Seamless Interworking of SDN and IP

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1. INTRODUCTION

Software Defined Networking (SDN) is a new paradigm of networking whose key tenets are: separation of data and control planes; a vendor agnostic interface such as OpenFlow [3] between the two; and a set of abstractions provided by the control plane such as a global network view, virtual network, or logical crossbar to make it easier to program and manage the networks. Transitioning the widely deployed Internet infrastructure to SDN represents a significant challenge and requires creative ideas for incremental deployment of SDN networks. During the transition, SDN networks need to coexist with traditional IP networks and any SDN deployment must be able to exchange reachability information, forward traffic, and express routing policies with existing IP networks. In this paper, we propose a solution for incremental deployment of SDN networks and how they can seamlessly peer with IP networks. The solution has been implemented and evaluated for feasibility and performance.

2. SDN-IP NETWORK PEERING

Peering between ASes (Autonomous Systems) on the Internet today is universally done with Border Gateway Protocol version 4 (BGPv4) [6]. Therefore we need a mechanism for an SDN AS to communicate with IP ASes via BGP.

The overall architecture is shown in Figure 1. This figure shows an SDN AS with gateway OpenFlow switches peering with external border routers from other ASes. To achieve peering, the centralized SDN control plane integrates a BGP process for the SDN AS. The BGP process handles routing updates with BGP peers on external IP networks. The entire SDN AS appears as a single router to its peers.

There is an SDN-IP peering application (including a BGP Route module and a Proactive Flow Installer) running on top of the network operating system (NOS). The BGP route module is responsible for synchronizing BGP route updates pushed by the BGP process and storing them in a local RIB (Route Information Base). The Proactive Flow Installer uses the routes learned through BGP to calculate and install the flow entries for Inter-AS traffic.

Figure 1. Architecture of SDN-IP Network Peering

2.1 RIB Synchronization

RIB updates from the BGP process are sent to the SDN-IP peering application running on the SDN NOS. We designed a RIB synchronization protocol for this purpose. This protocol is based on a REST API with GET, POST, and DELETE methods to sync the RIB, and additional APIs to coordinate behavior after process restart (Table 1). The API allows batching of RIB updates to send multiple updates in a single POST request. We plan to re-implement the protocol using a connection-based mechanism in the future, as we reach the speed, reliability and scaling limits of the current protocol.

<table>
<thead>
<tr>
<th>Function</th>
<th>REST API</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initialization / Restart</td>
<td>/wm/bgp/&lt;router-id&gt;/&lt;capability&gt;</td>
</tr>
<tr>
<td>Single update</td>
<td>/wm/bgp/&lt;router-id&gt;/&lt;prefix&gt;/&lt;nexthop&gt;</td>
</tr>
<tr>
<td>Batched updates</td>
<td>/wm/bgp/&lt;router-id&gt;/rib/json</td>
</tr>
</tbody>
</table>

2.2 Proactive Flow Installer

The proactive flow installer in the SDN-IP peering application is used to convert each route in the RIB to flow entries in the FIB (Forwarding Information Base), and to proactively calculate and install the flow entries onto OpenFlow switches in the SDN AS. This action is triggered by BGP updates.

We use a concept of SDN edge and core to reduce churn on the OpenFlow switches when BGP routes flap. We do prefix based lookup at the first hop switch and MAC based forwarding in the SDN core (Figure 2). We proactively install a full-mesh of flow
paths between all pairs of gateway OpenFlow switches based on
the gateways' MAC addresses. These flow paths are updated only
when the internal SDN topology changes. At the first-hop switch,
flow entries match external IP prefixes, and send packets on the
appropriate flow path to the next-hop router learned from the BGP
nexthop. When the nexthop for an IP prefix changes, the only thing
that needs to be updated is the flow entry in the first hop switch.
These flow entries update at the frequency of BGP route updates.

Figure 2. MAC Address Rewriting and Layer 2 Forwarding

2.3 Discussion on BGP Speaker

We chose a logically centralized BGP process for simplicity and
correctness. Since all the external paths are selected by BGP, we
are guaranteed not to break BGP semantics or create routing loops
because BGP is computing the best paths. Additional benefits are
centralized monitoring and software upgrade.

The BGP process needs to scale with number of peers and size of
the RIB. In public IP peering use cases, a single BGP process can
handle the full Internet routing table and the number of BGP peers.
In service provider VPN (Virtual Private Networks) use cases,
multiple BGP processes may be needed to handle the higher peer
scaling. Our demo implementation uses a single BGP process.

There are two ways of getting BGP packets from the gateway
OpenFlow switches to the BGP process. One approach is to
provision BGP flows from all gateway switches to a server or VM
(Virtual Machine) running the BGP process. Another is to intercept
BGP packets at the gateway switch and shunt them to the BGP
process through the control channel. The second approach is easier
to provision but can stress the slow control path of OpenFlow
switches. This demo uses the first approach and the deployment (in
Section 5) uses the second approach.

3. DEMO IMPLEMENTATION

The BGP process is ZebOS BGPd [5] modified to send RIB
updates to the SDN-IP peering application. The SDN AS is
controlled by ONOS (an experimental distributed SDN Operating
System) [2]. We implemented SDN-IP network peering as an
application on ONOS. The demo network is emulated using Mininet
[1]. Figure 3 shows the demo topology with SDN AS1 peering with
three IP ASes.

**Functional test:** We created an inter-AS flow from a host in SDN
AS1 to AS2, and a transit flow from AS3 to AS2. We demonstrate
successful re-convergence when SDN internal links or SDN-IP
external links fail.

**Performance test:** The SDN-IP peering application can scale to
10,000 RIB entries. The BGP process consumes 580 Mbytes of
physical memory while the SDN-IP peering application (together
with ONOS) consumes about 460 Mbytes (see Figure 4). It can
process 100 RIB updates per second.

Figure 3. Demo Scenario and Configuration

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4. RELATED WORK

RouteFlow [4] is one of the first implementations of IP routing on
OpenFlow switches. RouteFlow instantiates a VM for each
OpenFlow switch with as many virtual network interfaces as there
are active ports in the corresponding device, and runs a stack of
open-source routing protocols on the virtual topology. All control
messages are exchanged between VMs as if they are running a
distributed control plane. Such a solution incurs the overhead of
distribution without the benefits of scale. The SDN-IP Peering
Application is a simpler design, better integrated with SDN, and
easier to implement advanced features such as traffic engineering
and policy-based routing through the SDN domain.

5. FUTURE WORK

In collaboration with Google and REANNZ, we will deploy the
SDN-IP network peering system to a small active SDN network in
Wellington, New Zealand. Following this deployment we plan to
improve the scalability and fault tolerance of the system.

6. REFERENCES