Protocol Independent Forwarding

ONF PIF Project

2015-02-13

Underlined text records discussion

Agenda

- Overview (30 min)
  - Motivation and terminology
  - Projects and responsibilities
- Tour of AIR-IRI (30 min)
  - Sample datapath program
  - Overview of interpreter + infrastructure
- Work items and infrastructure (40 min)
  - Summary of work so far
  - Future work areas - IR development (interpreter+tools), IR samples, runtime interacting with IR
  - Software infrastructure and licensing
- Next steps - how to participate (20 min)

Why OpenFlow Next Generation / PIF etc?

- Vision - refactor architecture / design (*technology* push)
  - Support new approaches, e.g. more flexibly configured datapath => *Protocol Independent Forwarding*
  - Support new operations, e.g. stateful, delegated to switch, nested encapsulation
  - Optimize capacity, throughput - e.g. simpler, more parallel

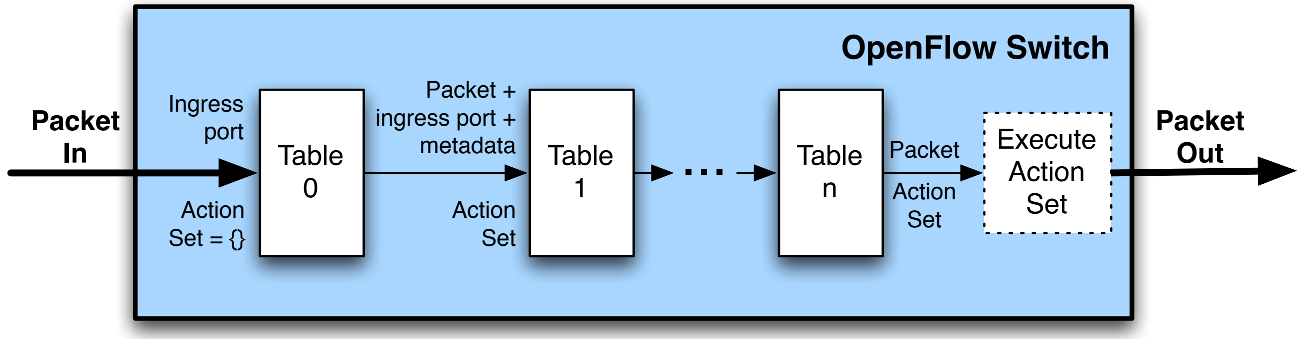
- Optimize processes / lifecycles (facilitate *ecosystem*)
  - Standards creation process (help ONF working group participants)
  - Development and deployment processes (help switch, controller, app vendors and users / operators)
    - Avoid cross product of controllers / apps and switch types

- Address specific requirements (*market* pull)
  - Support new use cases / market segments e.g. L4-L7 services / NFV
  - Refinement of capabilities / improved performance etc. for existing use cases

Interpretations of Protocol Independence

- Restructuring the existing OpenFlow *specification* - result:
  - Modular specification
  - Core or base does not refer to protocols
  - Each protocol / layer (e.g. Ethernet or IP) documented in its own add on
  - Result can express the same semantics as e.g. OpenFlow 1.3 - no impact on switches / controllers
  - Easier to add support for protocols in future - just write an add on module
- Introducing support for “*user defined” protocols* - result:
  - Match fields not limited to existing set of 40-ish OXMs
  - “Users” (vendors / operators…) describe new field as length + offset from already defined field etc.
  - Can be accomplished by extending existing OpenFlow 1.x specification
- More ambitious Protocol Independent Forwarding project - result:
  - More than just ability to define new protocol fields
  - Enables defining arrangement of OpenFlow pipeline in a more flexible way
  - “Datapath program” (in effect forwarding model) describes pipeline arrangement (matching tables, actions, QoS TM elements etc.) and behavior
  - Toolchains (compilers etc) enable configuring switches to “run” these “programs”

Elements in PIF World - New + Improved

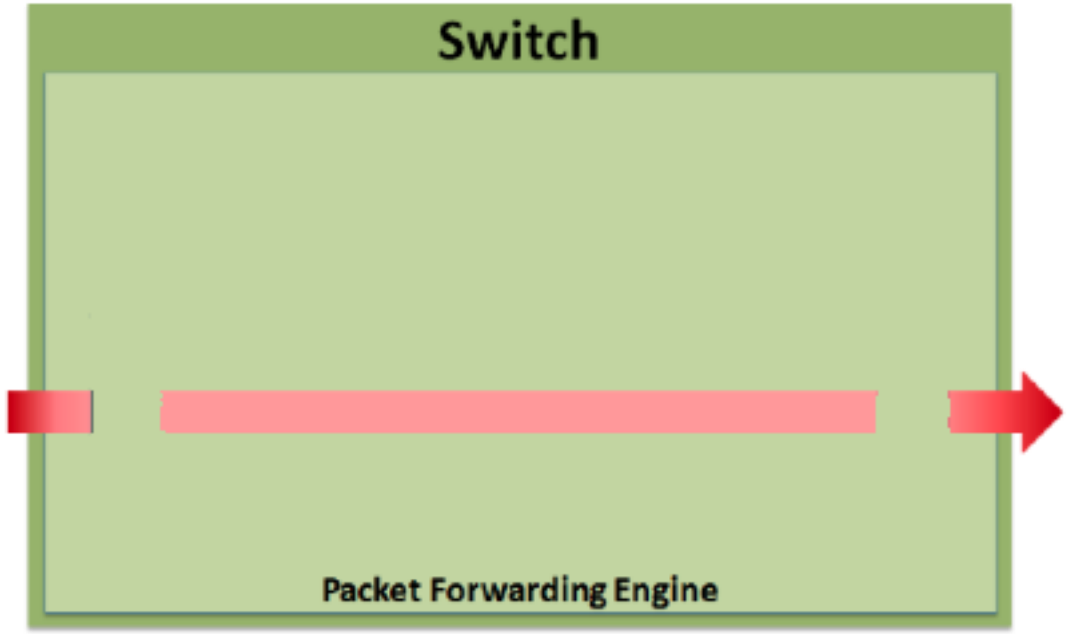


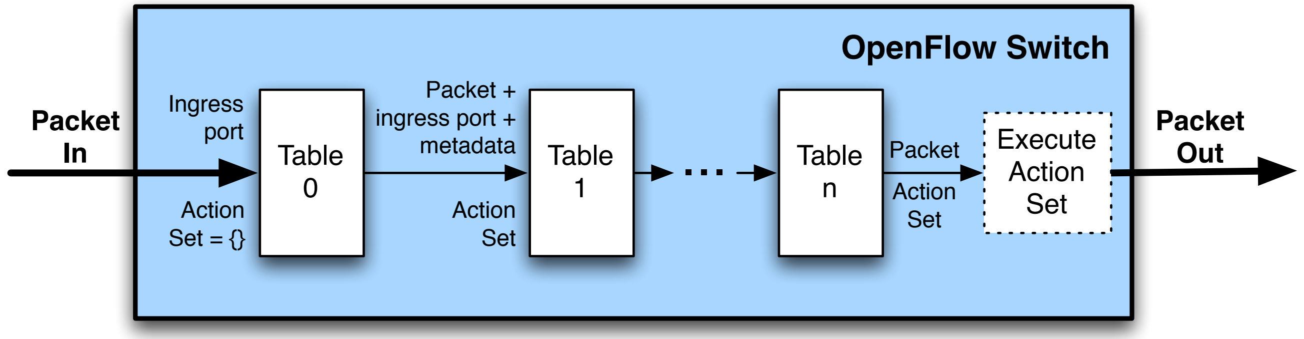
- Predefined Protocol Forwarding
  - OpenFlow specification defines protocols / fields, match/action behavior, overall control flow (tables can influence)
  - Set of supported protocols fixed by implementation

Elements in PIF World - New + Improved

- Config time

Datapath Program *in HL lang*





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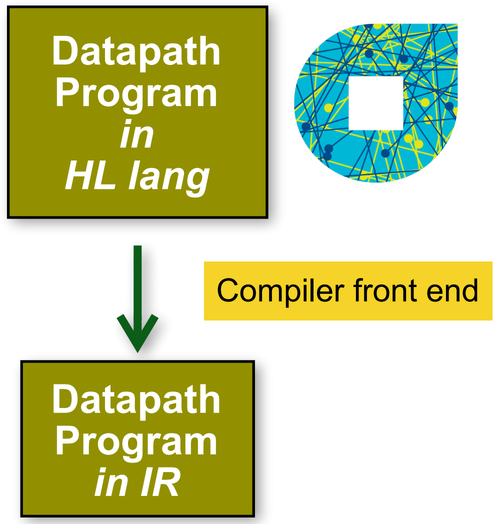

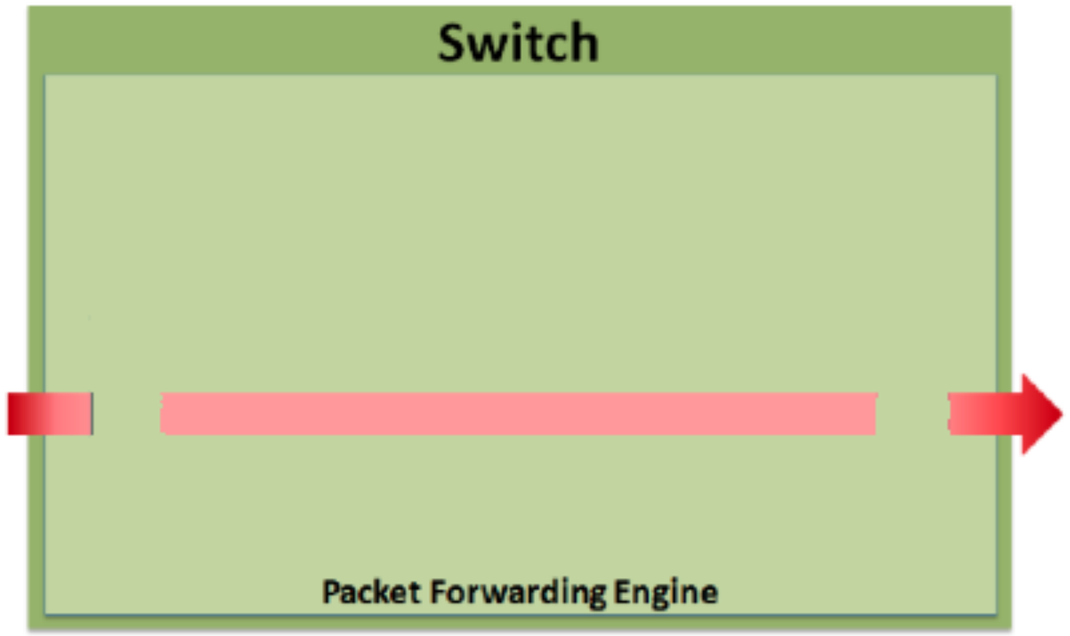

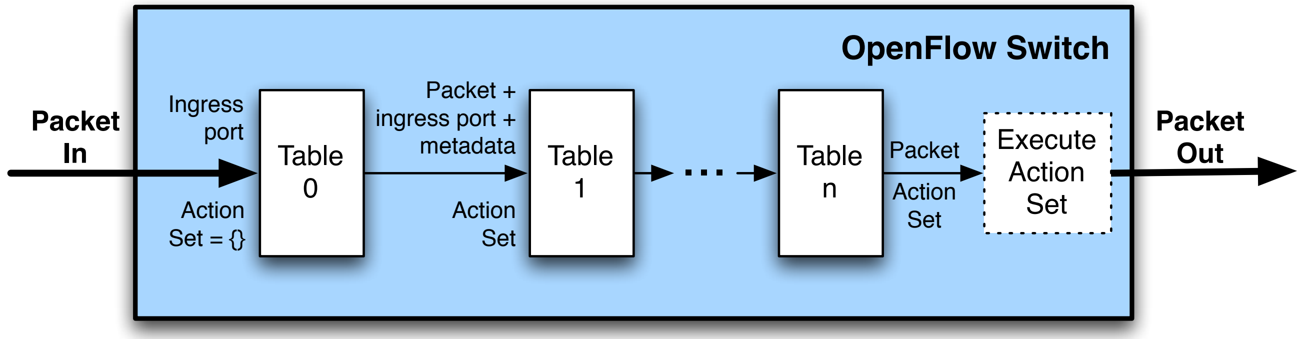

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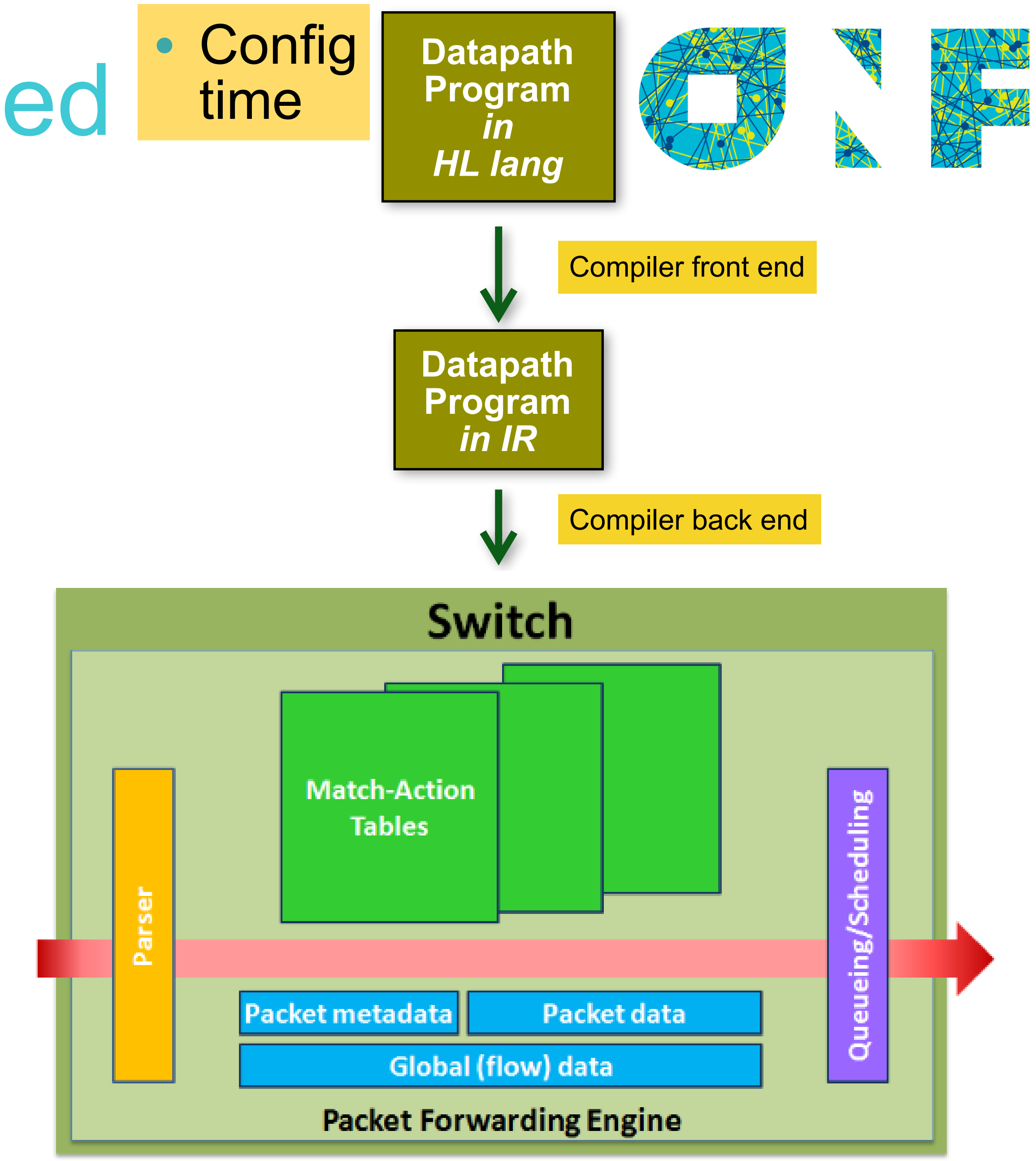

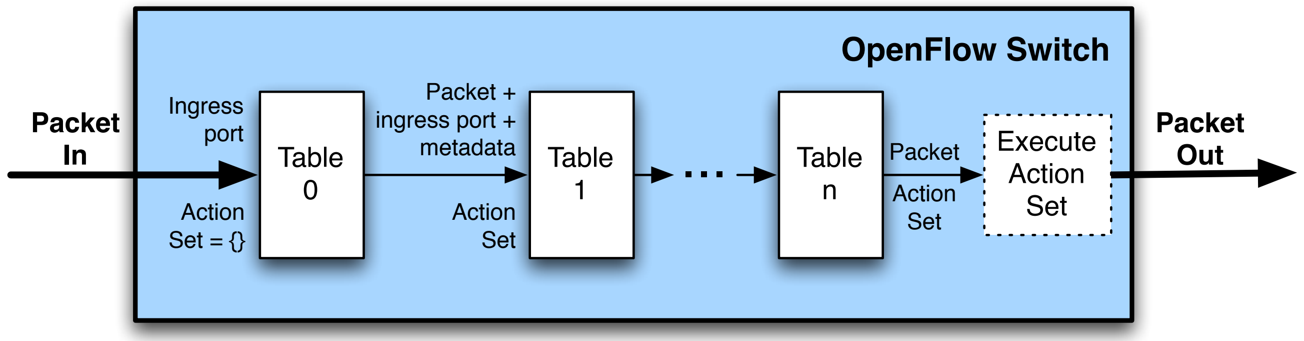

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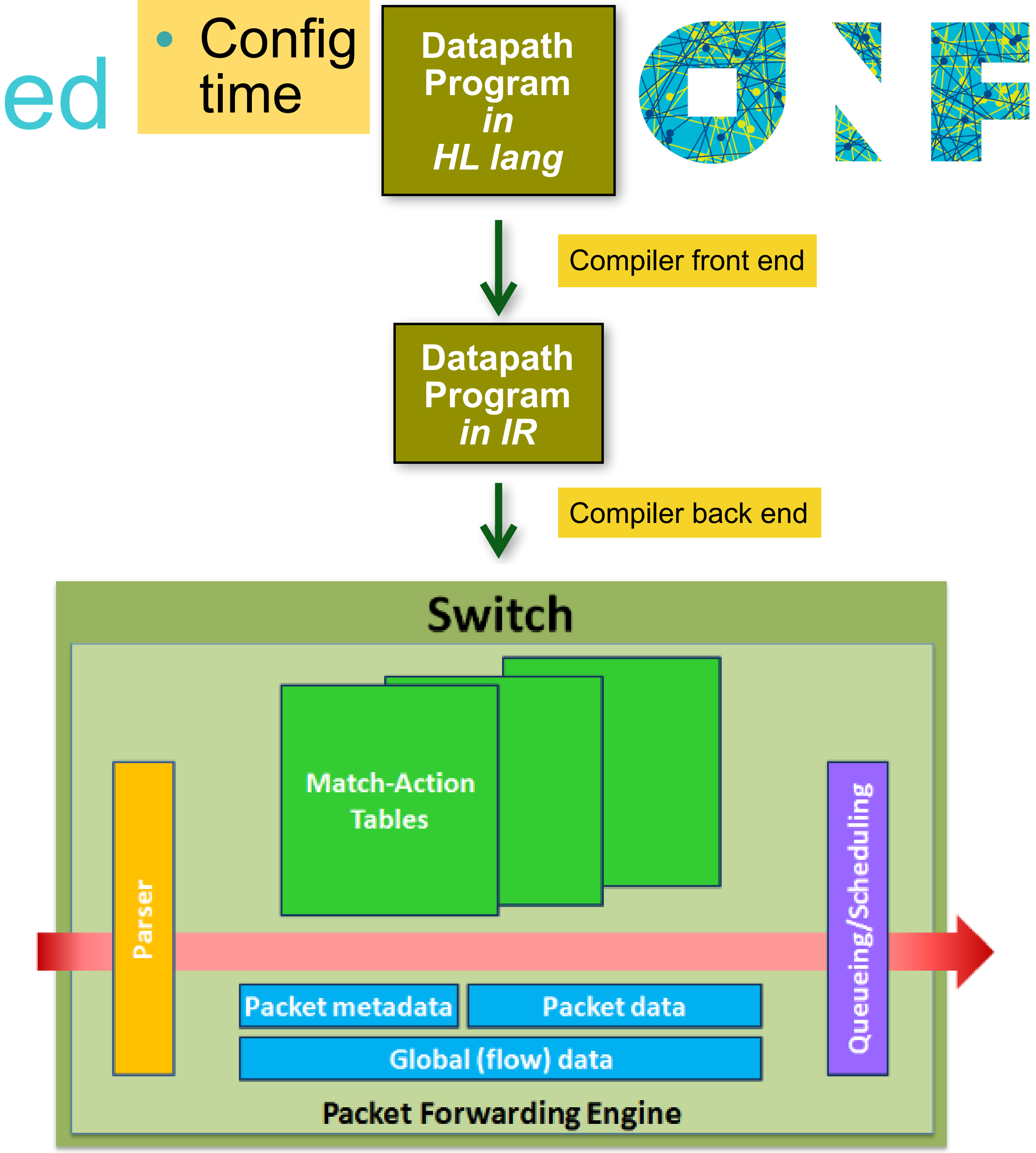

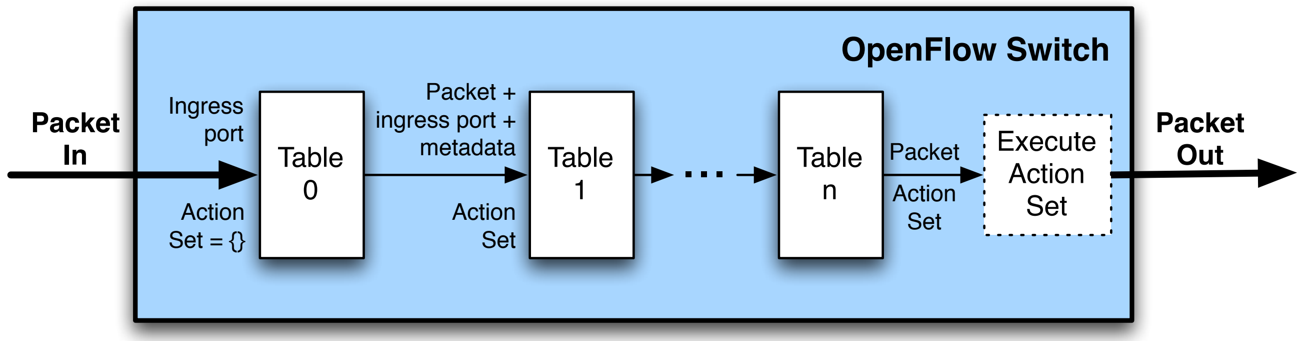

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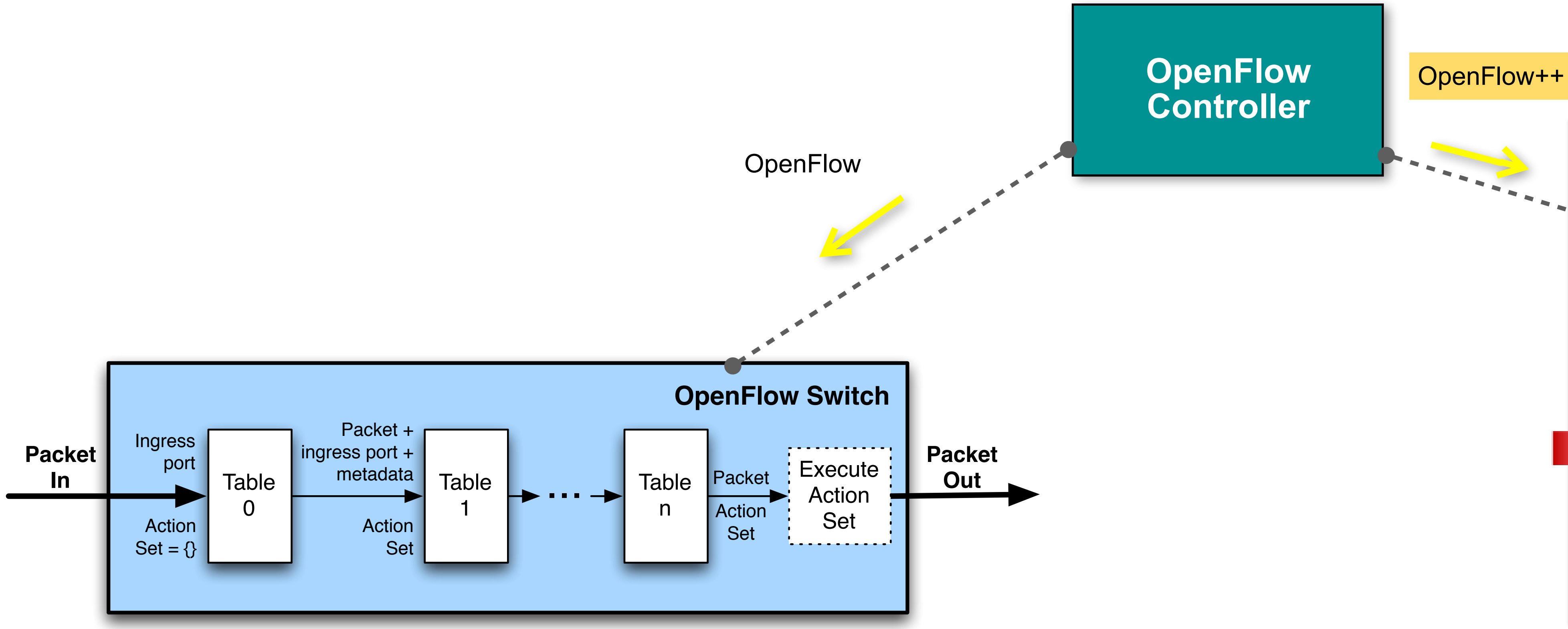
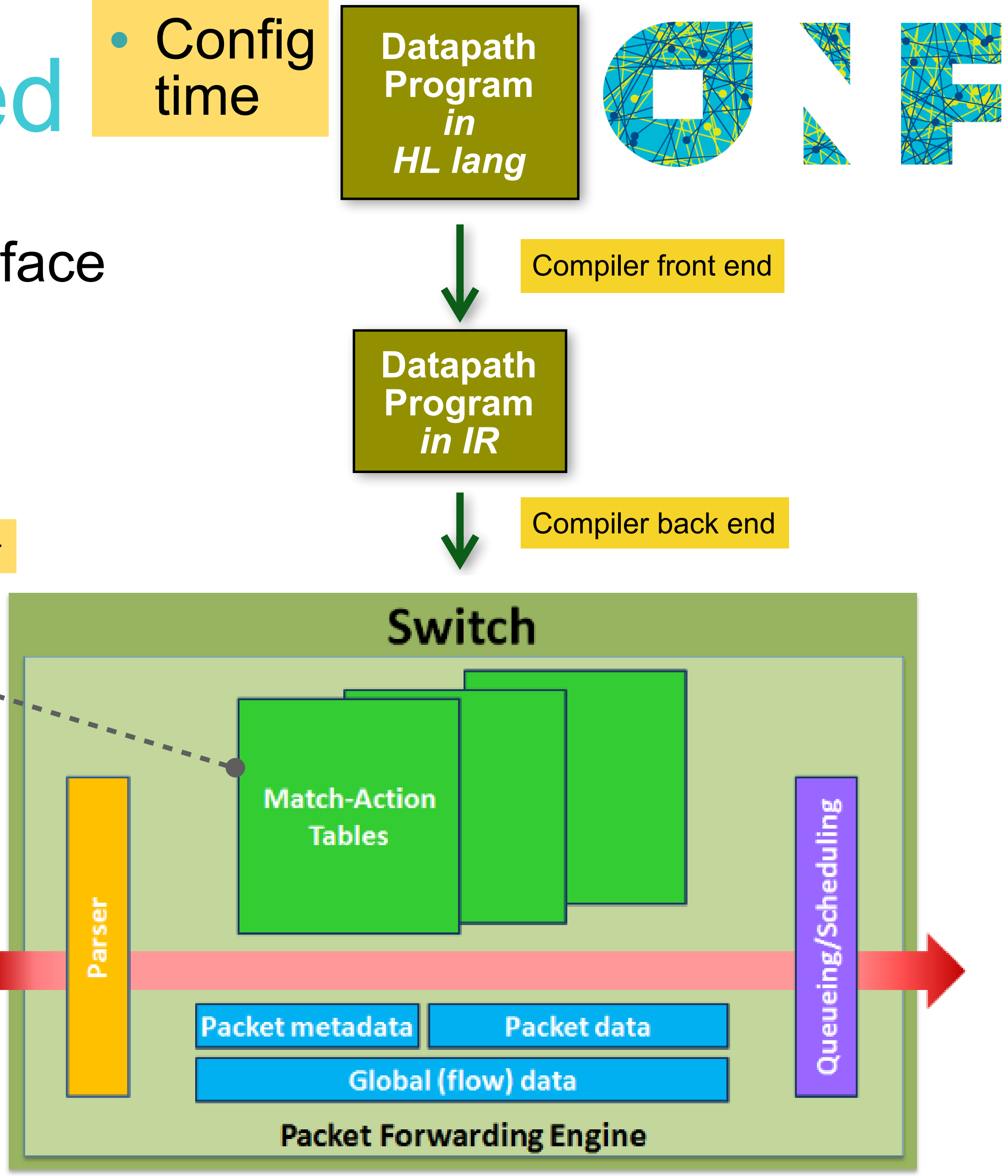
- Protocol Independent Forwarding (PIF) Configured ("Programmed") Datapath
  - Programs in language(s) describe datapath
    - Parse tree => protocol independent
    - Match/action tables (control flow arranges table sequence)
    - Packet metadata, per table or global state
    - QoS

Elements in PIF World - New + Improved

- Either way - need “southbound” interface for run-time interaction with switch...
  - Populate tables, receive statistics + events





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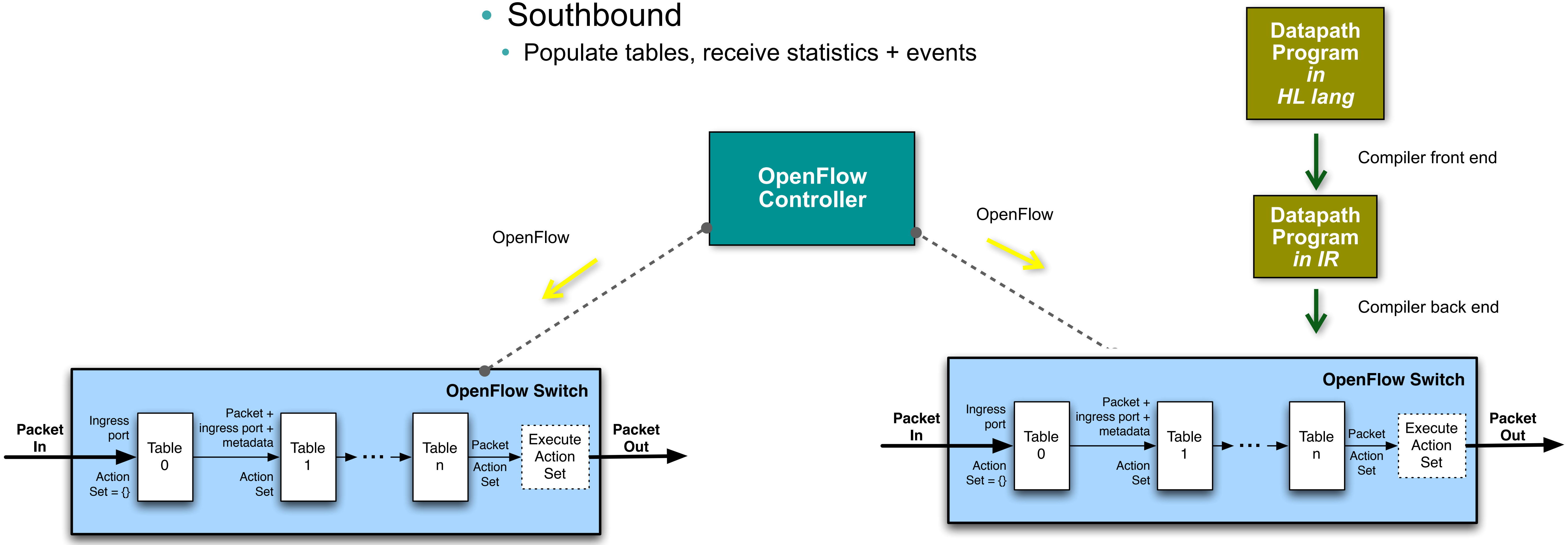
Emulating OpenFlow 1.x

- Southbound
  - Populate tables, receive statistics + events



Datapath Program *in HL lang*

Compiler front end

Datapath Program *in IR*

Compiler back end

OpenFlow Controller

OpenFlow

OpenFlow

OpenFlow Switch

Packet In

Ingress port

Action Set = {}

Table 0

Packet + ingress port + metadata

Action Set

Table 1

Table n

Packet

Action Set

Execute Action Set

Packet Out

OpenFlow Switch

Packet In

Ingress port

Action Set = {}

Table 0

Packet + ingress port + metadata

Action Set

Table 1

Table n

Packet

Action Set

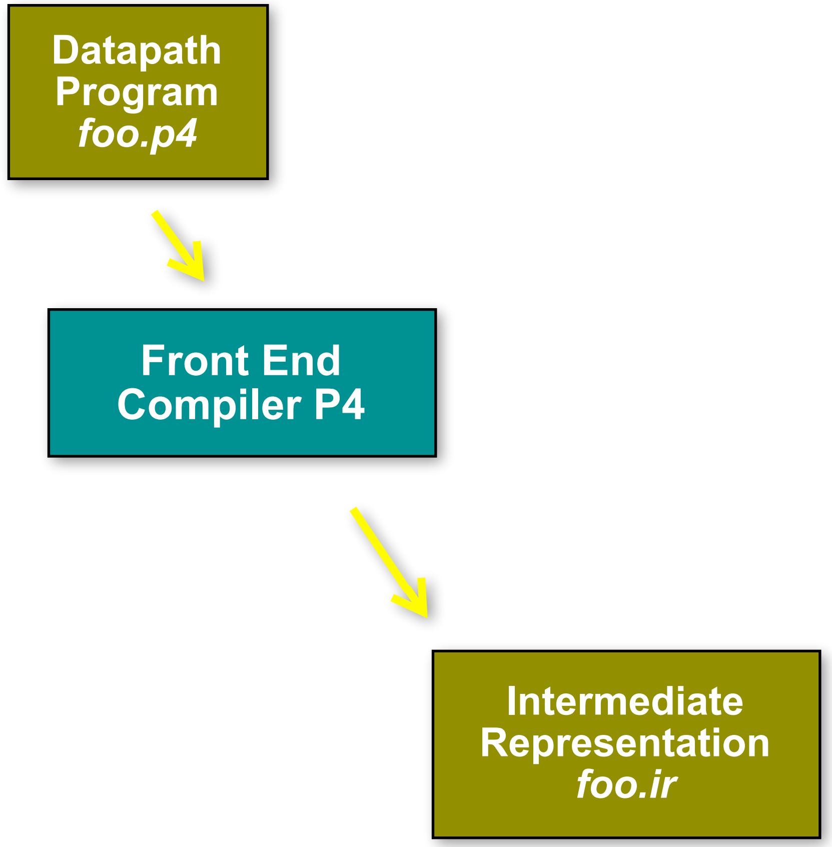
Execute Action Set

Packet Out

- Predefined Protocol Forwarding
  - Implements OpenFlow 1.x spec manually

- Configured (“Programmed”) Datapath
  - Program implements OpenFlow 1.x spec

Elements and Responsibilities



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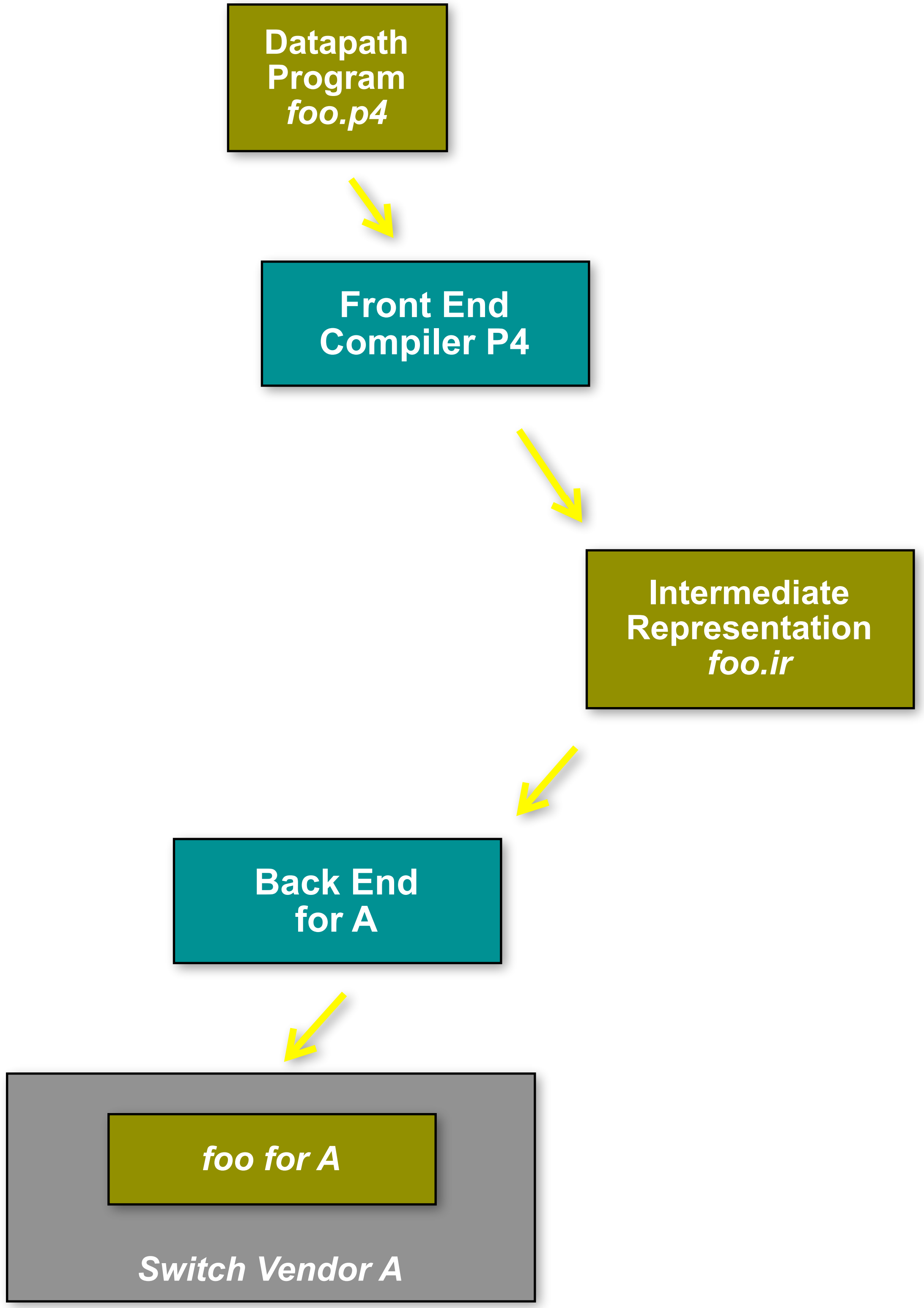


Datapath Program *foo.p4*

Front End Compiler P4

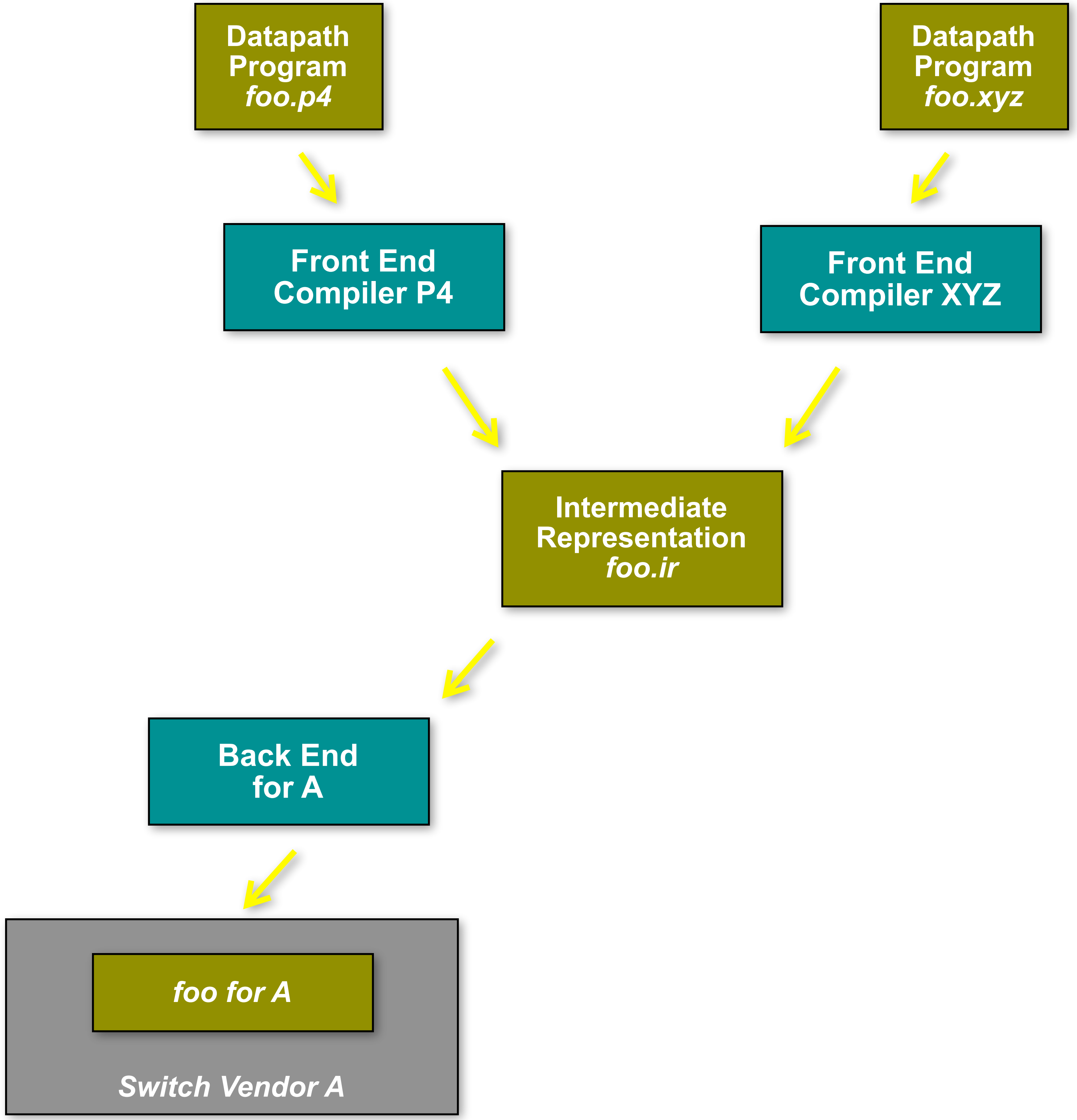
Intermediate Representation *foo.ir*

Back End for A

foo for A

Switch Vendor A

Elements and Responsibilities



Datapath Program *foo.p4*

Datapath Program *foo.xyz*

Front End Compiler P4

Front End Compiler XYZ

Intermediate Representation *foo.ir*

Back End for A

foo for A

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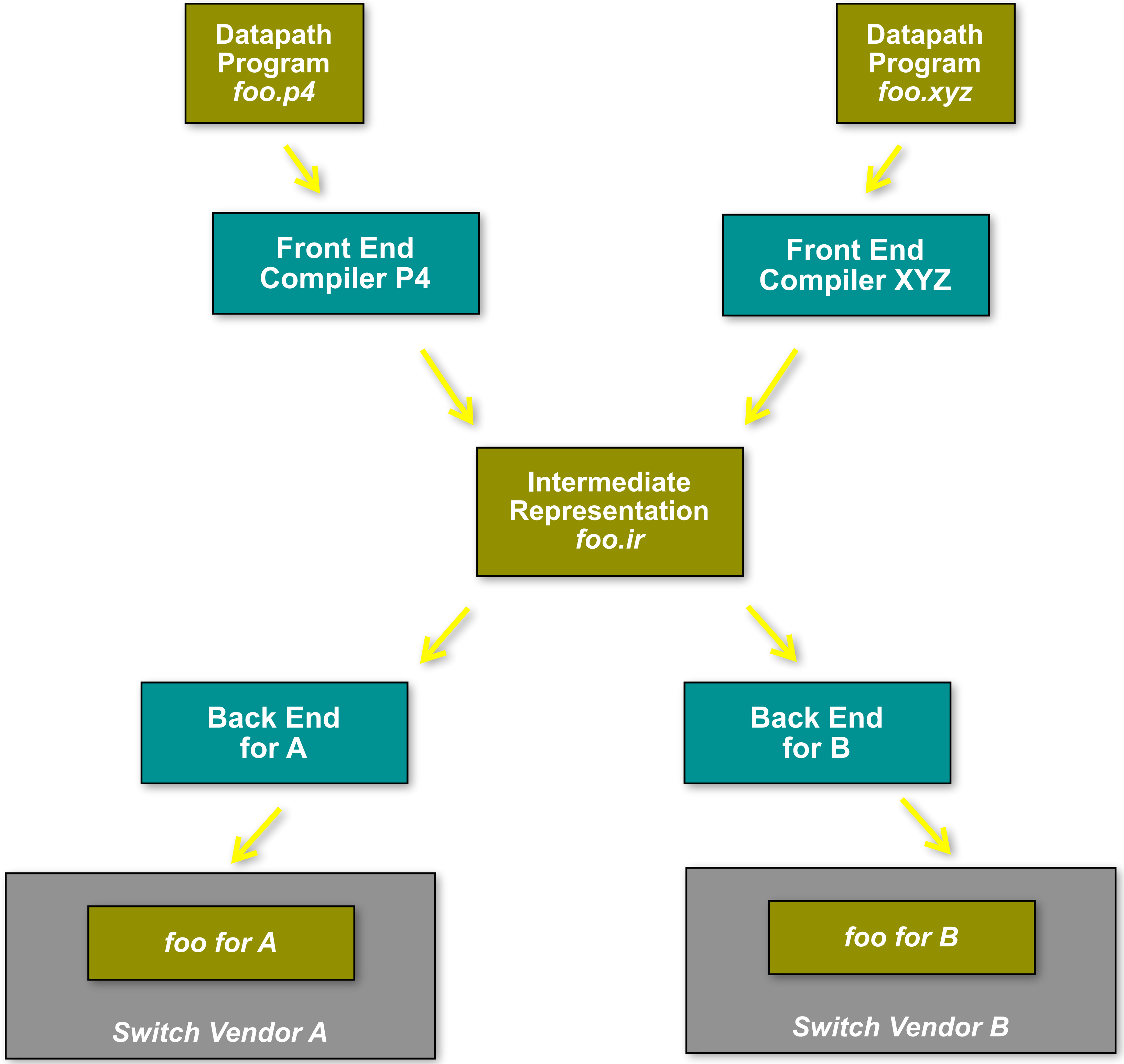

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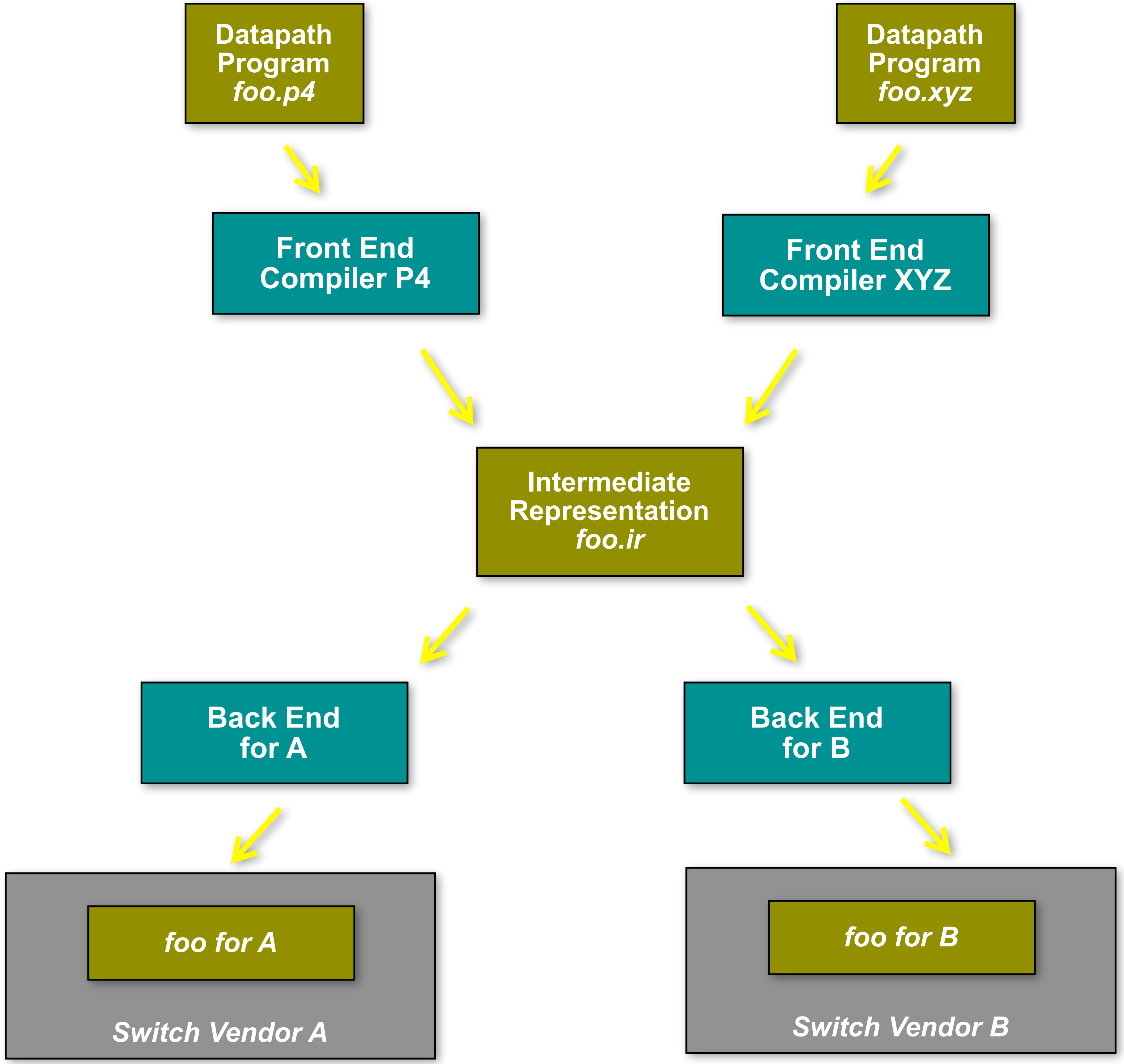
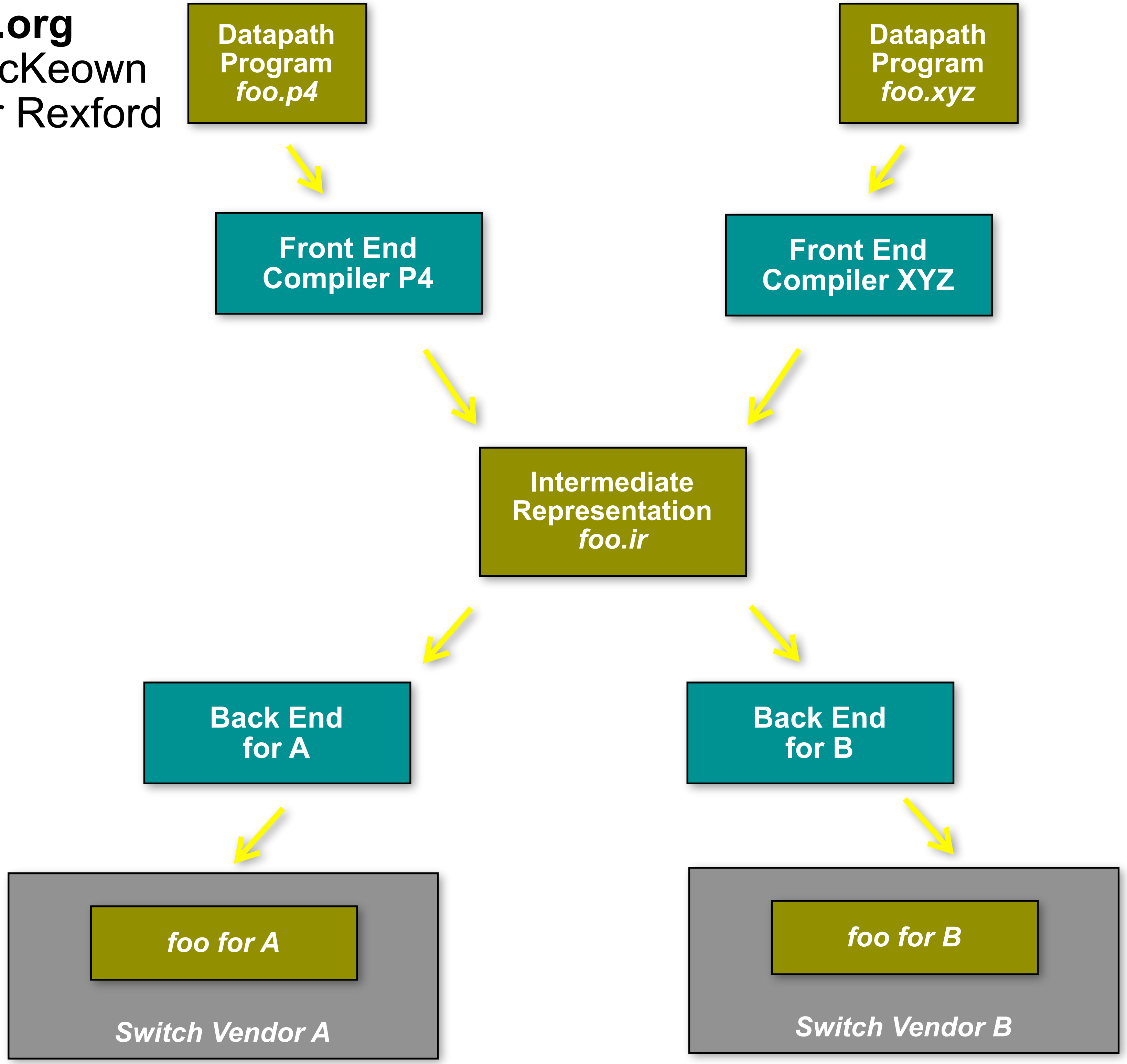


- Target platforms: various pipeline types, FPGAs, processors - CPU/NPU

Elements and Responsibilities

P4.org
Nick McKeown
Jennifer Rexford



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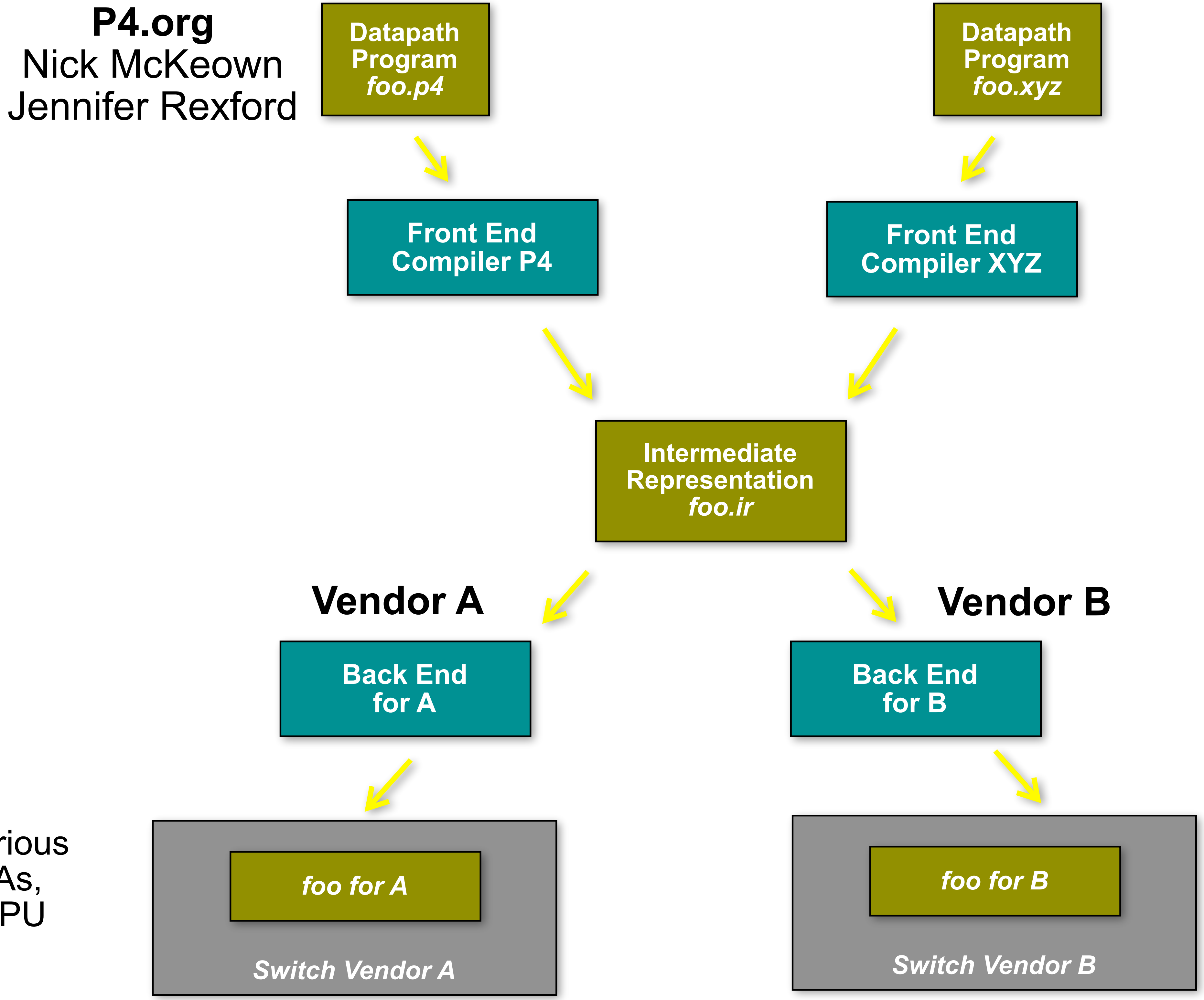

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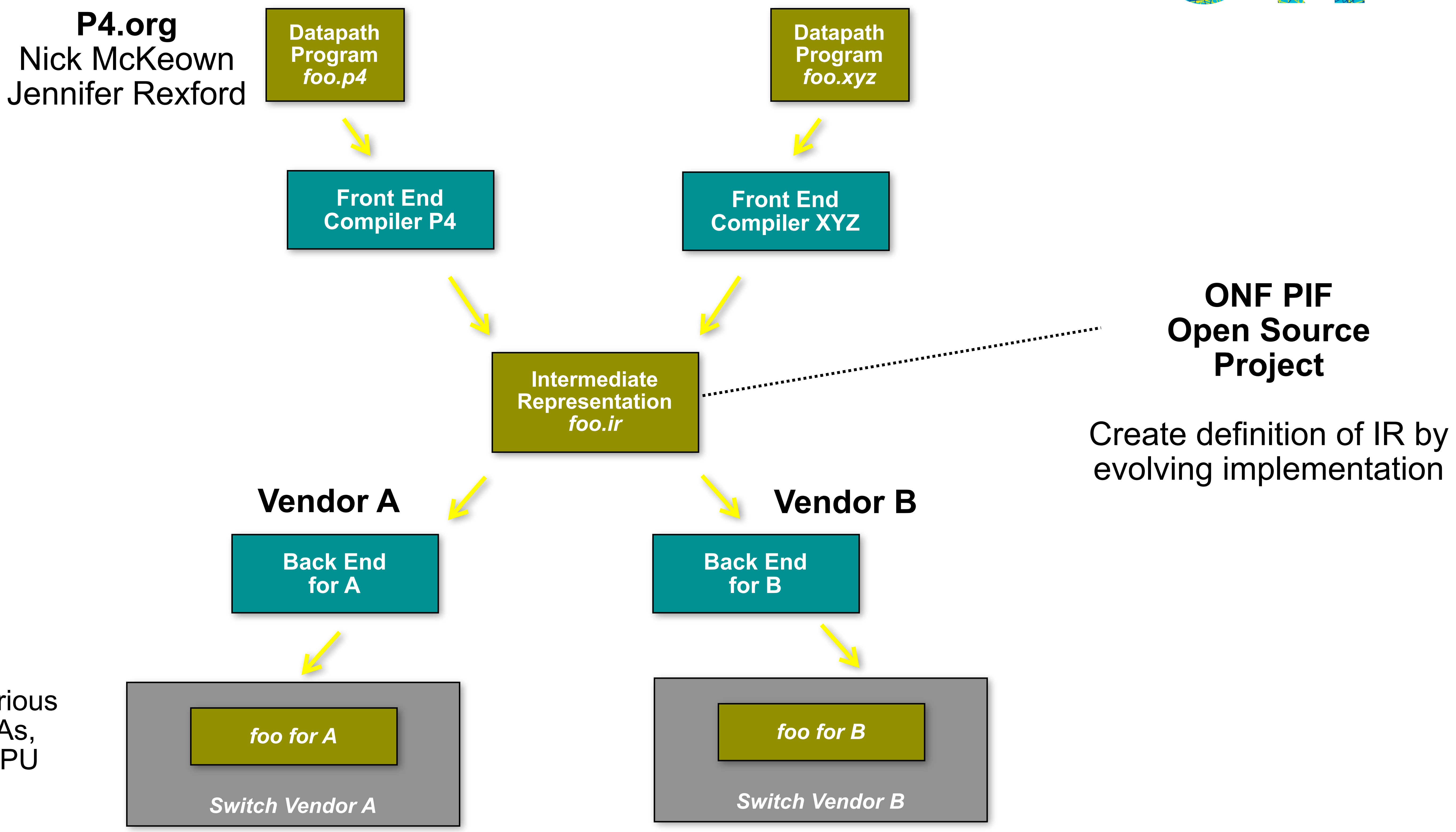

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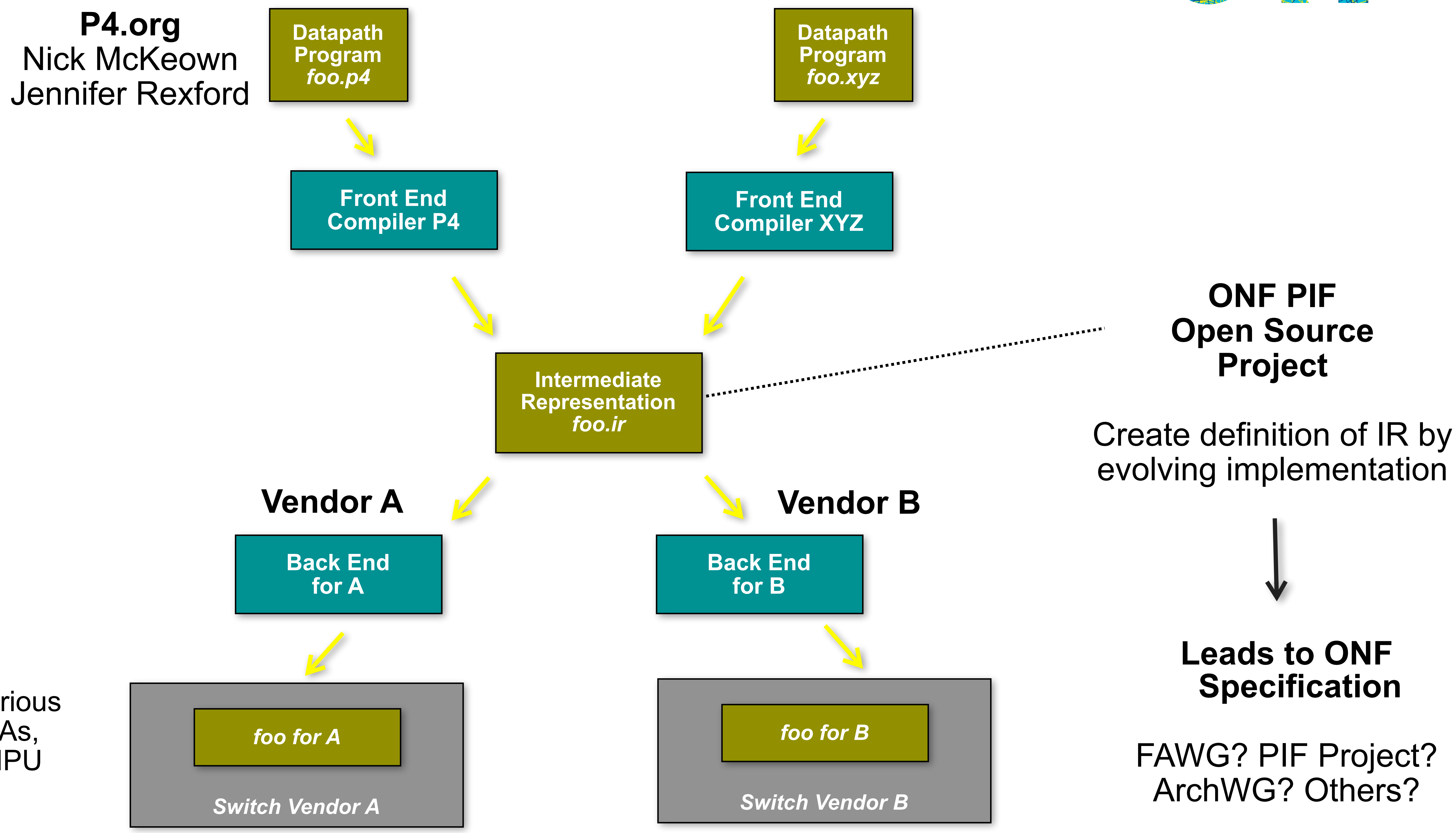

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Datapath Program
foo.p4

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Intermediate Representation
foo.ir

ONF PIF Open Source Project

Create definition of IR by evolving implementation

Leads to ONF Specification

FAWG? PIF Project? ArchWG? Others?

Vendor A

Back End for A

foo for A

Switch Vendor A

Vendor B

Back End for B

foo for B

Switch Vendor B

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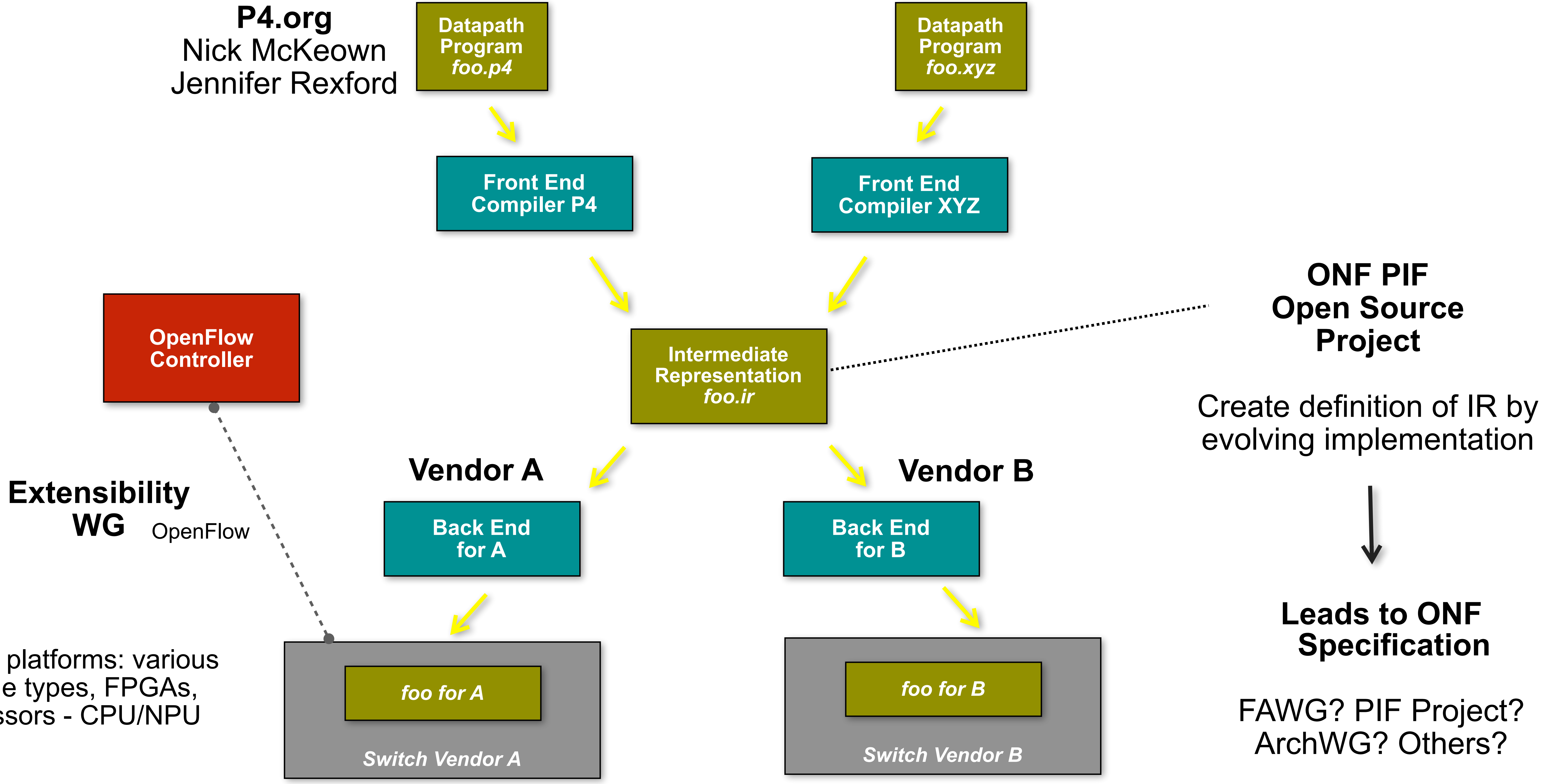
Elements and Responsibilities



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Extensibility WG

OpenFlow

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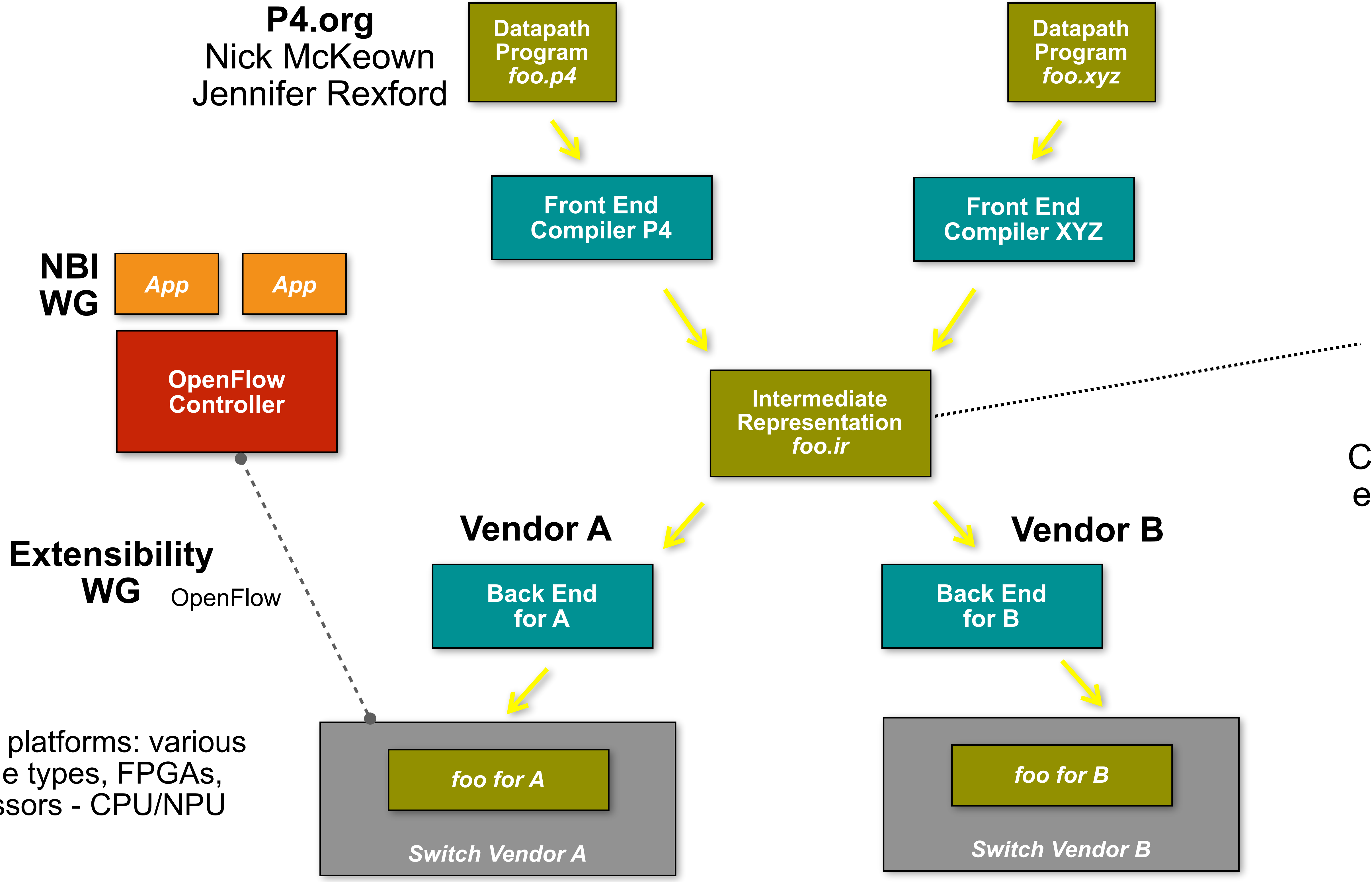

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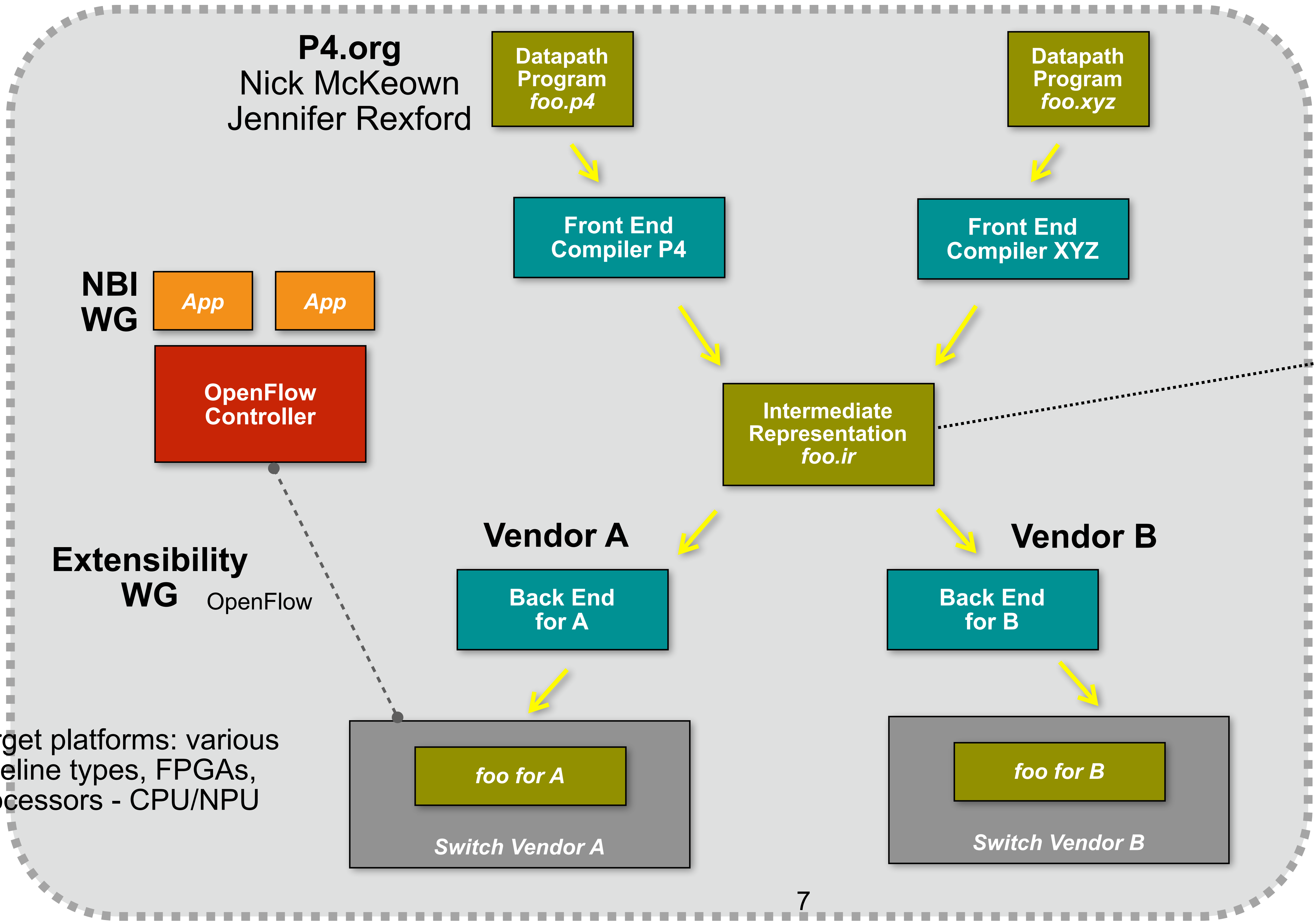

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FAWG
Wider OpenFlow-NG concerns e.g. lifecycles / forwarding models / capability profiles…

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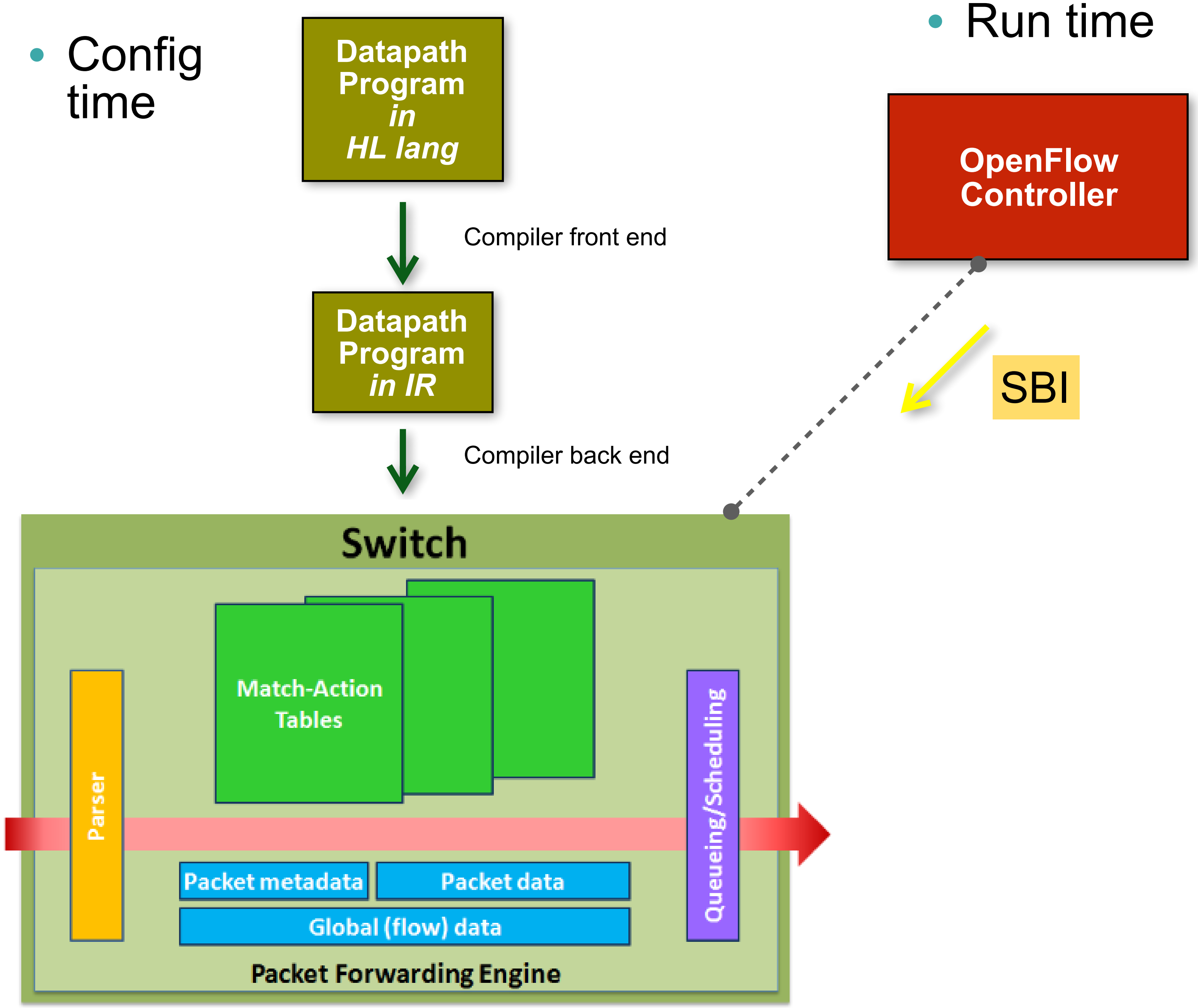
New Elements (Draft)

- Datapath program
  - Who writes it? vendor / operator / end user / their agents
  - What is it? monolitic / modular program (libraries) => ecosystem
- Front end compiler
  - Where does this run? — developer workstation or controller?
  - Who supplies it? — multi-vendor / de-facto standard?
- Back end compiler
  - Where does this run? — switch or controller?
  - Who supplies it? — almost certainly vendor specific

AIR-IRI: Prototype IR

- Config time

- Run time



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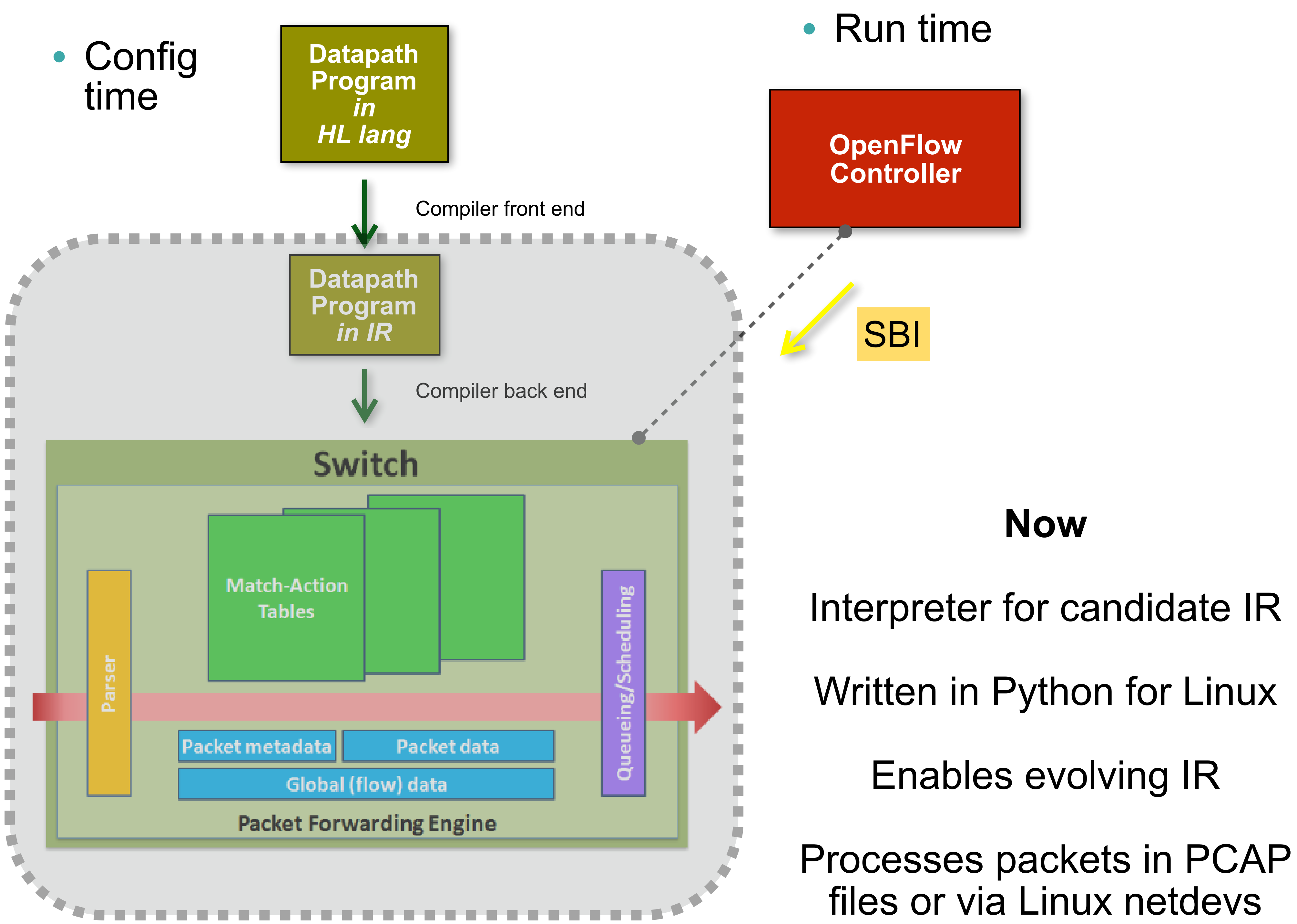

Now

Interpreter for candidate IR

Written in Python for Linux

Enables evolving IR

Processes packets in PCAP files or via Linux netdevs

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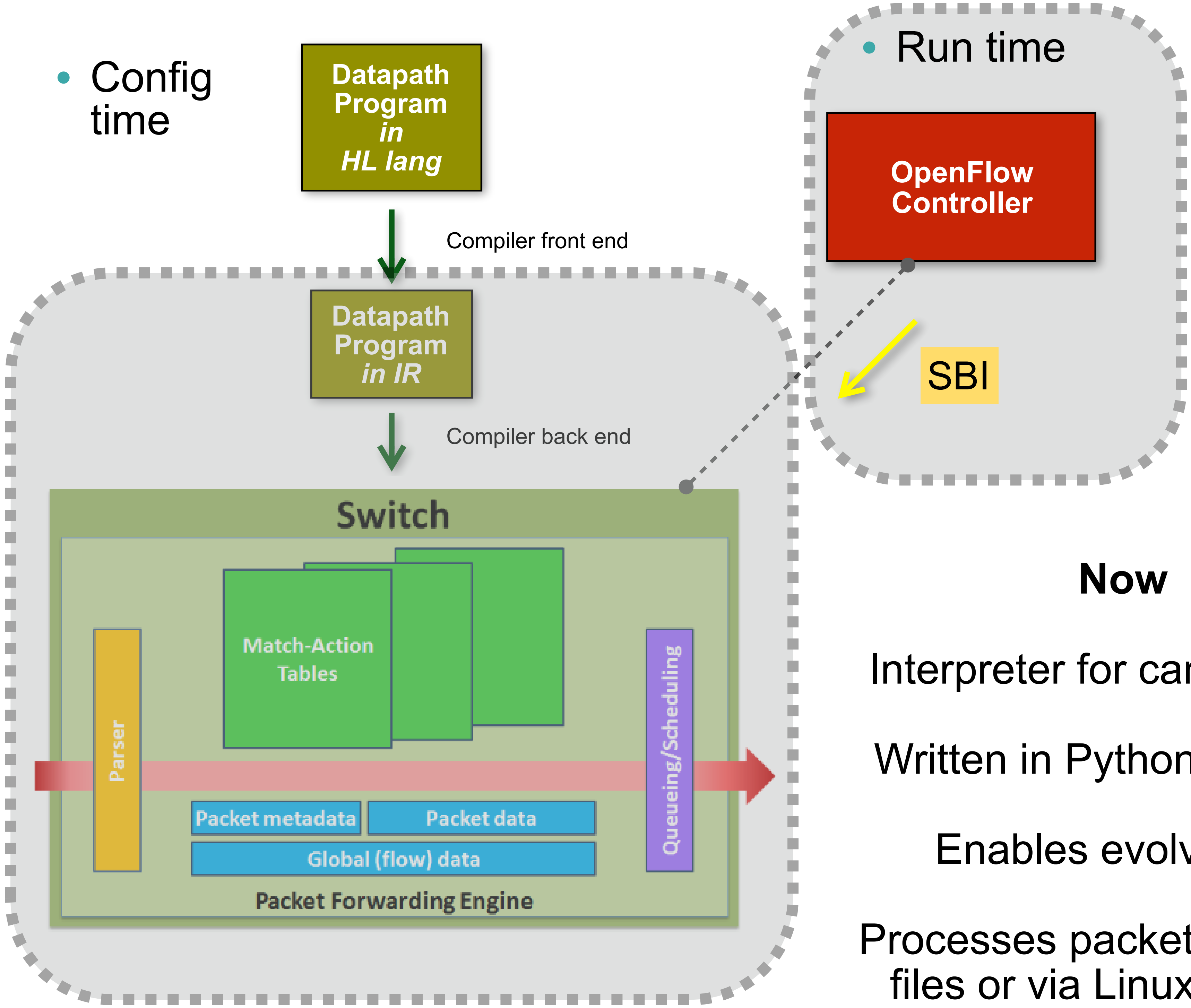

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Datapath Program *in IR*

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- Run time

OpenFlow Controller

SBI

Soon

Hook up to run-time interface
- Apache Thrift?
- OpenFlow 1.x?

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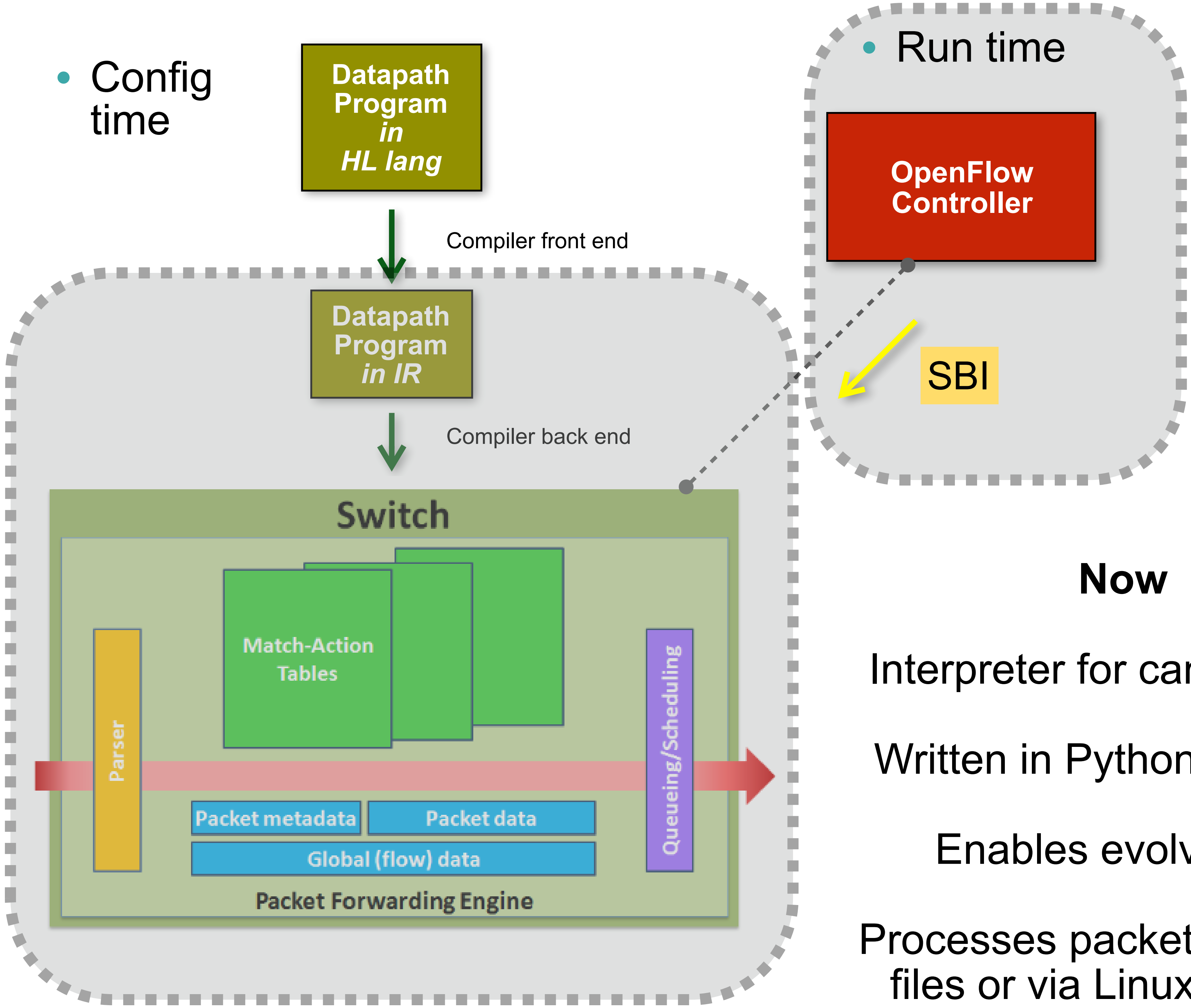

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ToDo for YOU!

Define new IR variant, improve interpreter to support it

Implement IR back end for your platform

Meta IR Facilitates Evolution / Experimentation

- AIR = framework for creating IR interpreters
  - Facilitates introducing classes of “objects”, e.g. match tables, action blocks, TM blocks
  - Each “object” has named attributes (like C structure)
  - air_meta.yml defines the objects and their attributes (declares classes/types)

- IRI = instance of an IR
  - Specific set of “objects” with implementation of each
  - Currently defined objects: value_set, value_map, table, header, metadata, action, parse_state, parser, control_flow, traffic_manager, processor_layout
  - Community invited to extend / modify this

IRI Elements: Types

```
# Complete list of types:
  - table
  - header
  - metadata
  - action
  - parse_state
  - parser
  - control_flow
  - traffic_manager
  - processor_layout
```

```
# Types with a process method:
  - control_flow
  - parser
  - traffic_manager
```

IRI Elements: Attributes per Type

```
# All support type and doc
air_attributes :
  table :
    - match_on
  header :
    - fields
    - max_depth # hdr stack if > 1
  metadata :
    - fields
    - initial_values
  action :
    - format
    - parameter_list
    - implementation
  parse_state :
    - extracts
    - select_value # Optional
```

```
# CONTINUED
  control_flow : *graph_attributes
  parser :
    - format
    - implementation
    - start_state
  traffic_manager : # Experimental
    - queues_per_port
    - dequeue_discipline
    - egress_spec_map
  processor_layout:
    - format
    - implementation
    - port_count
```

Layout: Top Level Pipeline Structure

```
layout:
  type : processor_layout
  doc  : "The layout specification for the switch instance"
  port_count : 4
  format : list
  implementation :
    - parser
    - ingress_flow
    - tm_queues
    - egress_flow
```

- Changes for each category of “datapath program” (e.g. with / without QoS)
- Simple list of processors currently implemented
  - Future: more complex topologies

Protocol / Metadata Fields and Actions

```
# Header object
ethernet :
  type : header
  doc : "The L2 header"
  fields :
    - dst_mac : 48
    - src_mac : 48
    - ethertype : 16
```

```
# Metadata object
pkt_md : # General metadata
  type : metadata
  doc : "General metadata for the packet"
  fields :
    # Virtual network instance identifier
    - vni : 16
```

```
# Action object
set_vni_a :
  type : action
  doc : "Set the VNI in metadata"
  format : action_set
  parameter_list :
    - vni_id
  implementation : >-
    modify_field(pkt_md.vni, vni_id);
```

- Protocol fields vary according to targeted network protocols
- Metadata fields and actions vary according to required behavior
- =>“Datapath programming” commencing in earnest

Protocol Details - Complete Parser

```
ethernet_p :
  type : parse_state
  doc : "Parse state for ethernet"
  extracts :
    - ethernet
  select_value :
    - ethernet.ethertype

vlan_p :
  type : parse_state
  doc : "Parse state for vlan tag"
  extracts :
    - vlan_tag
```

```
parser :
  type : parser
  doc : "Implementation of primary parser"
  format : dot
  start_state : ethernet_p
  implementation : >-
    digraph {
      ethernet_p -> vlan_p [value="0x8100"]
      ethernet_p -> vlan_p [value="0x9100"]
    }
```

- Parse tree currently specified in dedicated parser object (parsing before matching)
- Being considered: match protocol ID using a table, then trigger parsing next header (parse - match - parse - match)

Tables and Control Flow

```
vni :
  type : table
  doc : "Map VLAN to VNI"
  match_on :
    vlan_tag.vlan_id : ternary
    ethenet.src_mac : ternary

forward :
  type : table
  doc : "Forward based on L2 dest addr"
  match_on :
    pkt_md.vni : exact
    ethenet.dst_mac : exact

acl :
  type : table
  doc : "Perform ACL operations"
  match_on :
    pkt_md.vni : exact
    ethenet.dst_mac : exact
    ethenet.src_mac : exact
```

```
ingress_flow :
  type : control_flow
  doc : "The control flow for ingress"
  format : dot
  implementation : >-
    digraph {
      vni -> forward [action=set_vni_a]
      forward -> exit_control_flow [action=set_egress_a]
      forward -> exit_control_flow [action=drop_pkt_a]
    }

egress_flow :
  type : control_flow
  doc : "The control flow for egress"
  format : dot
  implementation : >-
    digraph {
      acl -> exit_control_flow [action=set_dst_mac_a]
      acl -> exit_control_flow [action=drop_pkt_a]
    }
```

AIR / IRI Evolution

- Evolve IR language interpreter
  - Enhance existing objects e.g. matching, actions, QoS
  - New concepts e.g. statefulness
- Tools operating on IR datapath programs
  - Visualization
  - Import / Export e.g. create NDM / TTP from IR program
  - Predict performance / capacity requirements
  - Transform - e.g. parse everything then match vs. incremental distributed parsing
- Introduce run-time
  - Callable auto-marshalled, e.g. Apache Thrift
  - Traditional protocol based, e.g. OpenFlow 1.x
  - Sample controller + sample applications on controller
- Samples
  - Sample datapath applications (in IR? in high level language once front end compilers ready?)
  - Libraries for common protocols, actions (+ infrastructure for this - templating)

Discussion + Next Steps