The Beacon OpenFlow Controller

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Agenda

• Motivation
• Design Space
• Beacon
• Questions
Motivation

• Back to circa 2008-2009
• The controller world == NOX
  – Single threaded event based C++ with SWIG glue to Python
  – Enabled great research and demos (Thanks Nicira!)
• Python apps interesting with <1k LOC
  – But could have language level runtime errors
  – SWIG hard to use, needed to expose C++ code to Python
  – Much slower than C++
• C++ only apps
  – Solved the Python app problems
  – Cryptic compilation errors (STL, templates, etc)
  – Runtime segfaults and other memory related issues
• I wanted to spend more time on interesting new features and less time fighting platform and/or language related challenges
Motivation cont...

• Was it possible to build a controller with
  – Rapid or no compilation time
    • Human readable errors/warnings
  – Reduced scope of runtime errors
    • Managed code
    • Static type checking
  – High developer productivity
    • Mature toolchains
    • Code generation/auto complete
  – Cross platform
  – Performant
    • Within 50% of a fast C++ implementation

• Note, these were primarily language questions
Design space

• Candidate language: Java
  – No existing OpenFlow protocol bindings
  – Performance?

• Early basic tests with OpenFlowJ
  – Object Oriented OpenFlow 1.0 protocol library
  – Simple sample hub/switch controller
    • NOX pyswitch 9369
    • Simple Python Controller 21019
    • NOX hub (C++) 124,897
    • Reference Hub (C++) 214,591
    • Java (1 thread) 252,246
    • Java (2 threads) 287,567
    • Java (4 threads) 348,762
Design space cont...

• Other desirable controller features
  – Fully multi-threaded
  – Build time modular
  – Run time modular
  – Easy to use and understand abstractions
  – Use existing familiar and well documented frameworks
  – Extensible Web UI and REST capabilities

• Possible to modify existing software?
  – Considered Tomcat
Beacon

• “Die Shot”

*Size not indicative of anything
How does the core work?

- Connects to switches
- Publishes IBeaconProvider service
- Other bundles use IBP

```java
protected IBeaconProvider beaconProvider;

public void startup() {
    beaconProvider.addOFLMessageListener(OFType.PACKET_IN, this);
}

public Command receive(IOFSwitch sw, OFMessage msg) {
    OFPacketIn pi = (OFPacketIn) msg;
    ...
    return Command.CONTINUE;
}
```

- Creates a pipeline...
Pipeline

Core -> PacketIn -> Device Manager -> Topology -> Routing

Decode

Applications

Stats

ETC
• Each app gets OFMessages from all threads
How do Bundles interact?

• Service abstraction
• Create an interface for service contract

```java
public interface ITopology {
    /**
     * Retrieves a map of all known link connections between OpenFlow switches
     * and the last time each link was known to be functioning
     * @return
     */
    public Map<LinkTuple, Long> getLinks();
}
```

• Export an object instance that implements the interface to the service registry
• Other bundles’ objects import and use services
• Enables easy service extension
Service Registry Example

Publishes

- Core
- Device Manager
- Topology
- Routing APSP

Consumes

- Device Manager
- Topology
- Routing

Controller

- IBeaconProvider
- IDeviceManager
- ITopology
- IRoutingEngine

Core

Device Manager

Topology

Routing APSP

Service Registry
Service Examples

• **Queryable**
  – “Give me a list of all connected switches”

• **Explicit Event Registration**
  – “Add me as a listener for OFPacketIn messages”
  – “Notify me when switches connect/disconnect”

• **Implicit Event Registration**
  – Export an *Aware service interface, consuming services post relevant events to all implementers
  – ITopologyAware, all implementers receive link updates
What Bundles are available?

• Beacon centric
  – OpenFlowJ (OF 1.0 Protocol)
  – Packet encoder/decoder (Ethernet, ARP, IPv4, LLDP, TCP, UDP)
  – Core, Learning Switch, Hub, Device Manager
  – Topology, Layer 2 Shortest Path Routing
  – ARP Proxy, DHCP Proxy, Multicast eliminator
  – Declarative routing (upload a text file)
  – Web UI

• Third party, basically anything
  – Just a JAR file with Metadata
  – Some may need YOU to generate the Metadata
  – Logging, Web Server, JSON parsing, Web framework, etc
Is there a NIB?

• Decentralized
  – Relevant bundles store the data and export query and event interfaces

• Currently soft-state only
  – Persistence engines can be added to extend existing capabilities
Why Bundles?

• Unit of modularity in OSGi
• Basic Building Block
• JAR (zipfile)
• May Contain
  – Metadata*
    • META-INF/MANIFEST.MF
  – Java Classes
  – Resources (xml, etc)
  – Other JAR files

* Required
What can Bundles do?

• Share code with other packages
  – Export-Package: net.beaconcontroller.core

• Consume other Java Packages
  – Import-Package: org.openflow.protocol

• Extend other Bundles
  – Fragments

• Run Code

```java
public void start() {
    listenSock = ServerSocketChannel.open();
    new Thread(...)
    ...
}
```
Advanced Bundles

• **Dynamic**
  – Stop, Start, Install, Replace while running

• **Versioned**
  – Can have multiple versions live simultaneously

• **Explicit Dependencies**
  – State which version(s) you need
Performance

• Measured June 2011

Cbench Test, part of Oflops suite
  - PacketIn to PacketOut/FlowMod throughput test, fills controller input buffers
  - 10 loops, 32 switches, 10s per loop

Test Machine
  - CPU: 1 x Intel Core i7 930 @ 3.33ghz, 9GB RAM, Ubuntu 10.04.1 x64

Controllers
  - Beacon, NOX (Destiny branch), Maestro

http://www.openflow.org/wk/index.php/Controller_Performance_Comparisons
Web UI

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Overview | OSGI | Ports
Web UI
Status

• 2010 April – 2011 September
  – Incubation and internal use
  – Limited external releases
• 2011 September 12
  – v1.0.0 Release
• Since
  – Ongoing active development
  – Accepting feature requests/suggestions/bug reports!
• Active user forum
• Many screencasts and guides available
Users?

• My research
  – Full time cluster of 80 machines
  – 97 switches (including vSwitches)
• Inside Big Switch Controller
  – Basis for Floodlight
• CS244 Stanford Graduate Networking course 2011
• FlowScale – load balancing
Lessons learned

- Met design goals
  - Productivity++
- Runtime dynamism does have a cost
- Seemingly minor changes can kill performance
  - 32 vs 64 bit
  - Spring proxies in the fast path
- Wide variety of I/O loop designs
  - With a correspondingly wide variety of fairness and performance consequences
Tutorial

• Unzip tutorial archive
• Launch Eclipse (eclipse subfolder)
  – File -> Import -> General -> Existing Projects into Workspace, Next
  – Point it to the src/ directory, Select All, Finish
• Follow tutorial instructions
  – http://goo.gl/Isuks :)}
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Thanks!

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http://www.beaconcontroller.net/