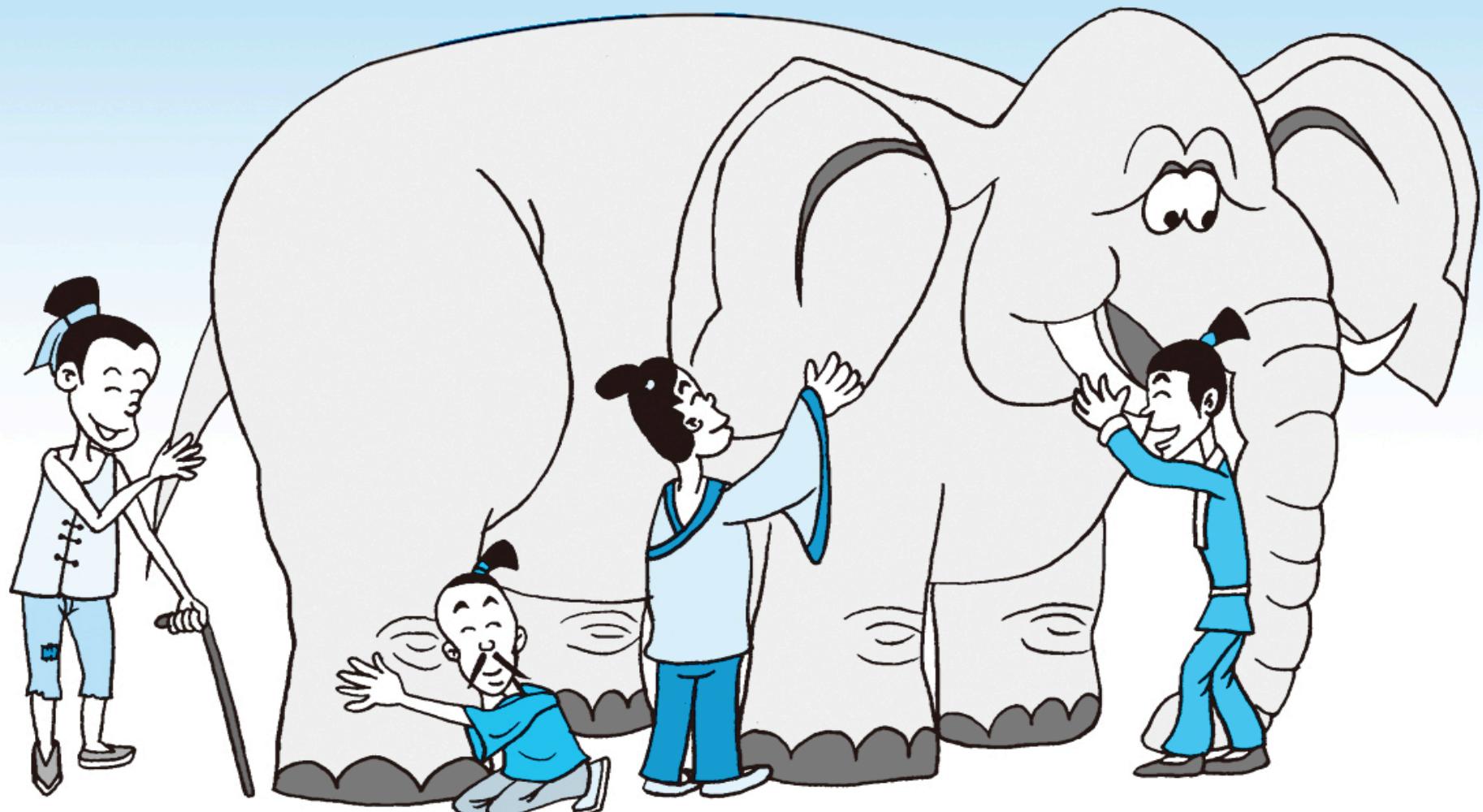


A Gentle Introduction to SDN

Y. Richard Yang
Yale/Tongji

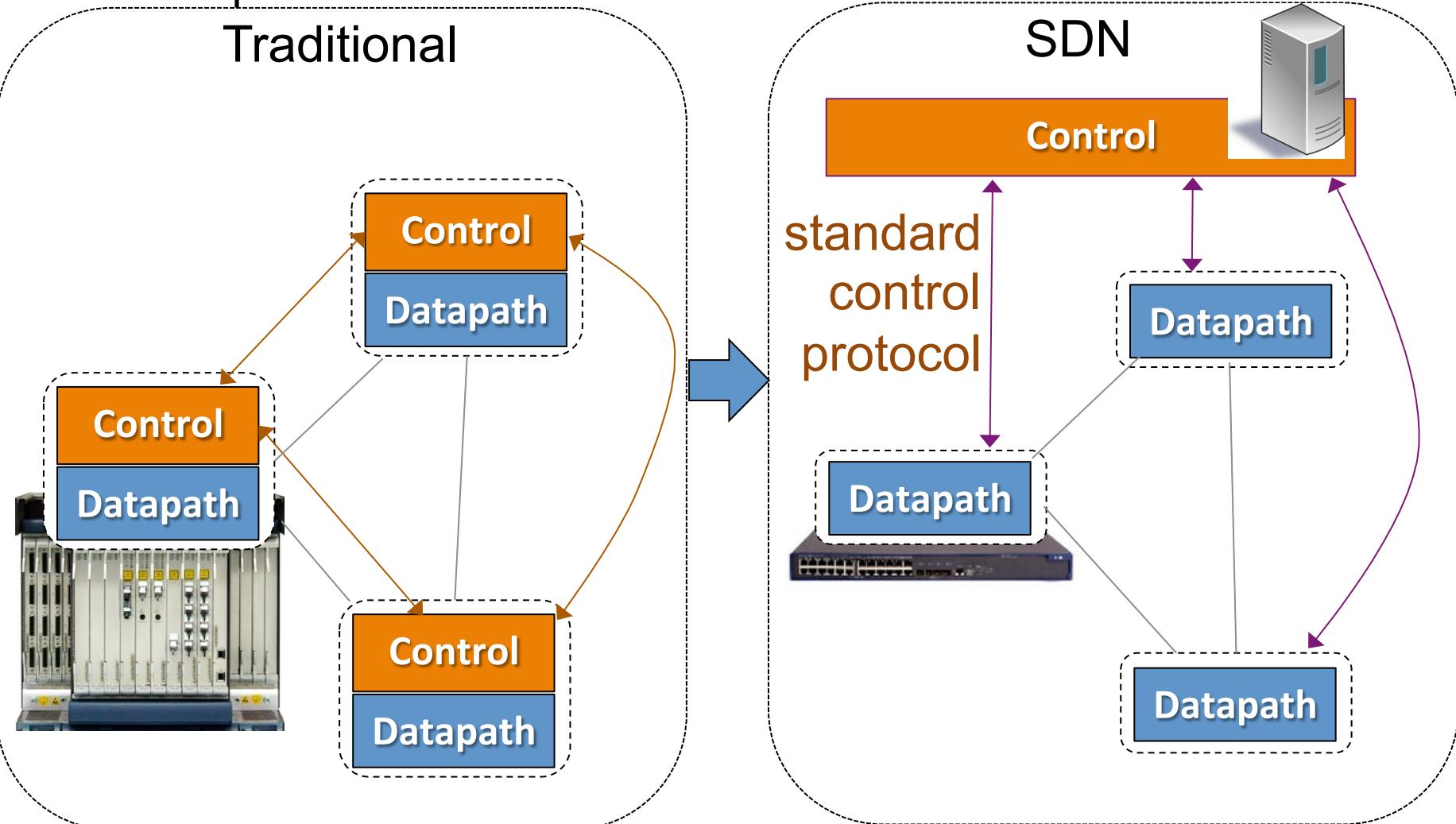
Dec. 4, 2015

What is Software Defined Networking (SDN)?

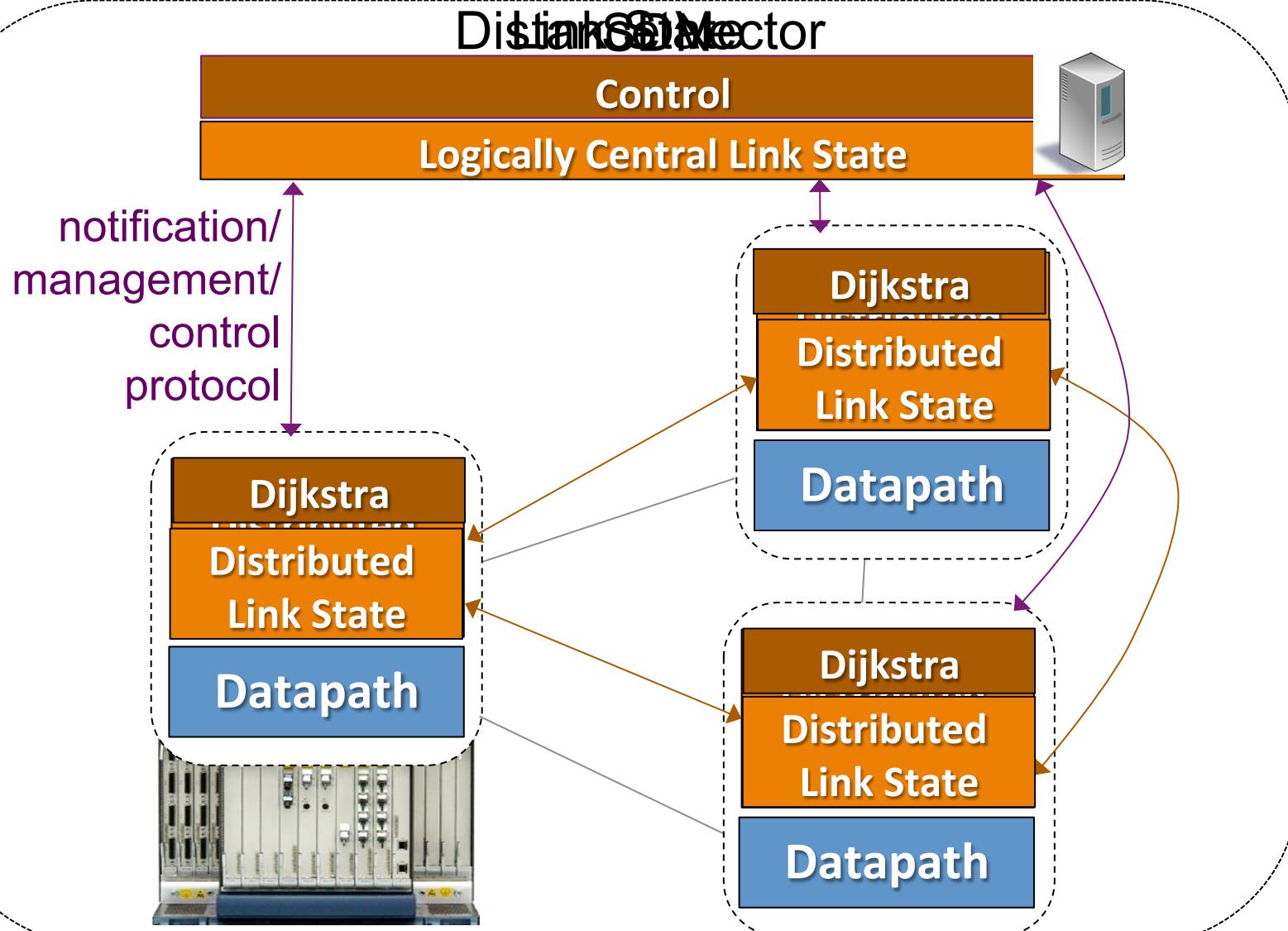


What is SDN: a “Main-Stream” View

- Separation of data and control paths, with a logically centralized control plan



An Evolution View of Intradomain Routing Toward SDN

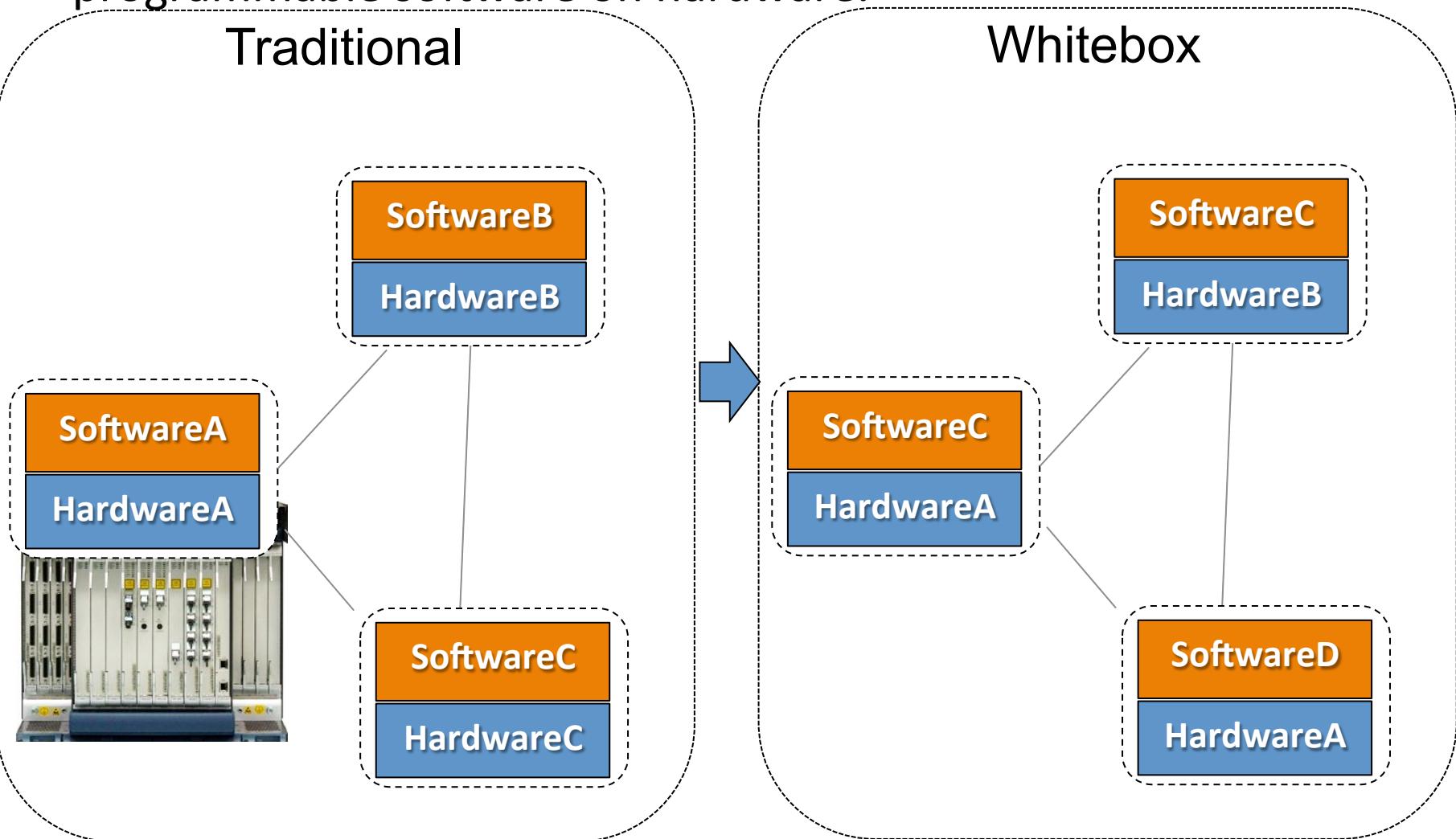


Why SDN (A “Wiseman” View)?

- Distributed computing is hard, e.g.,
 - FLP Impossibility Theorem
 - Arrow’s Impossibility Theorem
- Achieved good design for only few specific tasks (e.g., state distribution, leader election). Hence, one can consider SDN as a way of moving away from generic distributed computing, by focusing on utilizing the few well-understood primitives, in particular logically centralized state.

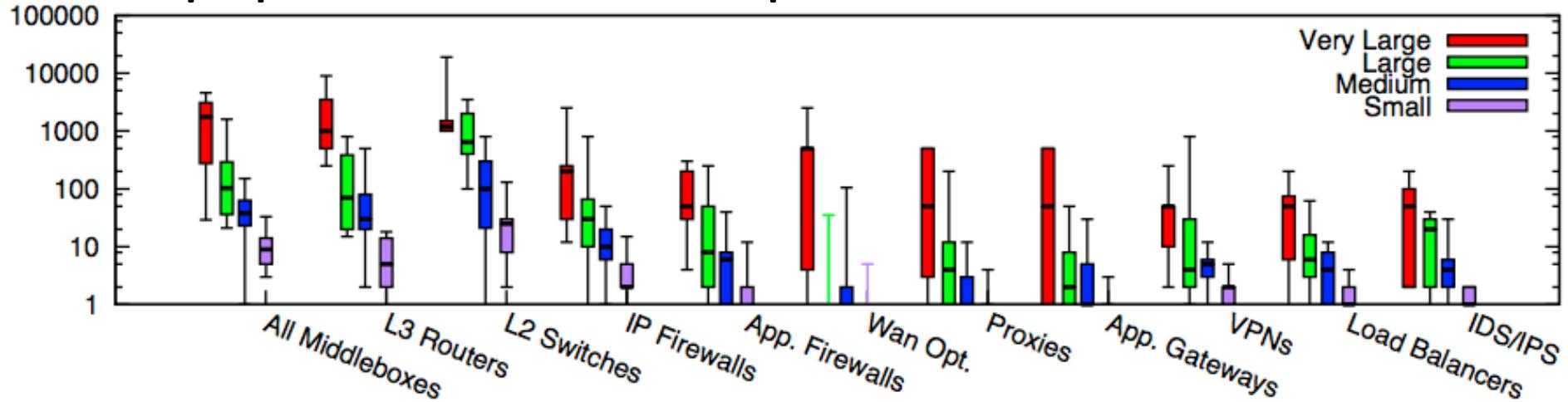
What is SDN: a “Whitebox”/Programmable-Network View

- Separation of switch hardware and software, or at least more programmable software on hardware.



Why SDN or More Programmable Networks?

- Modern networks contain diverse types of equipment from multiple vendors



Small: <=1k hosts; Medium: 1k-10k; Large: 10k-100k; Very Large: >= 100k Source: [Sherry, et. al SIGCOMM'12]

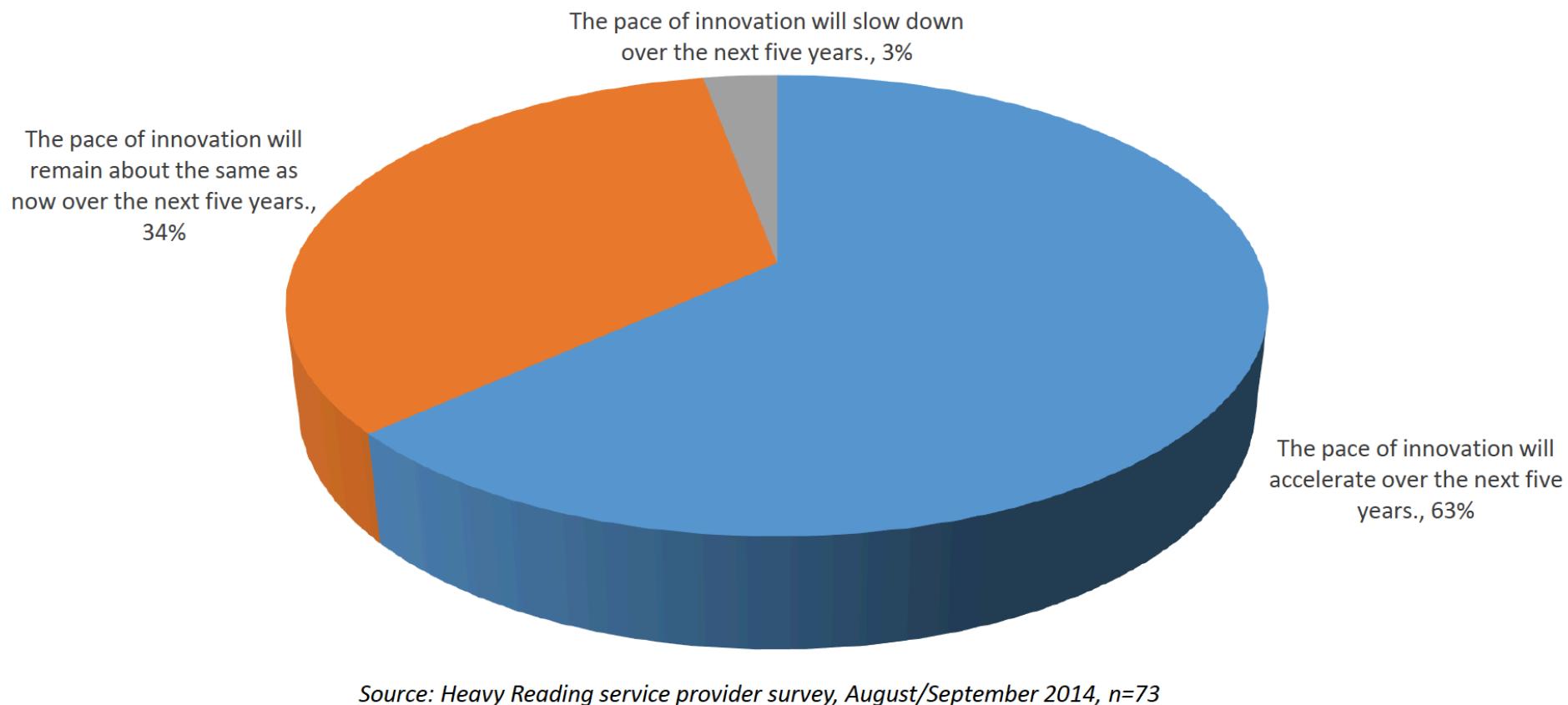
- In traditional settings, each type/vendor runs in its own hardware box, with its own software
- More programmable (new app, new VM, new net OS, open source...) => More flexibility, lower TCO

Why SDN or More Programmable Networks?

- Network customization/feature requests can be a slow process. Open/programmable systems can speedup the process and allow more **innovations**.

Type	ID	Name	Priority Class.	Severity	Estimate
Story	362	New Story	3 - Could Have		
Story	361	New Story	3 - Could Have		
Story	18	Show vacation history	3 - Could Have		
Story	17	Show employees' vacations	3 - Could Have		
Story	16	Send notification for approved request from Manager	3 - Could Have		
Story	15	Generate employee/team reports	3 - Could Have		
Story	14	Add explanation if the vacation is not approved	3 - Could Have		
Story	13	Send notification for vacation request response	3 - Could Have		
Story	12	Send notification for vacation request	2 - Should Have		
Story	11	Add different types of vacations	3 - Could Have	40	
Story	10	Add employees' roles to Employee Management	2 - Should Have	24	
Story	9	Add an employee/team management	2 - Should Have	48	
Story	8	Manage team calendar	2 - Should Have	32	
Story	7	Add company calendar's management	2 - Should Have	72	
Story	6	Add employees' vacation days manager	2 - Should Have	64	
Story	5	Show vacation days left	1 - Must Have	24	
Bug	5	Team events shows up in company's calendar	1 - Critical	12	

Service Provider Expectation on Pace Innovation



More Programmable Networks are a Well Recognized Trend

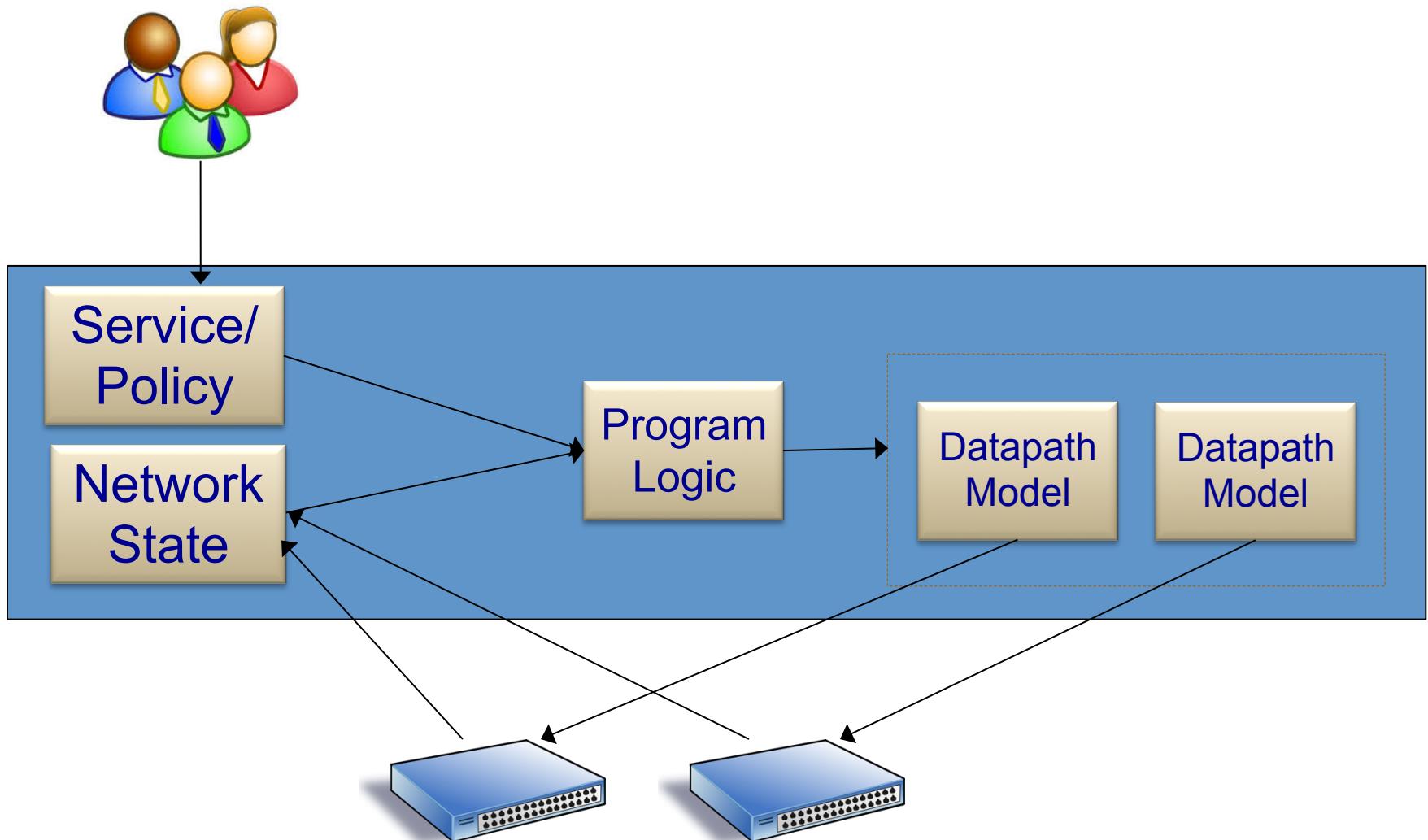
*"We are focusing on a market transition involving the move toward **more programmable, flexible, and virtual networks...** This transition is focused on moving from a hardware-centric approach for networking to a virtualized network environment that is designed to **enable flexible, application-driven customization of network infrastructures.***

-- Cisco Annual Report (pp2), Nov. 2015

What is SDN: A New Control-Plane Abstractions View

- “Modularity based on abstraction is the way things get done.” -- Barbara Liskov
- Major advances in many fields of computer science are based on simple, elegant, powerful abstractions
- A major lacking of networking is that we do not have enough good abstractions in network control plane
 - Three key areas for abstractions [Shenker’11]: **forwarding, distribution, configuration**

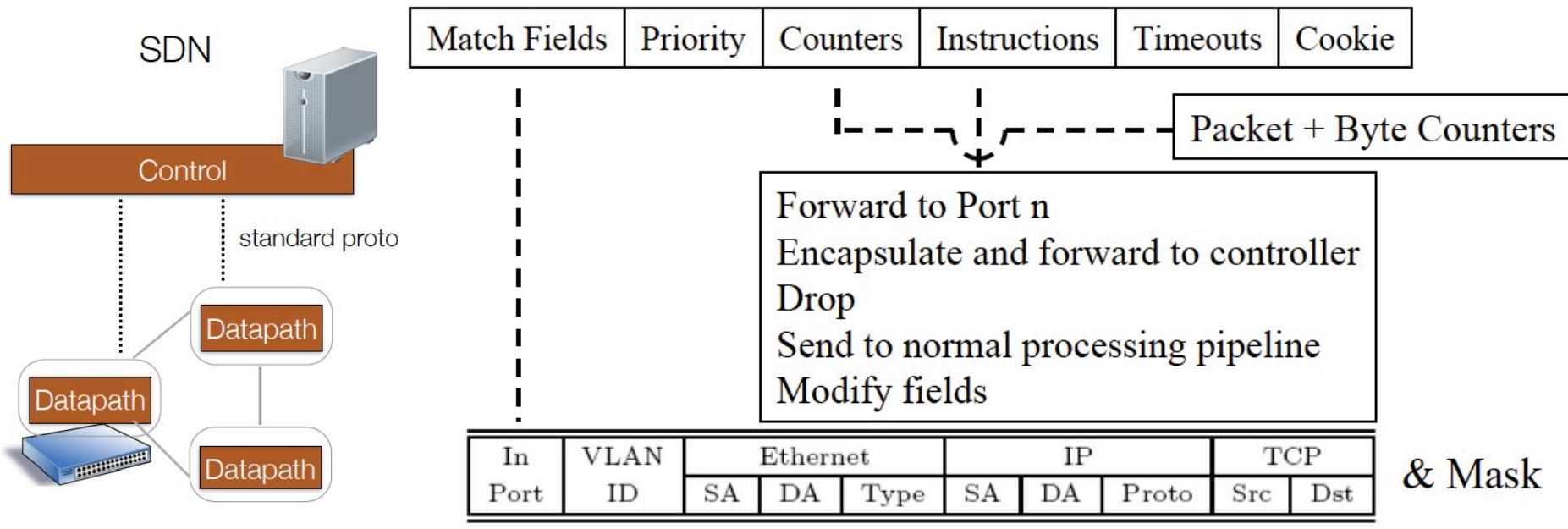
Major Areas of Control-Plane Abstraction



Outline

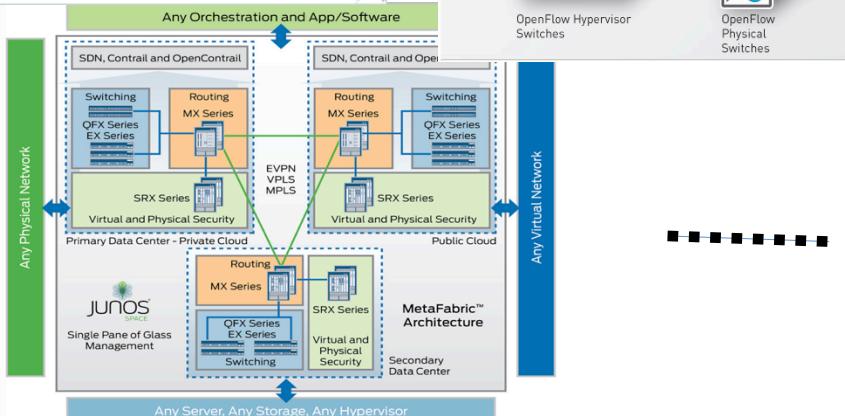
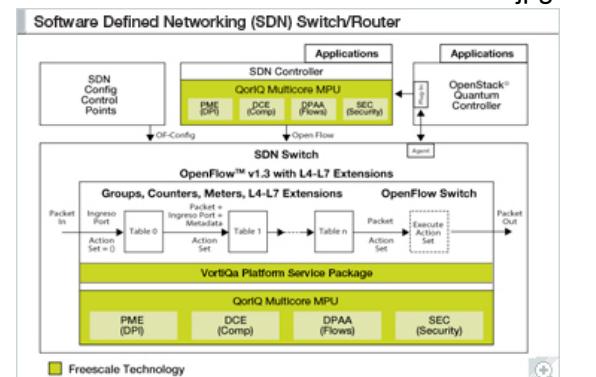
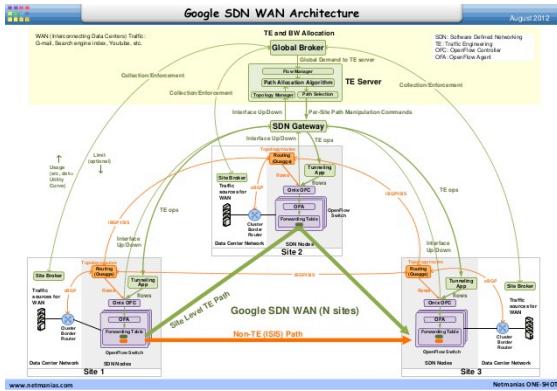
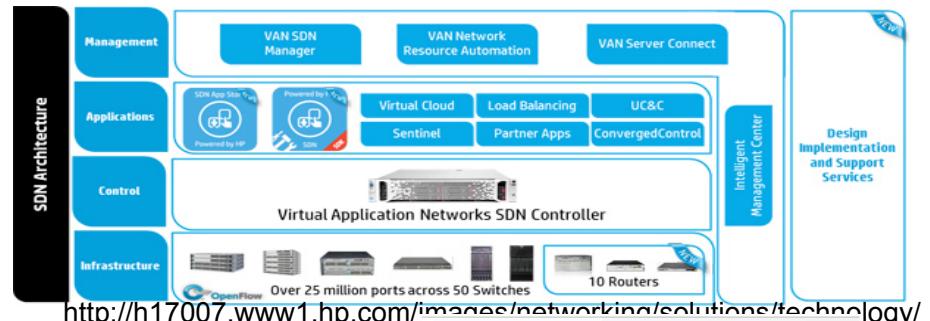
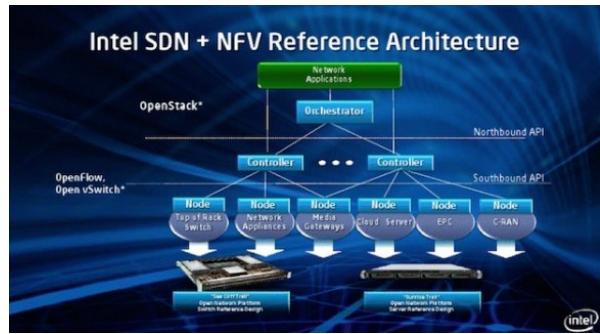
- What is and why SDN?
- SDN development

A Major SDN Milestone: OpenFlow



Priority	Match	Action
1000	tcp_dst:22	drop
20	ip_dst: 101.22.0.0/16	port 2
1	in_port:1, mac_dst: 0xffffffffffff	ports 2,3,4

Almost Every Network Vendor has an SDN Architecture



Multiple Open Source Communities

Total Contributors

Jun '14 – Jun '15

Total: 674

Floodlight 18

RYU 36

ONOS 68

Open Contrail

82

Open vSwitch

111

OpenDaylight

359

Total Commits

(Jun '14 – Jun '15)

Total 24,181

Floodlight 357

RYU 431

Open vSwitch 1,953

Open Contrail

3,825

ONOS

4,159

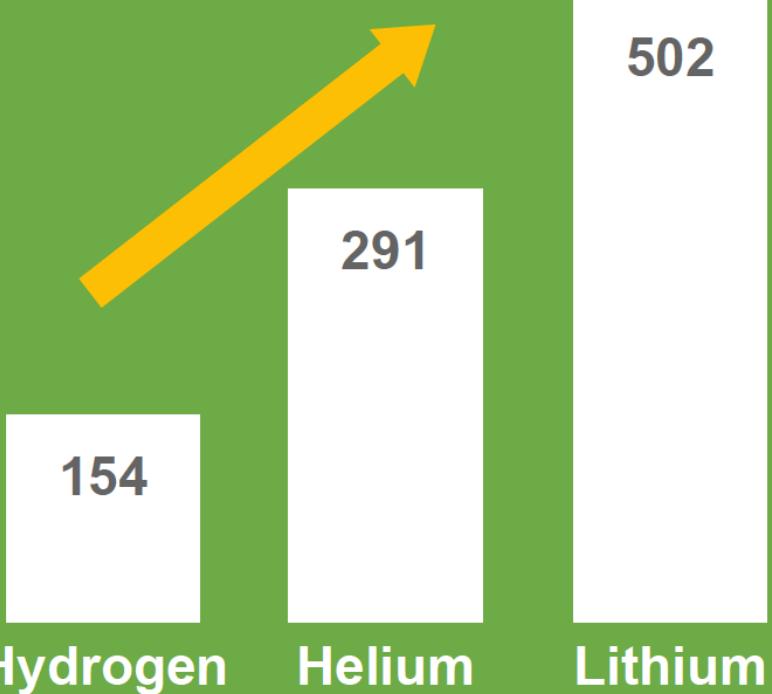
OpenDaylight

13,456

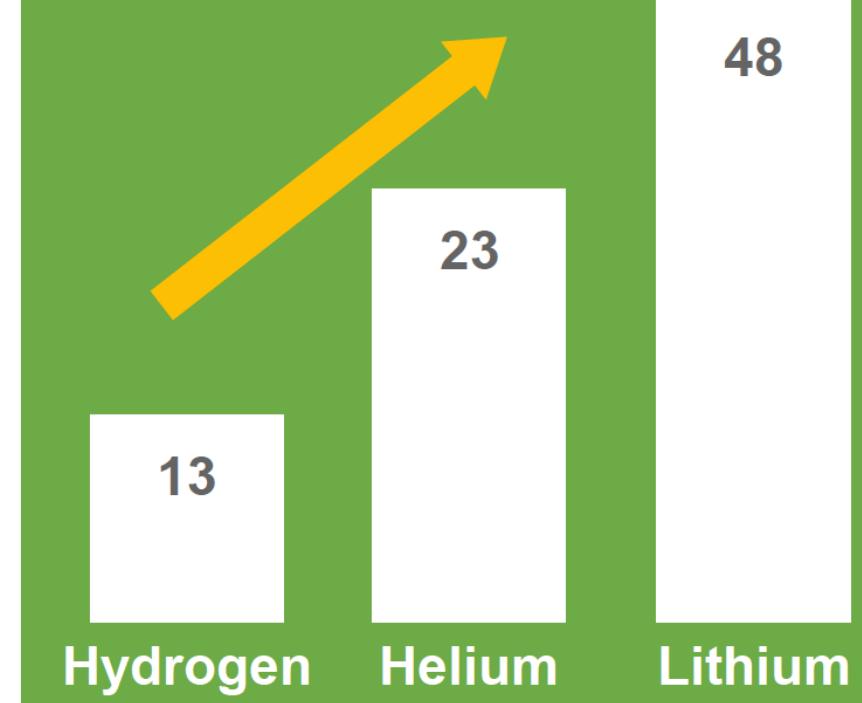
Source: Neela Jacques, July 2015.

Increasing Interests (ODL as an Example)

Total Contributors

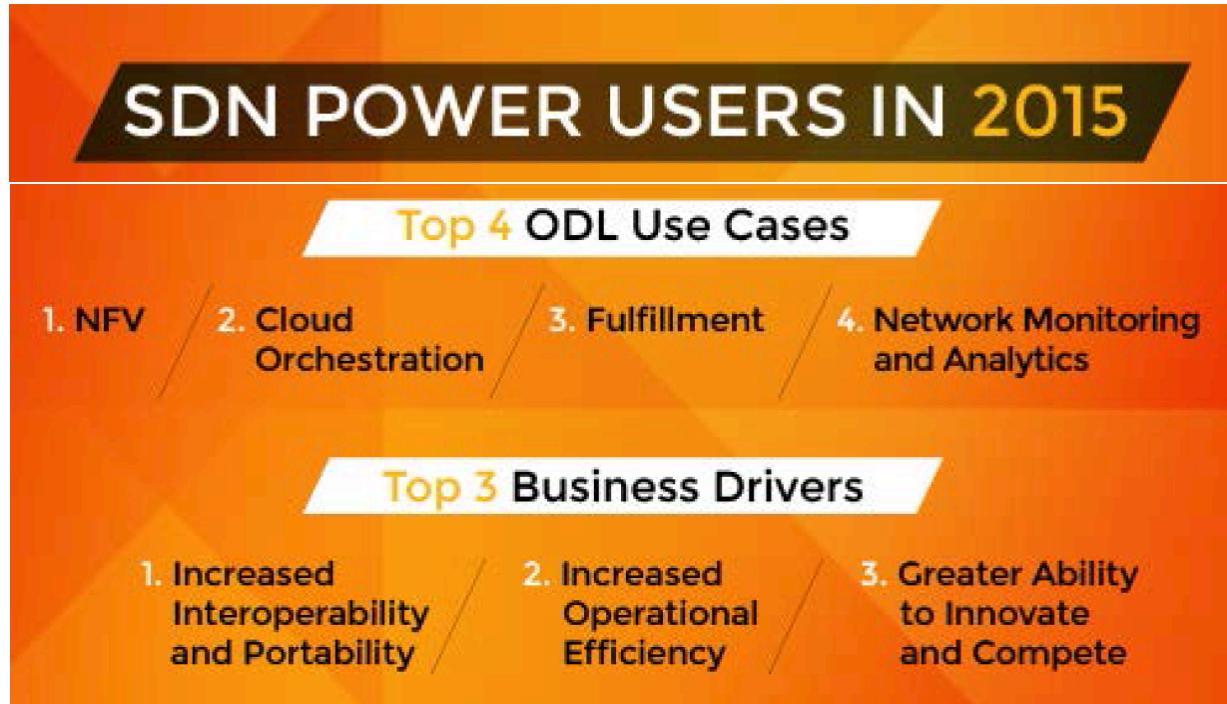


Projects Per Release



Source: Neela Jacques, July 2015.

Usage of SDN



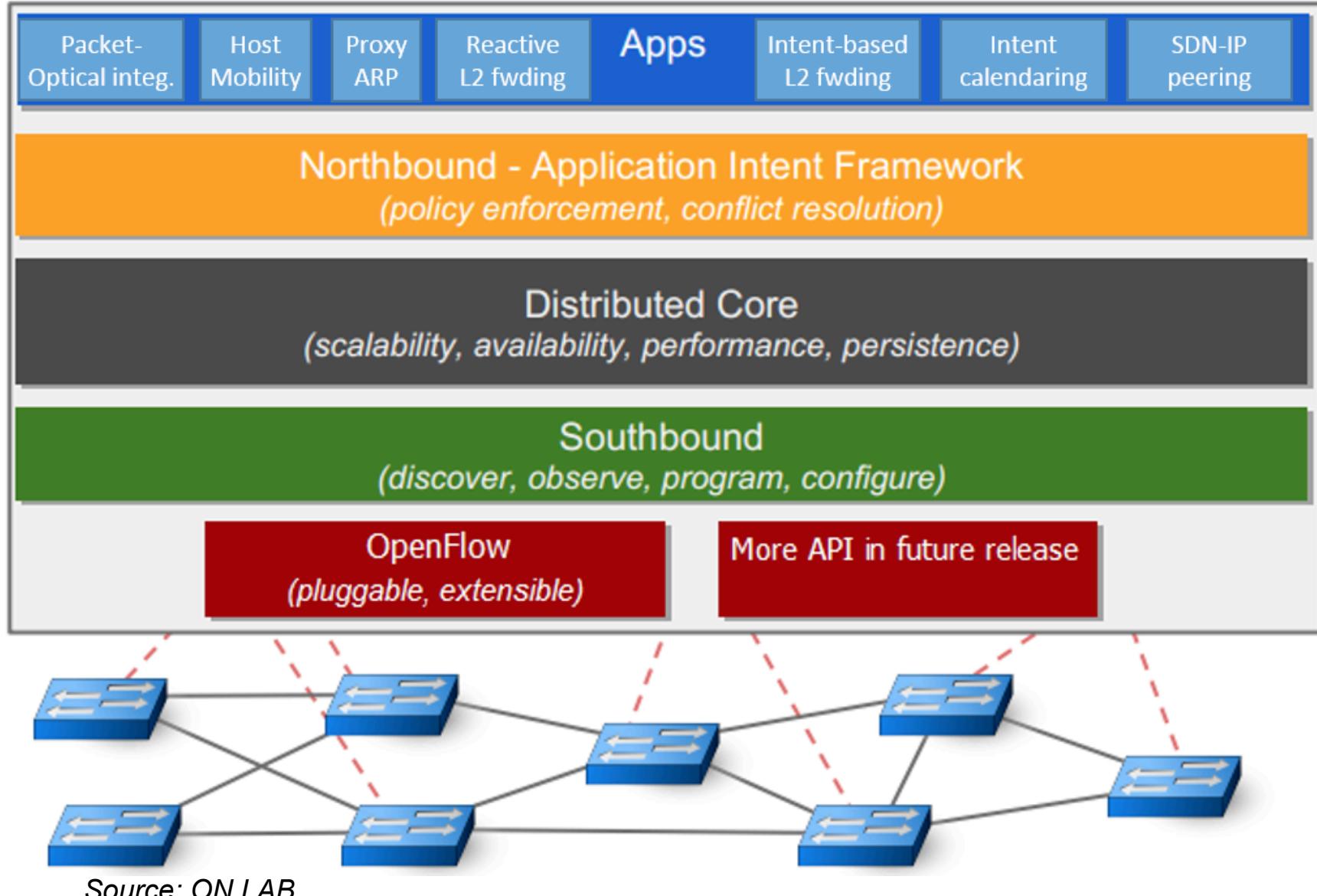
- 128 Companies responded
 - 31% Telcos/Service Providers
 - 24% Research/Academia
 - 20% Enterprises
 - 10% Services/Consulting
 - 9% Software/Hardware
 - 6% Other

Source: Neela Jacques, July 2015.

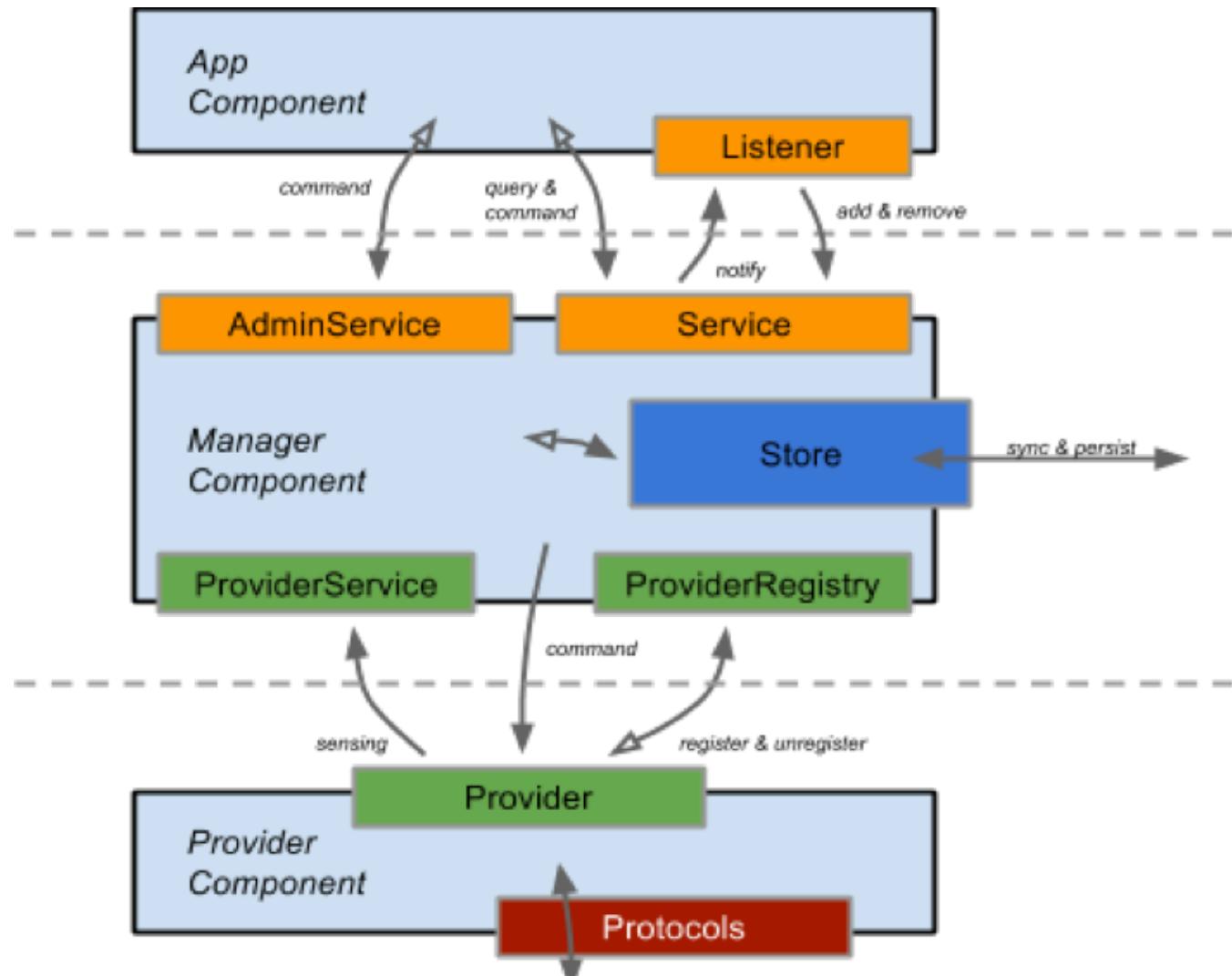
Outline

- What is and why SDN?
- SDN development
- Overview of key SDN technical aspects
 - Architecture

ONOS Architecture: Big Picture

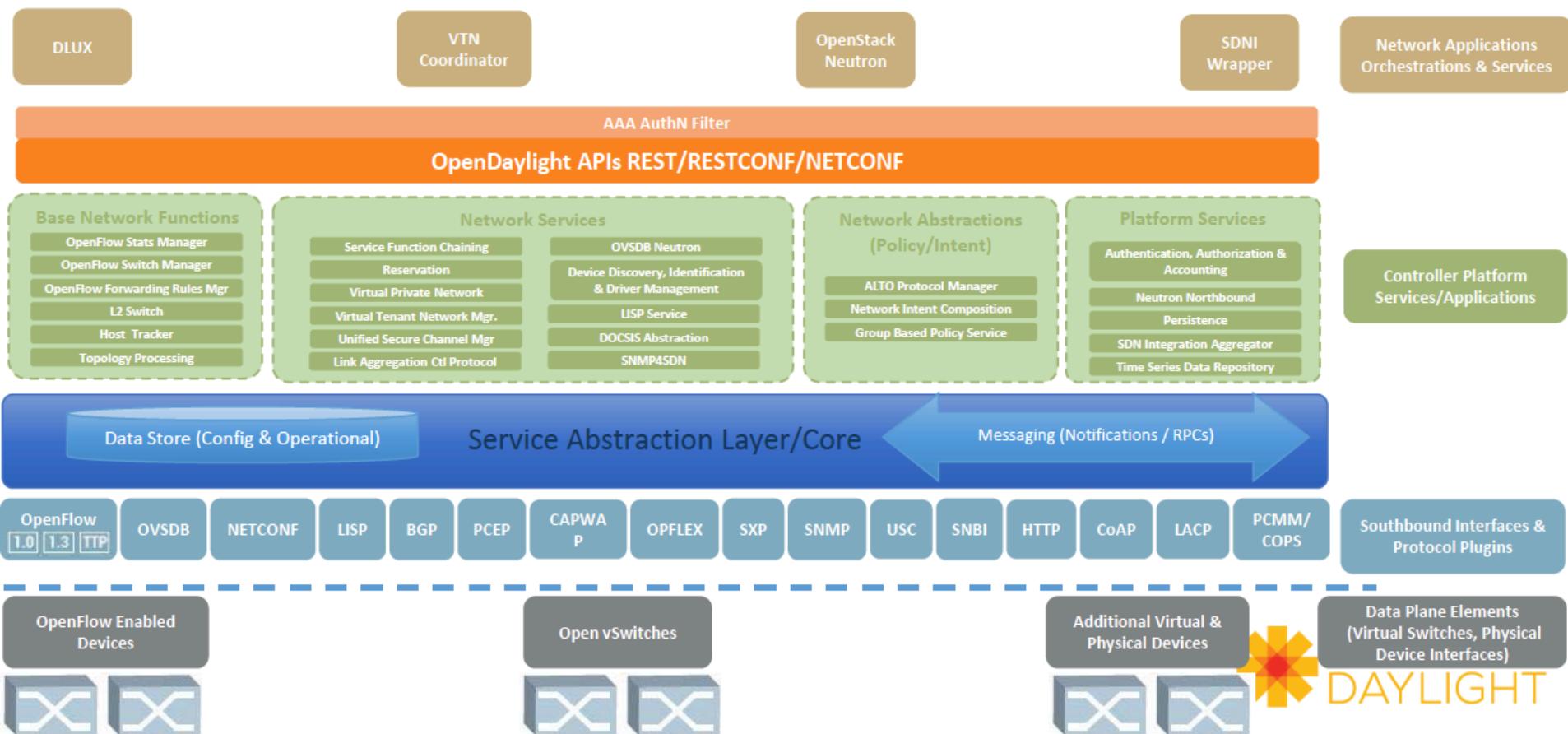


ONOS Architecture: Some Key Abstractions



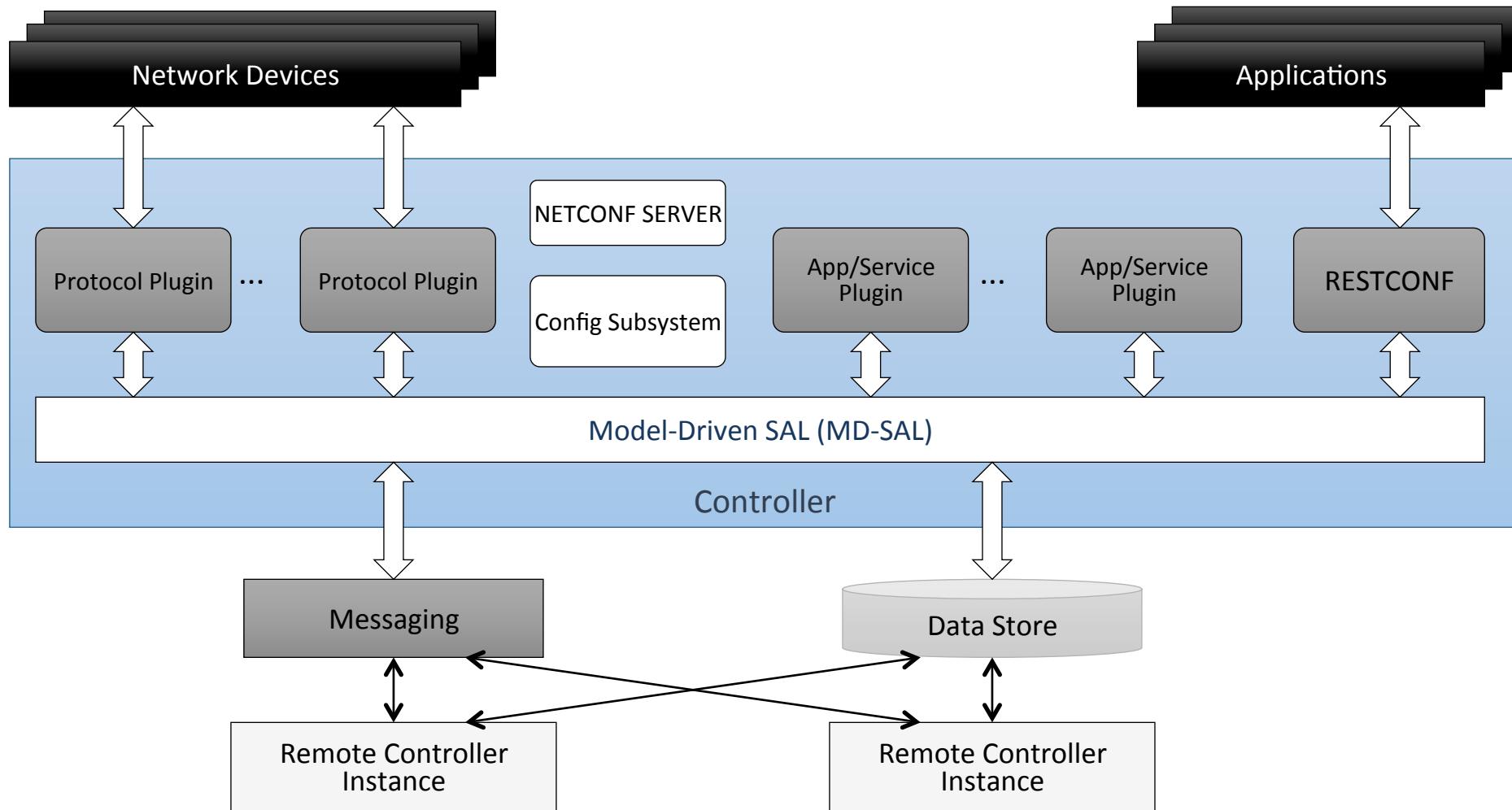
<https://wiki.onosproject.org/display/ONOS/System+Components>

OpenDaylight Architecture: Big Picture



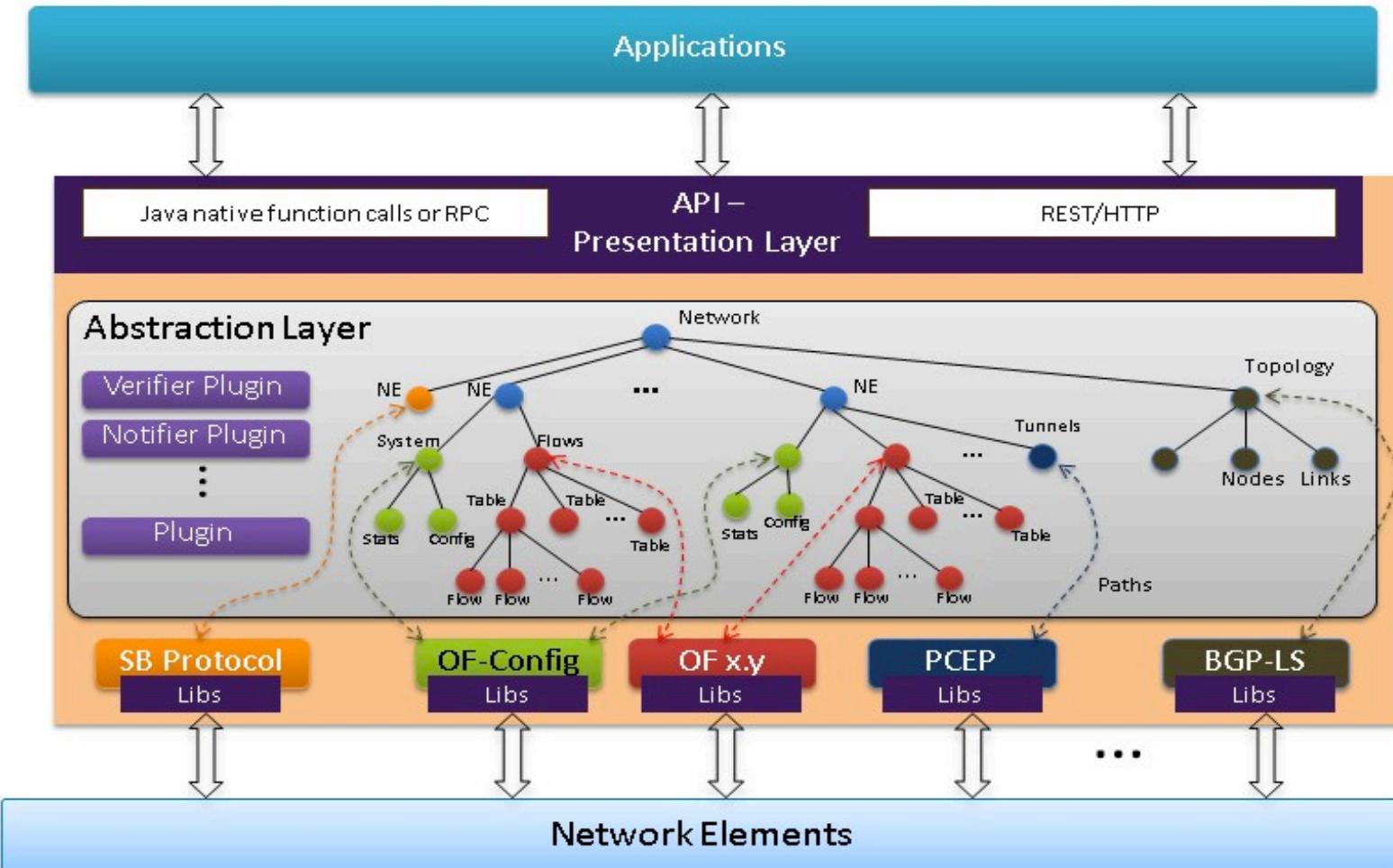
Source: Neela Jacques, July 2015.

OpenDaylight: Some Key Abstractions



Source: Ed Warnicke, July 27, 2015.

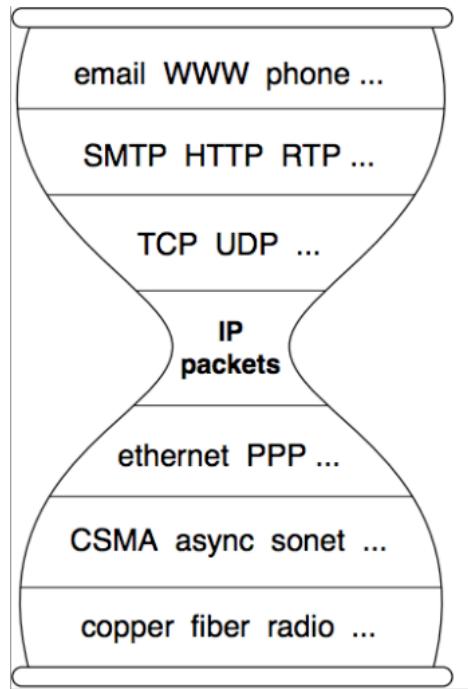
OpenDaylight: YANG Data Store



https://wiki.opendaylight.org/view/OpenDaylight_Controller:Architectural_Framework

Questions to Keep in Mind in ADL on Architecture

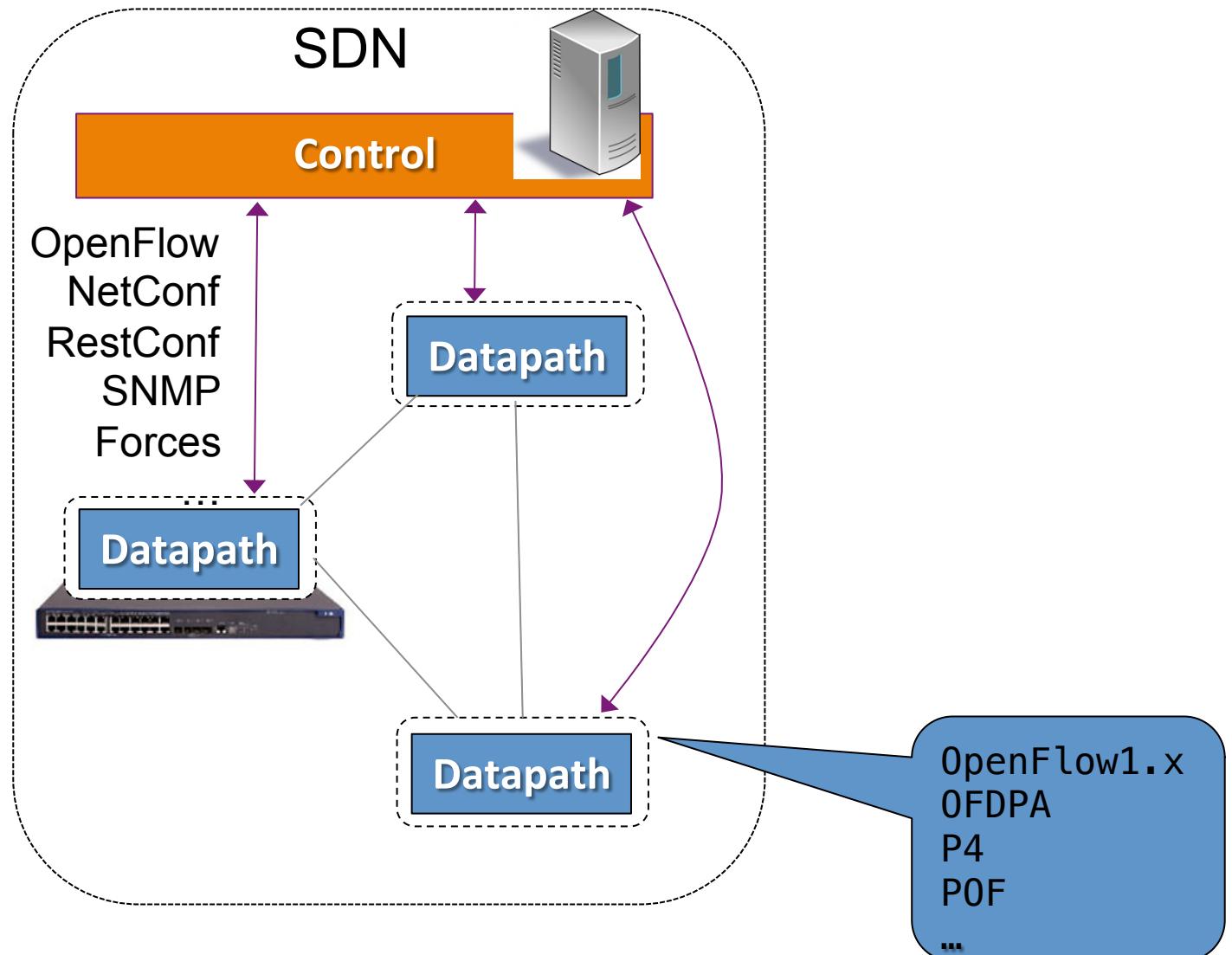
- Q-Arch1: What are the commonality and differences among the SDN architectures?
- Q-Arch2: Is it possible that there can be a reference architecture?



Outline

- What is and why SDN?
- SDN now
- Overview of key SDN technical aspects
 - Architecture
 - Datapath

Current SDN Data Path Designs



Key Datapath Question

Q-Datapath: What should be the data path of network devices?



flow tables

VM/container



Outline

- What is and why SDN?
- SDN now
- Overview of key SDN technical aspects
 - Architecture
 - Datapath
 - Programming abstractions and framework

Complexity of a Network Decision Process

Map<MAC, Location>
List<ACLItem>

....

```
hostTable.put(p.entry);
if ( !permit(p, acls) ) return drop();
Location src = p.ingressPort();
Location dst = hostTable.get( p.getPathDst() );
Route path = myRoutingAlg(topology(), src, dst);
return path;
```

..
..
..

Data path may need
to detect change
and update state

hostTable;
acls;

External process may
change states

Depends on
physical
states

t());

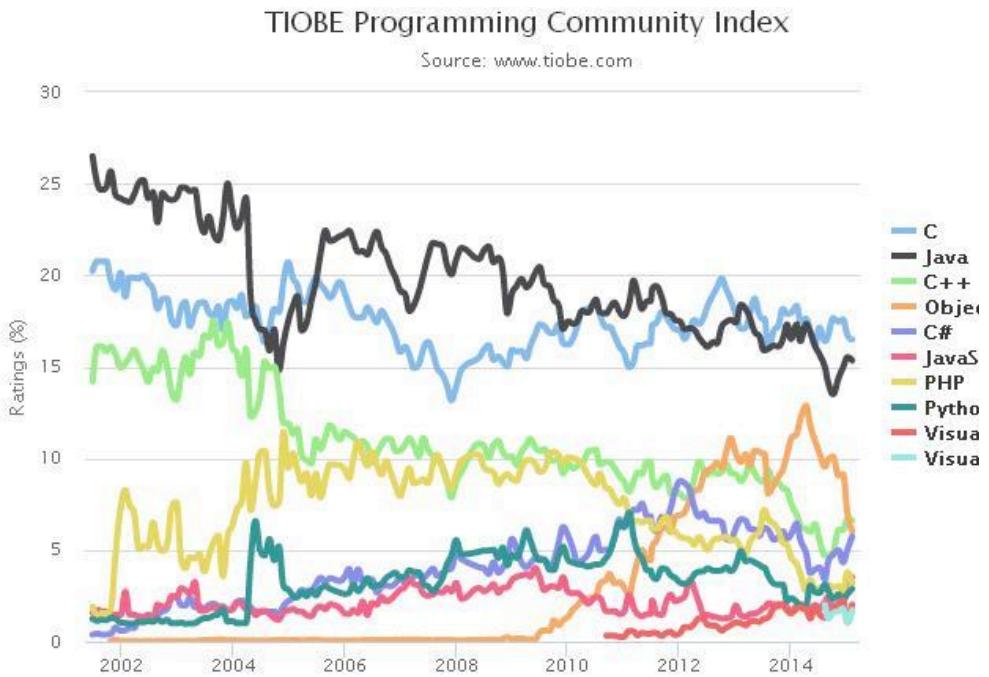
Depends on
policy state

Depends on pkt
attributes

May need
complex
computation

Question to Keep in Mind on SDN Programming

Q-Prog: What are the right programming abstractions and frameworks for SDN?



Source: <http://www.freaksense.com/wp-content/uploads/2013/07/10580033-it-a-full-collection-of-programming-language.jpg>

SDN vs Inherent Complexity

- Conjecture [Meyer]: Complexity in highly organized systems arises primarily from design strategies intended to create robustness to uncertainty in their environments and component parts.
 - Scalability is robustness to changes to the size and complexity of a system as a whole.
 - Evolvability is robustness of lineages to large changes on various (usually long) time scales.
 - Reliability is robustness to component failures.
 - Efficiency is robustness to resource scarcity.
 - Modularity is robustness to component rearrangements.

Q-Prog-Complexity: Can SDN programming solve (or at least reduce) inherent complexity?

Outline

- What is and why SDN?
- SDN now
- SDN key technical components
 - Architecture
 - Datapath
 - Programming abstractions and framework
 - SDN killer apps

Questions to Keep in Mind on SDN Killer Apps

Q-App: What are the killer apps of SDN?

hp SDN App Store

Sign In | | |

Category	Product Name	Description	Price	Rating	Status
Apps Circle 1 HP	Net Optimizer	Hewlett Packard Enterprise SDN Internal Application	\$1,999.00	★★★★★	Free
Apps Circle 2 Partner	Net Protector	Hewlett Packard Enterprise SDN Internal Application	\$999.00	★★★★★	\$3,199.00
Apps Circle 3 Community	Net Protector RepDV 250 users	HP PDF	\$999.00	★★★★★	\$4,799.00
Concept Apps	Net Protector RepDV 4k users	HP PDF	\$6,399.00	★★★★★	Free
Controller	Net Visualizer	HP SDN Internal Application	\$4,000.00	★★★★★	Free
Data Center	Net Visualizer: Trial	HP SDN Internal Application		★★★★★	
ODL Controller and Apps	Net Optimizer: Trial	Hewlett Packard Enterprise SDN Internal Application		★★★★★	
Optimization	Net Protector: Trial	HP PDF		★★★★★	

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Source: http://api.ning.com/files/qgybvJa4VHgEUDHXfn3PUL4Bru*HAQP7gtHz5BUaG6YH*1As0tr9MGh8eH34GQPpLsxPOh8iYgP3BRLEWSSCIN274raRTRX/killer_apps_600x300.jpg

What may lead to a fall of SDN?

- Unstable, increasingly complex data path?
- Fail to integrate key domains (e.g., wireline+wifi +cellular)?
- Cannot stand alone (e.g., still need connection to controller)?
- No killer apps?
-

Thank you and **enjoy** the rest of ADL!