Software Defined Networking

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In this course, you will learn about software defined networking and how it is changing the way communications networks are managed, maintained, and secured.

This Lesson: Protocol Independent Packet Processing

- Motivation
- Two examples
  - P4: Programming Protocol-Independent Packet Processors (main focus)
  - POF: Protocol Oblivious Forwarding

Material adapted from Jennifer Rexford's talk at ONS 2014

Over the Past Five Years...

Version	Date	# Headers
OF 1.0	Dec 2009	12
OF 1.1	Feb 2011	15
OF 1.2	Dec 2011	36
OF 1.3	Jun 2012	40
OF 1.4	Oct 2013	41

- Control and data not sufficiently decoupled
- No easy way to modify packet format
- Adding new features requires changing FE and controller

Desirable Features in SDN Switches

- Configurable packet parser
  - Not tied to a specific header format
- Flexible match+action tables
  - Multiple tables (in series and/or parallel)
  - Able to match on all defined fields
- General packet-processing primitives
  - Copy, add, remove, and modify
  - For both header fields and meta-data

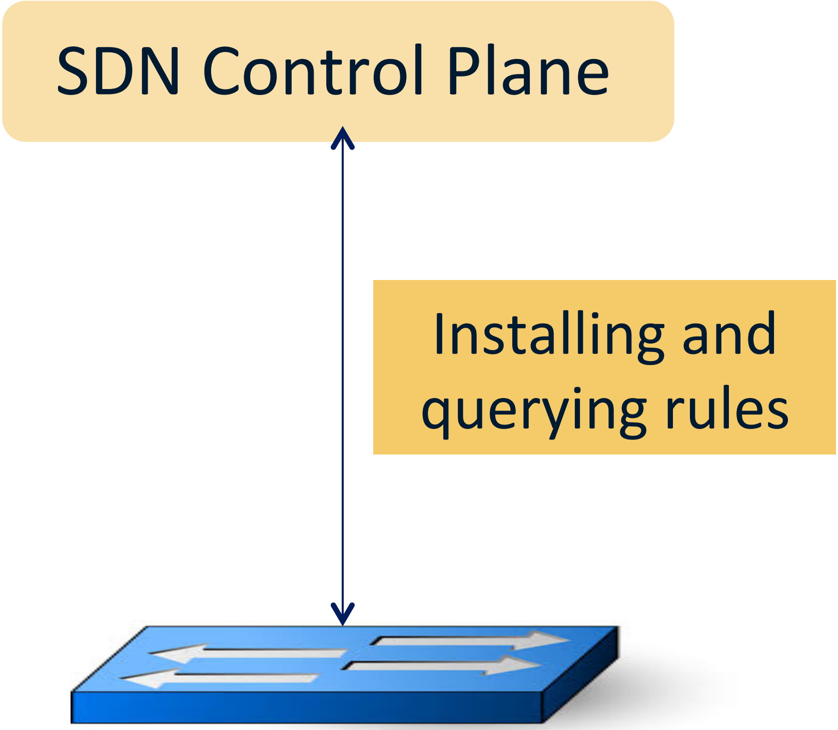
New Hardware Makes This Possible

- New generation of switch ASICs
  - Intel FlexPipe
  - RMT [SIGCOMM'13]
  - Cisco Doppler
- But, programming these chips is hard
  - Custom, vendor-specific interfaces
  - Low-level, akin to microcode programming

Three Goals

- Protocol independence
  - Configure a packet parser
  - Define a set of typed match+action tables
- Target independence
  - Program without knowledge of switch details
  - Rely on compiler to configure the target switch
- Reconfigurability
  - Change parsing and processing in the field

"Classic" OpenFlow (1.x)

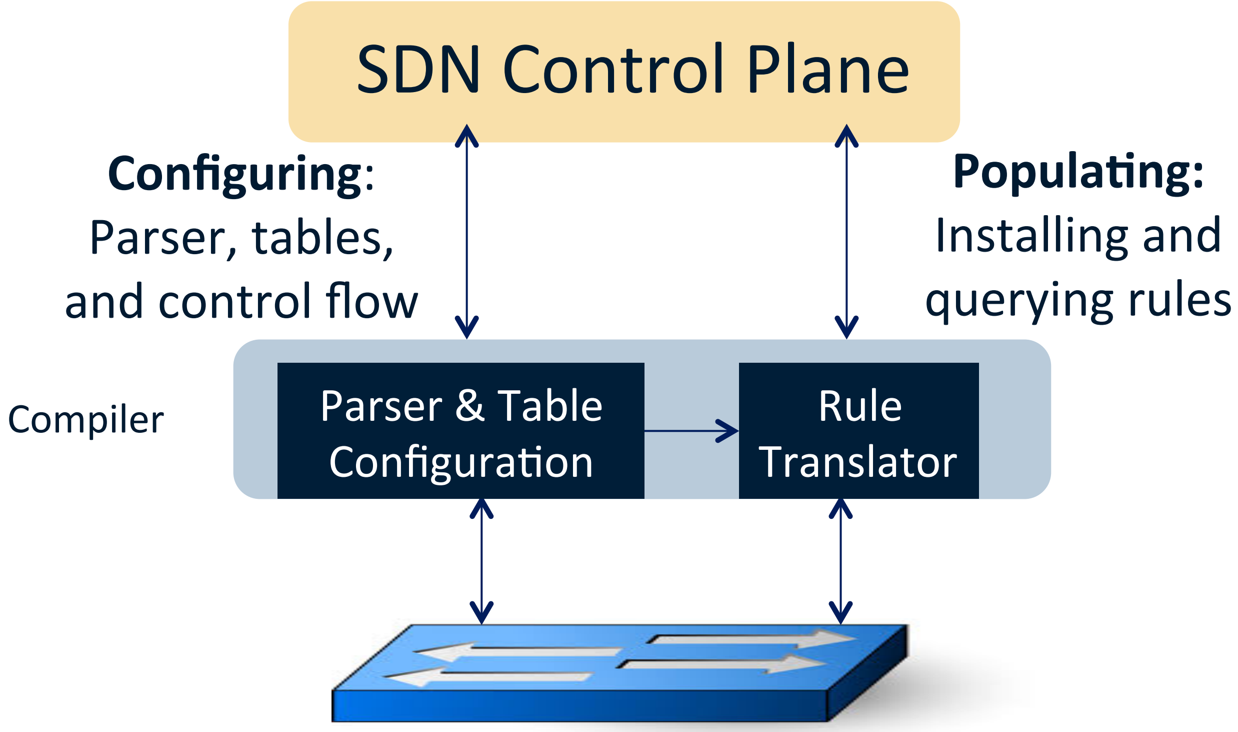


SDN Control Plane

Installing and querying rules

Software Defined Networking

"OpenFlow 2.0"



SDN Control Plane

Configuring:
Parser, tables,
and control flow

Populating:
Installing and
querying rules

Compiler

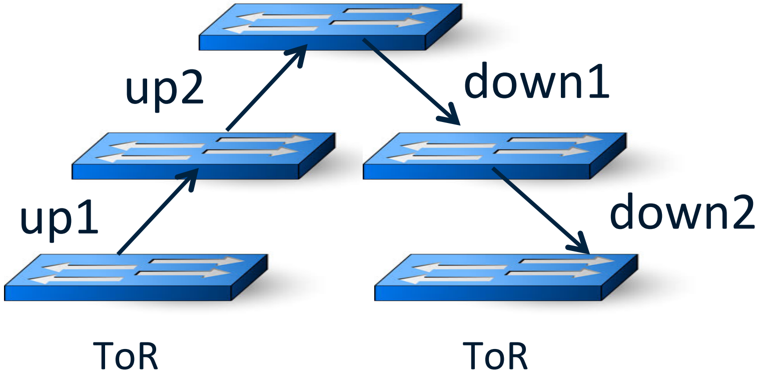
Parser & Table
Configuration

Rule
Translator

Simple Motivating Example

- Data-center routing
  - Top-of-rack switches
  - Two tiers of core switches
  - Source routing by ToR

- Hierarchical tag (mTag)
  - Pushed by the ToR
  - Four one-byte fields
  - Two hops up, two down



Header Formats

- Ordered list of fields
- A field has a name and width

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

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

```
header mTag {
  fields {
    up1 : 8;
    up2 : 8;
    down1 : 8;
    down2 : 8;
    ethertype : 16;
  }
}
```

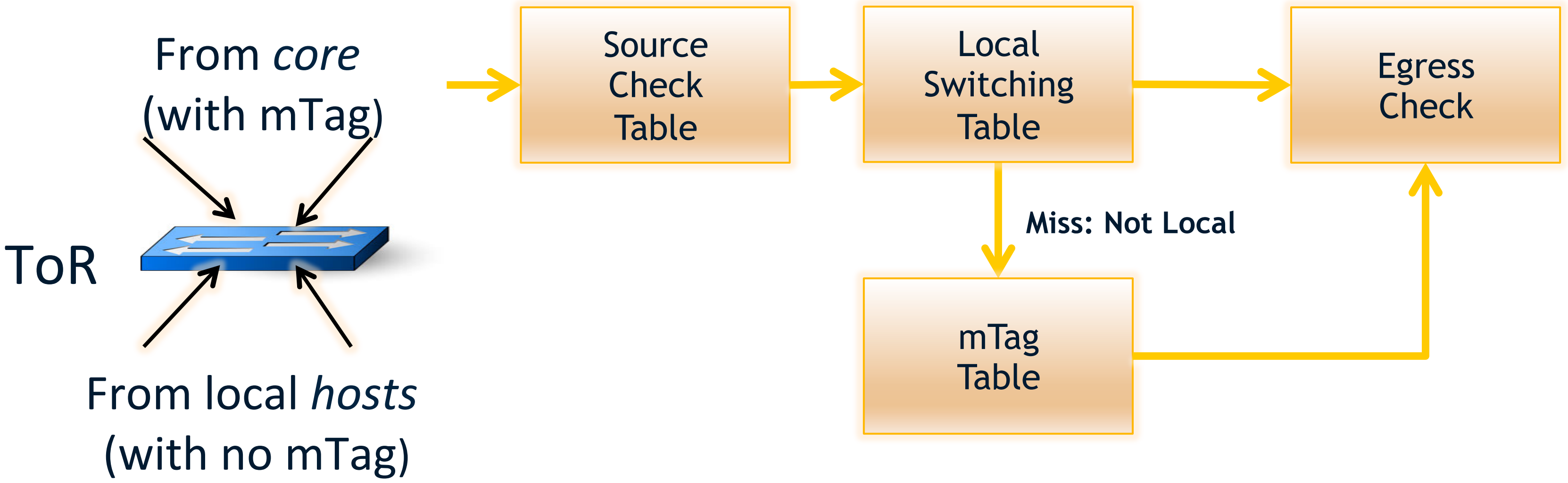
Typed Tables

- Describe each packet-processing stage
  - What fields are matched, and in what way
  - What action functions are performed
  - (Optionally) a hint about max number of rules

```
table mTag_table {
  reads {
    ethernet.dst_addr : exact;
    vlan.vid : exact;
  }
  actions {
    add_mTag;
  }
  max_size : 20000;
}
```

Control Flow

- Flow of control from one table to the next
  - Collection of functions, conditionals, and tables



P4 Compiler

- Parser
  - **Programmable parser:** translate to state machine
  - **Fixed parser:** verify the description is consistent
- Control program
  - **Target-independent:** table graph of dependencies
  - **Target-dependent:** mapping to switch resources
- Rule translation
  - Verify that rules agree with the (logical) table types
  - Translate rules to tables

Compiling to Target Switches

- Software switches
  - Directly map the table graph to switch tables
  - Use data structure for exact/prefix/ternary match
- Hardware switches with RAM and TCAM
  - RAM: hash table for tables with exact match
  - TCAM: for tables with wildcards in the match
- Switches with parallel tables
  - Analyze table graph for possible concurrency

Compiling to Target Switches

- Applying actions at the end of pipeline
  - Instantiate tables that generate meta-data
  - Use meta-data to perform actions at the end
- Switches with a few physical tables
  - Map multiple logical tables to one physical table
  - “Compose” rules from the multiple logical tables
  - … into “cross product” of rules in physical table

Conclusion

- OpenFlow 1.x
  - Vendor-agnostic API
  - But, only for fixed-function switches
- An alternate future
  - Protocol independence
  - Target independence
  - Reconfigurability in the field
- P4: a strawman proposal
  - Other proposals: POF