Extending OpenFlow for Managing Service Insertion and Payload Inspection

Robinson Udechukwu
Dr. Rudra Dutta
Dept. of Computer Science, North Carolina State University
Outline

• Big Picture
  • What is OpenFlow

• Contribution: External Processing Box
  • Design
  • Experiment
  • Results
Big Picture

- Software Defined Networking - a new paradigm for agile network policy evolution
  - Separation of policy and mechanism
  - OpenFlow: an open API between the two
  - Allows software realization of definitive network components: architectural, mgmt and control
  - Forwarding has to be wirespeed: need hardware
  - Anything on policy box may be software: agile traffic engineering
Big Picture

Problem: limited reach of traffic engineering application definition

- OpenFlow limits flow definition to L2, L3, L4
- Cannot expand broadly (say, L7) without sacrificing performance of forwarding engine
- Cannot outsource to policy box without sacrificing scalability of separation
Big Picture

- Our contribution
  - Propose, design, and demonstrate "helper box" idea
  - Specific extensions to flow definition in a separate box that can be optionally attached to mechanism box
  - Optionally traversed by data packets on need basis
  - Seamlessly controlled by the policy box with a natural extension of OpenFlow
OUR PROPOSED SOLUTION: EXTERNAL PROCESSING BOX
Proposed Solution

- Allows the forwarding engine to outsource traffic examination for L7 information

- This External Processing box, provides a middleware platform for Deep Packet Inspection (DPI) programs
Proposed Solution

- Assess this system by evaluating the perceived video quality on subjective and objective video assessment tools
EXTERNAL PROCESSING BOX - DESIGN
Inside the External Processing Box

Datapath

- Control data?
  - Yes: OpenFlow Dissector
  - No: DPI Engine

External Processing

- DPI Rules
- Traffic Shaper
- Policy Interface

Legend

- Faux Packet with OFP Encapsulated Data
- Data
- Writes a DPI Rule
- Restarts DPI Engine
- Sends OFP formatted payload
- DPI defined Alert Packet
- Data with a assigned VLAN ID attached

k:
- packet is RTSP, send to 3
- packet is RTP, send to 2
- Packet is RTCP, send to either 2 or 3 based on its source port
- Else drop the packet
EPB Components description

- **OpenFlow Dissector** – Parses EPB Policy Message from the UDP packet and transmits it to the Policy Interface.

- **Policy Interface** – Transforms received EPB Policy Messages into DPI Rules semantics.

- **DPI Rules** – Maintains a set of rules which the DPI Engine will allow access to the Traffic Shaper.

- **DPI Engine** – Packet sniffer application that categorizes the packet for shaping by the Traffic Shaper.

- **Traffic Shaper** – Shapes traffic using VLAN tags based on DPI Engine categorization of the packet.
## Bits on the wire: OFP Experimenter Action

<table>
<thead>
<tr>
<th>Offset</th>
<th>Octet</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>32</td>
<td>Control Port</td>
<td>Data Port</td>
<td>Library ID</td>
<td>Library Options</td>
</tr>
<tr>
<td>8</td>
<td>64</td>
<td>Library Options</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>96</td>
<td>Library Options</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>128</td>
<td>External Processing Search Field Type</td>
<td>Search Field Length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>160</td>
<td>External Processing Search Field Value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>192</td>
<td>External Processing Search Field Value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>224</td>
<td>External Processing Search Field Value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>256</td>
<td>External Processing Search Field Value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>288</td>
<td>External Processing Search Field Value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>320</td>
<td>External Processing Search Field Value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>352</td>
<td>External Processing Search Field Value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>384</td>
<td>External Processing Search Field Value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>416</td>
<td>External Processing Search Field Value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>448</td>
<td>External Processing Search Field Value</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Built using OpenFlow’s Action Experimenter Property
Bits on the wire: EPB Policy Message

| Octet | Bits | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|-------|------|---|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0     | 0    |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 4     | 32   |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 8     | 64   |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 12    | 96   |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 16    | 128  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 20    | 160  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 24    | 192  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 28    | 224  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 32    | 256  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 36    | 288  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 40    | 320  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 44    | 352  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 48    | 384  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 52    | 416  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 56    | 448  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 60    | 480  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 64    | 512  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 68    | 544  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 72    | 576  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 76    | 608  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 80    | 640  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Built using OpenFlow’s Experimenter Message
### Video-on-Demand Library Options - Examples

<table>
<thead>
<tr>
<th>Offset</th>
<th>Octet</th>
<th>Bits</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Octet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>48</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RTSP**
- **Operation Type**: Video-on-Demand Server Port Address
- **Expedited Port**: Regular Port
- **Unused**: Unused

<table>
<thead>
<tr>
<th>Offset</th>
<th>Octet</th>
<th>Bits</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Octet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>48</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RTP/RTCP**
- **Operation Type**: Client RTP Port Address
- **Client RTCP Port Address**: Server RTCP Port Address
- **Server RTCP Port Address**: Server RTCP Port Address

10/22/14
EXTERNAL PROCESSING BOX - EXPERIMENT
Experiment – Logical Topology

Legend

- Best-effort Route
- Expedited Route
Controller

OpenFlow

Data Plane

Datapath

Experimenter Actions and attached OpenFlow Match

k:
- packet is RTSP and contains specified URL, send with VLAN 5
- packet is RTCP and contains specified body, send with VLAN 6
- packet is RTP, send with VLAN 7

External Processing Box (EPB)

Multimedia Server

Experimenter Action

OFPExternalProcessingAction
- Send to EPB, packets needing additional processing
- Provide EPB with the EPB’s outgoing port (VLAN ID)
- Provide a Library ID and Library options for EPB Policy Instruction message

10/22/14
Experiment Flow

**Controller**

**OpenFlow**

**Datapath**

**Multimedia Server**

**External Processing Box (EPB)**

**Control Plane**

**Experimenter Action**

`OFPExternalProcessingAction`

- Send to EPB, packets needing additional processing
- Provide EPB with the EPB’s outgoing port (VLAN ID)
- Provide a Library ID and Library options for EPB Policy Instruction message

**Data Plane**

**Experimenter Actions and attached OpenFlow Match**

- packet is RTSP and contains specified URL, send with VLAN 5
- packet is RTCP and contains specified body, send with VLAN 6
- packet is RTP, send with VLAN 7
Points to Note

- No special or proprietary hardware
- No endpoint signaling / action necessary
- Open, reusable extension in OF-recommended manner
- General approach to OF-compatible service insertion
Video Demonstration

Legend

Best-effort Route

Expedited Route
Video Demonstration
Evaluation and Testing

- We used Video-Tester to perform objective video quality assessment and QoS measurements.

- Video-Tester comes equipped with a RTSP server and client, thus must be deployed on both client and the media server.

https://code.google.com/p/video-tester/
Take Away

- Demonstrates a seamless general-purpose in-network service insertion mechanism integrated with OpenFlow

- Allows value added network services to be dynamically included on the fly
  - Improve jitter rendered video in real-time
  - Context-sensitive services: Public Service Information
EXTRA SLIDES
EXTERNAL PROCESSING BOX - RESULTS
### Test Suite

<table>
<thead>
<tr>
<th>Identifier</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Baseline, no Traffic Controller or EPB involved</td>
</tr>
<tr>
<td>B</td>
<td>EPB with Traffic Controller 1 activated</td>
</tr>
<tr>
<td>C</td>
<td>EPB with both Traffic Controllers activated</td>
</tr>
<tr>
<td>D</td>
<td>Only Traffic Controller 1 activated</td>
</tr>
<tr>
<td>E</td>
<td>Both Traffic Controllers activated</td>
</tr>
<tr>
<td>F</td>
<td>EPB with Traffic Controller 1 and Expedited Routes activated</td>
</tr>
<tr>
<td>G</td>
<td>EPB with both Traffic Controllers and Expedited Routes activated</td>
</tr>
</tbody>
</table>
Jitter Experienced by the three videos

- Test A
- Test D
- Test E
Jitter

![Graph showing jitter experienced in different test scenarios.](image-url)
Jitter

![Graph showing Jitter Experienced: Foreman with test scenarios C, E, and G. The graph plots milliseconds against test scenarios.]
PSNR-MOS Score

Test Scenarios

Mean Opinion Score

PSNR defined MOS Akiyo

Test B  Test D  Test A  Test F

PSNR-MOS Score

00110001001110010011011000110111
PSNR-MOS Score

Mean Opinion Score

PSNR defined MOS: Akiyo

Test Scenarios

Test C

Test E

Test G

10/22/14
SSIM

SSIM:Football

Test Scenarios

Test B  Test D  Test A  Test F

0.4  0.45  0.5  0.55  0.6  0.65  0.7  0.75
SSIM

SSIM: Football

Test C  Test E  Test G

Test Scenarios
EXTRA SLIDES
Experiment – Actual Setup

- Switch
- PC 2
- Ryu Controller
- Media Server
- PC 1
- LINC (datapath)
- TC 1
- EPB
- TC 2
For UDP packet from port 2 or 3, forward to DPI port 5, for processing

For TCP packet with a port 8554, forward to DPI port 5, for processing

k:
- if packet is for Video Stream 1
  - RTP, send to 2
  - RTCP or RTSP, send to either 2 or 3 based on its destination
- Any other Video Stream
  - RTP, send to 6
  - RTCP or RTSP, send to either 6 or 7 based on its destination
Legend for Animation Slide

- Blue circle: RTSP Data
- Orange circle: Best-Effort RTP/RTCP Data
- Green circle: Expedited RTP/RTCP Data
Experiment – Traffic Flow: Best-Effort Model

RTSP traffic faces delay as it goes through Traffic Controller 1.

Traffic Controller 2 does **NOT** introduce any delay.

Checks whether this packet belongs to an expedited stream, if so tells the Datapath to expedite otherwise tells it use best-effort.

Sending PC 1 video after replying to this message.

Legend:
- Best-effort Route
- Expedited Route
RTSP traffic faces delay as it goes through Traffic Controller 1. EPB intercepts Client ports to allow access for future traffic patterns and saves the URL associated to this flow.

Traffic Controller 2 does NOT introduce any delay.

Sending PC 1 video after replying to this message.

Checks whether this packet belongs to an expedited stream, if so tells the Datapath to expedite otherwise tells it use best-effort.