Programmable Networks – P4 overview

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Worlds Fastest Most Programmable Networks Barefoot Networks white paper, 2016.

P4: Programming protocol-independent packet processors. *ACM SIGCOMM Computer Communication Review*, 2014 Pat Bosshart† , Dan Daly* , Glen Gibb† , Martin Izzard† , Nick McKeown‡ , Jennifer Rexford** , Cole Schlesinger**, Dan Talayco† , Amin Vahdat¶ , George Varghese§ , David Walker** †Barefoot Networks * Intel ‡Stanford University **Princeton University ¶Google §Microsoft Research.

Why programmable networks

- Deploy tests and probes, can reduce time to recover from an outage
- Monitoring networks can be eliminated because network can now monitor itself
- Eliminate redundant equipment. For example, big data-centers today commonly deploy expensive middleboxes – load-balancers, address translators, complex Network Function Virtualization (NFV) cluster of thousands of servers to load-balance incoming packets across web servers.
- Only slow networks are programmable now. NPUs and FPGAs exist and are flexible. But are 1/100th performance of fixed-function ASICs

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Barefoot Networks

- Created first programmable chip that performs like ASIC
- P4 - Programming Protocol-independent Packet Processors – www.p4.org exists now as an independent entity to develop a rich open source ecosystem
- P4 offers a programming abstraction that is familiar to network owners rather than VHDL
- Proposed architecture does for networking what DSP did for signal processing, GPU did for graphics and TPU is doing for machine learning
- Programs are written in a high level domain specific language (P4), compiled down by Barefoot Capilano compiler, and optimized to run at full line-rate on PISA device

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P4

P4 is a high-level language for programming protocol-independent packet processors

OpenFlow explicitly specifies protocol headers on which it operates. This set has grown from 12 to 41 fields in a few years, increasing complexity of specification

(1) Reconfigurability : Programmers should be able to change way switches process packets once deployed

(2) Protocol independence: Switches should not be tied to any specific network protocols

(3) Target independence: independent of specifics of underlying hardware

Future switches should support mechanisms for parsing packets and matching header allowing controller applications to leverage capabilities of common, open interface (i.e., a new \OpenFlow 2.0" API).

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What does it do

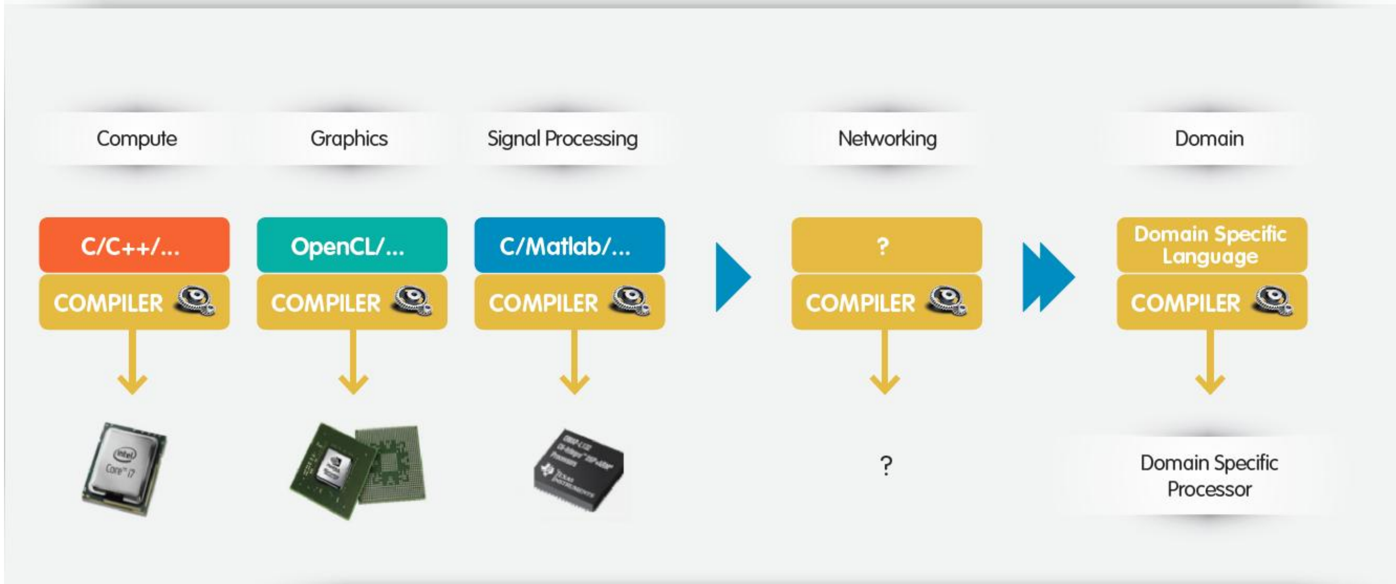

FIGURE 1 Opportunity to "compile" the networks

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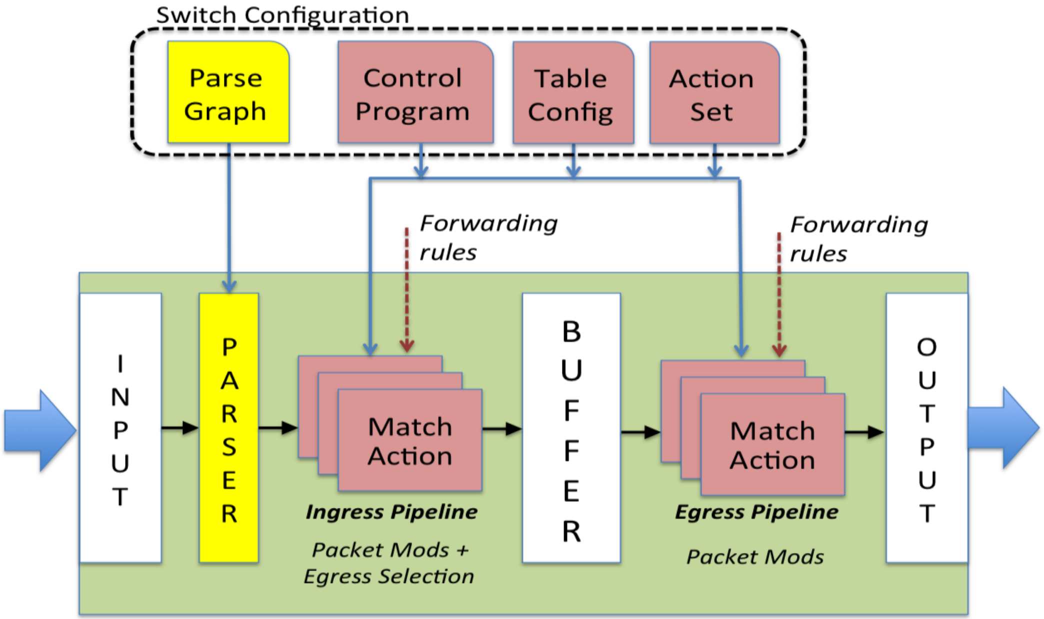
Steps in P4



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Header Formats

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

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


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Packet Parser

Parsing starts in start state and proceeds until an explicit stop state is reached

Extracted headers are forwarded to match+action processing

```
parser start {
        ethernet;
}
parser ethernet {
        switch(ethertype) {
        case 0x8100: vlan;
        case 0x9100: vlan;
        case 0x800: ipv4;
        // Or cases
        }
}
parser vlan {
        switch(ethertype) {
        case 0xaaaa: mTag;
        case 0x800: ipv4;
        // Or cases
        }
}
parser mTag {
        switch(ethertype) {
        case 0x800: ipv4;
        // Or cases
}
}
```


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Table specification

- Programmer describes how header fields are to be matched in match+action stages (e.g., should they be exact matches, ranges, or wildcards?) and what actions should be performed when a match occurs
- Reads attribute declares which fields to match, qualified by match type (exact, ternary, etc)
- Actions attribute lists possible actions which may be applied to a packet by table

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Table action

P4's primitive actions include:
set field: Set a header to a value. Masked sets are supported.
copy field: Copy one field to another.
add header: Set a specific header instance (and all its fields) as valid.
remove header: Delete (\pop") a header (and all its fields) from a packet.
increment: Increment or decrement value in a field.
checksum: Calculate a checksum over some set of header fields (e.g., an IPv4 checksum).

```
action add_mTag(up1, up2, down1, down2,
egr_spec) {
        add_header(mTag);
        // Copy VLAN ethertype to mTag
        copy_field(mTag.ethertype, vlan.ethertype);
        // Set VLAN's ethertype to signal mTag
        set_field(vlan.ethertype, 0xaaaa);
        set_field(mTag.up1, up1);
        set_field(mTag.up2, up2);
        set_field(mTag.down1, down1);
        set_field(mTag.down2, down2);
        // Set  destination egress port as well
        set_field(metadata.egress_spec, egr_spec);
}
```


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Control Program

Once tables and actions are defined, only remaining task is to specify flow of control from one table to next

Control flow is specified as a program via a collection of functions, conditionals, and table references

```
control main() {
	// Verify mTag state and port are
consistent
table(source_check);
	// If no error from source_check,
continue
	if (!defined(metadata.ingress_error))
{
	// Attempt to switch to end hosts
table(local_switching);
	if (!defined(metadata.egress_spec))
{
	// Not a known local host; try
mtagging
```


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Conclusion

- Proposed a step towards more flexible switches whose functionality is specified and may be changed once deployed
- Programmer decides how forwarding plane processes packets without worrying about implementation details
- A compiler transforms an imperative program into a table dependency graph that can be mapped to many target switches, including optimized hardware implementations