OFSwitch13: Enhancing ns-3 with OpenFlow 1.3 Support

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Outline

❖ Introduction
❖ Software-Defined Networking
❖ The OFSwitch13 module
❖ Case study scenario
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Introduction

- Global IP traffic is increasing at a compound annual growth rate of 23%.
- Mobile data represents near 57% of global IP traffic.
- Software-Defined Networking will be a key differentiator of future (mobile) systems.

Introduction

- OFSwitch13 development was motivated by SDN and LTE integration issues in Mininet
- Alternative to the outdated ns-3 OpenFlow module
  - ns-3 OpenFlow version: 0.8.9 (2008)
  - Latest specification version: 1.5.1 (2015)
- The OFSwitch13 enhances ns-3 with OpenFlow 1.3 support
Software-Defined Networking

- Decouples the control plane from the data plane
- Network intelligence is centralized in software
- Simplified distributed forwarding hardware
- More agile and cost-effective networks
OpenFlow protocol

- SDN southbound interface
- Basic primitives to program the forwarding plane of OpenFlow switches
- Concepts of flows to identify network traffic
- **Switch datapath specification**
OFSwitch13 module overview

OpenFlow 1.3 controller app interface
OpenFlow 1.3 switch device
External ofsoftswitch13 library
OpenFlow 1.3 switch device

- OpenFlow switch device used to interconnect ns-3 nodes over CSMA network devices and channels
- Internal collection of ports for packet input/output
- OpenFlow receive callback for packet input on CsmaNetDevice

OpenFlow switch datapath implementation provided by the ofsoftswitch13 library
OpenFlow 1.3 switch device

- Packets for output actions are sent to the OpenFlow 1.3 queue on the correct output port
- Internal collection of queues with unique IDs
- Compatibility with CsmaNetDevice and ns-3 models
OpenFlow 1.3 controller interface

- Provides the basic functionalities for controller implementation
- Manage a collection of OpenFlow switches
- DPCTL utility is used to build OpenFlow messages
- Collection of handlers for processing messages from switches

OFSwitch13 Learning Controller working as a learning bridge device
OpenFlow 1.3 channel

- Interface that connects each switch to an OpenFlow controller
  - Using standard ns-3 network devices and channels to provide realist control plane out-of-band connections
  - It is possible to use an external OpenFlow controller running on the local machine with the help of the TapBridge
    - Not validated yet 😞
ofsoftswitch13 library

- **User-space software switch compiled as a library**
- Provides the complete switch datapath implementation
- Original implementation slightly modified for ns-3 integration
  - Functions related to packet input/output marked as *weak symbols*
  - *Callbacks* used to notify the ns-3 about packet changes and drops
ofsoftswitch13
library architecture

Library architecture highlighting the OFSwitch13 interconnection points
Current limitations

- Only supported by GNU/Linux platforms
- No support for auxiliary connections nor multiple controllers
- OpenFlow channel without TLS encryption
Case study scenario

Two OpenFlow controllers
Two 10 Mbps long-distance connections
Four client nodes with a single TCP uplink flow for each client
New OpenFlow QoS controller

- Implement QoS functionalities exploiting OpenFlow 1.3 features
  - Link aggregation at MAC level
  - Load balancing at application level
  - QoS per-flow metering solution
- QoS controller manages both border and aggregation switches
Link aggregation

- **Combine multiple connections to increase throughput**
- OpenFlow Groups are used to randomly select the output port for each packet
- Both border and aggregation switches split the traffic over the two narrowband long-distance connections

![Network throughput comparison](image)
Load balancing

- Implement a server farm and distribute the workload
- OpenFlow extensible match is used to filter ARP requests
- Set-field action is used to replace IP packet headers
- Border switch forwards new requests to controller, which selects the internal server for each connection
Per-flow meters

- Limit flow throughput to ensure network policy
  - OpenFlow Meters are used to measure and limit flow throughput
  - Border switch implements the rate limiter mechanism

![Graph showing TCP connection throughput with and without meter entries over simulation time.](image-url)
Conclusions and future work

❖ The OFSwitch13 enhances ns-3 with OpenFlow 1.3 support
   ❖ Requires minimal changes to ns-3 source code
   ❖ Available as free software at www.lrc.ic.unicamp.br/ofswitch13
   ❖ Complete documentation, examples, and a VM ready for use

❖ As future work…
   ❖ Overcome some of the module current limitations
   ❖ Implement a set of ns-3 tests to endorse module validation
   ❖ Possible incorporation within ns-3 source code
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