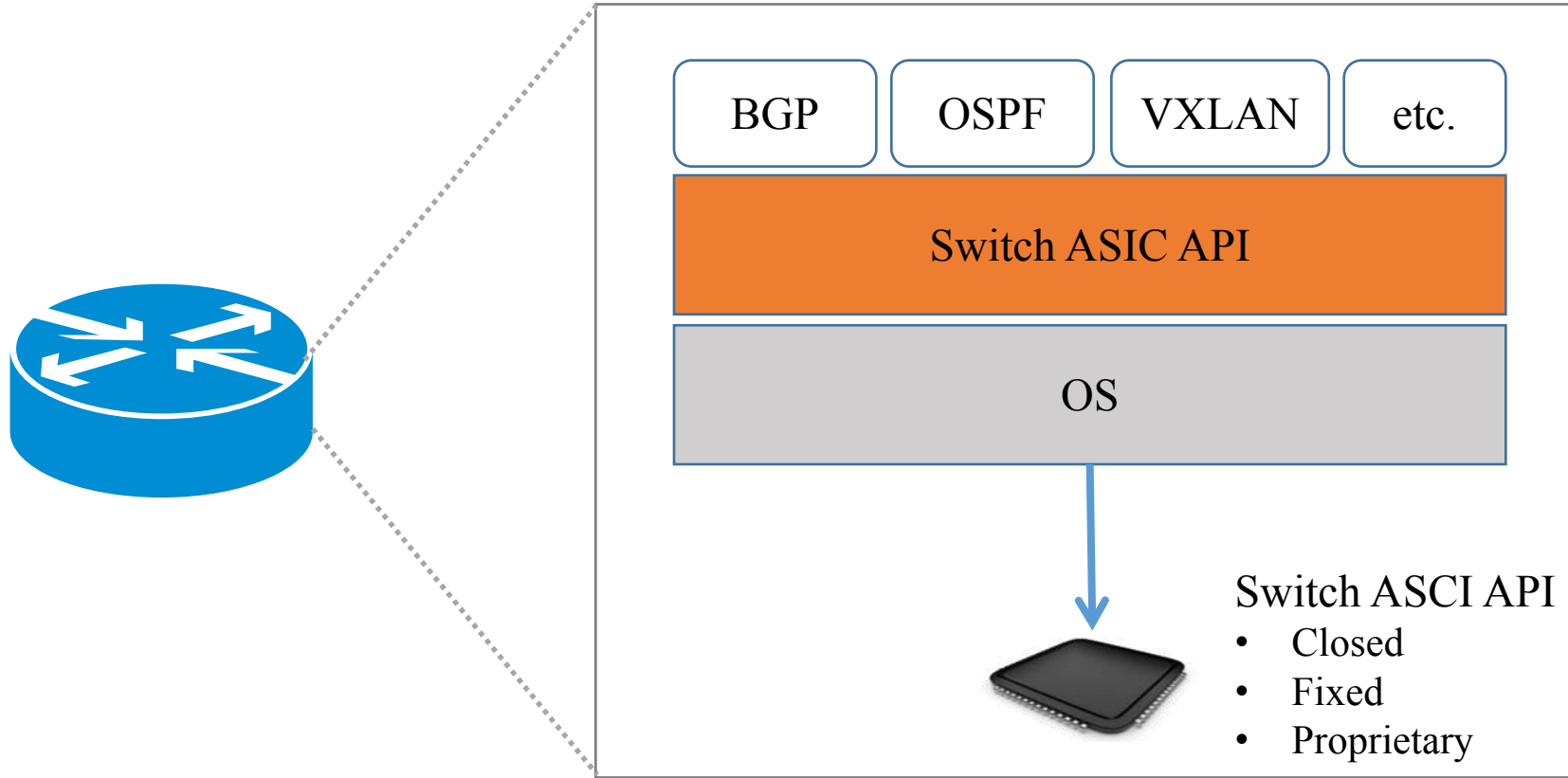


OPEN
DAYLIGHT

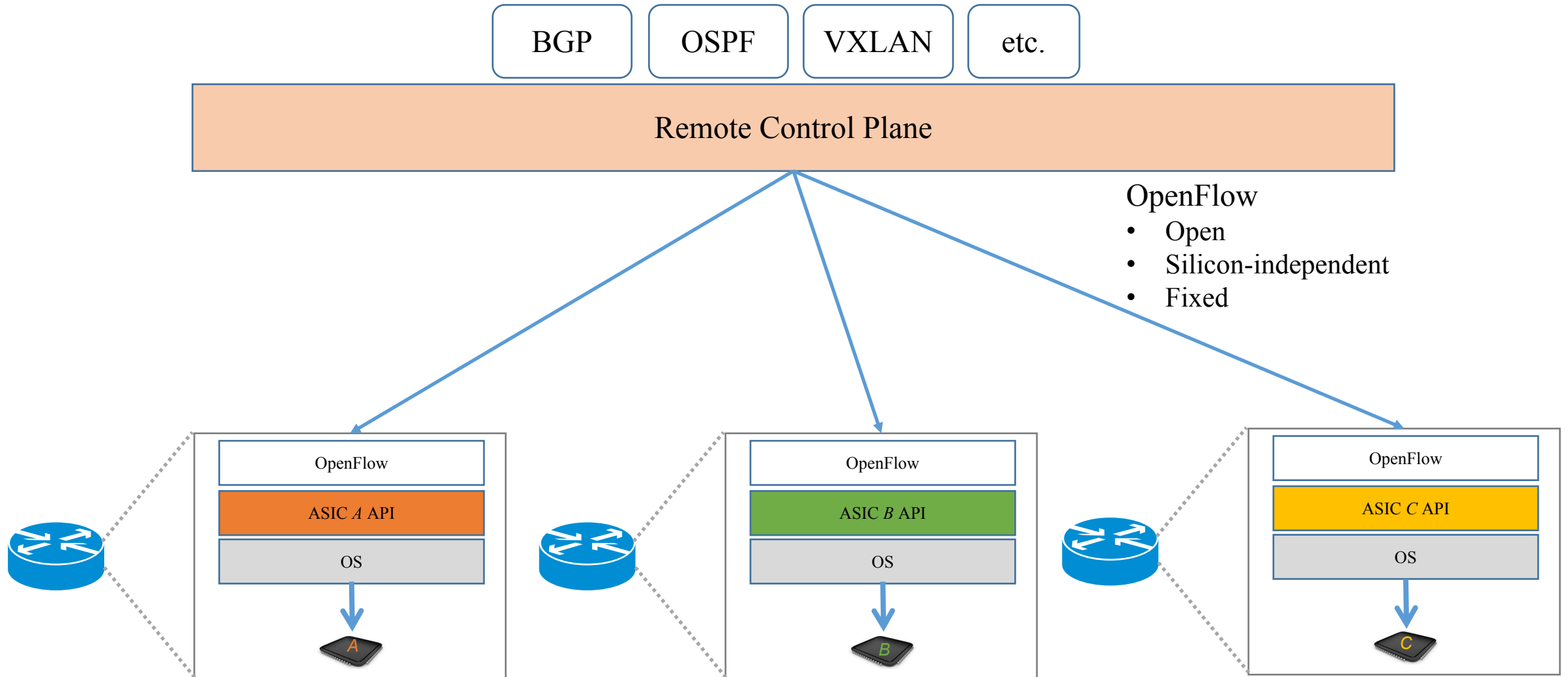
P4 Runtime integration with ODL



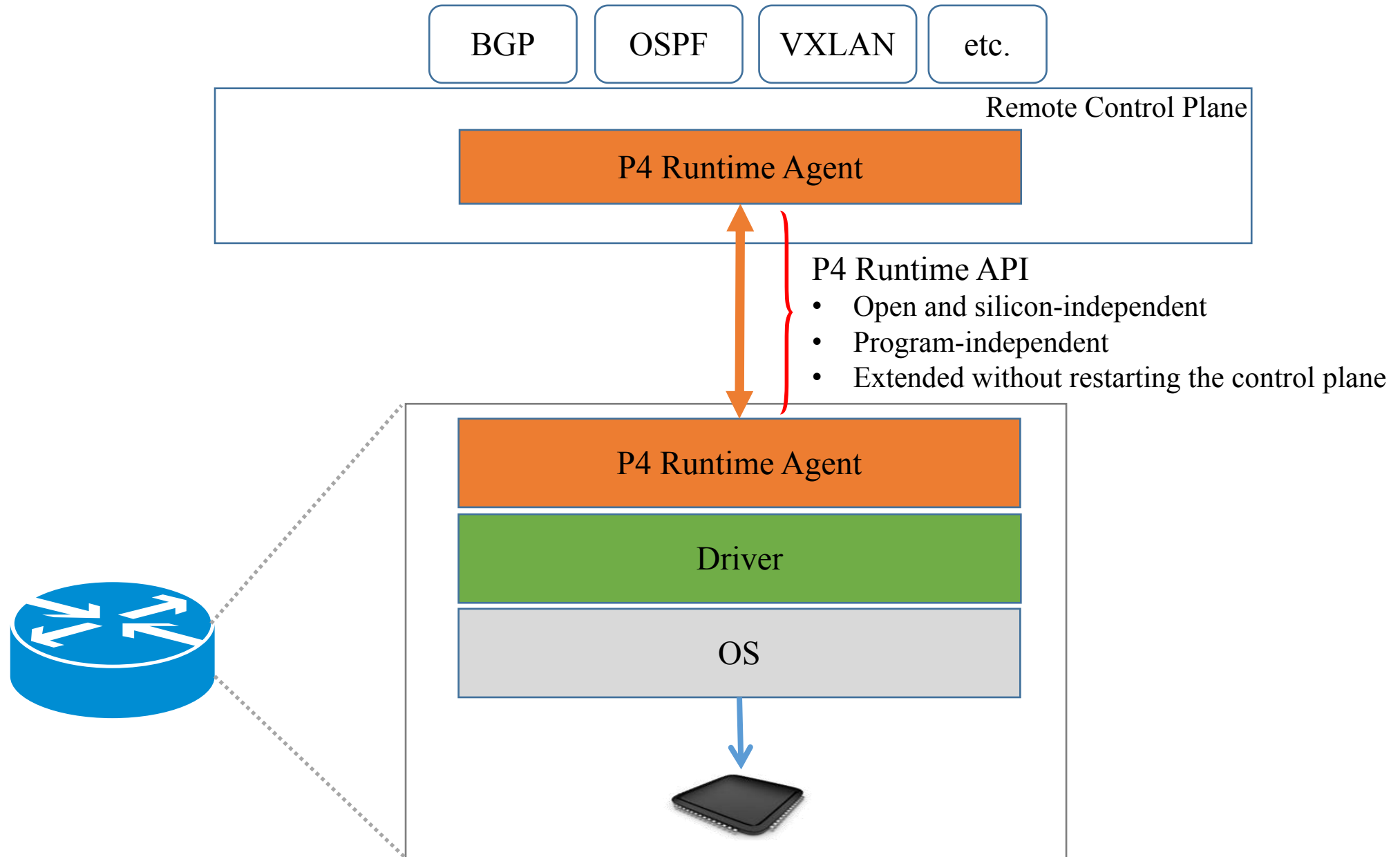
Traditional Network Equipment



In The SDN Era



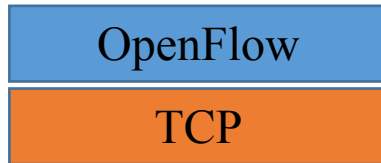
After P4 Generation



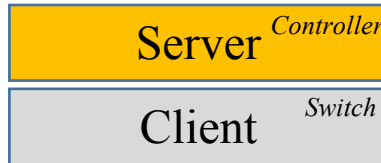
South Channel Compare and Contrast


➤ OpenFlow

- OpenFlow protocol



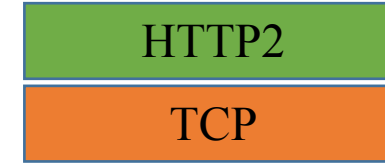
- Client and Server



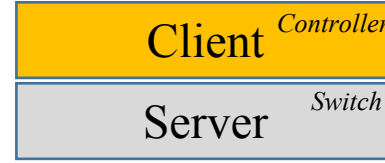
- It only gives us a way to populate a set of well-known tables
- Device discovery
- 
- etc.


➤ P4 Runtime

- gRPC/protoBuf

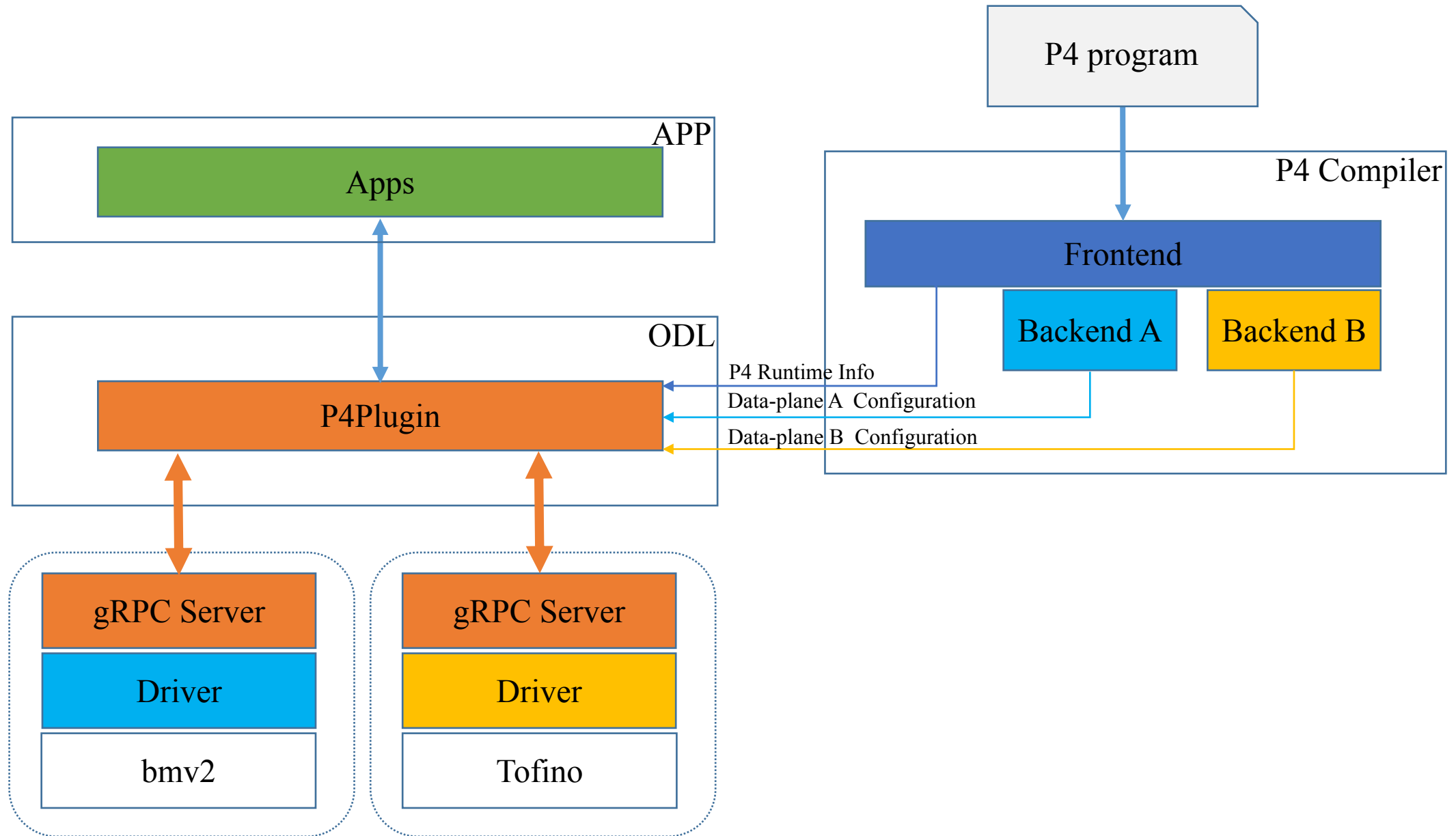


- Client and Server

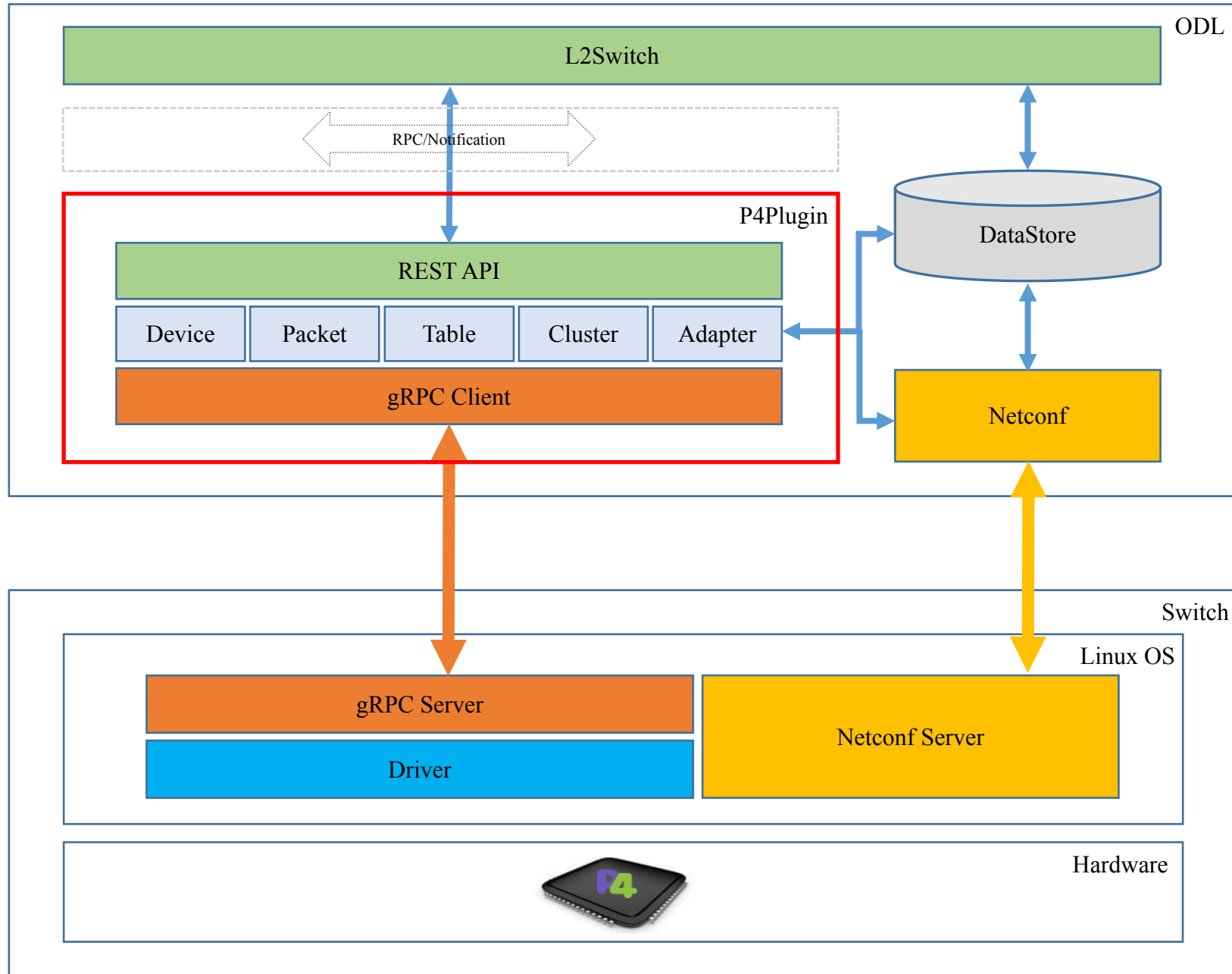


- It is a protocol-independent API, it doesn't be tied to any specific network protocols
- 
- Set pipeline config
- etc.

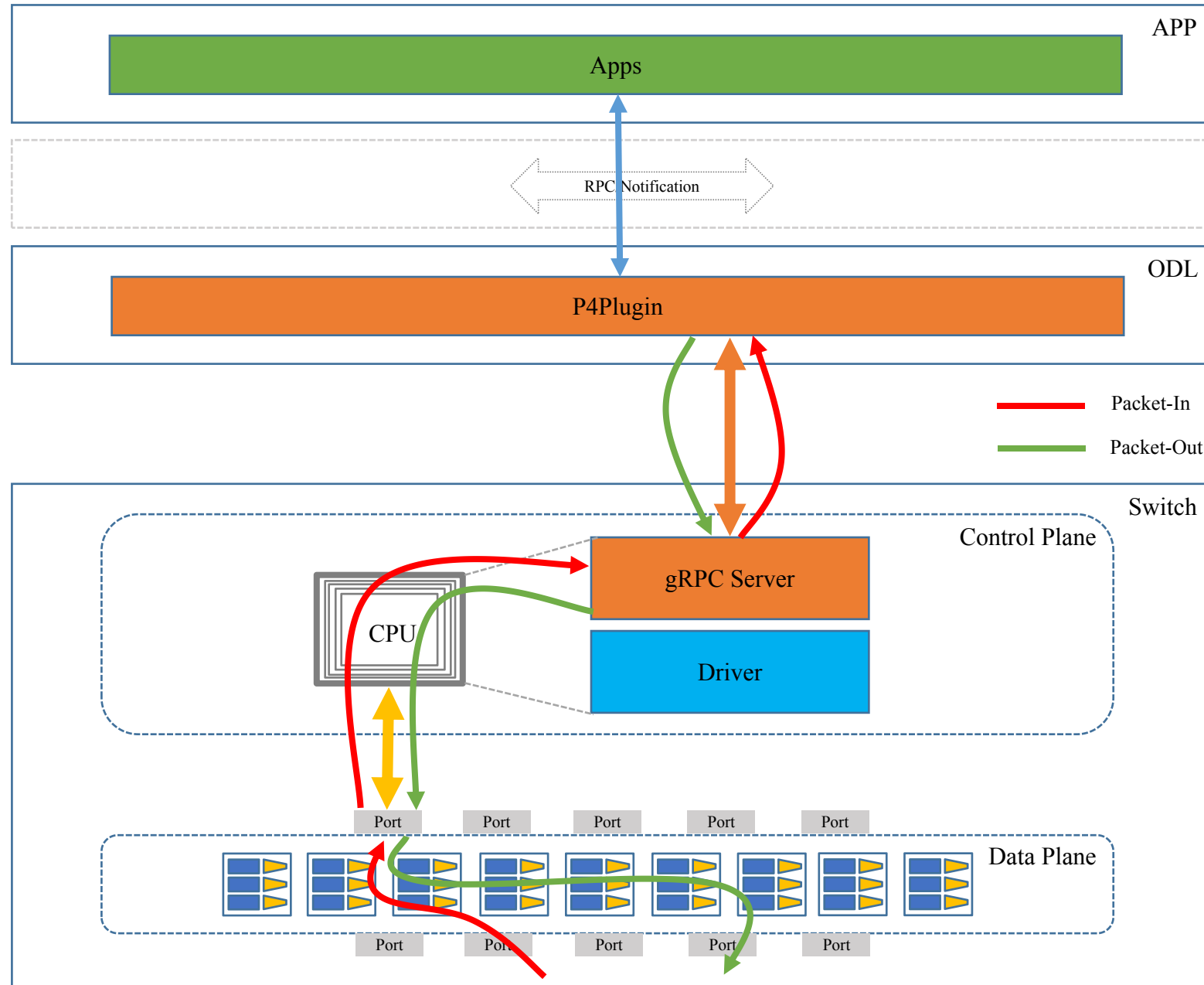
How to Use P4 Runtime



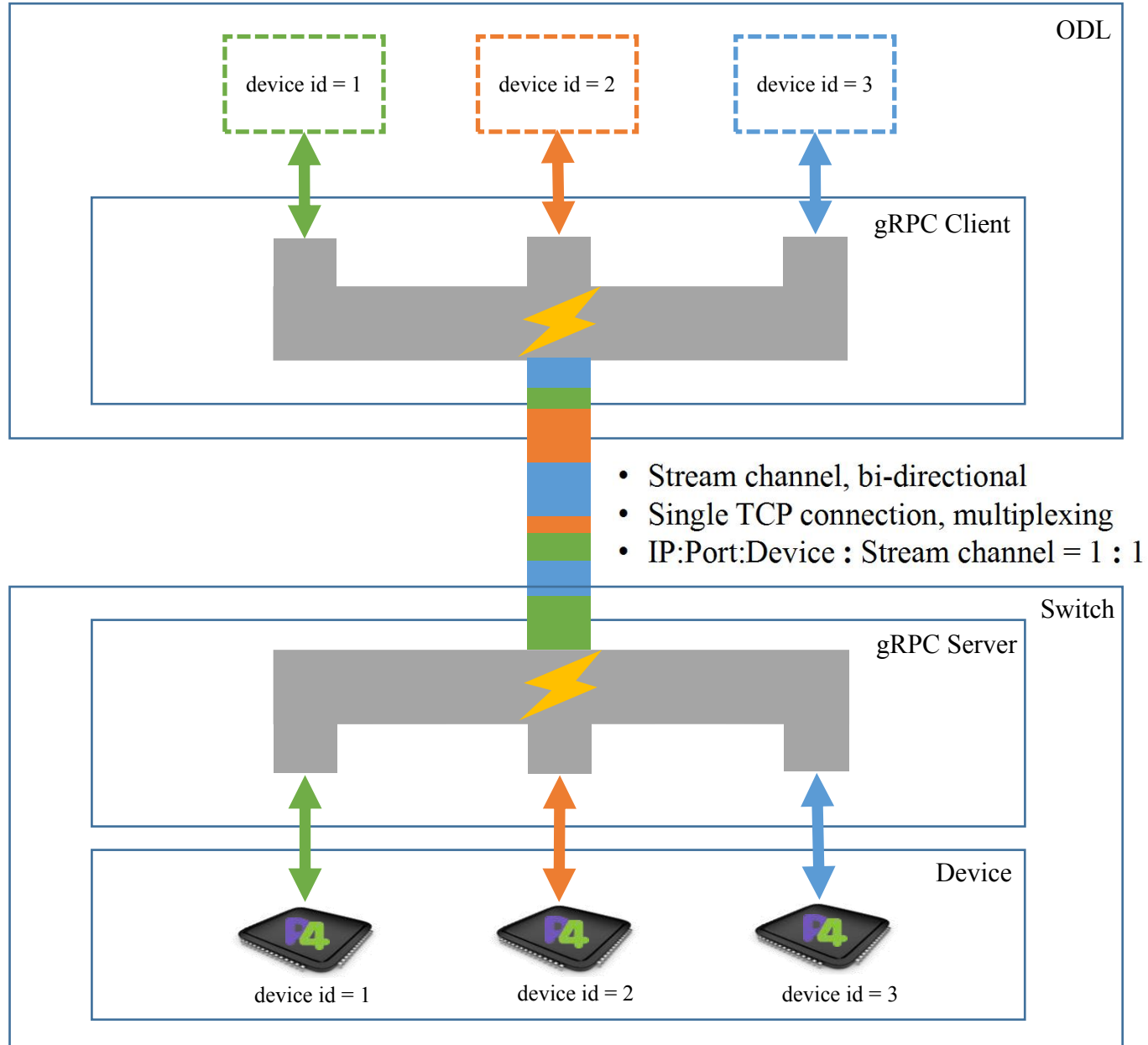
Introduce to P4Plugin in ODL



Packet-In/Out



Stream Channel



How to Implement Program Independent

```
service P4Runtime {
  rpc Write(WriteRequest) returns ...
  rpc Read(ReadRequest) returns ...
  ...
}
```

```
message WriteRequest {
  uint64 device_id = 1;
  Uint128 election_id = 2;
  repeated Update updates = 3;
}
```

```
message Update {
  enum Type {
    UNSPECIFIED = 0;
    INSERT = 1;
    MODIFY = 2;
    DELETE = 3;
  }
  Type type = 1;
  Entity entity = 2;
}
```

```
message Entity {
  oneof entity {
    TableEntry table_entry = 2;
    ...
  }
}
```

```
message TableEntry {
  uint32 table_id = 1;
  repeated FieldMatch match = 2;
  TableAction action = 3;
}
```

```
message TableAction {
  oneof type {
    Action action = 1;
    ...
  }
}
```

```
message Action {
  uint32 action_id = 1;
  message Param {
    uint32 param_id = 2;
    bytes value = 3;
  }
  repeated Param params = 4;
}
```

```
message FieldMatch {
  uint32 field_id = 1;
  ...
  message Exact {
    bytes value = 1;
  }
  message Ternary {
    bytes value = 1;
    bytes mask = 2;
  }
  message LPM {
    bytes value = 1;
    int32 prefix_len = 2;
  }
  oneof field_match_type {
    Exact exact = 2;
    Ternary ternary = 3;
    LPM lpm = 4;
    ...
  }
}
```

- Map-like message sequences, each message contains an unique ID and a value.
- Due to the use of **bytes**, the value will not be subject to any restrictions.
- What about API exposed to SDN Apps?

P4 Runtime Information

```

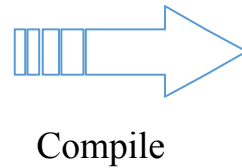
header_type ethernet_t { ... }
header_type ipv4_t { ... }
header ethernet_t ethernet;
header ipv4_t ipv4;
parser start { ... }
parser parse_ethernet { .. }
action set_nhop(nhop_ipv4, port) { ... }

table ipv4_lpm {
  reads {
    ipv4.dstAddr : lpm;
  }
  actions {
    set_nhop;
    _drop;
  }
  size: 1024;
}

control ingress {
  if(valid(ipv4) and ipv4.ttl > 0) {
    apply(ipv4_lpm);
    apply(forward);
  }
}

```

simple_router.p4



```

tables {
  preamble {
    id: 33581985
    name: "ipv4_lpm"
    alias: "ipv4_lpm"
  }
  match_fields {
    id: 1
    name: "ipv4.dstAddr"
    bitwidth: 32
    match_type: LPM
  }
  action_refs {
    id: 16812204
  }
  action_refs {
    id: 16784184
  }
  action_refs {
    id: 16800567
    annotations:
    "@defaultonly()"
  }
  size: 1024
}

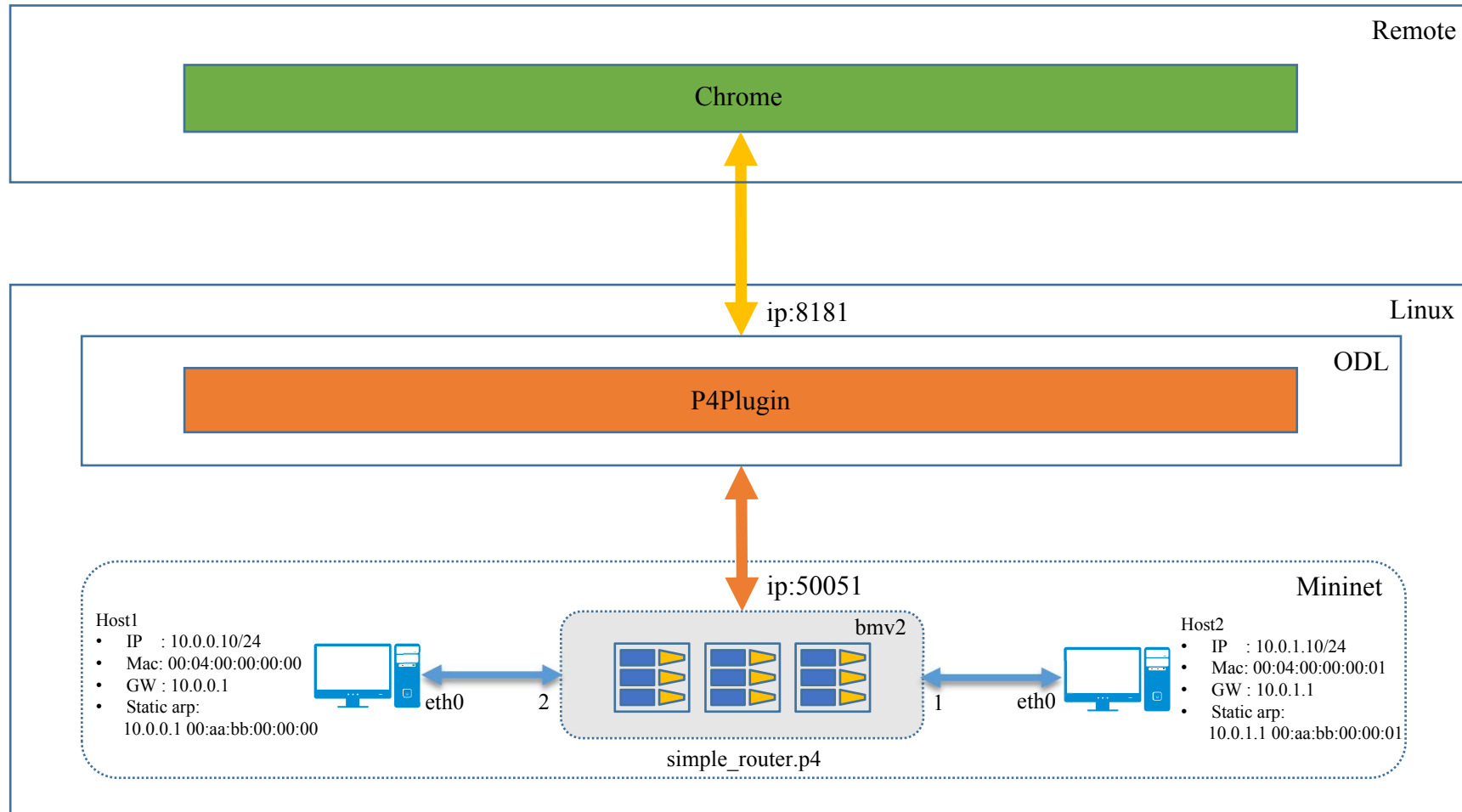
actions {
  preamble {
    id: 16812204
    name: "set_nhop"
    alias: "set_nhop"
  }
  params {
    id: 1
    name:
    "nhop_ipv4"
    bitwidth: 32
  }
  params {
    id: 2
    name: "port"
    bitwidth: 9
  }
  actions {
    preamble {
      id: 16784184
      name: "_drop"
      alias: "_drop"
    }
  }
}

```

simple_router.proto.txt

ODL & P4 Demo

- Simple router based on bmv2



Hit '<tab>' for a list of available commands
and '[cmd] --help' for help on a specific command.
Hit '<ctrl-d>' or type 'system:shutdown' or 'logout' to shutdown OpenDaylight.
opendaylight-user@root>feature:install odl-p4plugin-a
odl-p4plugin-adapter odl-p4plugin-all
opendaylight-user@root>feature:install odl-p4plugin-all

```
hll@hll:/home/opendaylight/p4lang/behavioral-model/mininet$ sudo
python ./1sw_grpc_demo.py --behavioral-
exe ../targets/simple_switch_grpc/simple_switch_grpc --cpu-port 64
[sudo] password for hll:
*** Creating network
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(h1, s1) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
*** Starting 1 switches
s1 Starting P4 switch s1.
../targets/simple_switch_grpc/simple_switch_grpc --no-p4 -i 1@s1-eth1 -i 2@s1-eth2 --
nanolog ipc:///tmp/bm-0-log.ipc --device-id 0 --log-console -- --cpu-port 64
P4 switch s1 has been started.
```

```
*****
h1
default interface: eth0          10.0.0.10          00:04:00:00:00:00
*****
*****
h2
default interface: eth0          10.0.1.10          00:04:00:00:00:01
*****
Ready !
*** Starting CLI:
mininet>
```

Detailed Steps II

- Add node

The screenshot displays the OpenDaylight Yangman web interface. The top navigation bar includes the OpenDaylight logo, the user name 'Yangman', a menu icon, and a 'Logout (admin)' link. The left sidebar shows a tree of operations under the 'p4plugin-core-device rev.2017-08-08' module, with 'add-node' highlighted by a red box. The main content area shows the configuration for the 'POST /operations /p4plugin-core-device:add-node' endpoint. It includes buttons for 'SEND', 'SAVE', and 'PARAMETERS'. Below these, there are radio buttons for 'FORM' (selected) and 'JSON', and a checked checkbox for 'Fill form with received data after execution'. The status is '200 OK' and the time is '1584 ms'. A red box highlights the 'input' section of the form, which contains the following fields:

Field	Value
node-id	node1
config-file	/home/opendaylight/p4lang/behavioral-model/mininet/simple_router.json
runtime-file	/home/opendaylight/p4lang/behavioral-model/mininet/simple_router.proto.txt
ip	10.42.94.144
port	50051
device-id	0

Below the input section, there is an 'output' section with a 'result' field and a toggle switch for 'F' (False) and 'T' (True).

Detailed Steps III

- Set pipeline config

The screenshot displays the OpenDaylight Yangman web interface. The top navigation bar includes the OpenDaylight logo, the user name 'Yangman', and a 'Logout (admin)' button. The left sidebar shows a list of operations under the 'p4plugin-core-device rev.2017-08-08' module, with 'set-pipeline-config' highlighted. The main content area shows the details for the 'POST /operations /p4plugin-core-device:set-pipeline-config' endpoint. It includes buttons for 'SEND', 'SAVE', and 'PARAMETERS'. Below these, there are radio buttons for 'FORM' (selected) and 'JSON', and a checked checkbox for 'Fill form with received data after execution'. The status is '200 OK' and the time is '871 ms'. The form itself has an 'input' section with a 'node-id' field containing 'node1', and an 'output' section with a 'result' field and a toggle switch set to 'T'.

module p4plugin-core-device rev.2017-08-08

OPERATIONS

- > set-pipeline-config
- > add-node
- > get-pipeline-config
- > remove-node
- > query-nodes

POST /operations /p4plugin-core-device:set-pipeline-config

SEND SAVE PARAMETERS

☒ FORM ☐ JSON ☒ Fill form with received data after execution Status: 200 OK Time: 871 ms

set-pipeline-config

input

node-id node1

output

result F T

Detailed Steps IV

- TCP connection

```
hll@hll:/home/opendaylight/p4lang/behavioral-model/mininet$ netstat -tuan | grep 50051
tcp6      0      0 :::50051          :::*               LISTEN
```

```
hll@hll:/home/opendaylight/p4lang/behavioral-model/mininet$ netstat -tuan | grep 50051
tcp6      0      0 :::50051          :::*               LISTEN
tcp6      0      0 10.42.94.144:38464 10.42.94.144:50051 ESTABLISHED
tcp6      0      0 10.42.94.144:50051 10.42.94.144:38464 ESTABLISHED
```

- Captured packet

```
hll@hll:/home/opendaylight/p4lang/behavioral-model/mininet$ sudo tcpdump -i lo port 50051
tcpdump: listening on lo, link-type EN10MB (Ethernet), capture size 262144 bytes
11:22:33.475071 IP 10.42.94.144.38464 > 10.42.94.144.50051: Flags [S], seq 2577324257 ...
11:22:33.475088 IP 10.42.94.144.50051 > 10.42.94.144.38464: Flags [S.], seq 3272263691 ...
11:22:33.475101 IP 10.42.94.144.38464 > 10.42.94.144.50051: Flags [.], ack 1, win 86, ... length 0
11:22:33.475375 IP 10.42.94.144.50051 > 10.42.94.144.38464: Flags [P.], seq 1:28, ack 1 ... length 27
11:22:33.475387 IP 10.42.94.144.38464 > 10.42.94.144.50051: Flags [.], ack 28... length 0
11:22:33.478076 IP 10.42.94.144.38464 > 10.42.94.144.50051: Flags [P.], seq 1:71, ack 28 ... length 70
11:22:33.478089 IP 10.42.94.144.50051 > 10.42.94.144.38464: Flags [.], ack 71 ... length 0
11:22:33.478180 IP 10.42.94.144.50051 > 10.42.94.144.38464: Flags [P.], seq 28:37, ack 71 ... length 9
11:22:33.479914 IP 10.42.94.144.38464 > 10.42.94.144.50051: Flags [P.], seq 71:80, ack 37 ... length 9
11:22:33.482040 IP 10.42.94.144.38464 > 10.42.94.144.50051: Flags [P.], seq 80:208, ack 37... length 128
11:22:33.482076 IP 10.42.94.144.50051 > 10.42.94.144.38464: Flags [.], ack 208 ... length 0
```

- Log

```
hll@hll:/home/opendaylight/p4lang/behavioral-model/mininet$ more /tmp/p4s.s1.log
Thrift port was not specified, will use 9090
Calling target program-options parser
Adding interface s1-eth1 as port 1
[09:50:25.359] [bmv2] [D] [thread 4008] Adding interface s1-eth1 as port 1
Adding interface s1-eth2 as port 2
[09:50:25.425] [bmv2] [D] [thread 4008] Adding interface s1-eth2 as port 2
Server listening on 0.0.0.0:50051
P4Runtime SetForwardingPipelineConfig
[10:11:56.557] [bmv2] [D] [thread 4025] Set default entry for table 'ipv4_lpm': NoAction -
[10:11:56.557] [bmv2] [D] [thread 4025] Set default entry for table 'forward': NoAction -
[10:11:56.557] [bmv2] [D] [thread 4025] Set default entry for table 'send_frame': NoAction -
[10:11:56.559] [bmv2] [D] [thread 4761] [0.0] [cxt 0] Processing packet received on port 1
[10:11:56.559] [bmv2] [D] [thread 4761] [0.0] [cxt 0] Parser 'parser': start
[10:11:56.559] [bmv2] [D] [thread 4761] [0.0] [cxt 0] Parser state 'start' has no switch, going to
default next state
[10:11:56.559] [bmv2] [T] [thread 4761] [0.0] [cxt 0] Bytes parsed: 0
[10:11:56.559] [bmv2] [D] [thread 4761] [0.0] [cxt 0] Extracting header 'ethernet'
[10:11:56.559] [bmv2] [D] [thread 4761] [0.0] [cxt 0] Parser state 'parse_ethernet': key is 86dd
[10:11:56.559] [bmv2] [T] [thread 4761] [0.0] [cxt 0] Bytes parsed: 14
[10:11:56.559] [bmv2] [T] [thread 4761] [0.0] [cxt 0] Skipping checksum 'cksum' verification
because target field invalid
[10:11:56.559] [bmv2] [D] [thread 4761] [0.0] [cxt 0] Parser 'parser': end
[10:11:56.559] [bmv2] [D] [thread 4761] [0.0] [cxt 0] Pipeline 'ingress': start
[10:11:56.559] [bmv2] [T] [thread 4761] [0.0] [cxt 0] simple_router.p4(153) Condition "and" is
false
[10:11:56.559] [bmv2] [D] [thread 4761] [0.0] [cxt 0] Pipeline 'ingress': end
[10:11:56.559] [bmv2] [D] [thread 4761] [0.0] [cxt 0] Egress port is 0
[10:11:56.559] [bmv2] [D] [thread 4762] [0.0] [cxt 0] Pipeline 'egress': start
[10:11:56.559] [bmv2] [T] [thread 4762] [0.0] [cxt 0] Applying table 'send_frame'
[10:11:56.559] [bmv2] [D] [thread 4762] [0.0] [cxt 0] Looking up key:
* standard_metadata.egress_port: 0000
```


Detailed Steps IV

- Add table entry (Form format)

OPEN DAYLIGHT

Yangman

Logout (admin)

module p4plugin-core-table rev.2017-08-08

OPERATIONS

> add-action-profile-member

> modify-action-profile-member

> read-action-profile-member

> add-action-profile-group

> add-table-entry

> read-table-entry

> modify-action-profile-group

> read-action-profile-group

> modify-table-entry

> delete-action-profile-member

> delete-table-entry

> delete-action-profile-group

POST /operations /p4plugin-core-table:add-table-entry

SEND SAVE PARAMETERS

FORM JSON

☒ Fill form with received data after execution

Status: 200 OK Time: 357 ms

add-table-entry

input

node-id

node1

action-type

DIRECT-ACTION

action-name

set_nhop

action-param

param-name

nhop_ipv4

param-value-type

PARAM-VALUE-TYPE-STRING

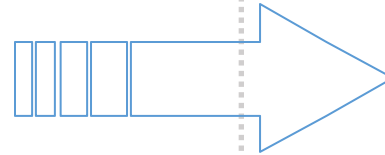
param-string-value

10.0.0.10

Detailed Steps IV (continued)

- Json format

```
{
  "add-table-entry": {
    "input": {
      "node-id": "node1",
      "action-name": "set_nhop",
      "action-param": [
        {
          "param-name": "port",
          "param-string-value": "1"
        },
        {
          "param-name": "nhop_ipv4",
          "param-string-value": "10.0.0.10"
        }
      ],
      "priority": "0",
      "controller-metadata": "0",
      "table": "ipv4_lpm",
      "field": [
        {
          "field-name": "ipv4.dstAddr",
          "lpm-string-value": "10.0.0.0",
          "lpm-prefixLen": "24"
        }
      ]
    }
  }
}
```



- Data

```
P4Runtime Write
updates {
  type: INSERT
  entity {
    table_entry {
      table_id: 33581985
      match {
        field_id: 1
        lpm {
          value: "\n\000\000\000"
          prefix_len: 24
        }
      }
    }
    action {
      action {
        action_id: 16812204
        params {
          param_id: 2
          value: "\000\001"
        }
        params {
          param_id: 1
          value: "\n\000\000\n"
        }
      }
    }
    controller_metadata: 0
  }
}
```

Detailed Steps V

• Ping test

```
*** Starting CLI:
mininet>
mininet> pingall
*** Ping: testing ping reachability
h1 -> h2
h2 -> h1
*** Results: 0% dropped (2/2 received)
mininet> h1 ping h2 -c 4
PING 10.0.1.10 (10.0.1.10) 56(84) bytes of data.
64 bytes from 10.0.1.10: icmp_seq=1 ttl=63 time=1.32 ms
64 bytes from 10.0.1.10: icmp_seq=2 ttl=63 time=1.42 ms
64 bytes from 10.0.1.10: icmp_seq=3 ttl=63 time=2.07 ms
64 bytes from 10.0.1.10: icmp_seq=4 ttl=63 time=1.14 ms

--- 10.0.1.10 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3004ms
rtt min/avg/max/mdev = 1.149/1.494/2.070/0.347 ms
```

• Packet processing log

```
[15:57:51.603] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Processing packet received on port 1
[15:57:51.603] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Parser 'parser': start
[15:57:51.603] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Parser state 'start' has no switch, going to default next state
[15:57:51.603] [bmv2] [T] [thread 27525] [25.0] [cxt 0] Bytes parsed: 0
[15:57:51.603] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Extracting header 'ethernet'
[15:57:51.603] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Parser state 'parse_ethernet': key is 0800
[15:57:51.603] [bmv2] [T] [thread 27525] [25.0] [cxt 0] Bytes parsed: 14
[15:57:51.603] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Extracting header 'ipv4'
[15:57:51.603] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Parser state 'parse_ipv4' has no switch, going to default next state
[15:57:51.603] [bmv2] [T] [thread 27525] [25.0] [cxt 0] Bytes parsed: 34
[15:57:51.603] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Verifying checksum 'cksum': true
[15:57:51.603] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Parser 'parser': end
[15:57:51.603] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Pipeline 'ingress': start
[15:57:51.603] [bmv2] [T] [thread 27525] [25.0] [cxt 0] simple_router.p4(153) Condition "and" is true
[15:57:51.603] [bmv2] [T] [thread 27525] [25.0] [cxt 0] Applying table 'ipv4_lpm'
[15:57:51.604] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Looking up key:
* ipv4.dstAddr : 0a00010a
[15:57:51.604] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Table 'ipv4_lpm': hit with handle 1
[15:57:51.604] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Dumping entry 1
```

```
Match key:
* ipv4.dstAddr : LPM 0a000100/24
Action entry: set_nhop - a00010a,2,
```

```
[15:57:51.604] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Action entry is set_nhop - a00010a,2,
[15:57:51.604] [bmv2] [T] [thread 27525] [25.0] [cxt 0] Action set_nhop
[15:57:51.604] [bmv2] [T] [thread 27525] [25.0] [cxt 0] simple_router.p4(104) Primitive nhop_ipv4, port) { ...
[15:57:51.604] [bmv2] [T] [thread 27525] [25.0] [cxt 0] simple_router.p4(104) Primitive port) { ...
[15:57:51.604] [bmv2] [T] [thread 27525] [25.0] [cxt 0] simple_router.p4(107) Primitive add_to_field(ipv4.ttl, -1)
[15:57:51.604] [bmv2] [T] [thread 27525] [25.0] [cxt 0] Applying table 'forward'
[15:57:51.604] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Looking up key:
* routing_metadata.nhop_ipv4: 0a00010a
```

```
[15:57:51.604] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Table 'forward': hit with handle 1
[15:57:51.604] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Dumping entry 1
Match key:
* routing_metadata.nhop_ipv4: EXACT 0a00010a
Action entry: set_dmac - 4000000001,
```

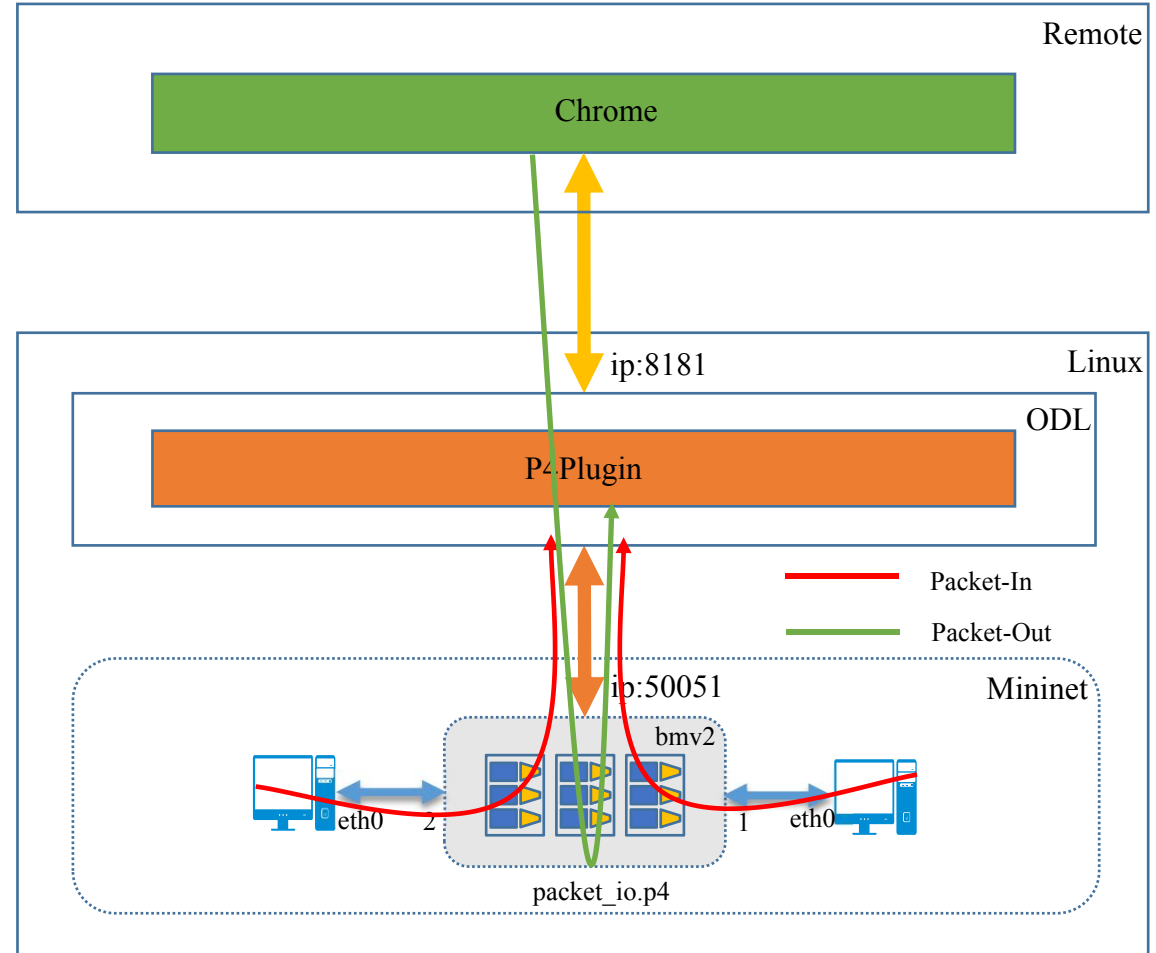
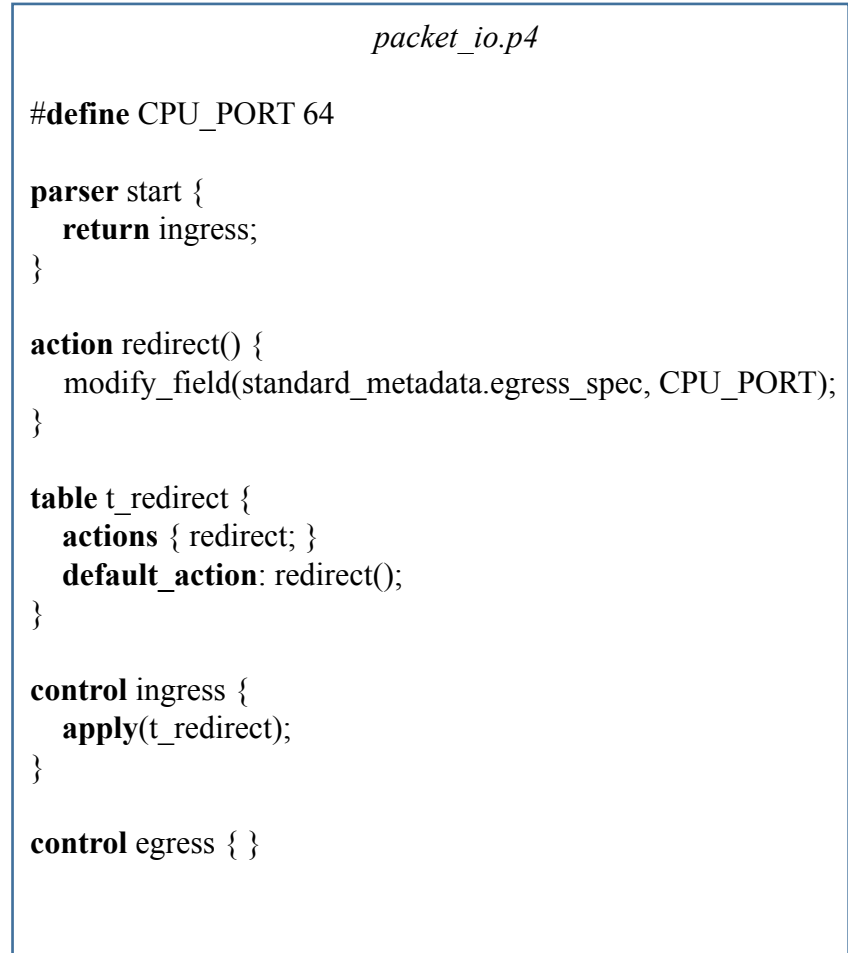
```
[15:57:51.604] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Action entry is set_dmac - 4000000001,
[15:57:51.604] [bmv2] [T] [thread 27525] [25.0] [cxt 0] Action set_dmac
[15:57:51.604] [bmv2] [T] [thread 27525] [25.0] [cxt 0] simple_router.p4(121) Primitive dmac) { ...
[15:57:51.604] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Pipeline 'ingress': end
[15:57:51.604] [bmv2] [D] [thread 27525] [25.0] [cxt 0] Egress port is 2
[15:57:51.604] [bmv2] [D] [thread 27528] [25.0] [cxt 0] Pipeline 'egress': start
[15:57:51.604] [bmv2] [T] [thread 27528] [25.0] [cxt 0] Applying table 'send_frame'
[15:57:51.604] [bmv2] [D] [thread 27528] [25.0] [cxt 0] Looking up key:
* standard_metadata.egress_port: 0002
```

```
[15:57:51.604] [bmv2] [D] [thread 27528] [25.0] [cxt 0] Table 'send_frame': hit with handle 1
[15:57:51.604] [bmv2] [D] [thread 27528] [25.0] [cxt 0] Dumping entry 1
Match key:
* standard_metadata.egress_port: EXACT 0002
Action entry: rewrite_mac - 10203040506,
```

```
[15:57:51.604] [bmv2] [D] [thread 27528] [25.0] [cxt 0] Action entry is rewrite_mac - 10203040506,
[15:57:51.604] [bmv2] [T] [thread 27528] [25.0] [cxt 0] Action rewrite_mac
[15:57:51.604] [bmv2] [T] [thread 27528] [25.0] [cxt 0] simple_router.p4(136) Primitive smac) { ...
[15:57:51.604] [bmv2] [T] [thread 27528] [25.0] [cxt 0] simple_router.p4(138) Primitive
modify_field(standard_metadata.egress_port, 2)
[15:57:51.604] [bmv2] [D] [thread 27528] [25.0] [cxt 0] Pipeline 'egress': end
[15:57:51.604] [bmv2] [D] [thread 27528] [25.0] [cxt 0] Deparser 'deparser': start
[15:57:51.604] [bmv2] [T] [thread 27528] [25.0] [cxt 0] Updating checksum 'cksum'
[15:57:51.604] [bmv2] [D] [thread 27528] [25.0] [cxt 0] Deparsing header 'ethernet'
[15:57:51.604] [bmv2] [D] [thread 27528] [25.0] [cxt 0] Deparsing header 'ipv4'
[15:57:51.604] [bmv2] [D] [thread 27528] [25.0] [cxt 0] Deparser 'deparser': end
[15:57:51.604] [bmv2] [D] [thread 27530] [25.0] [cxt 0] Transmitting packet of size 98 out of port 2
```

ODL & P4 Demo

- Packet in/out based on bmv2



Detailed Steps I

- Packet in
 - Transmit and Capture

The image shows two terminal windows titled "Node: h1".

The left window shows the execution of the `hping3` command to ping 10.41.166.16. It reports 5 packets transmitted, 0 received, and 100% packet loss. The round-trip times are all 0.0 ms.

The right window shows the execution of `tcpdump` to capture traffic on `eth0` destined for 10.41.166.16. It displays three captured packets from 10.0.0.10 to 10.41.166.16. Each packet has a length of 20 bytes. The hex dump and ASCII representation of the packet data are shown for each capture.

```

root@h1l:/home/opendaylight/p4lang/behavioral-model/mininet# cd ~
root@h1l:~# hping3 -c 5 -d 20 --file hp.txt 10.41.166.16
HPING 10.41.166.16 (eth0 10.41.166.16): NO FLAGS are set, 40 headers + 20 data bytes
[main] memlockall(): Operation not supported
Warning: can't disable memory paging!

--- 10.41.166.16 hping statistic ---
5 packets transmitted, 0 packets received, 100% packet loss
round-trip min/avg/max = 0.0/0.0/0.0 ms
root@h1l:~#

root@h1l:/home/opendaylight/p4lang/behavioral-model/mininet# cd ~
root@h1l:~# tcpdump -i eth0 -XX dst 10.41.166.16
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on eth0, link-type EN10MB (Ethernet), capture size 262144 bytes
11:05:10.685145 IP 10.0.0.10.1461 > 10.41.166.16.0: Flags [none], seq 1364336626
:1364336646, win 512, length 20
    0x0000: 00aa bb00 0000 0004 0000 0000 0800 4500 .....E.
    0x0010: 003c 2433 0000 4006 9c46 0a00 000a 0a29 .<$3..@..F.....)
    0x0020: a610 05b5 0000 5152 1ff2 3301 212a 5000 .....QR..3.!*P.
    0x0030: 0200 d011 0000 5a54 4520 4f70 656e 6461 .....ZTE,Openda
    0x0040: 796c 6967 6874 2050 340a                ylight,P4.
11:05:11.685861 IP 10.0.0.10.1462 > 10.41.166.16.0: Flags [none], seq 486322916:
486322936, win 512, length 20
    0x0000: 00aa bb00 0000 0004 0000 0000 0800 4500 .....E.
    0x0010: 003c b3a6 0000 4006 0cd3 0a00 000a 0a29 .<....@.....)
    0x0020: a610 05b6 0000 1cfc b2e4 60cc 35af 5000 .....^..5.P.
    0x0030: 0200 2f24 0000 5a54 4520 4f70 656e 6461 ../$...ZTE,Openda
    0x0040: 796c 6967 6874 2050 340a                ylight,P4.
11:05:12.686009 IP 10.0.0.10.1463 > 10.41.166.16.0: Flags [none], seq 342010982:
342011002, win 512, length 20
    0x0000: 00aa bb00 0000 0004 0000 0000 0800 4500 .....E.
    0x0010: 003c 0d0b 0000 4006 b36e 0a00 000a 0a29 .<....@..n.....)
    0x0020: a610 05b7 0000 1462 ac66 5630 f4c4 5000 .....b.fV0..P.
    0x0030: 0200 89c1 0000 5a54 4520 4f70 656e 6461 .....ZTE,Openda
  
```

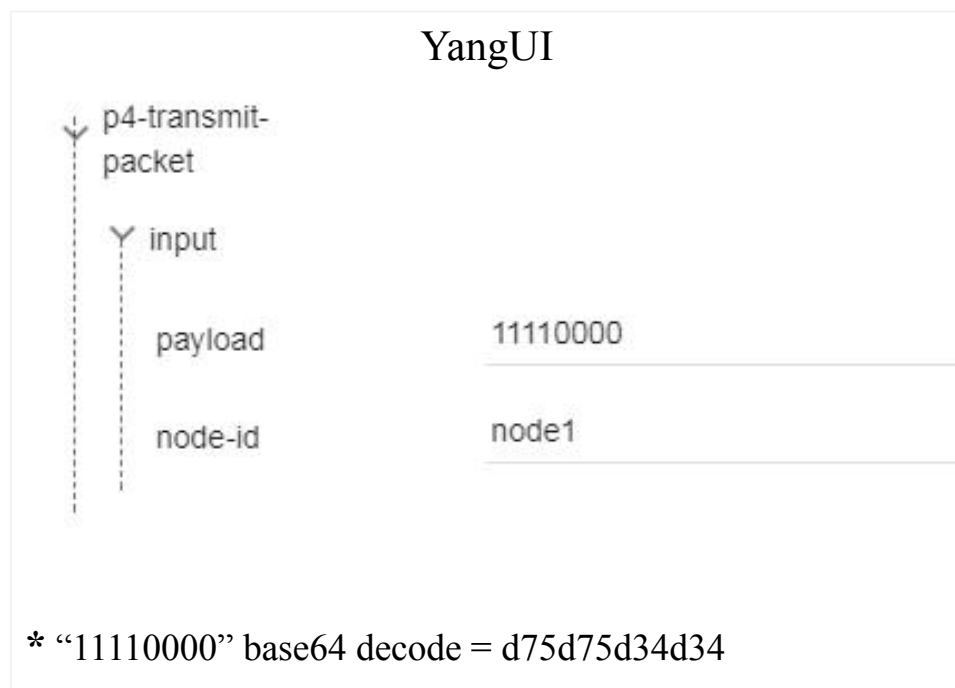
- Receive log

```

2017-11-17 11:05:13.687 | INFO | fault-executor-6 | P4RuntimeStub | 286 - org.opendaylight.
ght.p4plugin.core.impl - 0.1.0.SNAPSHOT | Receive packet from node = node1, body = 00aabb00000000004000000000
080045000003cd5f700004006ea810a00000a0a29a61005b800003e38cdca12bd3fc65000020036f800005a5445204f70656e6461796
c696768742050340a.
  
```


Detailed Steps II

- Packet out
 - Transmit and Capture



```

"Node: s1" (root)
root@h11:~#
root@h11:~# tcpdump -i lo -XX port 50051
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on lo, link-type EN10MB (Ethernet), capture size 262144 bytes
11:54:15.082970 IP 10.42.94.144.37720 > 10.42.94.144.50051: Flags [P.], seq 3897
52896:389752920, ack 644477983, win 124, options [nop,nop,TS val 2650554532 ecr
2650543068], length 24
    0x0000: 0000 0000 0000 0000 0000 0000 0800 4500 .....E.
    0x0010: 004c 9651 4000 4006 d2e6 0a2a 5e90 0a2a .L.Q@.@...*^.*
    0x0020: 5e90 9358 c383 173b 2840 2669 f41f 8018 ^..X...:(&i....
    0x0030: 007c d1b2 0000 0101 080a 9dfc 40a4 9dfc .!.....@...
    0x0040: 13dc 0000 0f00 0000 0000 0000 0300 000a .....
    0x0050: 1208 0a06 d75d 75d3 4d34 .....]u.M4
11:54:15.083980 IP 10.42.94.144.50051 > 10.42.94.144.37720: Flags [P.], seq 1:22
, ack 24, win 344, options [nop,nop,TS val 2650554532 ecr 2650554532], length 21
    0x0000: 0000 0000 0000 0000 0000 0000 0800 4500 .....E.
    0x0010: 0049 3544 4000 4006 33f7 0a2a 5e90 0a2a .I5D@.@.3..*^.*
    0x0020: 5e90 c383 9358 2669 f41f 173b 2858 8018 ^....X&i...:(X..
    0x0030: 0158 d1af 0000 0101 080a 9dfc 40a4 9dfc .X.....@...
    0x0040: 40a4 0000 0c04 0000 0000 0000 0400 0265 @.....e
    0x0050: 4600 0500 0265 46 .....F....eF
11:54:15.083996 IP 10.42.94.144.37720 > 10.42.94.144.50051: Flags [.], ack 22, w
in 124, options [nop,nop,TS val 2650554532 ecr 2650554532], length 0
    0x0000: 0000 0000 0000 0000 0000 0000 0800 4500 .....E.
  
```

- Receive log

```

2017-11-17 11:21:52,218 | INFO | 1480256041-14325 | P4RuntimeStub | 286 - org.ope
ght.p4plugin.core-impl - 0.1.0.SNAPSHOT | Transmit packet = d75d75d34d34 to node = nodel.
2017-11-17 11:21:52,222 | INFO | fault-executor-9 | NotificationServiceProvider | 286 - org.ope
ght.p4plugin.core-impl - 0.1.0.SNAPSHOT | Notification publish!
2017-11-17 11:21:52,222 | INFO | fault-executor-9 | P4RuntimeStub | 286 - org.ope
ght.p4plugin.core-impl - 0.1.0.SNAPSHOT | Receive packet from node = nodel, body = d75d75d34d34.
  
```

Thank you.