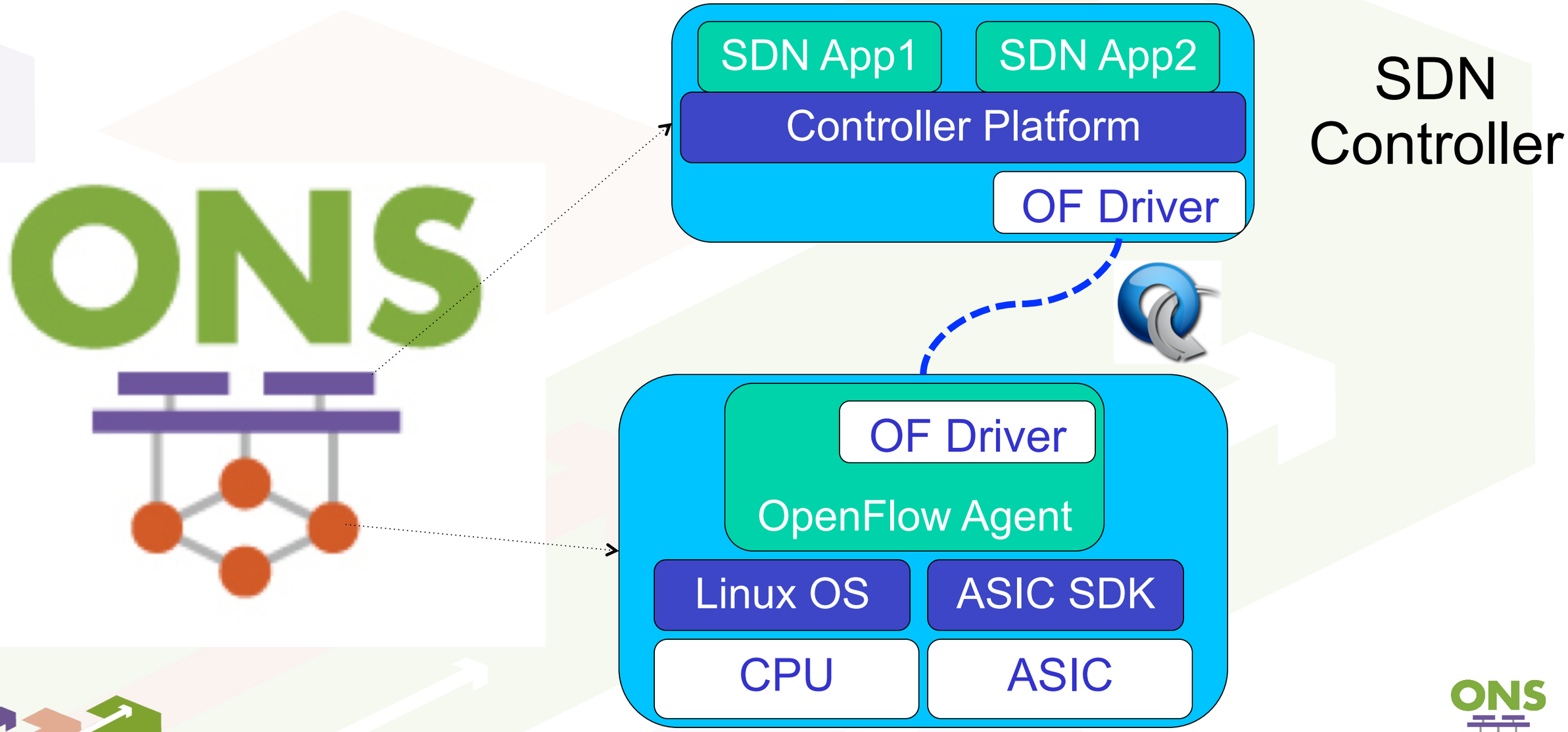
Floodlight and the OpenSDN Stack

Rob Sherwood – Big Switch Networks

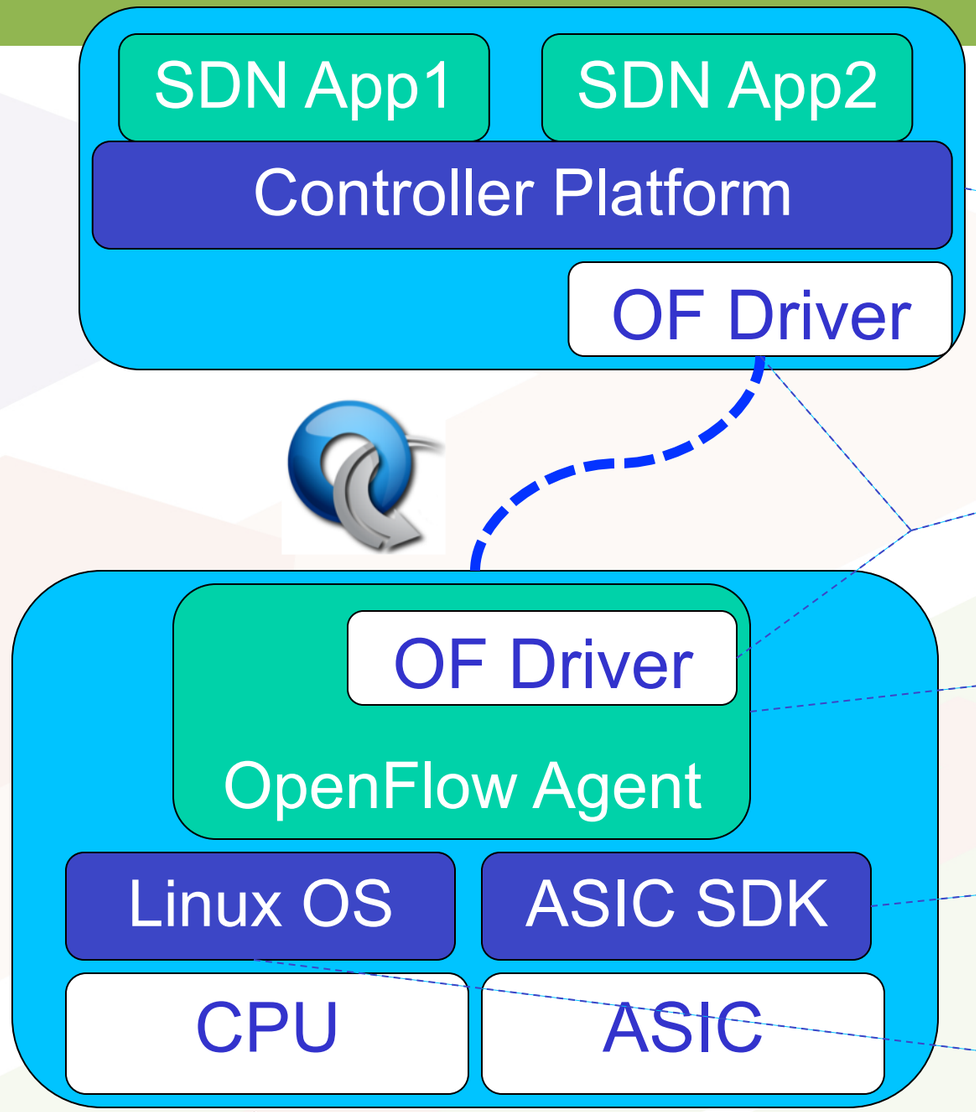
Joseph Tardo – Broadcom

Douglas Flint – Broadcom

Example SDN Stack: Derived from ONS Logo



This workshop: Top-to-Bottom *Open* SDN Stack



Floodlight SDN Controller

LOXIGEN – LOCI, OpenFlowJ

Indigo OpenFlow Agent

NEW!

OF-Datapath Abstraction (OF-DPA)

NEW!

Open Network Linux

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Outline/Schedule: Working Bottom-Up

Time	Event
8:30-9:00a	Open SDN Stack Overview
9:00-10:00a	Open Source Switch OS: Open Network Linux
10:00-11:30a	OF-DPA: Open API for Broadcom StrataXGS Architecture
11:30-12:30p	***Lunch***
12:30-1:00p	Indigo OpenFlow 1.3 Architecture
1:00-2:00p	Floodlight, LOXI, and OpenFlow 1.3 Support

Overview Outline: 8:30-9:00a

- Introductions
- Open SDN Stack Component Summary

Components	
Hardware Design	OpenFlow Agent
Operating System	OpenFlow Protocol Driver
Hardware SDK	SDN Controller

- OpenFlow – the short, short version
  - For detailed introduction to OpenFlow, see other tutorials

Introductions: Who Are We?

- Rob Sherwood
  - CTO at Big Switch Networks
- Joseph Tardo
  - Associate Technical Director, OpenFlow and SDN technologies, Broadcom
- Douglas Flint
  - Principal Engineer - Software Systems, Broadcom

Introductions: Who Are You?

By a show of hands…

- Developers with Floodlight or Indigo experience?
- Developers with Other SDN experience?
- Developers with Networking Experience?
- Developer with Other Experience?
- Technical, but not a developer?
- Non-technical?

Open Hardware

- Open Compute Project (OCP) hosts open hardware designs
  - http://opencompute.org/network
- Hardware designs:
  - Schematics, board layout
  - Recommended devices
  - Port counts, fans, power requirements

Components	
Hardware Design	OpenFlow Agent
Operating System	OpenFlow Protocol Driver
Hardware SDK	SDN Controller

Open Operating System

- Open Network Linux: Linux distribution for network devices
  - http://github.com/opennetworklinux/ONL
- Based on Debian Wheezy, but adds:
  - Open Network Install Environment (ONIE) compatibility
  - Lots of switch-specific device drivers: I2C, GPIO, device tree files for non-x86
  - Niceties for switches: network booting, overlayfs over flash
  - Support for increasing number of network devices

Components	
Hardware Design	OpenFlow Agent
Operating System	OpenFlow Protocol Driver
Hardware SDK	SDN Controller

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Hardware SDK

- OpenFlow Datapath Abstraction
  - TBD – press release today!
- From Documentation:
  - *"OpenFlow Data Plane Abstraction (OF-DPA) is an application software component that implements an adaptation layer between OpenFlow and the Broadcom Silicon SDK. OF-DPA enables scalable implementation of OpenFlow 1.3 on Broadcom switch devices. "*

Components	
Hardware Design	OpenFlow Agent
Operating System	OpenFlow Protocol Driver
Hardware SDK	SDN Controller

OpenFlow Agent

- Indigo OpenFlow Agent
  - http://projectfloodlight.org/indigo
- Supports:
  - OpenFlow 1.0 and OpenFlow 1.3
  - x86-based vSwitch: http://www.projectfloodlight.org/indigo-virtual-switch/
  - Broadcom-based Hardware switches, including OF-DPA
- Uses LOXI for its OpenFlow driver

Components	
Hardware Design	***OpenFlow Agent***
Operating System	OpenFlow Protocol Driver
Hardware SDK	SDN Controller

OpenFlow Protocol Driver

- LoxiGen: Generates OF language specific protocol bindings
  - http://github.com/floodlight/loxigen
- Generates OpenFlow v1.0-v1.3.1+ bindings for:
  - C – for Indigo
  - Java – for Floodlight
  - Python – for OFTest: https://github.com/floodlight/oftest
  - Wireshark/Lua: http://www.projectfloodlight.org/openflow.lua

Components	
Hardware Design	OpenFlow Agent
Operating System	***OpenFlow Protocol Driver***
Hardware SDK	SDN Controller

SDN Controller

- Floodlight SDN Controller
  - http://projectfloodlight.org
- Supports:
  - OpenFlow 1.0 → TODO: Update to OpenFlow 1.3/Loxigen/OpenFlowJ
  - Example apps: learning switch, hub, skeleton OpenStack Neutron support
  - Last year: example use cases from CERN/Caltech and Mellanox/Radware
  - This year: many of the Research Track papers implement on Floodlight

Components	
Hardware Design	OpenFlow Agent
Operating System	OpenFlow Protocol Driver
Hardware SDK	***SDN Controller***

OpenFlow – the short, short version

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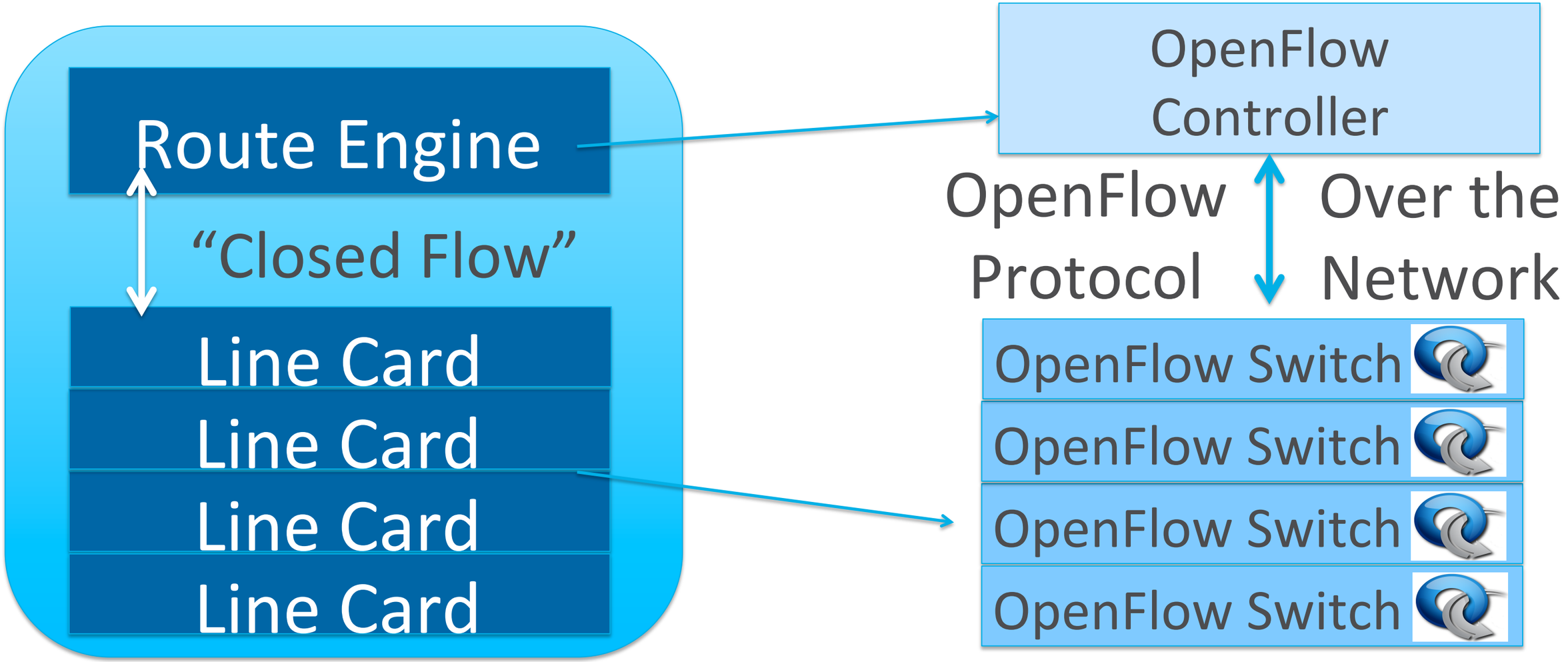
EXISTING NETWORK DEVICES – “CLOSEDFLOW”

Exact Same Process for: STP

“128.8.0.0/16”

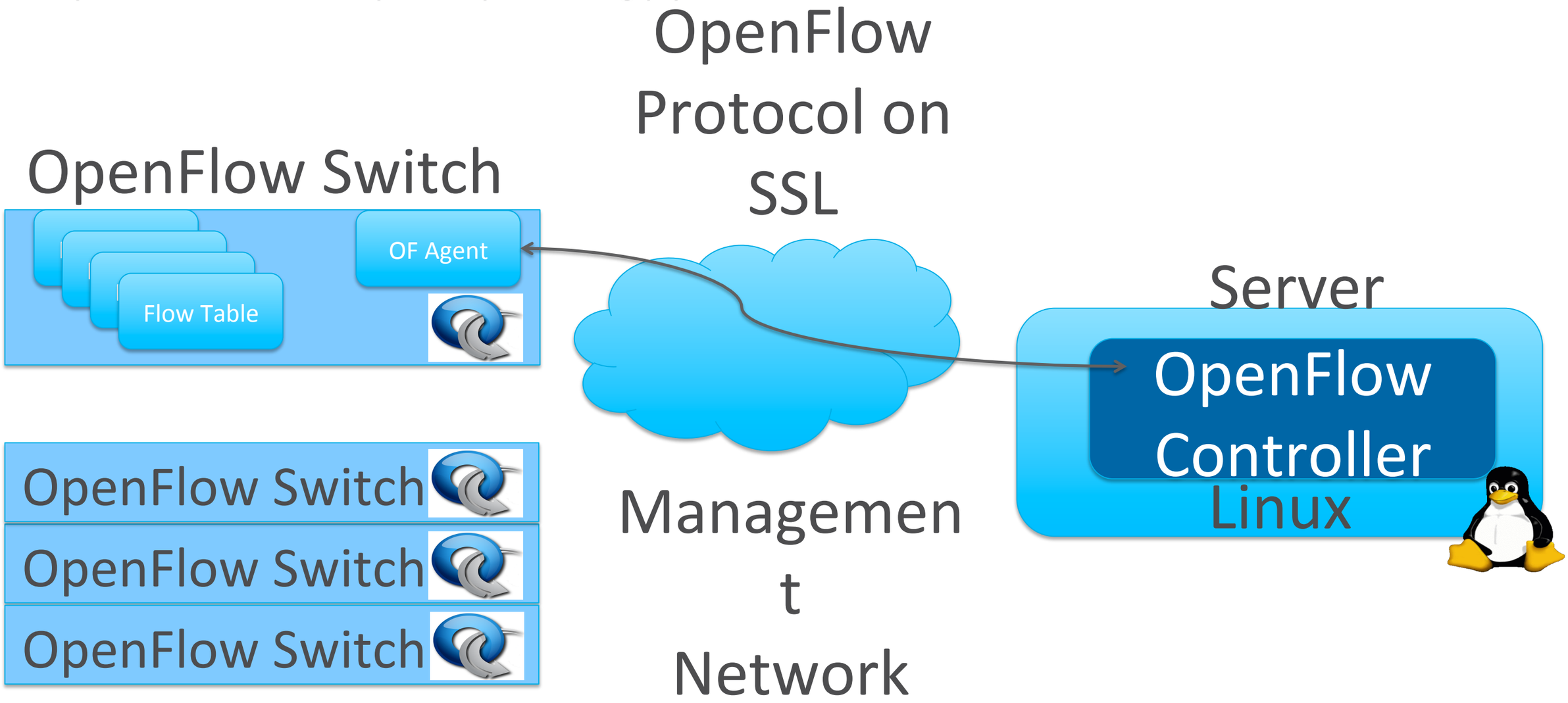
OPENFLOW IS REMOTE CONTROL PLANE PROTOCOL

Just like "closed flow", but over network and *open!*



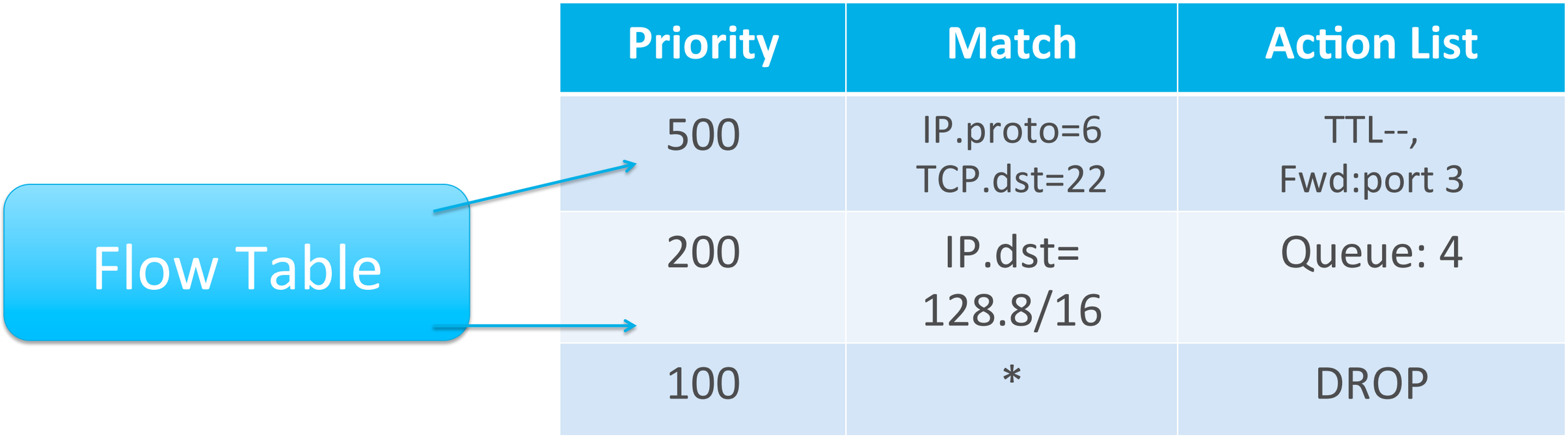
OPENFLOW IN PRACTICE

Sequence of tables in a packet processing pipeline



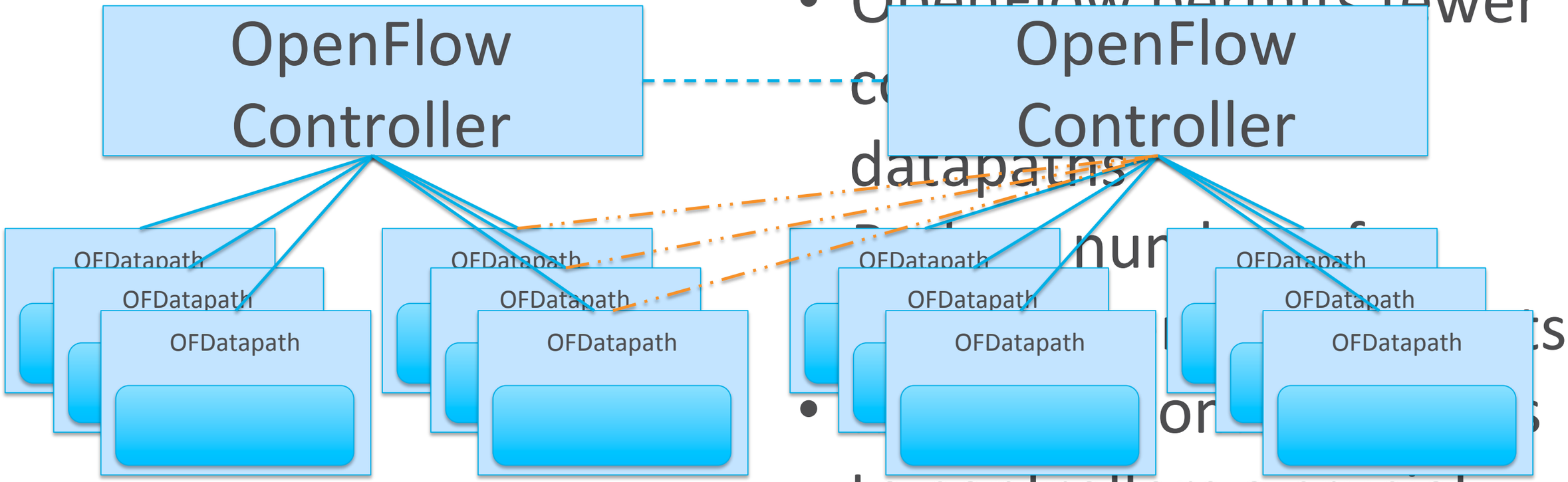
FLOW TABLE ABSTRACTION

Sequence of tables in a packet processing pipeline



- Existing networking hardware *actually* very flexible
  - FUD: Large + narrow versus small + wide match tables
- Active work in the Open Networking Foundation to bring OpenFlow to feature parity with "closed flow"

DECOUPLE CONTROL FROM FORWARDING



- OpenFlow permits fewer c
  datapaths
- nur
- or
  to controllers a crucial
  network design question!

OpenFlow does *not* imply single point of failure!

Allows load balancing and failover

Done: Overview Outline: 8:30-9:00a

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Open Network Linux

A Common Linux Platform for Open Network Devices

Rob Sherwood
Big Switch Networks
CTO

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Open Network Linux: Outline

History

Motivation

- Elements of a Linux Distribution
- Tower of Babel
- Benefits for users, vendors

Technical details

- Multi-platform support: x86, PPC, and x86 VM
- Full “Server-like” experience on network hardware
- Network booting and image management

OPEN NETWORK LINUX (ONL) HISTORY

- **Switch Light is a Big Switch Networks commercial product**
  - Switch Light = Indigo + ONL
- **Proposed to open source the Linux bits of Switch Light to OCP**
  - November OCP Network meeting
  - Lots of good community feedback
- **Source code went live for OCP 1/27/2014 Summit**
- **Work in progress: github.com/opennetworklinux/ONL**
  - Needs website, pre-compiled binaries
  - Lots of interest from the ODM community

BACKGROUND – DISTRIBUTION

"Linux" proper is just the kernel

- **"Distribution" is everything else**
  - e.g., RedHat, Ubuntu, Slackware, Gentoo, etc.
  - Libc, compiler, user space binaries
  - Configuration, file system layout, startup scripts
  - Package management, full-featured boot loader
- **A lot of work goes into making a good distribution**
  - Default configurations, daemons
  - Q/A (lots and lots)
- **Lots of possibilities for niche distributions**
  - e.g., embedded environments differ from server
  - Bootloaders vs. full fledged systems

BACKGROUND – PLATFORM SUPPORT

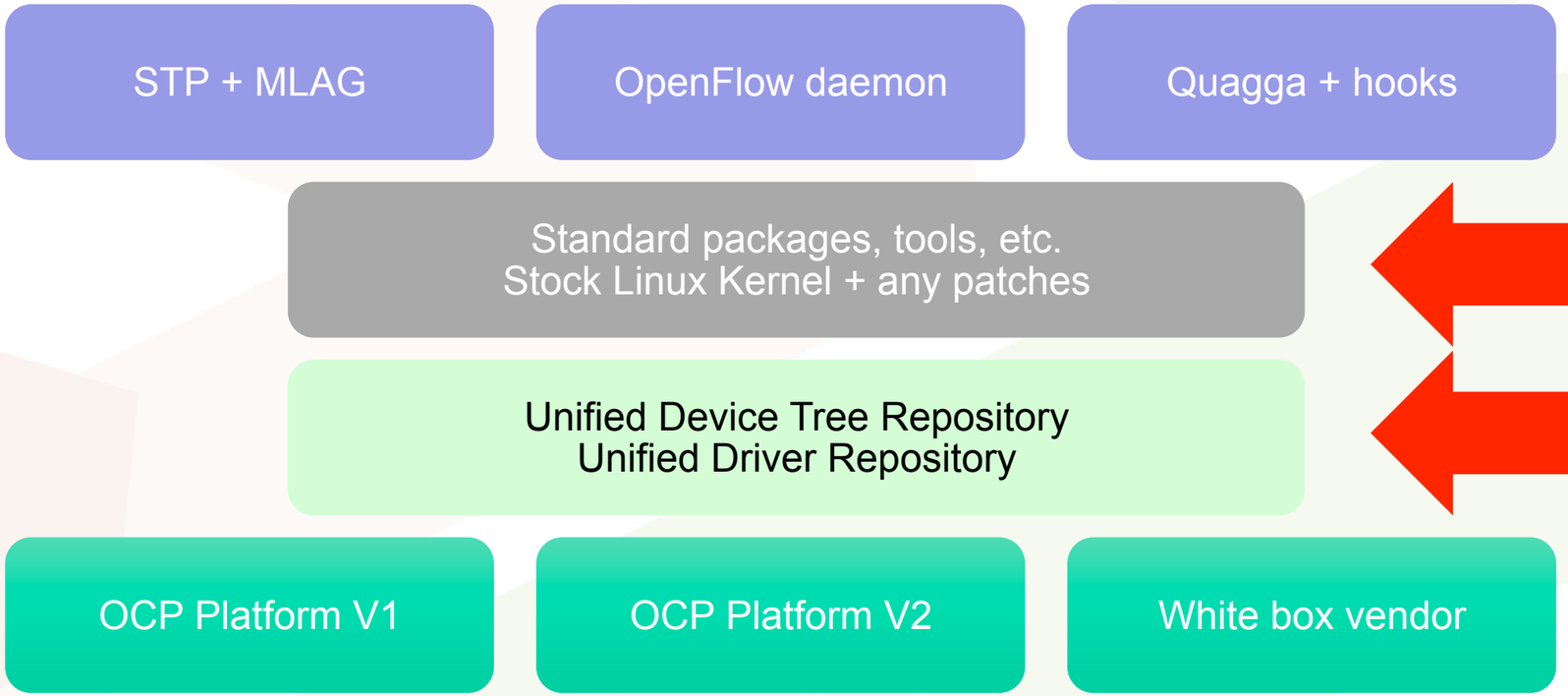
Sometimes we forget, but the boot process is horrible

- **Server and switch platforms have many idiosyncrasies**
  - Litany of little devices we never think of…
  - USB, GPIO, flash, PCI, serial, RTC, EEPROM, DMA, Crypto chips
  - MPIC - Multiple programmable interrupt controller
  - … all at platform-specific memory locations
- **x86-based standards shield us from low-level platform details**
  - Vendor must write a BIOS for each platform, e.g., ACPI standard
  - Operating systems (e.g., Linux) discovery devices via BIOS
- **But switch platform ecosystem is not as evolved**
  - Includes switch specific devices, like I2C, GPIOs, etc.
  - Manual map/inventory of hardware → memory address via Device Tree Source (DTS) files

Motivation: Tower of Babel is Bad

Stack #1	Stack #2	Stack #3	
STP + MLAG	OpenFlow daemon	Quagga + hooks	Switch Agent(s)
Fedora Linux Kernel	Std. Debian Linux Kernel	BusyBox Linux Kernel	Platform Independent
Device Tree #1 Initrd #1	Device Tree #2 Initrd #2	Device Tree #3 Initrd #3	Platform Dependent
OCP Platform V1	OCP Platform V2	White box vendor	Hardware Layer

Proposal: Common Linux Platform



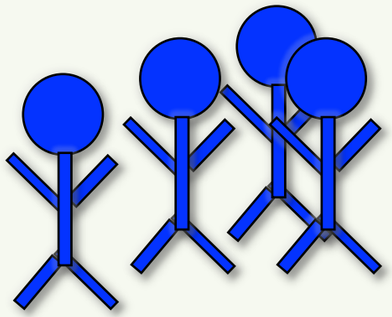
Keep differentiation in switch agents

Come together around the common bits

Maximize hardware abstraction

Benefits for Users

- Help foster an OSS ecosystem sandbox
  - Easy OS binary to download and play with
- Vendor agnostic common Linux platform
  - Deploy your non-switch tools on any box
    - e.g., Chef/puppet/custom
  - Manage the switch like any other server
- Central repository for DTS files
  - Less friction to support new platforms
  - Easy hardware validation



Benefits for vendors

- All vendors already have their own distributions
  - Informal check: most are based off of Debian Wheezy
  - No significant space for differentiation, might as well standardize
  - Reduce engineering effort
- Reduce the effort to support new platforms
  - Open up the ecosystem – good for everyone
  - Central repository for hardware vendors to test their drivers
- Normalize hardware compatibility lists

Open Network Linux: ***Goals***

Accelerate adoption of OCP and other switch hardware

Users: download image, install via ONIE

Vendors: common Linux platform for new drivers, testing

Create an open community

Target: Linux portable to all networking devices

License: Eclipse Public License and GPL for Kernel

“What’s in it for me?”

Engineering efficiencies

Better development and deployment experience

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Open Network Linux: ***Status***

Lots of support from community – thanks!

Github went live : 1/27/2014

Main repository: github.com/opennetworklinux/ONL

Builds ONIE-compatible images for:

Generic x86 platforms: Interface Masters not ***yet*** tested

Many PPC platforms: Quanta LY2, LB9, LB8D, Accton 5652

x86 VM build: for testing – qcow2 (vmdk via convert)

Stability level: “works for us”

Feedback welcome

ONS

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Technical Overview

Code builds two main artifacts:

ONL installer/loader: like grub, but multi-platform with netboot

ONL **SWI** file: zip'd ***SW***itch ***I***mage with root fs, kernel, initrd

Code is divided into multiple sub-modules

ONL: main repository – auto pulls in other repos

linux-3.9.6: extracted kernel code

loader: scripts and code for boot loader process

infra and *common*: libraries, shared routines, faultd

Quick Aside: Open Network Install Environment (ONIE)

- Open source project to install/uninstall network OS
  - http://github.com/onie/onie **or** http://onie.github.io/onie/
- Think of it like a hybrid PC BIOS and Grub/LILO/Sysimage
- Co-operative project: OCP, Cumulus, Big Switch, Others
  - In practice: Curt Brune from Cumulus Networks does almost all of the work
- Allows a network admin to install/uninstall a network OS
  - In practice, it is itself a ~4MB mini-Linux installation
  - More details later

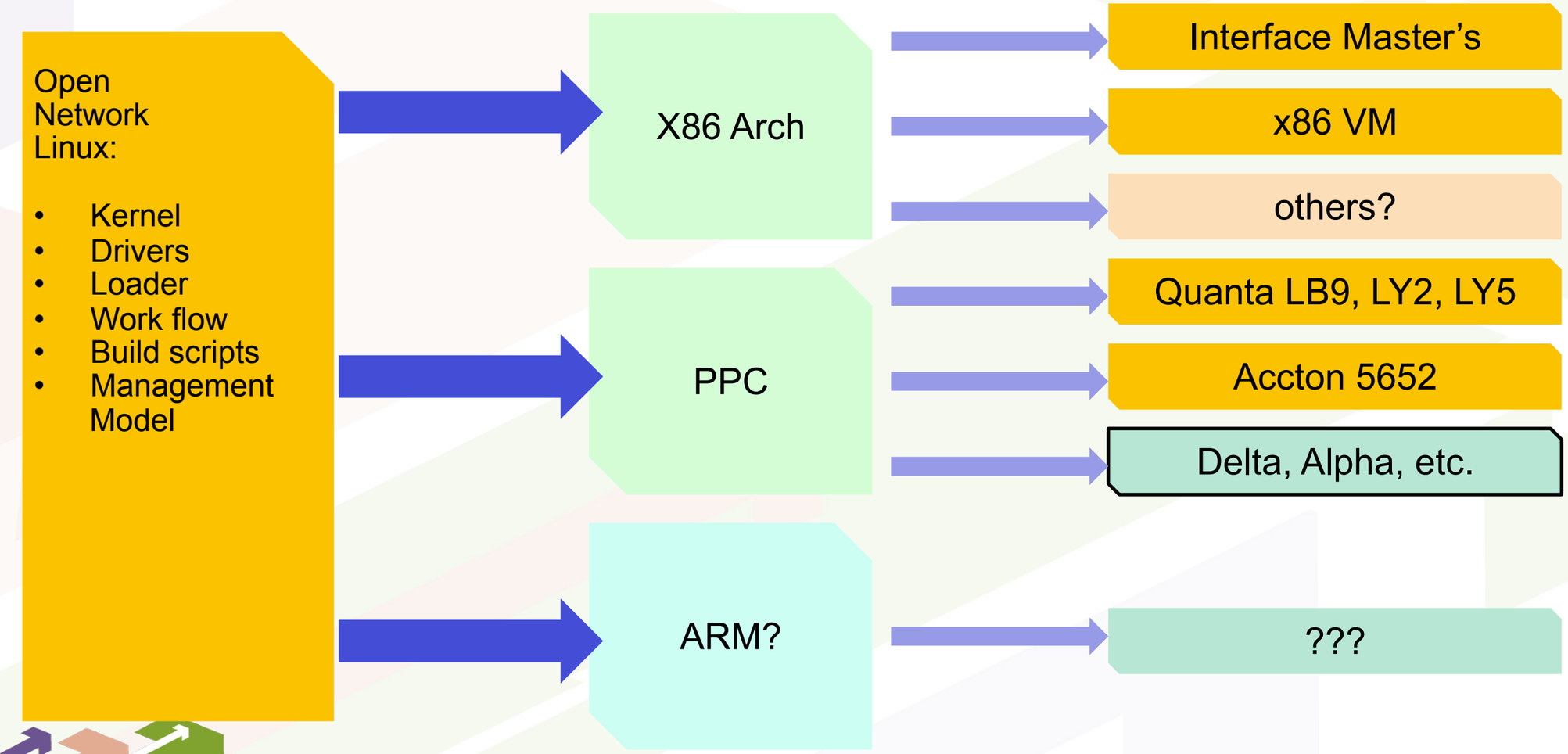
Deployment Overview

Full documentation in README in ONL repository

1. Get code from github.com/opennetworklinux/ONL
2. (only for ppc) Build a cross-compilation workspace
3. Build ONL installer/loader image
4. Put ONL installer/loader image on ONIE server
5. Boot switch and install ONL via ONIE
6. Build one or more ONL SWI's
7. Netboot from scp/nfs/http/ftp/etc. to install ONL SWI

ONL is Multi-Platform

Support many boxes from the same code-base



Install Using ONIE then Boot ONL

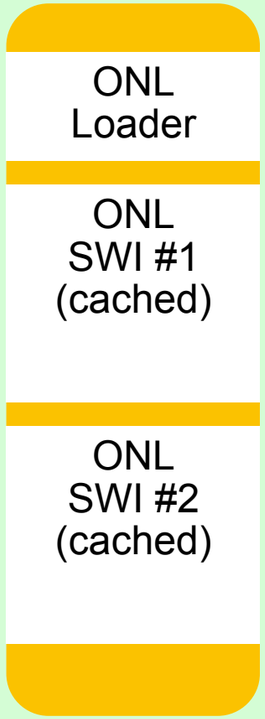
~64MB

Boot Flash

Boot Logic:

1. uBoot POSTs
2. $nos_boot_cmd is read from ENVs
3. run $nos_boot_cmd
   - If $nos_boot_cmd returns, run ONIE
   - On install, ONIE sets $nos_boot_cmd to load ONL loader
4. Loader downloads specified SWI URL if not cached
5. Loader mounts rootfs as ramdisk with overlayfs
6. ONL loader kexec's SWI kernel

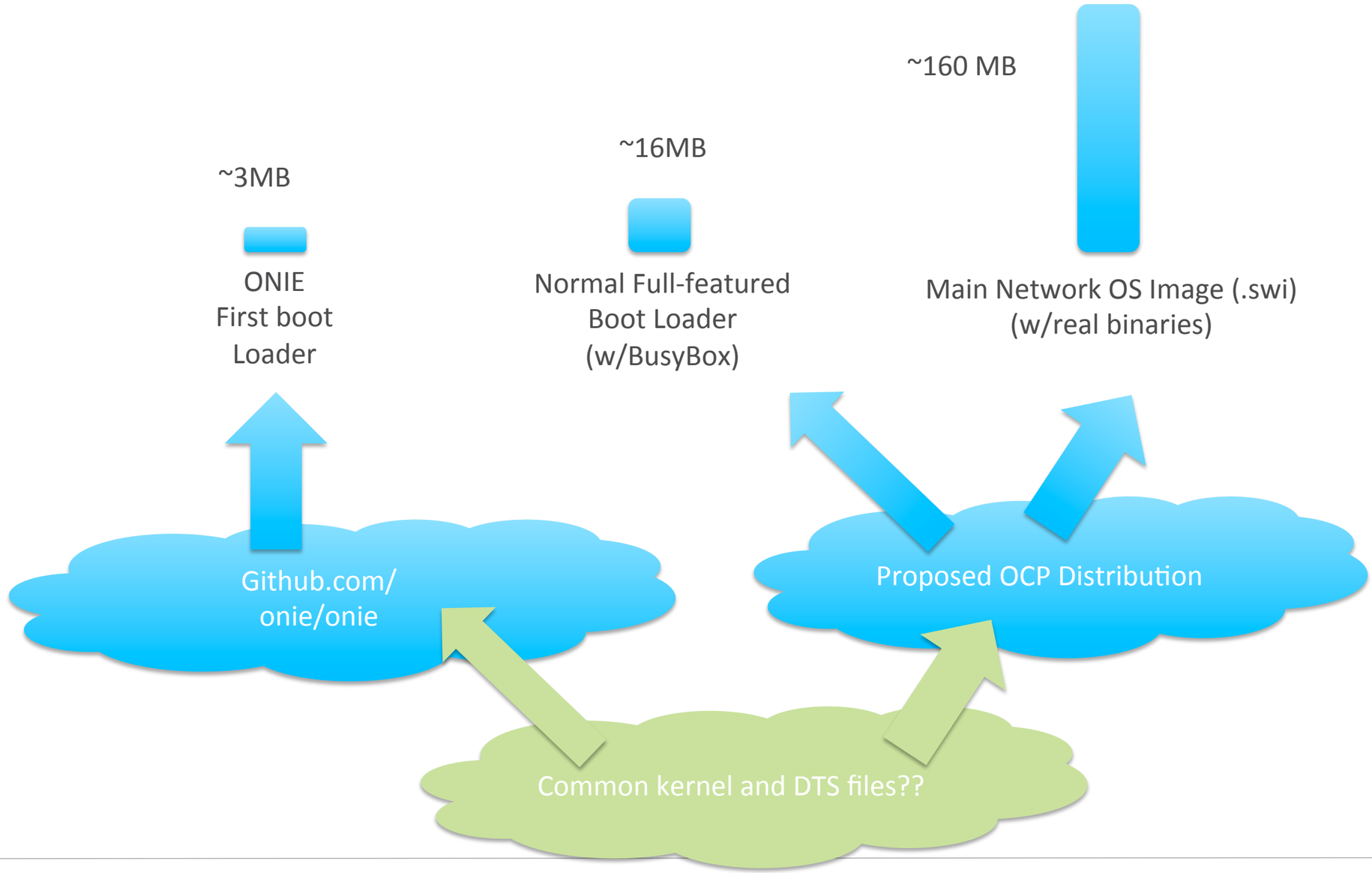
~2GB



Mass Storage

PERSPECTIVE RELATIVE TO ONIE

Different tools for different use cases – but maximize code reuse



Tricks to Use Switches Like Servers

Switches have flash, not hard drives

Problem 1: Maximum flash cycle time limit disk writes

Problem 2: Flash and ram more limited than typical servers

Fix: Use overlayfs to overlay copy-on-write ram disk over flash

ONL uses full-featured binaries

For size, most switch OS's use stripped binaries, e.g., busybox

Bigger binaries uses additional space, but ok with overlayfs

Install/use proper Debian binaries using apt-get

Useful for development or operations, e.g., gcc or Chef/Puppet

ONL Supports Net Booting Natively

Boot SWIs over the network once ONL Loader installed

- SWIs are cached locally for performance, resilience
- Simplifies operational management, upgrades
- Supports http, ftp, tftp, nfs, ssh/scp, or ZTN

Zero-touch Networking (ZTN): auto-discover SWIs

- Like PXE for your switches
- Query all http servers in local subnet, use SWI of first hit
- Just like ONIE

Netboot makes managing your network ***much*** easier

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… hand over to Broadcom folks.

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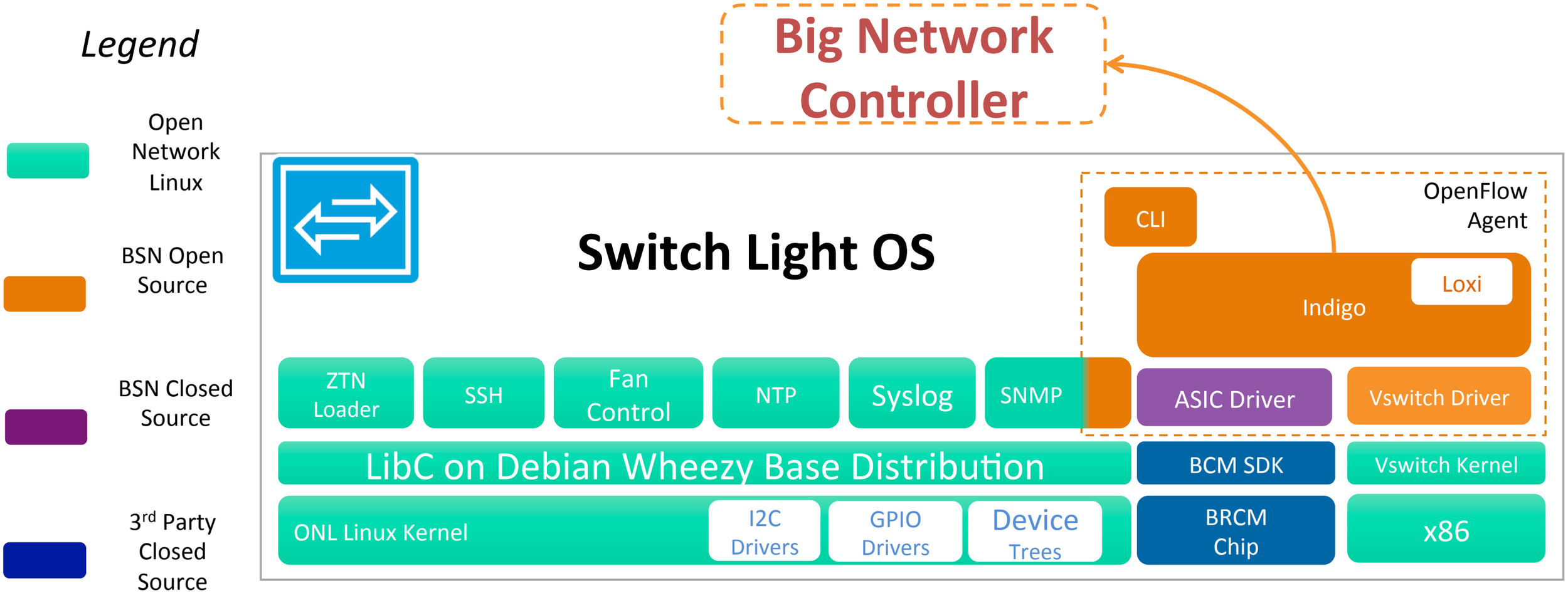
Indigo OpenFlow Agent

- Different from “Indigo v1”
  - Complete rewrite
  - Uses LoxiGen/Loci – not openflow.h
- Design Goal:
  - Highly portable across ASICs, platforms, operating systems
  - Top half/bottom half design: separate hardware dependent bits
  - Roughly Agnostic to OpenFlow version – work on intermediate form
  - Composed of lots and lots of modular libraries

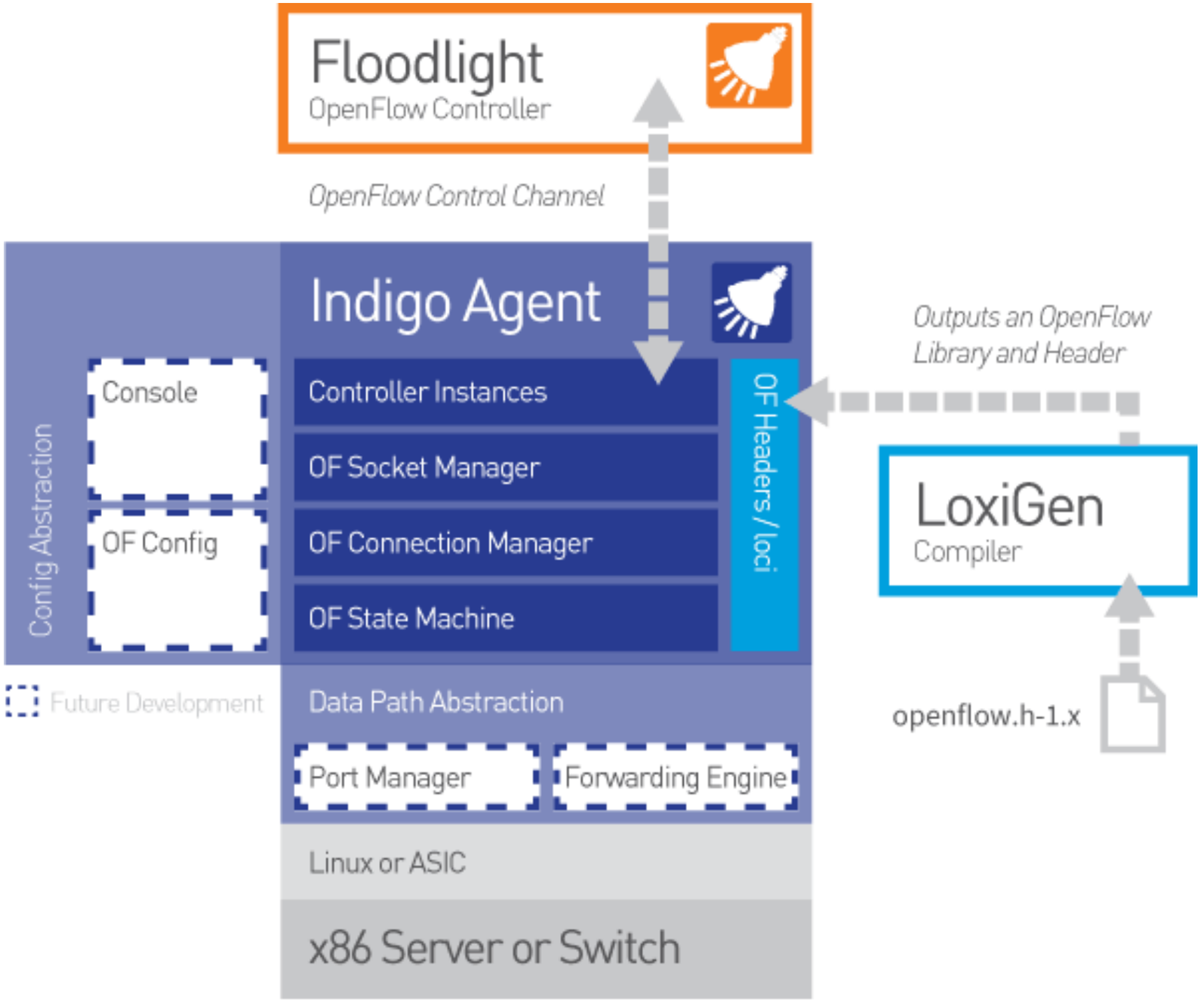
Indigo "Bottom Half" Ports

- Indigo Virtual Switch – http://projectfloodlight.org/indigo-virtual-switch
- Broadcom SDK – Binary only
- Broadcom OF-DPA – source code with OF-DPA distribution
- Mellanox's SDK – Demo only (?)
- And others…

Switch Light Architecture



Switch Light is our Indigo OpenFlow Agent running on Open Network Linux on x86 or Broadcom hardware.


Floodlight
OpenFlow Controller
OpenFlow Control Channel
Indigo Agent
Controller Instances
OF Socket Manager
OF Connection Manager
OF State Machine
OF Headers / loci
Config Abstraction
Console
OF Config
Future Development
Data Path Abstraction
Port Manager
Forwarding Engine
Linux or ASIC
x86 Server or Switch
Outputs an OpenFlow Library and Header
LoxiGen
Compiler
openflow.h-1.x

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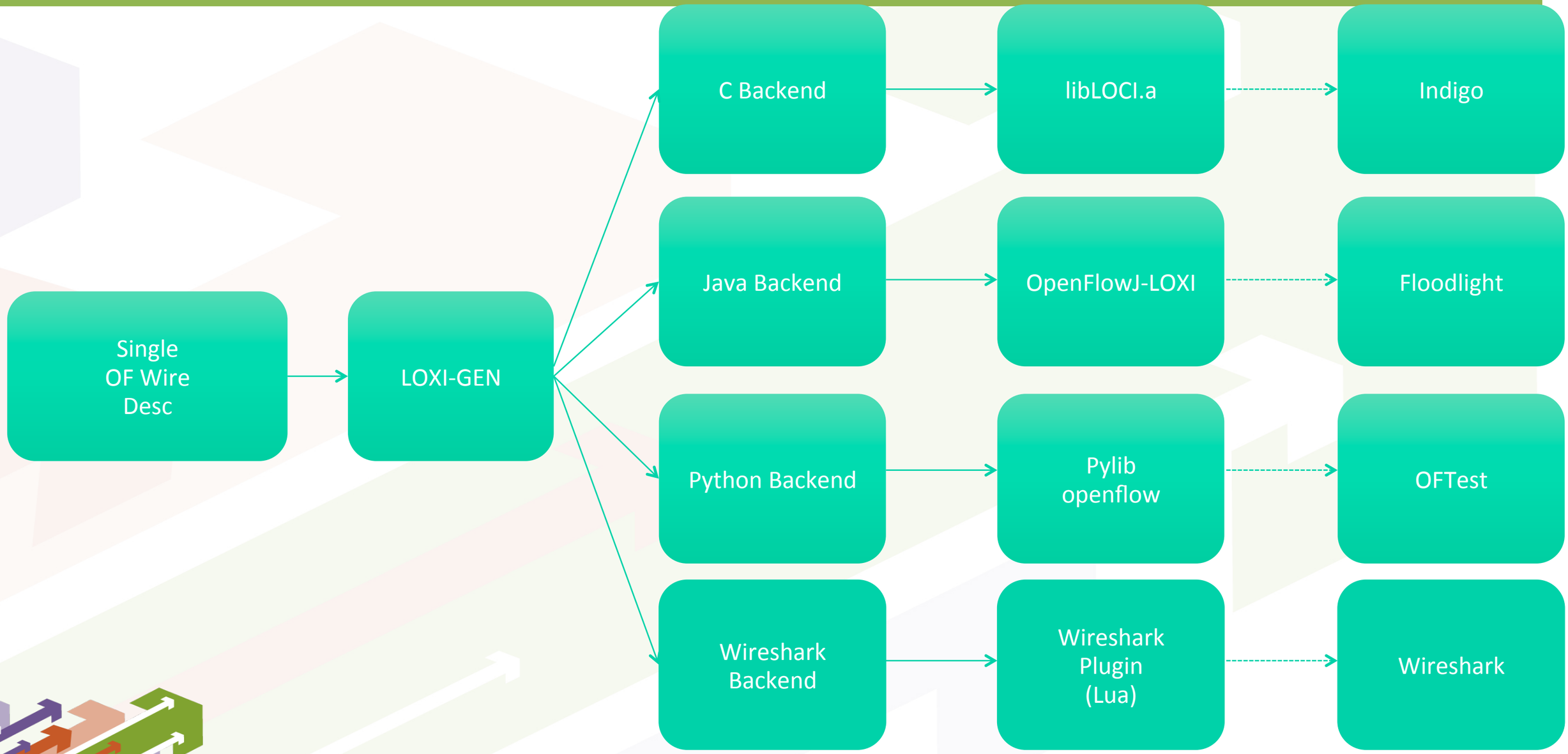
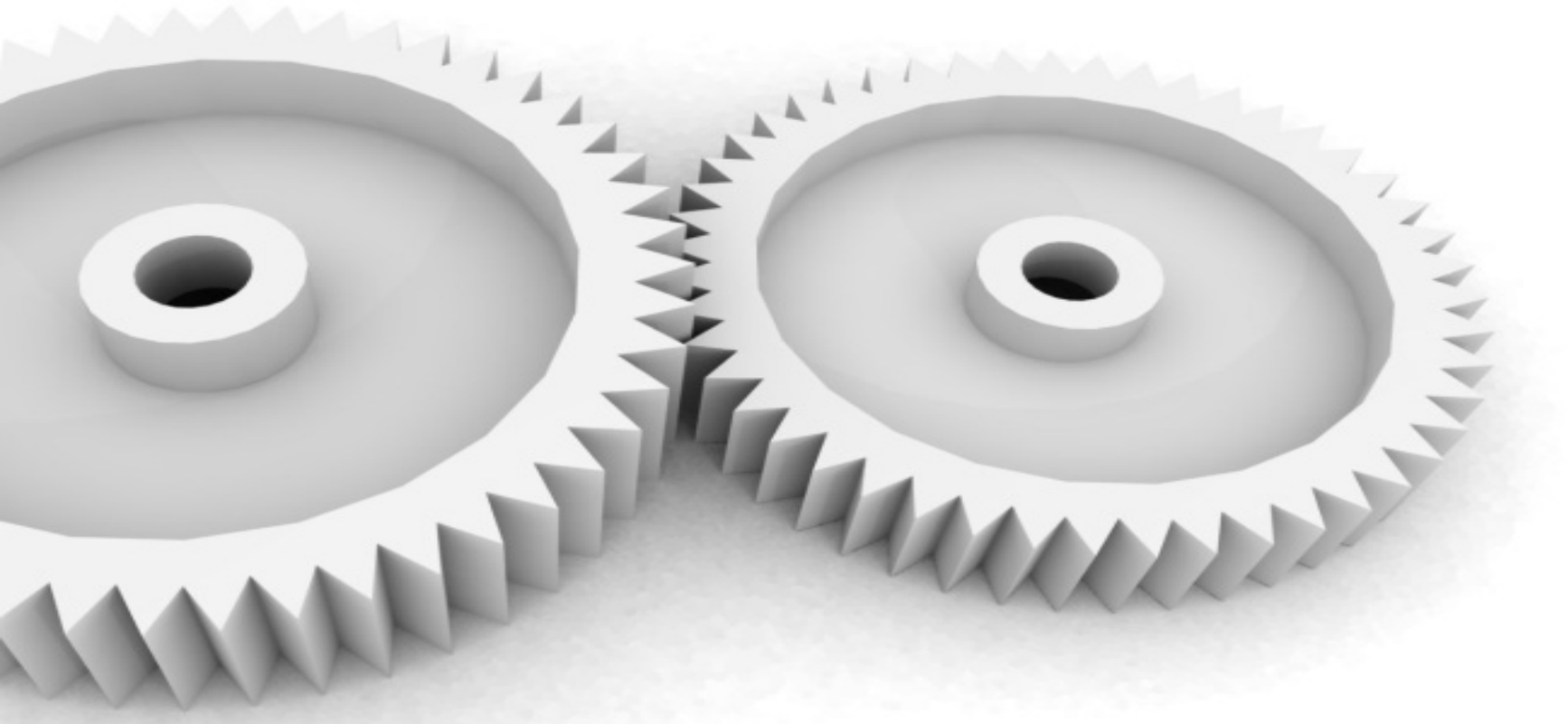
Challenge: Floodlight Needs OpenFlow 1.3 Support!

- All of the right bits are there
  - All of the language bindings are done
- Just need to update the handshaking and example code
  - A mere mater of days of work – “TM”
  - But I haven’t had the time
- Is this a possible community activity?
  - “openflow-1.3” branch on github.com/floodlight/floodlight

LOXI is fully OF1.3.1

git://github.com/floodlight/loxigen



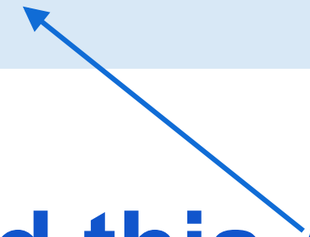


OpenFlowJ*ng*: Architecture Ideas for OF 1.x compatibility

What's this about?

A new OpenFlow API for Floodlight with support for OF1.[0-3+]

- Message classes
- Message/wire conversions
- Types



How should this API look like?

It's not...

...about **implementation details**

Code generated by LOXI, but that's beside the point.

Higher Level Stuff: Not Today!

Portability:
abstract away OF
version / hardware
differences
virtualize resources

Network model:
a **higher level / network wide forwarding**
forwarding abstraction

Hard problems!

Solutions to be built on top of this

Why?

- Current API has prob... err, optimization potential
  - mutable state passed around 100s lines of code
  - int bitmasks -> people use magic numbers
  - manual housekeeping of line format metadata
    - Forgot to update size, anyone?
  - messages don't guarantee invariants…
- A convenient/safe API helps
  - test coverage
  - correctness

Design Goals

Multiple Versions support

- OF 1.[0-3]+ compatibility
  - Easy upgrade path for newer versions
  - Support for Vendor extensions
  - Expose extended features
  - **Provide "1.0 compatible" baseline**

Bug Resilience

- Type safety (enums vs. short type)
- No Integer bitmasks
  - necessary for multi-version support
- No manual housekeeping of wireformat properties
- Localize state mutation / limit passing of mutable state

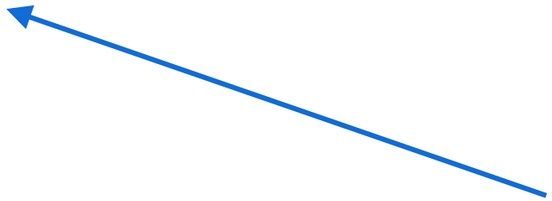
More...

- Convenience, also for manual creation
  - Unit tests!
- Enable Performance optimizations
  - Lazy parsing
  - Caching of messages

Design Goals - in a nutshell

"Work hard in the API to make life easy for apps/clients"

Architecture



(no UML[*]. Promised.)

[*] almost

Interfaces and Value Classes

Interfaces
All OF Message types exposed as Interfaces

(Messages, Actions, Matches etc.)

Value Classes

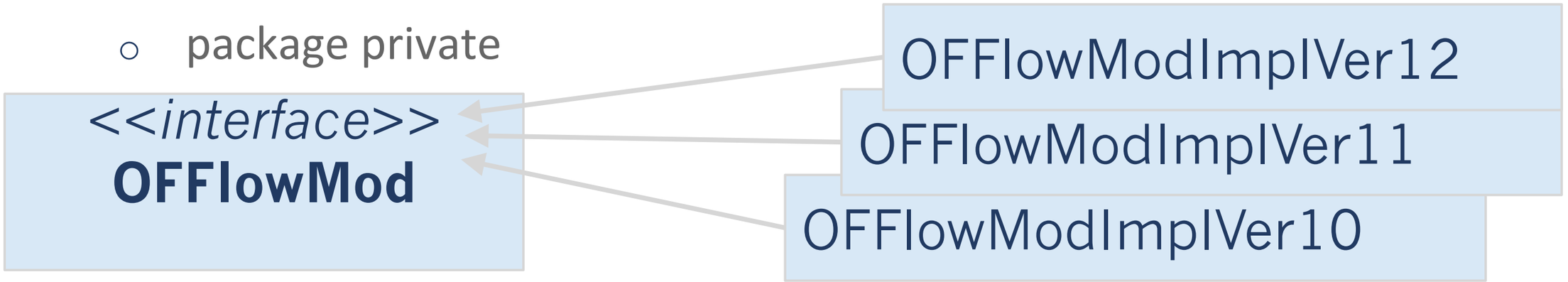
for constant, simple concepts (IPv4Address, MacAddress)

stuff that (potentially) changes between versions

stuff that always stays the same

Interfaces

- One Interface for all versions
  - provides Union of the features
  - supports querying for features
  - throws UnsupportedOperationException()
- version specific implementations
  - package private



Immutability

Immutability

All Message / Value
Objects are immutable(*)

threadsafe
cacheable
safe to pass around

How do you create stuff?

(*) externally visible

Instance creation

Instance controlled

No constructors. Ever.

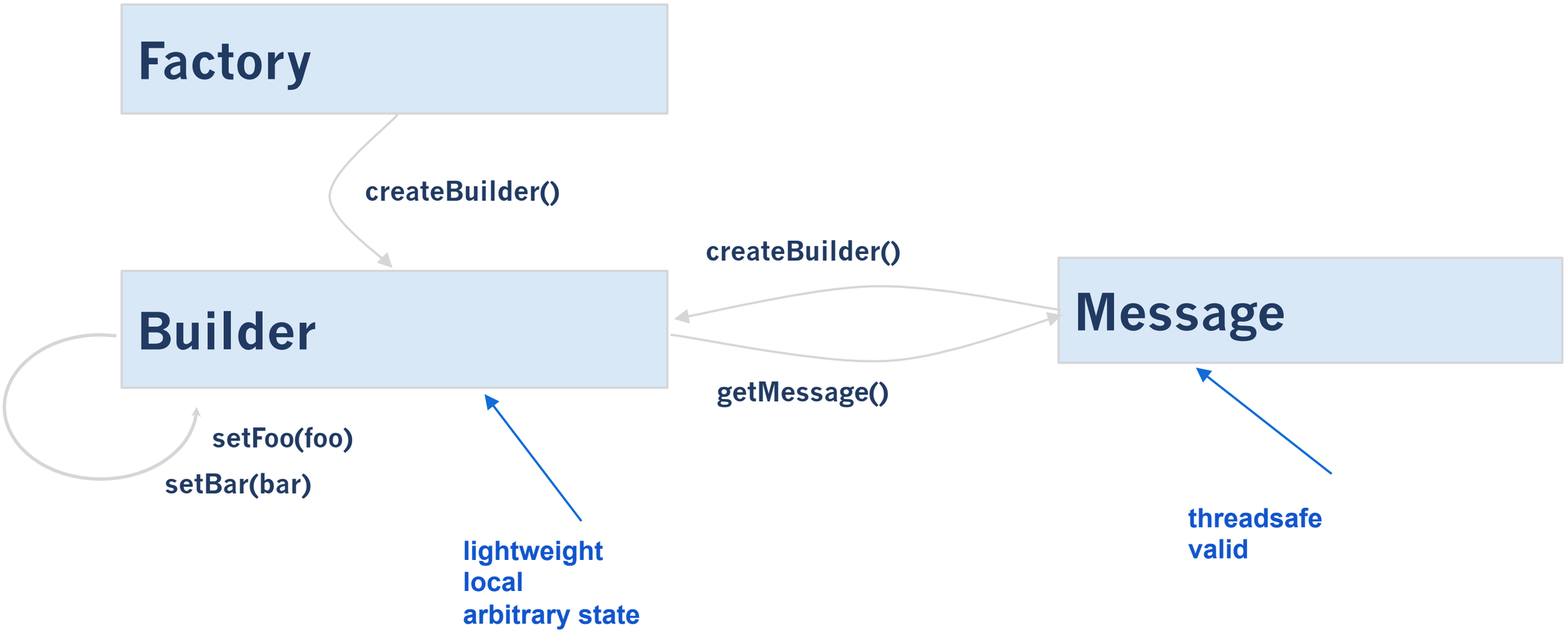
Complex OF Message types:
Factories / Builders
factory.createBuilder()

Simple Value Objects:

Factory Methods
IPv4.of("1.2.3.4/24")

But I hate factories!!! ☠

Message Objects and Builders



Sample Packet Loop

```
OFConnection conn = switch.getConnection();
while (true) {
    // read from wire
    OFGenericMessage message = conn.readMessage;

    switch (message.getType()) {
        case ECHO_REQUEST:
            send(message.asEchoRequest().createReply());
            break;
        case PACKET_IN:
            handlePacketIn(conn, message.asPacketIn());
            break;
        case FLOW_STATS_REPLY:
            updateStats(message.asFlowStatsReply());
            break;
}
```

Wire Transfer is done by messageFactory

createReply() convenience function

GenericMessage has getType() and as${type}()

Create a Match

```
private Match createMatch(OFMessageFactory fact, OFPacketIn packetIn) {
    MatchBuilder builder = factory.createMatchBuilder();

    if (builder.supportsField(IN_PORT))
        builder.setField(IN_PORT, OFPort.of(12));

    if (builder.supportsMask(ETH_DST))
        builder.setMasked(ETH_DST,
            packetIn.getMatch().getMasked(ETH_DST));

    if (builder.supportsWildcards(IPV6_DST))
        builder.setMaskedMatch(IPV6_DST, IPv6Mask.of("00:01:02::/64"));

    IPv4 field = builder.getField(IPV4_SRC);

}
```

Match builder can be queried for supported fields

typesafe

Create a FlowMod

```
private void handlePacketIn(OFConnection conn, OFPacketIn packetIn) {

    OFMessageFactory factory = conn.getMessageFactory();
    OFFlowModBuilder fb = factory.createFlowModBuilder();


    fb.setCookie(123).setMatch(createMatch());
    fb.addAction(messageFactory.actionOutput(10));
    OFFlowMod flowMod = fb.getMessage();
    send(flowMod);

    OFFlowMod modifiedFlowMod =
        flowMod.createBuilder().setInport(12).getMessage();
    send(modifiedFlowMod);
}
```

chained setters

builders are mutable, single threaded + dirt cheap to construct

Builder used inline to 'modify' (create modified copy) of msg

Summary

- OpenFlowJ/Loxi: major update to Floodlight's OpenFlow API
  - OF **multi version** support *(but doesn't manage the differences for you)*
  - Bug resilience
- 1st Milestone: 2Q
- Check out a demo of the client side API

https://github.com/andi-bigswitch/openflowj-demo

Outline/Schedule: Working Bottom-Up

Time	Event
8:30-9:00a	Open SDN Stack Overview
9:00-10:00a	Open Source Switch OS: Open Network Linux
10:00-11:30a	OF-DPA: Open API for Broadcom StrataXGS Architecture
11:30-12:30p	***Lunch***
12:30-1:00p	Indigo OpenFlow 1.3 Architecture
1:00-2:00p	Floodlight, LOXI, and OpenFlow 1.3 Support

Conclusion: Open SDN Stack

- Phew! – Large Brain Dump
- But, first top-to-bottom Open SDN stack
  - Hardware, OS, ASIC SDK, OpenFlow Agent, OpenFlow Driver, SDN Controller
- Thanks!
- If you're not bored of me, join me in the Research Track ☺

Thank You