Control of Multiple Packet Schedulers for Improving QoS on OpenFlow/SDN Networking

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Outline

1. Introduction
2. QoSFlow
3. Performance Evaluation
4. Conclusion and Future Work
QoS in OpenFlow

Versions

- OpenFlow (OF) has improved since it was released
- Queues have come up in OF 1.0
  - OF can forward packets to queues through enqueue action
  - Queues are configured from dpctl and tc tools
  - To enable traffic shaping
- Latest version 1.3
  - It has brought rate limiting feature through meter tables
  - QoS configuration of entire network from control plane
QoS in OpenFlow

Related Work

- Kim [Kim et al., 2010] proposes a framework to provide automated traffic shaping on OpenFlow networks
- Sonkoly [Sonkoly et al., 2012] describes the importance to have bandwidth slicing mechanism on Ofelia testbed
- Cinvalar [Cinvalar et al., 2010] and Egilmez [Egilmez et al., 2012] work introduced routing mechanism by considering packet delay and loss criteria
QoSFlow Proposal

Goal

- QoSFlow is a proposal to enable control of multiple packet schedulers available in the Linux kernel.
- Currently, QoSFlow provides control of such packet schedulers:
  - HTB (Hierarchical Token Bucket)
  - SFQ (Stochastic Fairness Queueing)
  - RED (Randomly Early Detection)
  - FIFO - default scheduler
- The current implementation is based on OF 1.0 and extends the datapath based on it.
QoSFlow Proposal
Design of Datapath Extension: Addition of QoS modules

Traffic Shaping
Packet Scheduler
Enqueue

User Space
Kernel Space

Port N (Virtual Queues)

Port 2 (Virtual Queues)

Port 1 (Virtual Queues)

Physical Interface Card
Physical Interface Card
Physical Interface Card
QoSFlow Proposal
How Does the Control Plane Attach Schedulers?

- OpenFlow protocol is extended
- New messages are added to OF protocol in order to enable control plane to attach packet schedulers
  - Header (OF Type): OFPT_QUEUEING_DISCIPLINE
  - Subtypes for: HTB, SFQ, RED and FIFO
  - Body: where specific parameters of each scheduler are carried
- The datapath handles such messages properly by converting them into Netlink message (low-level message)
- Then, the datapath opens a channel with the Linux kernel for configuration
Performance Evaluation

Methodology

The assessments consist of:

- Response time of a switch to configure packet schedulers
- Maximum throughput achieved by switch
- CPU and RAM overhead (use of `top` tool)
- Bandwidth isolation feature
- QoE (use of `Evalvid` framework)

The testbed is done over TP-Link 1043ND switch model with OpenWrt Backfire (embedded Linux)

QoSFlow datapath executes on top of OpenWrt as a daemon
Performance Evaluation

Methodology

- **Maximum throughput**
  - TCP flow
  - Iperf tool
- **Bandwidth isolation**
  - TCP and UDP flows
  - Iperf tool
- **QoE**
  - Two identical videos
  - Evalvid framework

**Network Topology**
Performance Evaluation

Switch Capacity

- Maximum throughput achieved by OF and QoSFlow switches

Maximum Throughput (TP-Link 1043ND)

<table>
<thead>
<tr>
<th>Number of Switches in Line</th>
<th>Average Received Bitrate (Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1sw</td>
<td>~54Mbps</td>
</tr>
<tr>
<td>2sw</td>
<td>~53Mbps</td>
</tr>
<tr>
<td>3sw</td>
<td>~52Mbps</td>
</tr>
</tbody>
</table>

- 1sw: OpenFlow-enabled switch
- 2sw: OpenFlow-enabled switch
- 3sw: QoSFlow-enabled switch

~44Mbps ~43Mbps ~42Mbps
Performance Evaluation

Bandwidth Isolation

- Ability of bandwidth slicing
Performance Evaluation

QoE

- FIFO vs SFQ performance

PNSR Evaluation of Two Video Flows

Average PSNR (dB)

- Video 1: FIFO 17.41, SFQ 35.92
- Video 2: FIFO 24.09, SFQ 35.92
Performance Evaluation
Methodology

- **Response time**
  - Difference time before and after a QoS operation

- **CPU and RAM overhead**
  - `top -p <pid>`
  - Display Linux processes

![Network Topology](image)
Performance Evaluation

Response Time

- Communication delay from user-space to kernel-space

![Response Time of QoS Operations (TP-Link 1043ND)](chart)

- HTB
- PFIFO
- BFIFO
- SFQ
- RED

**Response Time of QoS Features (ms)**

- Add
- Remove
- Update
Performance Evaluation
Number of Queues Impact: CPU and RAM usage

Output port: 8 queues \times 5 \text{ Mbps} vs 1 queue \times 40 \text{ Mbps}
Conclusion and Future Work

- QoSFlow brings Linux packet schedulers into OF networks by extending standard datapath and the OF protocol
- We believe that QoSFlow can be used on backbone networks for QoS and QoE improvement
- The focus of this work is the datapath performance
- As work ahead..
  - Investigation of other packet schedulers
  - Assessments on more sophisticated OF switches
  - Analysis on impact of schedulers over other QoE metrics
  - Policy-based management framework
- We’ve been implementing the current features into OF 1.3
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Thank You!
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