Taming SDN Controllers in Heterogeneous Hardware Environments

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Motivation

Software Defined Network abstraction

- Centralized controller
- Collection of programmable forwarding devices
- Communication over well-defined API (e.g. OpenFlow)
Heterogeneity of forwarding devices is an inherent property of Software Defined Networks

How does this effect the responsiveness of SDN applications?
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Example: Datacenter Migration

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Main causes for flow installation latencies at a switch:
- number of messages queued for processing (load dependent)
- rate of processing control messages (switch dependent)
We model the control message processing mechanism of SDN switches as a queueing model.

\[ A(t) \] control message arrivals at switch
\[ D(t) \] control message activations
\[ S(t) \] amount of messages processed over different time intervals
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Experimental setup for service curve estimation:

- forward constant (maximal) rate through traffic
  - inject a burst of control messages into switch with *flowmod* action (or other)
  - capture through traffic and evaluate times between modified header fields

Evaluated two switches implementing OpenFlow 1.0
- OpenVSwitch on quad core Xeon server
- pica8 48x1GB port switch
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Service Curve Estimation: Results

- **mean service with CI**
- **lower bound on service (95%)**

**Software switch**

**Hardware switch**

<table>
<thead>
<tr>
<th>time [s]</th>
<th># of control messages / $10^3$</th>
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<tr>
<td>0</td>
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<tr>
<td>0.2</td>
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</table>
Improving the Controller Interface

How can SDN applications seamlessly benefit from information about switch capabilities?

Current state of OpenFlow

► Rate limiting of control messages offered by some controller frameworks
► OpenFlow barrier messages enable coarse application control
► Applications cannot be tuned to heterogeneous switch capabilities
► No mechanism for estimating the maximum time required for a flow to become active at a switch.
Given bounds on the arrival of control messages, network calculus model enables calculation of maximum delay bounds.
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Improving the Controller Interface

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Proposed approach:
- extend interface of controller framework with *token bucket* regulator
- parametrize regulator for each type of deployed switch such that a specific delay bound holds
Example: configure maximum delay as 0.2s

![Graph showing the relationship between time and the number of control messages.]
Example: configure maximum delay as 0.2s

- HW switch service
- HW switch regulated arrivals

Configured delay bound: $\sigma_{HW}$

$\rho_{HW}$

Graph showing the number of control messages per 10^3 over time [s] with two curves representing HW switch service and HW switch regulated arrivals.
Example: configure maximum delay as 0.2s

![Diagram showing comparison between HW switch service, HW switch regulated arrivals, SW switch service, and SW switch regulated arrivals over time.](image-url)
Benefits of our approach

- Enables SDN applications to gauge flow instantiation time:
  - if control message is accepted by interface it will become active after a predefined maximum time
  - adapt message generation rate by querying processing rate and currently available number of tokens for each connected switch

- TB mechanism allows us to reserve part of switch service for high priority control messages

- Simple extension which does not alter current SDN architecture

- Service curve parameters may be stored in database or exchanged as part of control connection handshake (feature_response)
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Conclusions and Outlook

Contributions

- We showed that device heterogeneity may lead to unpredictable behaviour in SDN applications and must be considered during design phase of increasingly complex SDN applications
- Outlined a model and a measurement approach to characterize control message processing capabilities of SDN switches
- Proposed an unintrusive controller framework mechanism enabling applications to consider substrate capabilities

Our work is a starting point for a number of research directions

- Extend to distributed controller frameworks
- What are the effects of higher abstraction layers on network responsiveness
- How should SDN applications be designed?
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