

# P4 Compiler in SDN

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Slides available at: [federicobruzzone.github.io/activities/presentations/p4-compiler-in-SDN.pdf](https://federicobruzzone.github.io/activities/presentations/p4-compiler-in-SDN.pdf)

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# Network Programmability

The ability of the software or the hardware to execute an externally defined processing algorithm<sup>2</sup>

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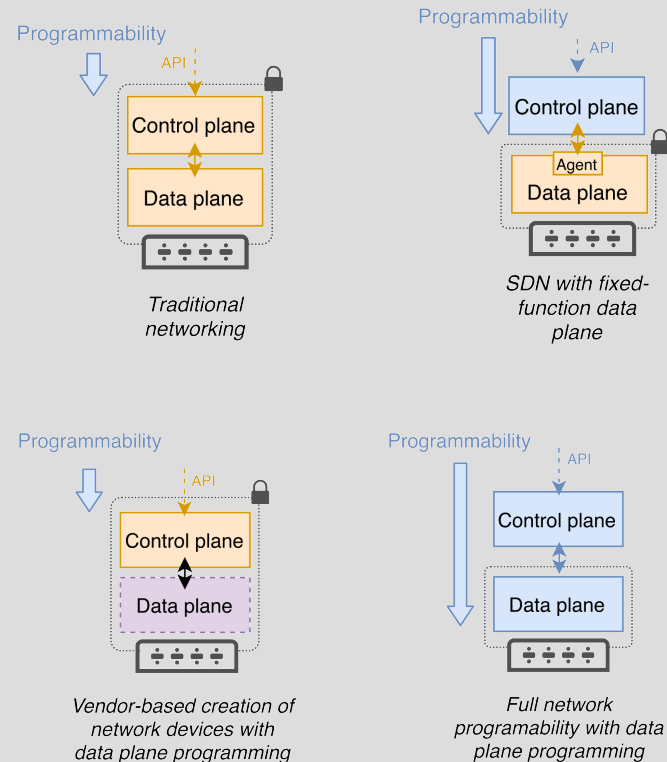
<sup>2</sup>Hauser et al., “A Survey on Data Plane Programming with P4: Fundamentals, Advances, And Applied Research”.

# Open Networking Foundation (ONF)

- Non-profit consortium founded in 2011
- Promotes networking through **Software Defined Networking** (SDN)
- Standardizes the **OpenFlow** protocol

# Software Defined Networking (SDN)

- Born to overcome the limitations of traditional network architectures
- Decouples the control plane from the data plane
- Centralizes the control of the network



# OpenFlow Protocol

- Gives access to the **forwarding plane** (data plane) of a network device
- Mainly used by switches and controllers
- Layered on top of the **Transport Control Protocol** (TCP)
- De-facto standard for SDN

# OpenFlow Development

- First appeared in 2008<sup>3</sup>
- In April 2012, Google deploys OpenFlow in its internal network with significant improvements (Urs Hölzle promotes it<sup>4</sup>)
- In January 2013, NEC rolls out OpenFlow for Microsoft Hyper-V
- Latest version is 1.5.1 (Apr 2015)

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<sup>3</sup>McKeown et al., “Openflow: Enabling Innovation in Campus Networks”.

<sup>4</sup>Inter-Datacenter WAN with centralized TE using SDN and OpenFlow.

# Fields in OpenFlow Standard

Version	Date	Header Fields
OF 1.0	Dec 2009	12 fields (Ethernet, TCP/IPv4)
OF 1.1	Feb 2011	15 fields (MPLS, inter-table metadata)
OF 1.2	Dec 2011	36 fields (APR, ICMP, IPv6, etc.)
OF 1.3	Jun 2012	40 fields
OF 1.4	Oct 2013	41 fields

More Details on the OpenFlow v1.0.0 Switch Specification<sup>5</sup>

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<sup>5</sup><https://opennetworking.org/wp-content/uploads/2013/04/openflow-spec-v1.0.0.pdf>

# OpenFlow is protocol-dependent

Fixed set of fields and parser based on standard protocols

(Ethernet, IPv4/IPv6, TCP/UDP)



# P4: Programming Protocol-Independent Packet Processors

Bosshart believed that future generations of OpenFlow would have allowed the controller to *tell the switch how to operate*<sup>6</sup>

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<sup>6</sup>Bosshart et al., “P4: Programming Protocol-Independent Packet Processors”.

## Goals and Challenges

**Reconfigurability:** the controller should be able to redefine the packet parsing and processing in the field

**Protocol Independence:** the switch should *headers* using parsing and processing using *match+action* tables

**Target Independence:** a compiler from *target-independent* description to *target-dependent* binary

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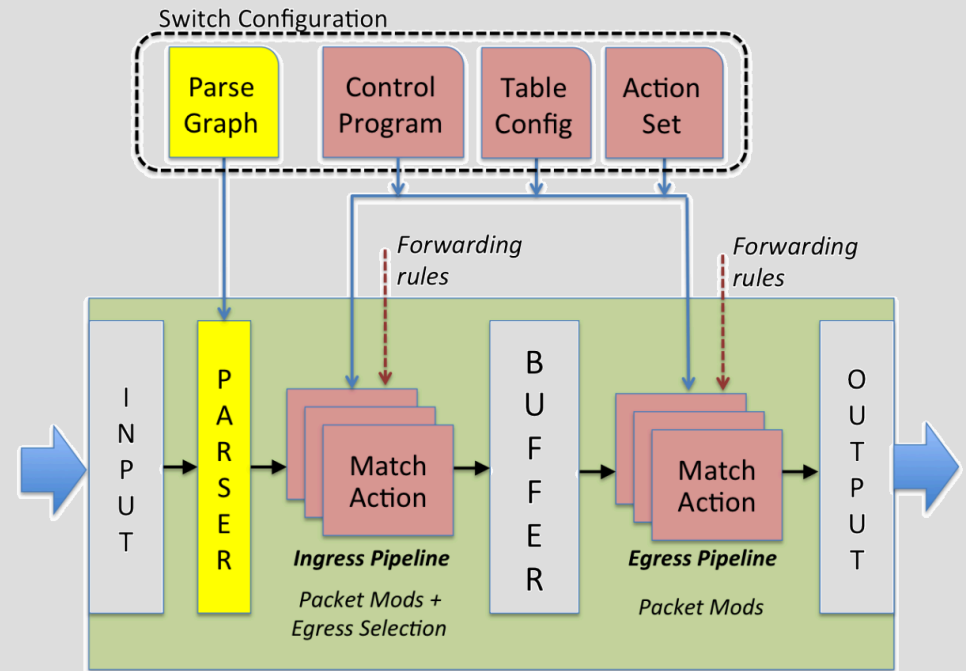
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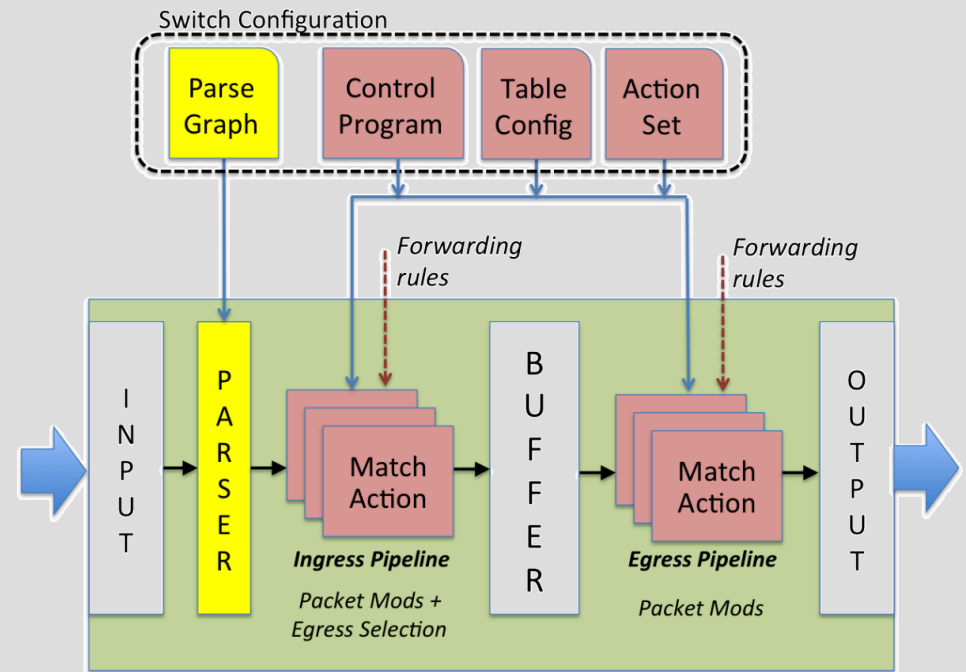
# Abstract Forwarding Model (AFM)

1. Parsing the packet headers
2. The fields are passed to the match-action pipeline.
  - **Ingress:** determines the egress port/queue
  - **Egress:** per-instance header modifications
3. Metadata processing (e.g., timestamp)
4. As in OpenFlow, the queuing discipline is chosen at switch configuration time (e.g., minimum rate)



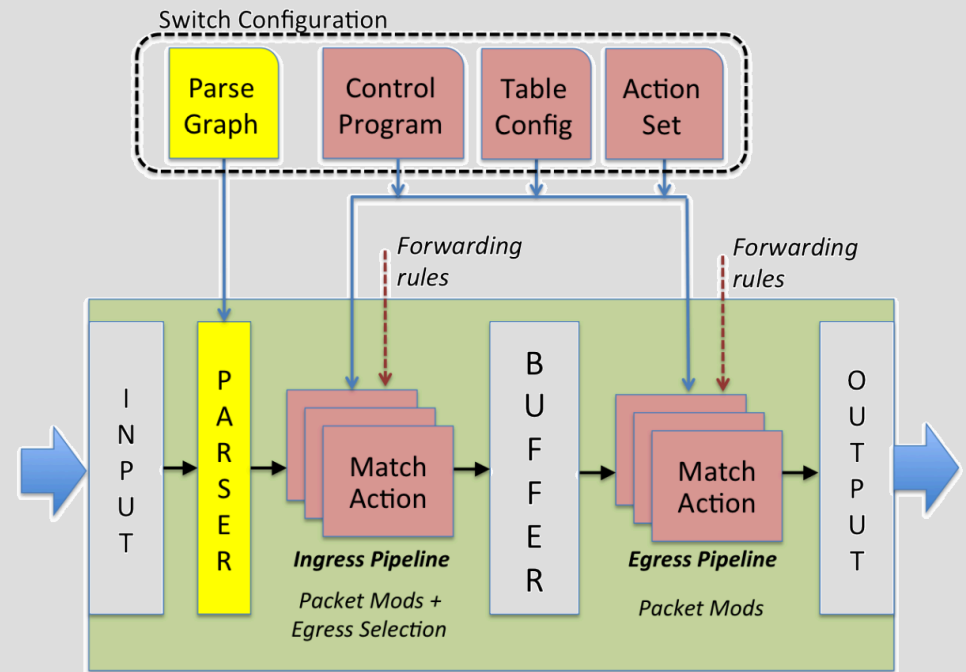
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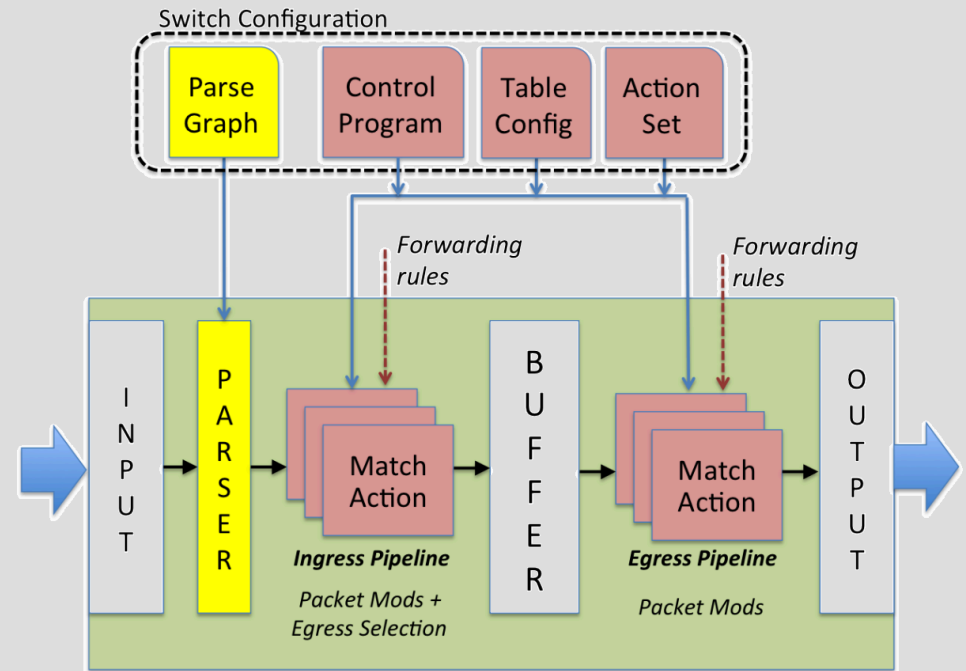
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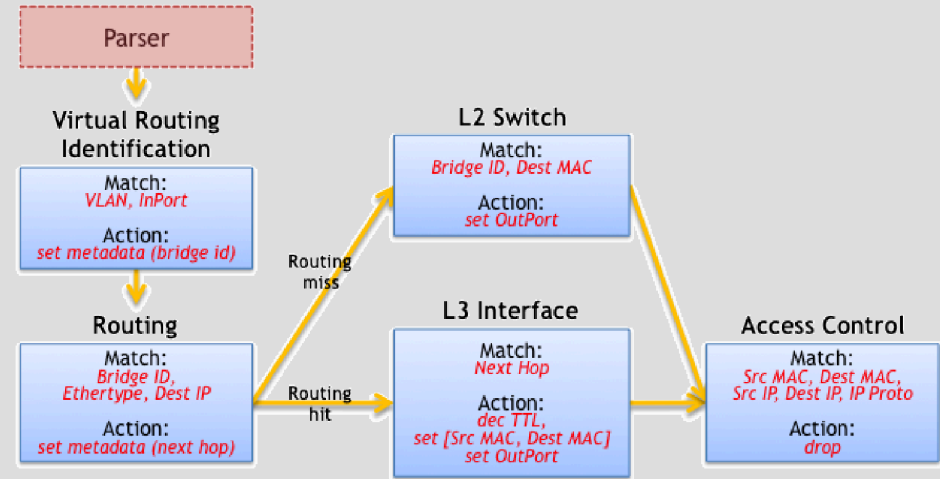




# Two-stage Compilation

Imperative control flow program based on AFM

1. The compiler translate the P4 program into **TDGs** (Table Dependency Graphs)
2. The TDGs are compiled into **target-dependent code**



# Language Design

Header: Describes the structure of a series of fields including the widths and constraints on values

Parser: Specifies how to identify headers and valid header sequences within packets

Tables: The P4 program defines the fields on which a table may match and the actions it may execute

Actions: P4 supports construction of complex actions from simpler protocol-independent primitives. These complex actions are available within match+action

Control Programs: The control program determines the order of match+action tables that are applied to a packet. A simple imperative program describe the flow of control between match+action

# Header

```
header ethernet {  
    fields {  
        dst_addr: 48; // bits  
        src_addr: 48;  
        ethertype: 16;  
    }  
}
```

```
header vlan {  
    fields {  
        pcp: 3;  
        cfi: 1;  
        vid: 12;  
        ethertype: 16;  
    }  
}
```

# Parser

# Tables

# Actions

Define the operations that can be performed on the packet

# Control Programs

Define the control flow of the packet processing pipeline

