PINS: P4 Integrated Network Stack

EMPOWERING OPEN.

OCP GLOBAL SUMMIT

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SAN JOSE, CA

PINS = SONiC + SDN

- **SONiC** is widely deployed, modular, open source, and vendor agnostic
  - Runs a traditional control plane (e.g. BGP)
  - Solid foundation for SDN-enabled switch OS

- **Software-Defined Network (SDN)** brings many features and capabilities to the network which is difficult to achieve using traditional embedded control planes

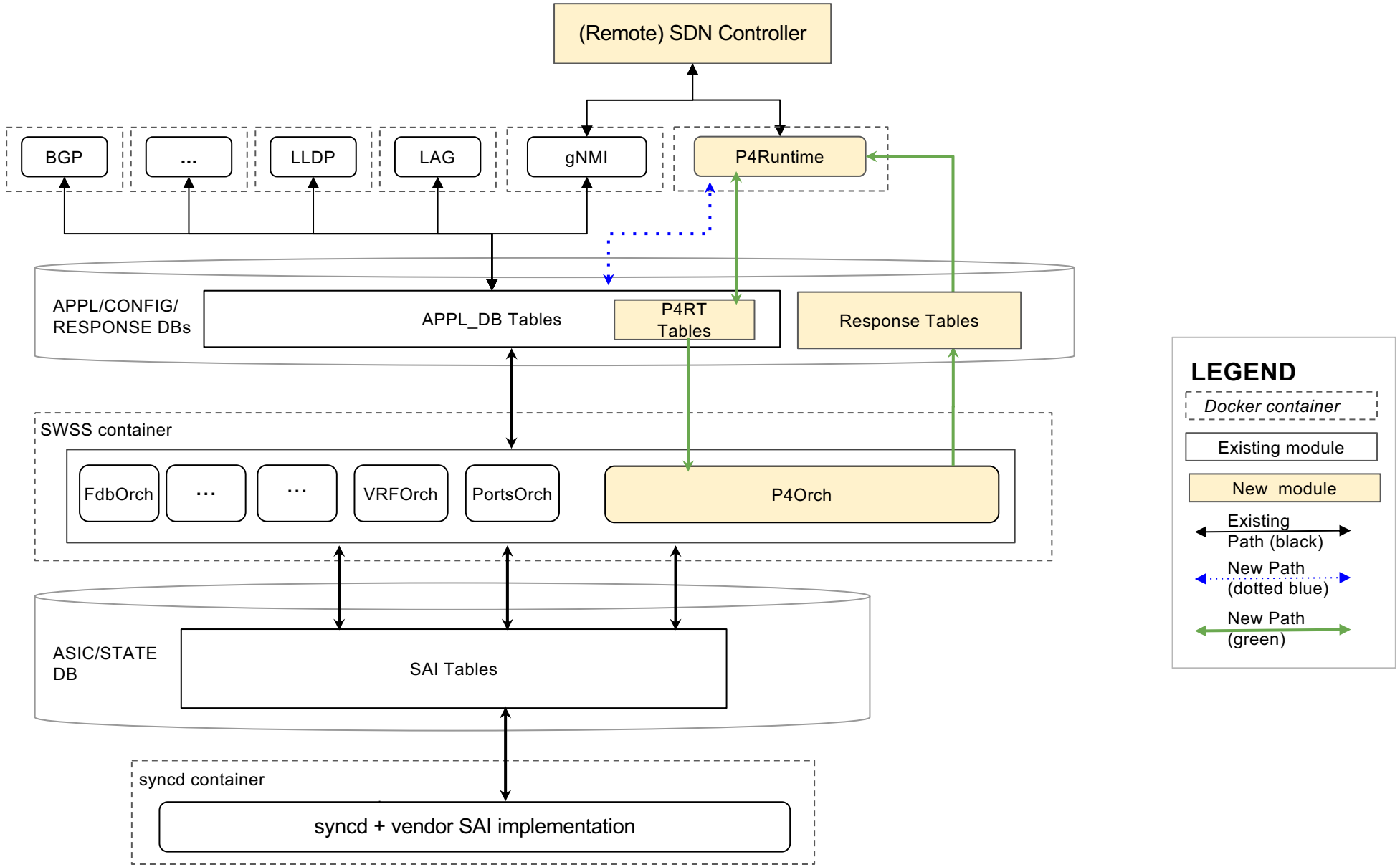
- **P4 Integrated Network Stack (PINS)** adds SDN capabilities to SONiC:
  - *Formal Pipeline Specification*: **P4** used to model the SAI pipeline
  - *Remote API*: **P4Runtime** used to program objects into the pipeline

SONiC for PINS

SONiC is adapted to work with remote SDN controllers by adding the support for P4Runtime protocol

- Optional: Gives network operators a choice to incrementally migrate towards an SDN solution
- Switch Abstraction Interface (SAI) pipeline is modelled in P4 (SAI.p4)
- PINS translates between P4 entities and SAI API calls
- A response path is used to immediately inform the controller when an update succeeds or fails, compared to the fire-and-forget approach of other SONiC apps
- Remote packet I/O capability added for the SDN controller

PINS Architecture



SAI P4 Routing

Legend:
P4 Table *(maps to SAI header)*

sai/routing.p4

```
...

@p4runtime_role(P4RUNTIME_ROLE_ROUTING)
 @id(ROUTING_IPV4_TABLE_ID)
 table ipv4_table {
   key = {
     // Sets vrf_id in sai_route_entry_t.
     local_metadata.vrf_id : exact @id(1) @name("vrf_id")
         @refers_to(vrf_table, vrf_id);
     // Sets destination in sai_route_entry_t to an IPv4 prefix.
     headers.ipv4.dst_addr : lpm @format(IPV4_ADDRESS) @id(2)
                                 @name("ipv4_dst");
   }
   actions = {
     @proto_id(1) drop;
     @proto_id(2) set_nexthop_id;
     @proto_id(3) set_wcmp_group_id;
   }
   const default_action = drop;
   size = ROUTING_IPV4_TABLE_MINIMUM_GUARANTEED_SIZE;
 }

...
```

IP Routing *(sairoute.h)*

Match Keys:
- VRF ID
- IP Dest

Action (one of):
- Set Next Hop Group ID
- Set Next Hop ID

or

Next Hop Group
(sainexthopgroup.h)

Match Keys:
- Next Hop Group ID

Action:
- Set Next Hop ID **via WCMP**

Next Hop *(sainexthop.h)*

Match Keys:
- Next Hop ID

Action:
- Set RIF ID
- Set Neighbor IP

Router Interface
(sairouterinterface.h)

Match Keys:
- RIF ID

Action:
- Set Dest Port
- Set Src MAC

Neighbor
(saineighbor.h)

Match Keys:
- RIF ID
- Neighbor IP

Action:
- Set Dest MAC

SAI P4 ACLs

sai/custom/acl_ingress.p4

```
...

 table acl_ingress_table {
   key = {
     headers.ipv4.isValid() || headers.ipv6.isValid() : optional
     headers.ipv4.isValid() : optional
     headers.ipv6.isValid() : optional
     headers.ethernet.ether_type : ternary
     headers.ethernet.dst_addr : ternary
     headers.ipv4.dst_addr : ternary
     headers.ipv6.src_addr : ternary
     headers.ipv6.dst_addr : ternary
     ttl : ternary
     dscp : ternary
     ecn : ternary
     ip_protocol : ternary
     headers.icmp.type : ternary
     local_metadata.l4_dst_port : ternary
     local_metadata.ingress_port : optional
                     @sai_field(SAI_ACL_TABLE_ATTR_FIELD_IN_PORT);
     headers.arp.target_proto_addr : ternary
   }
   actions = {
     copy();
     trap();
     forward();
     acl_drop(standard_metadata);
     @defaultonly NoAction;
   }
   const default_action = NoAction;
   meters = acl_ingress_meter;
   counters = acl_ingress_counter;
   size = 128;
 }

...
```

```
@sai_field(SAI_ACL_TABLE_ATTR_FIELD_ACL_IP_TYPE/IP);
@sai_field(SAI_ACL_TABLE_ATTR_FIELD_ACL_IP_TYPE/IPV4ANY);
@sai_field(SAI_ACL_TABLE_ATTR_FIELD_ACL_IP_TYPE/IPV6ANY);
@sai_field(SAI_ACL_TABLE_ATTR_FIELD_ETHER_TYPE);
@sai_field(SAI_ACL_TABLE_ATTR_FIELD_SRC_IP);
@sai_field(SAI_ACL_TABLE_ATTR_FIELD_DST_IP);
@sai_field(SAI_ACL_TABLE_ATTR_FIELD_SRC_IPV6);
@sai_field(SAI_ACL_TABLE_ATTR_FIELD_DST_IPV6);
@sai_field(SAI_ACL_TABLE_ATTR_FIELD_TTL);
@sai_field(SAI_ACL_TABLE_ATTR_FIELD_DSCP);
@sai_field(SAI_ACL_TABLE_ATTR_FIELD_ECN);
@sai_field(SAI_ACL_TABLE_ATTR_FIELD_IP_PROTOCOL);
@sai_field(SAI_ACL_TABLE_ATTR_FIELD_ICMPV6_TYPE);
@sai_field(SAI_ACL_TABLE_ATTR_FIELD_L4_DST_PORT);


                    @composite_field(

   @sai_udf(base=SAI_UDF_BASE_L3, offset=24, length=2),
   @sai_udf(base=SAI_UDF_BASE_L3, offset=26, length=2)
);
```

Users can define custom ACLs in P4

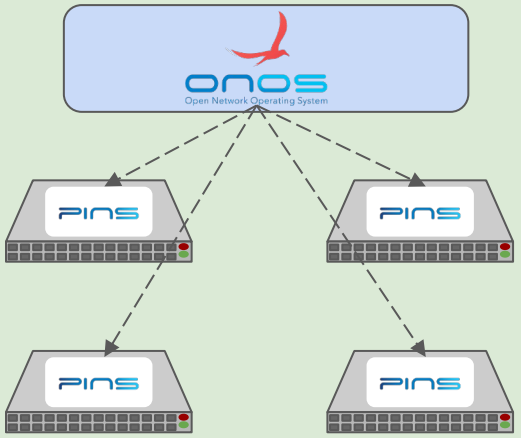
- Match fields
- Actions
- Counter
- Meters
- Table Size

P4 fields mapped to SAI using annotations

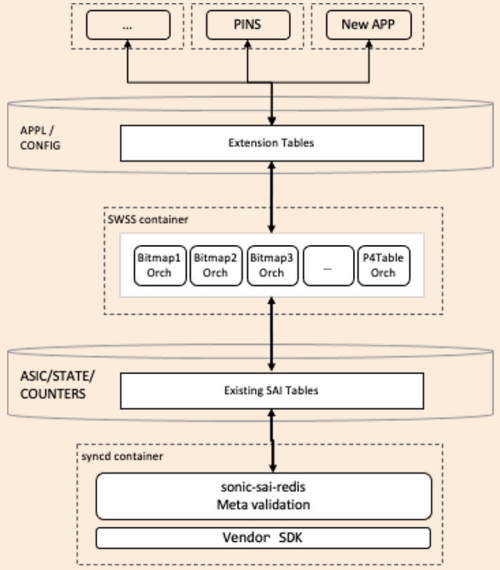
ACL tables are configured on the switch when the P4 pipeline is pushed via P4Runtime

PINS Topics

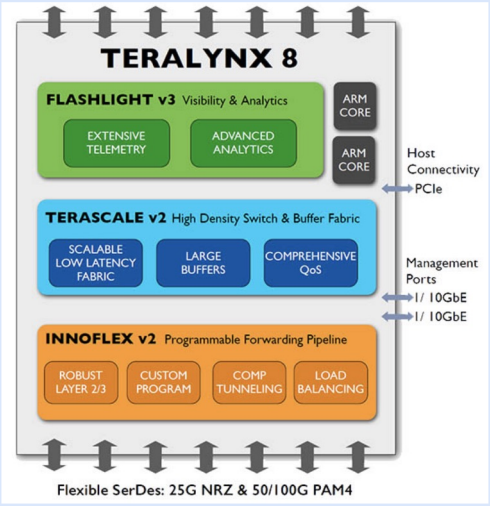
Use Cases: Weighted Cost MultiPath (WCMP)



SAI Generic Path Extension



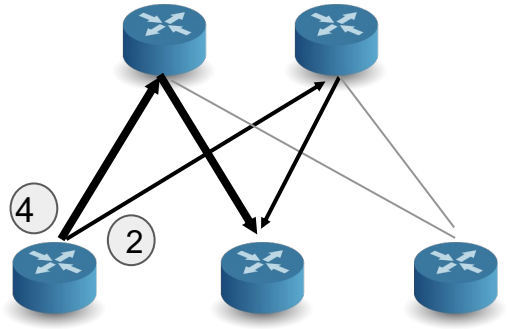
PINS for Marvell



Weighted Cost MultiPath (WCMP)

WCMP distributes traffic flows on multiple links proportionally to the assigned weights

- Helps optimally distribute traffic in unbalanced networks
- Watch Google's presentation on WCMP for more information here:



ONOS
Open Network Operating System

We implement WCMP using the open source ***ONOS*** and ***SD-Fabric*** platforms.

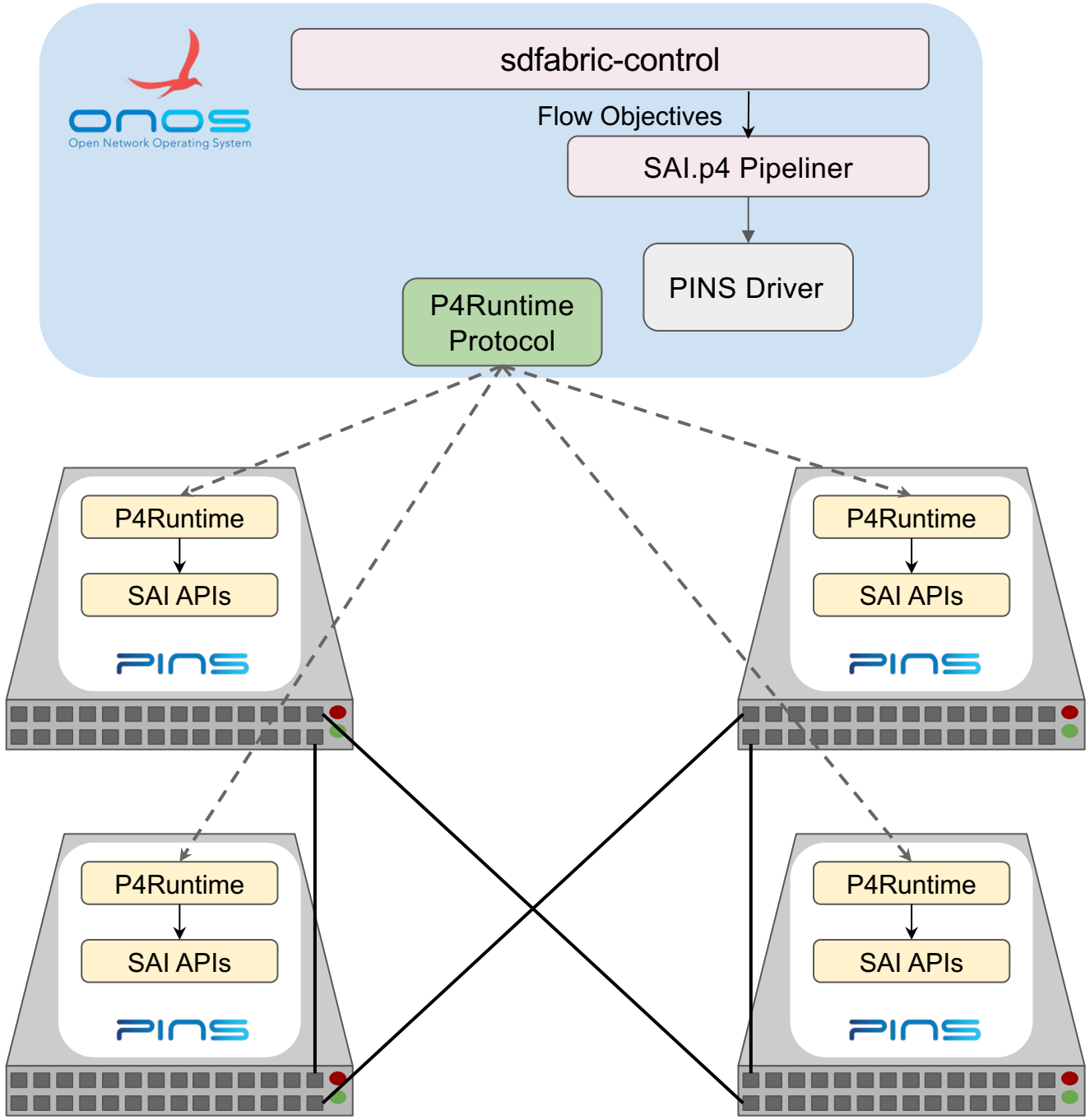
SD-FABRIC

PINS: P4 Integrated Network Stack - Mythil Raman and Konstantin Weitz, Google (2021 P4 Workshop Keynote)
https://www.youtube.com/watch?v=HL9msGD4OMU

End-to-End Architecture

SD-Fabric is a P4 programmable network fabric that includes:

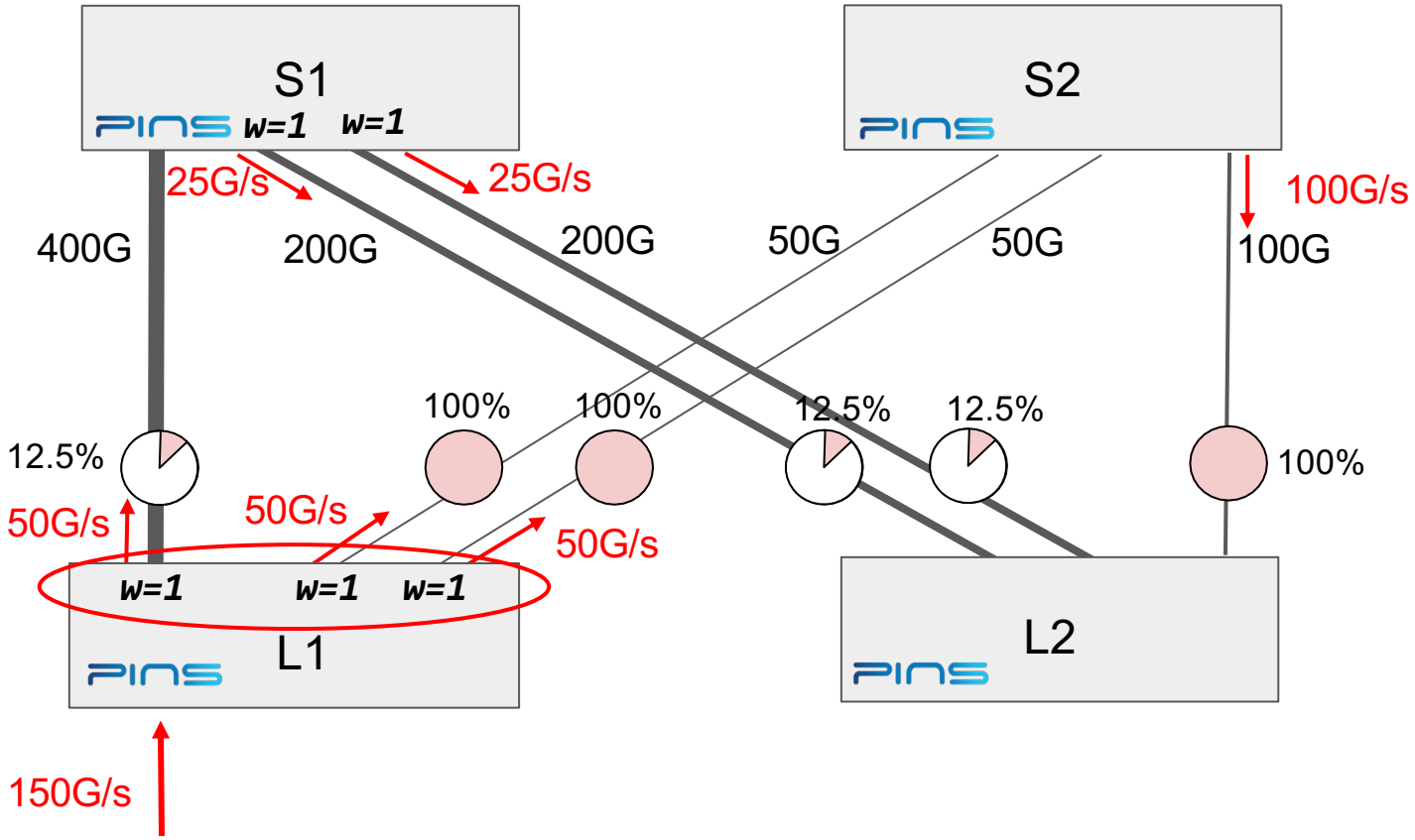
- SDN Controller
  - ONOS
  - sdfabric-control application
- Leaf-spine fabric of programmable switches
  - P4 Integrated Network Stack (PINS)
    - sai.p4
    - P4 entities to SAI APIs call
    - Remote Packet I/O



WCMP vs ECMP

ECMP Weight Distribution Example

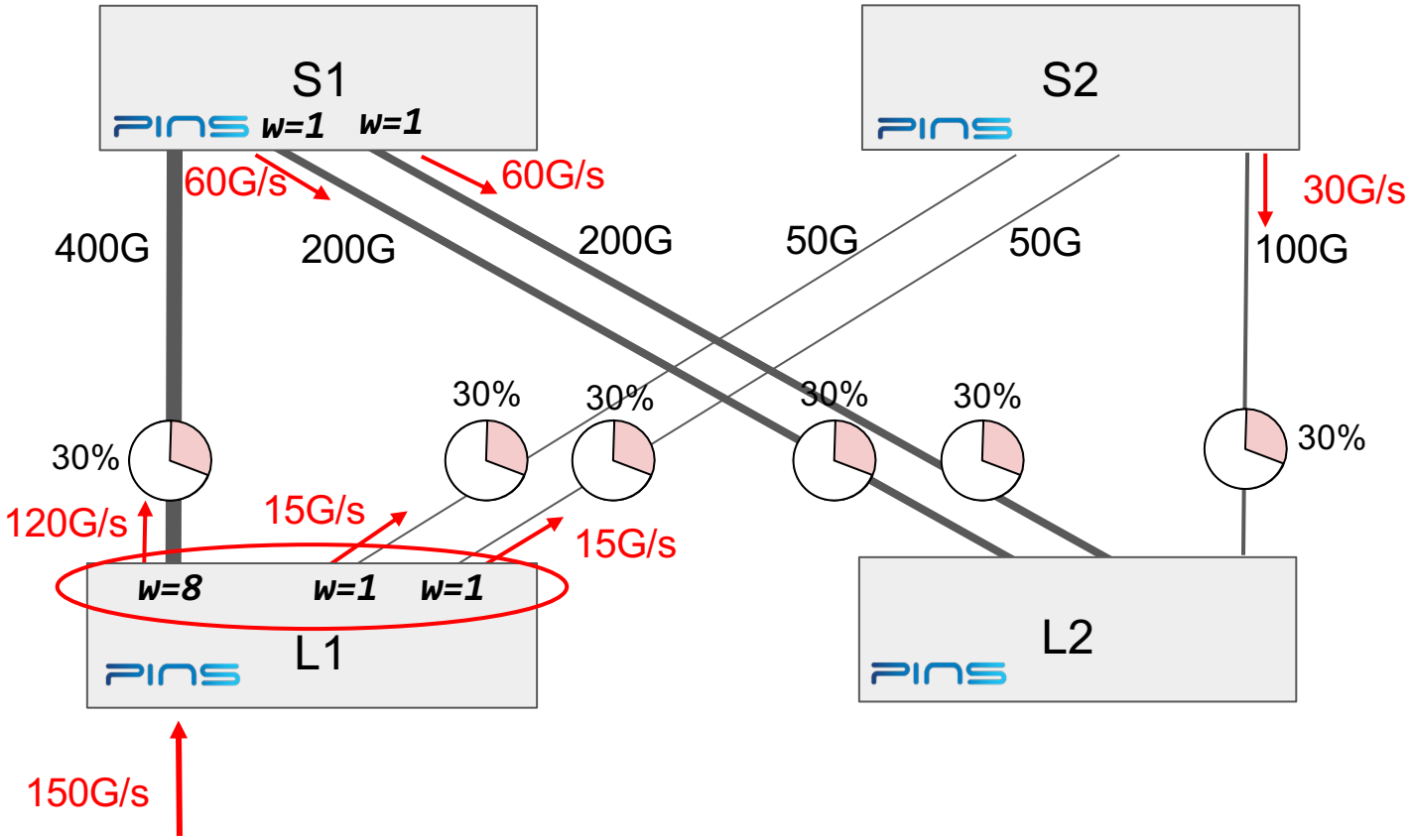
- ECMP equally distributes the traffic through the links
- Not optimal with unbalanced networks



WCMP vs ECMP

WCMP Weight Distribution Example

- WCMP distributes the traffic through the links according to their **weight**
- Can reach optimality with unbalanced networks



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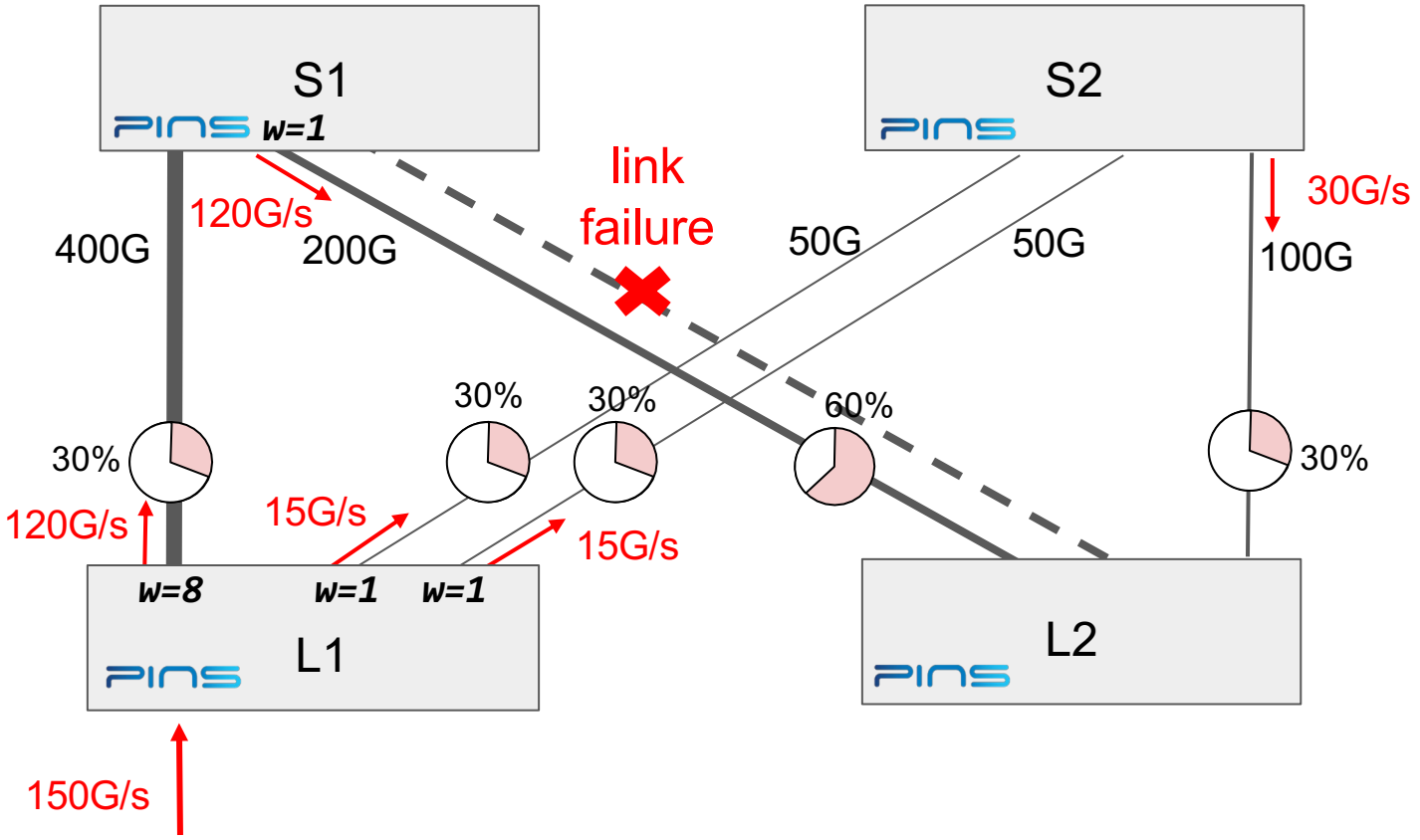

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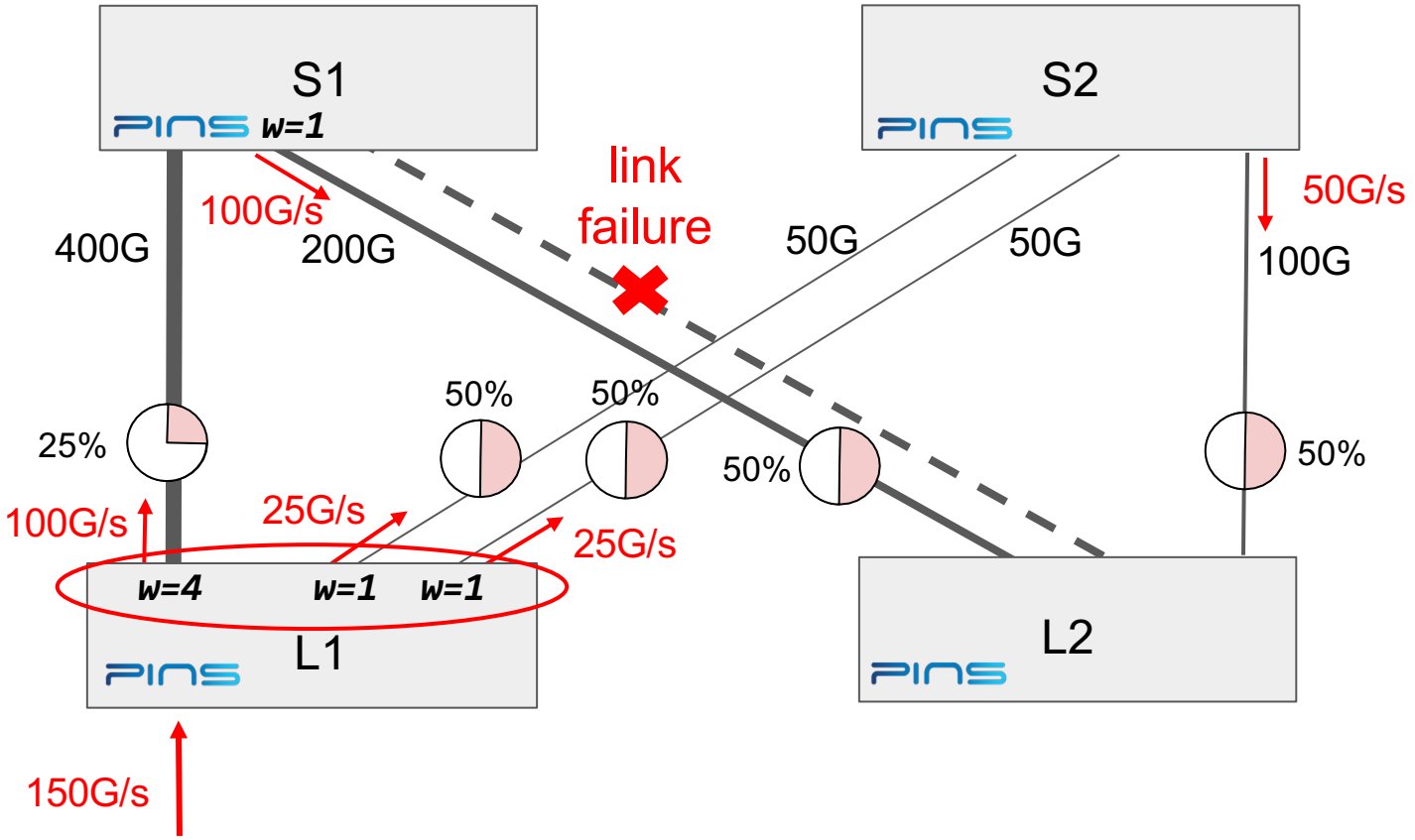
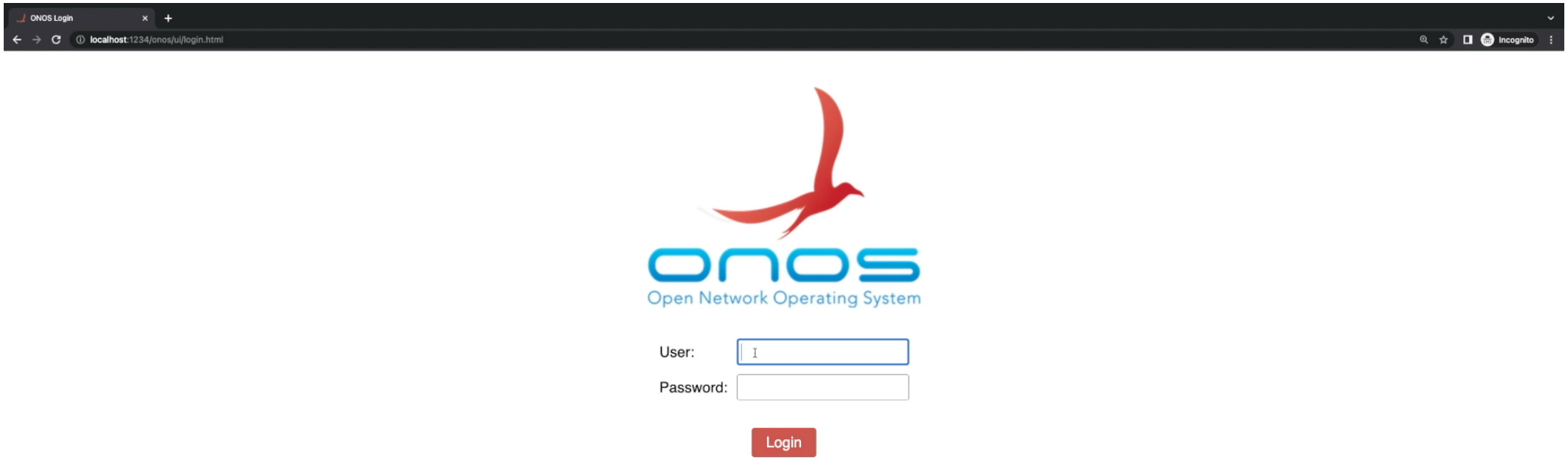


WCMP Demo Using PINS and ONOS



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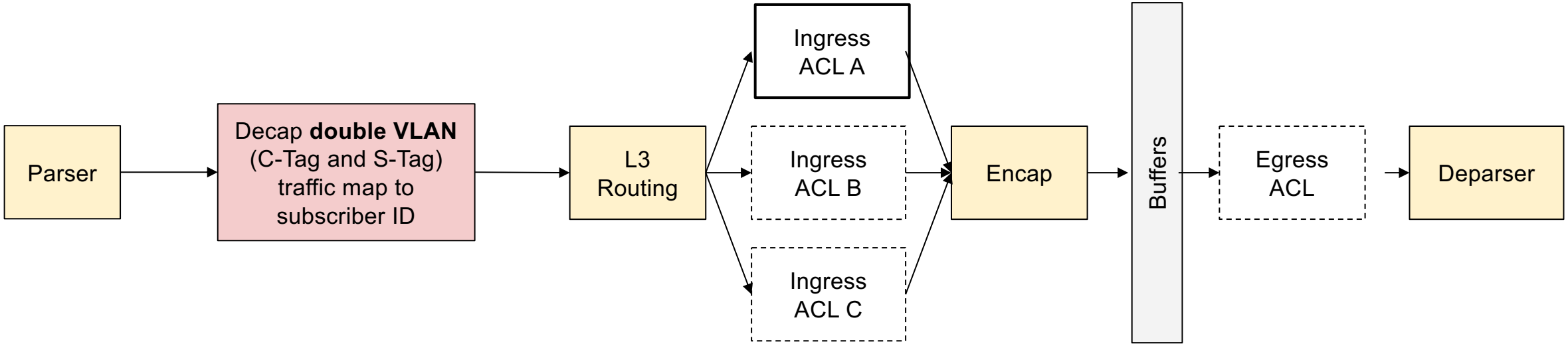
PINS Generic SAI Extensions

OCP Demo

PINS Generic SAI Extensions

- Faster development/deployment cycle for features extension to SAI pipeline
- Uniform P4Runtime abstraction
- Solution enables SDN managed
  - SAI tables
  - SAI Extension tables
- Field upgradeable and extensible
- Brings agility and differentiation with specialized use cases
  Customer-specific network headers and data plane functions

Extension example to SAI.p4 Pipeline



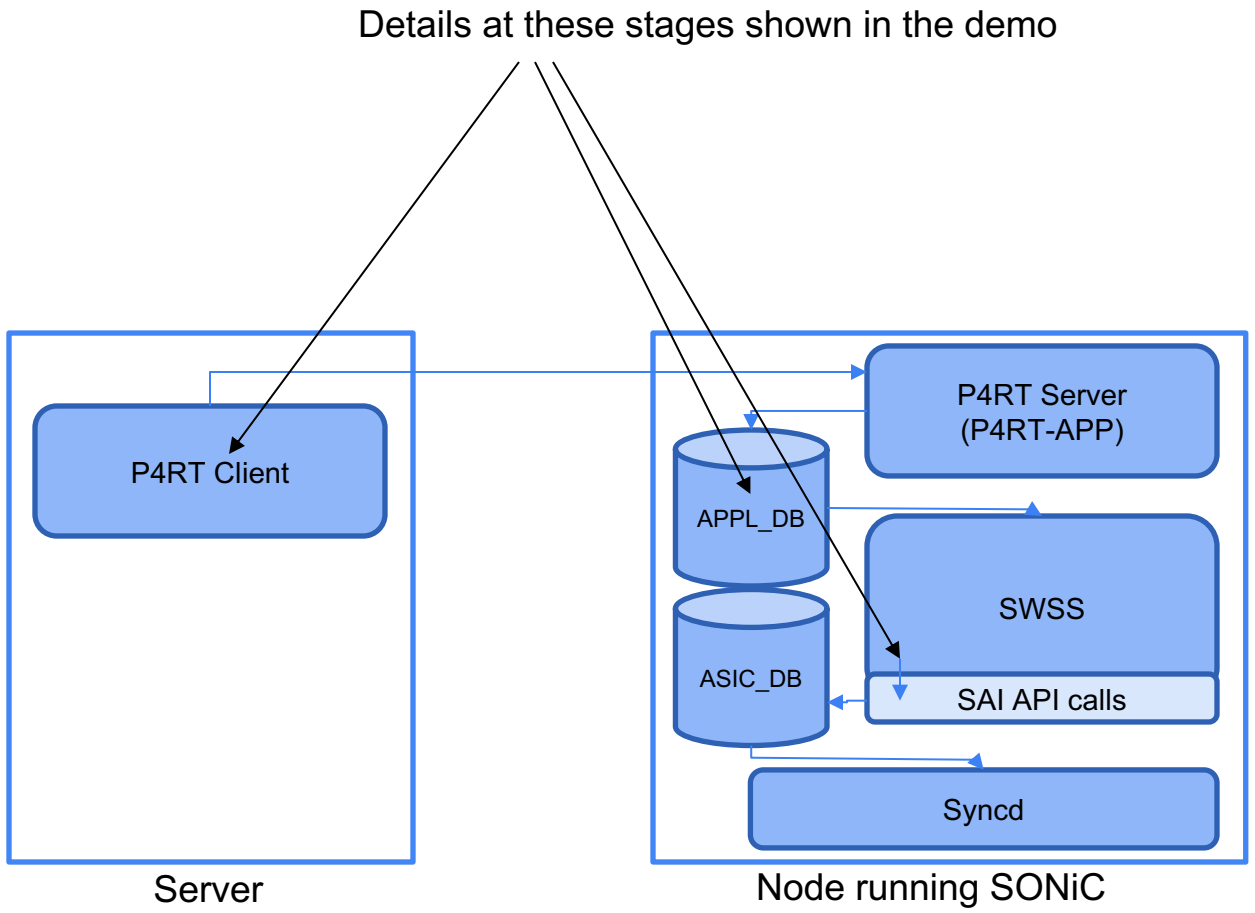
APPL_DB:
"P4RT_TABLE:EXT_QINQ_TABLE:{\"match/inner_vlan\":\"0x07b\",\"match/outer_vlan\":\"0x12c\"}"
1) "action"
2) "set_subscriber_id"
3) "param/subscriber_id"
4) "0x000007d0"

Attributes in ASIC_DB:

SAI_GENERIC_PROGRAMMABLE_ATTR_OBJECT_NAME: qinq_table
SAI_GENERIC_PROGRAMMABLE_ATTR_ENTRY:
[{"inner_vlan":{"datatype":"SAI_ATTR_VALUE_TYPE_UINT16","value":"0x07b"}},{"outer_vlan":{"datatype":"SAI_ATTR_VALUE_TYPE_UINT16","value":"0x12c"}},{"set_subscriber_id":[{"subscriber_id":{"datatype":"SAI_ATTR_VALUE_TYPE_UINT32","value":"0x000007d0"}}]}]

This demo shows:

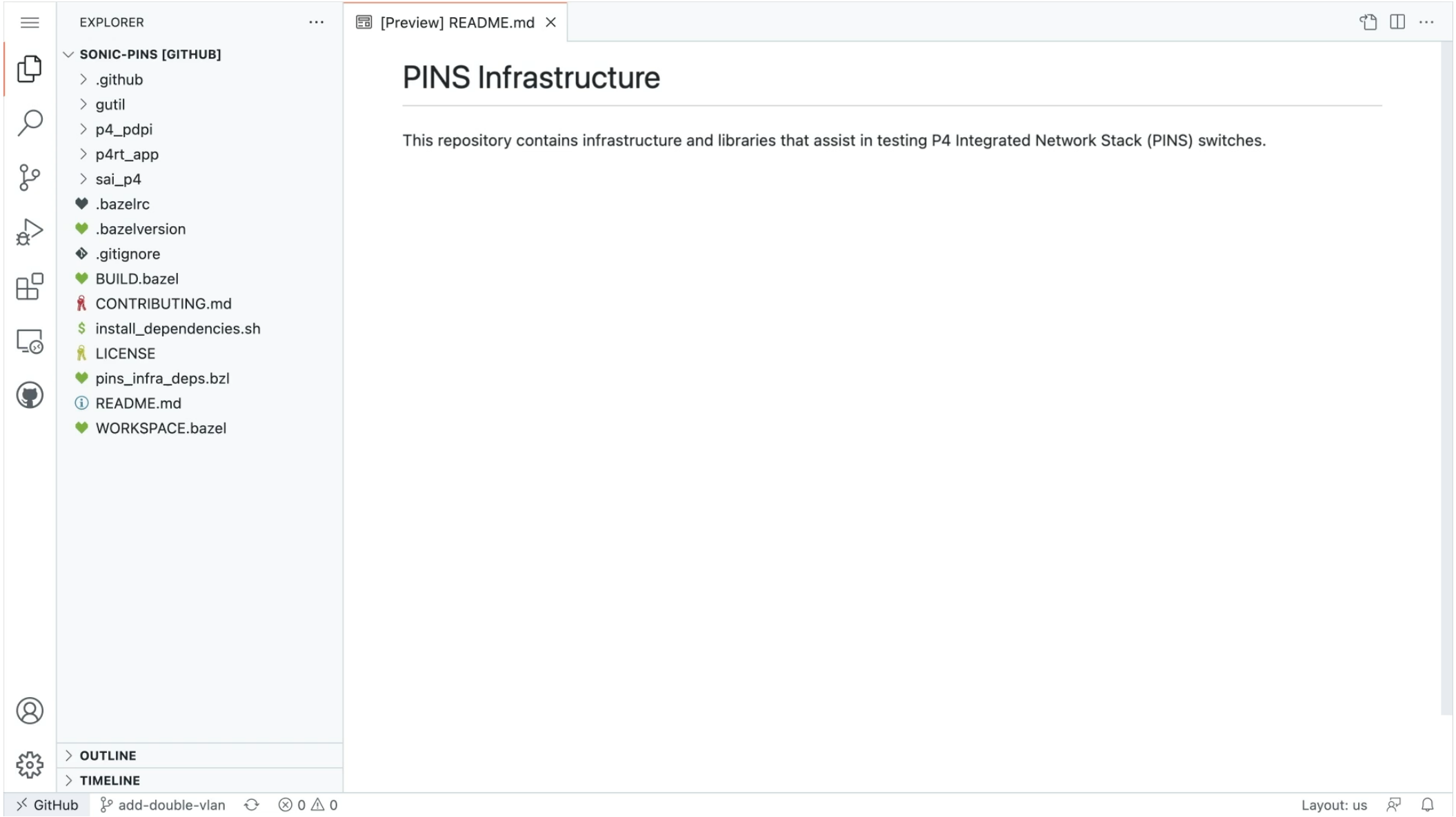
- New table definition extending SAI.p4
- Use of P4RT shell as P4RT Client
  - Connects to P4RT Server running SONiC
  - Triggers creation/removal of extension table entries
- SONiC APPL_DB
  - P4RT Tables definitions in APPL_DB
  - Addition/removal of extended table entries in APPL_DB
- Generic SAI Extension API parameters



Work in Progress

- Extension APIs approved and currently in process of integration with SONiC
- SONiC control-plane design reviewed with community

PINS SAI Extensions Demo



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PINS for Marvell

- Marvell has implemented PINS on their Teralynx® devices
- Supporting SONiC 202111 and SAI 1.9
- Features include:
  - ACLS
  - WCMP
  - Routing
  - Mirroring
  - CPU Path RX/TX
  - Fast Reset (sub 100ms)
- Visit the Marvell booth for more details

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Intel technologies may require enabled hardware, software or service activation.

No product or component can be absolutely secure.

Your costs and results may vary.

Thank you!
Questions?

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