Taming SDN Controllers in Heterogeneous Hardware Environments

Zdravko Bozakov Amr Rizk

Leibniz Universität Hannover
Fakultät für Elektrotechnik und Informatik
Institut für Kommunikationstechnik

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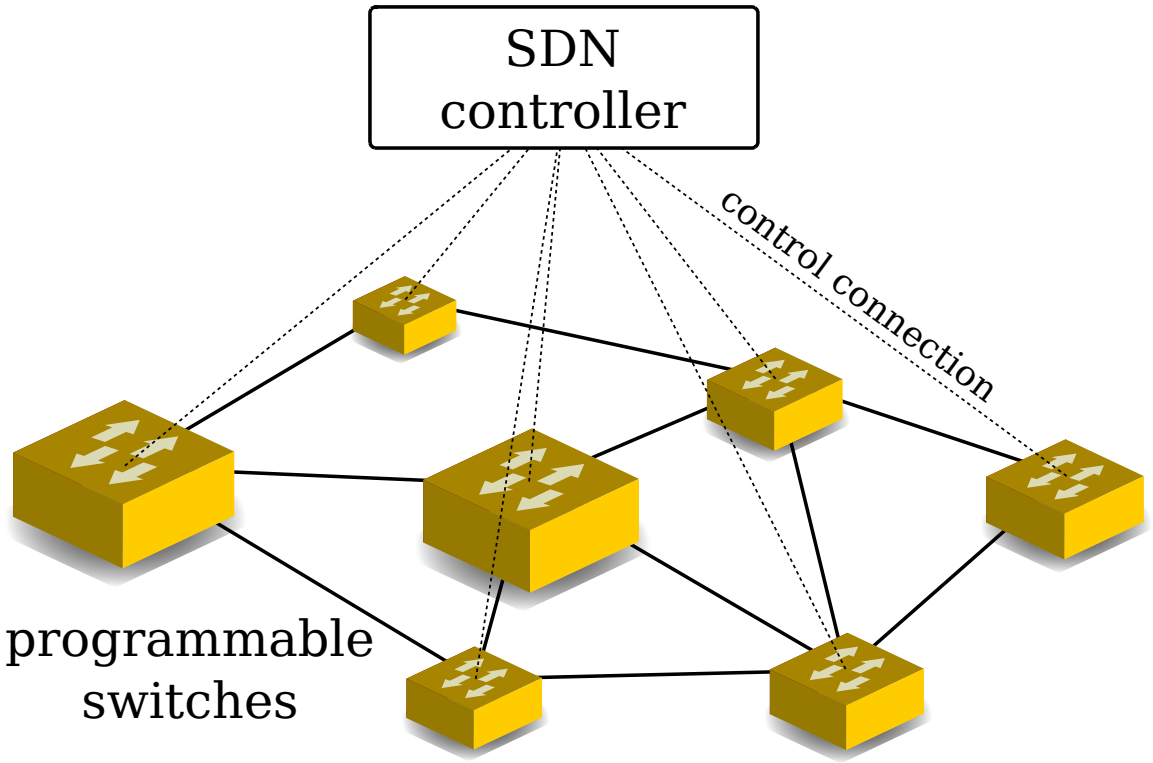
Software Defined Network abstraction



- 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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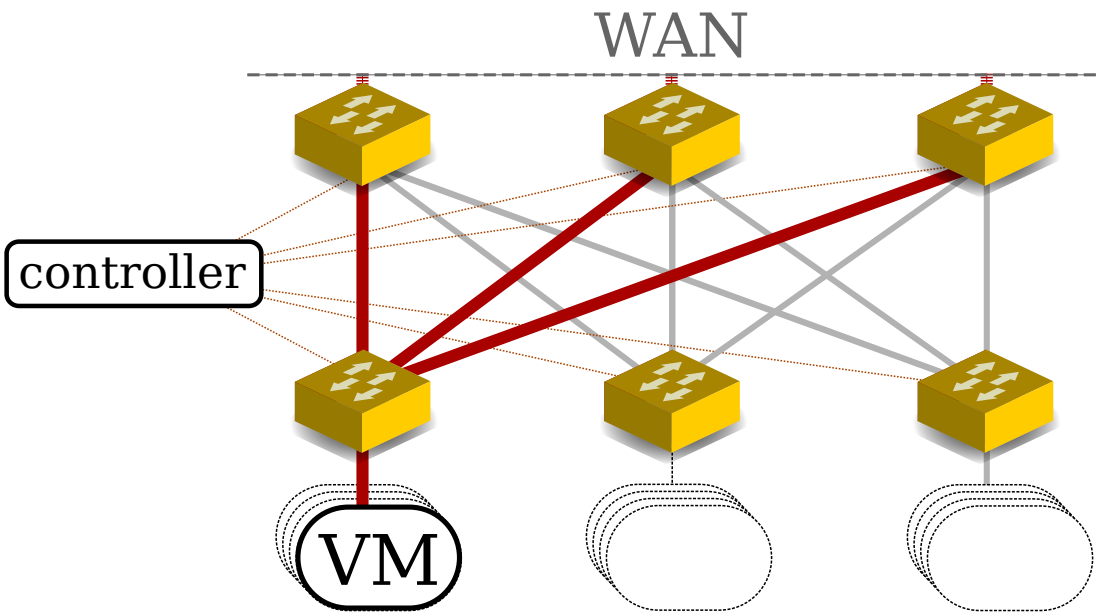
Varying processing capability of control logic in switches yields unpredictable delays for SDN applications



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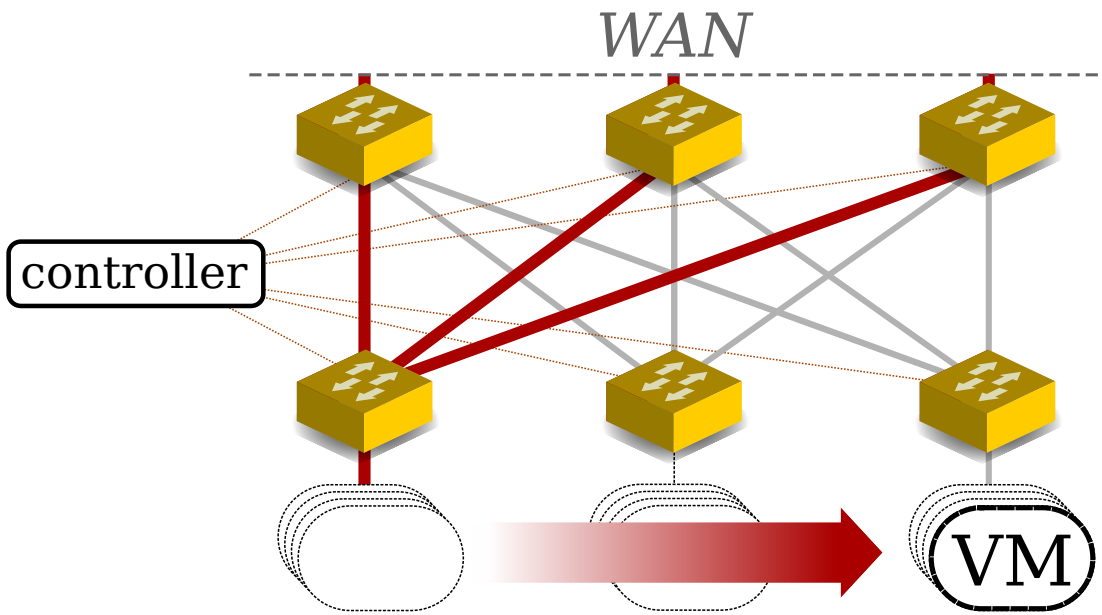

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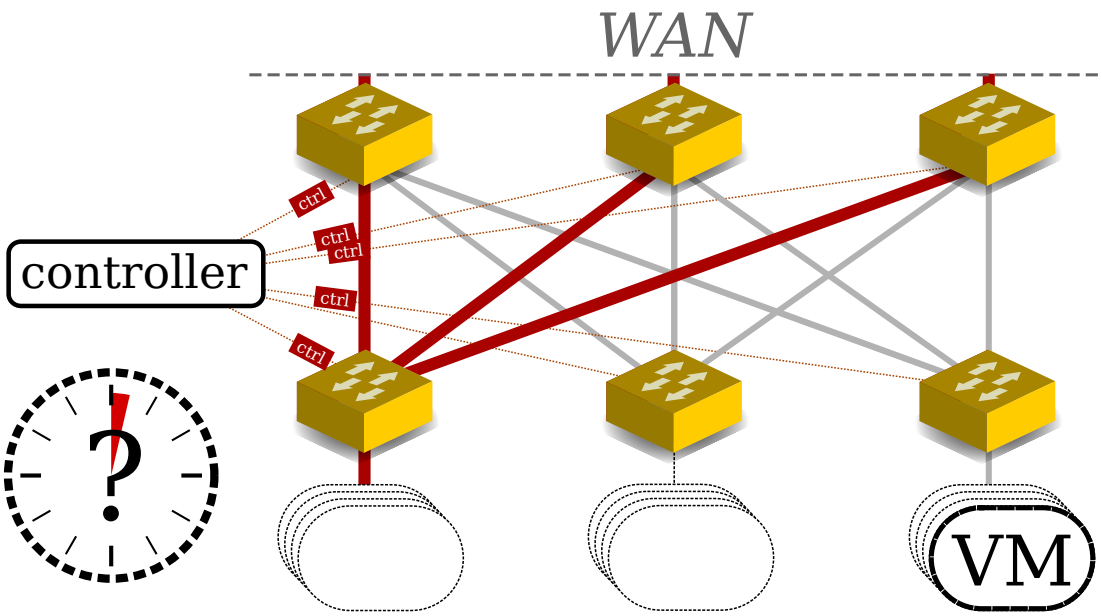

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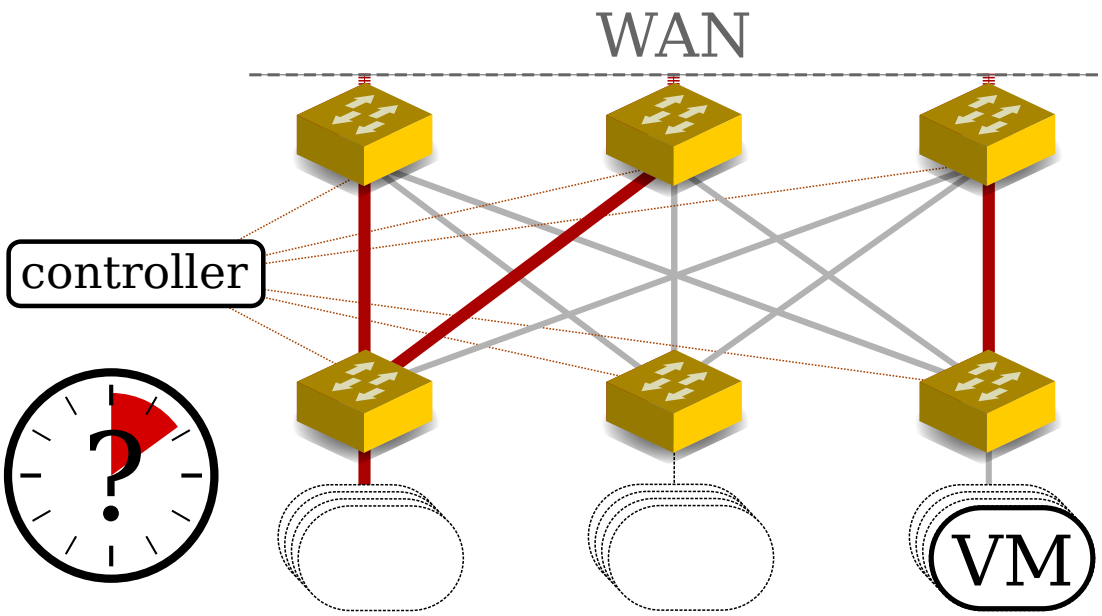

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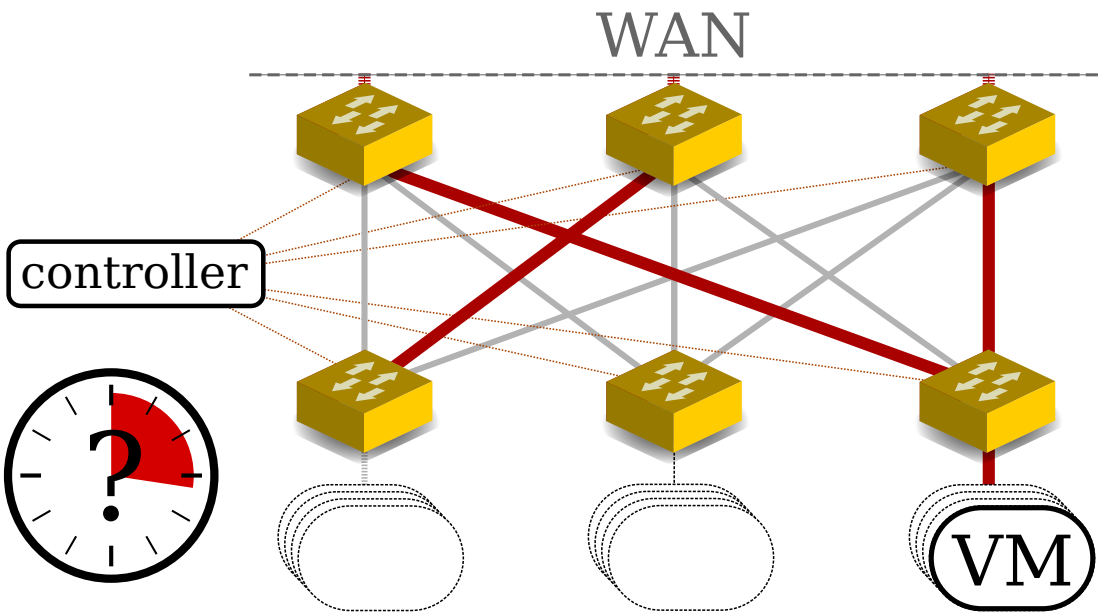

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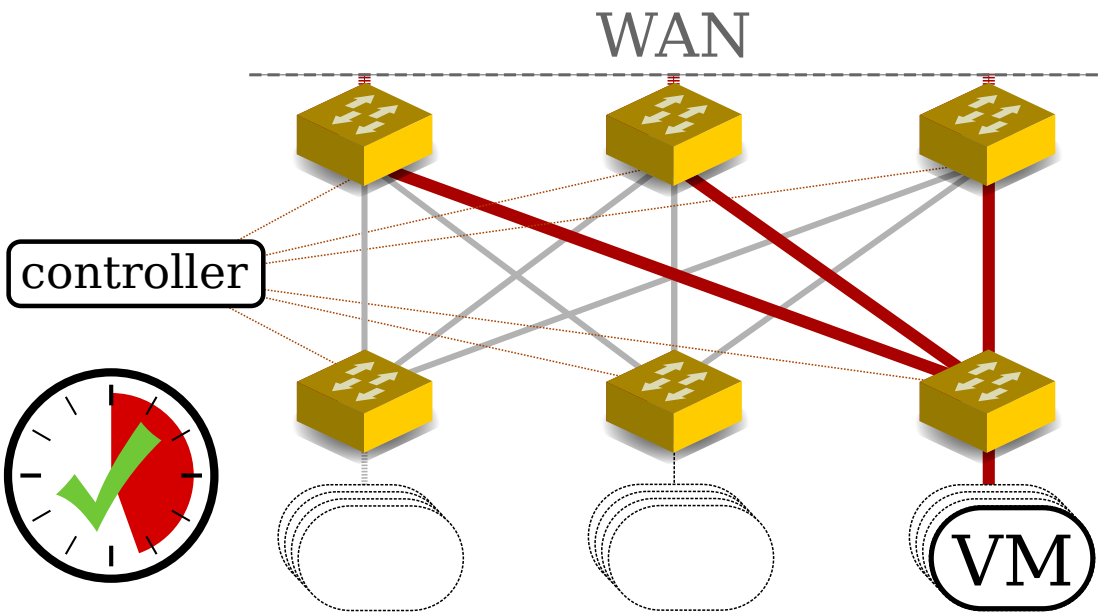

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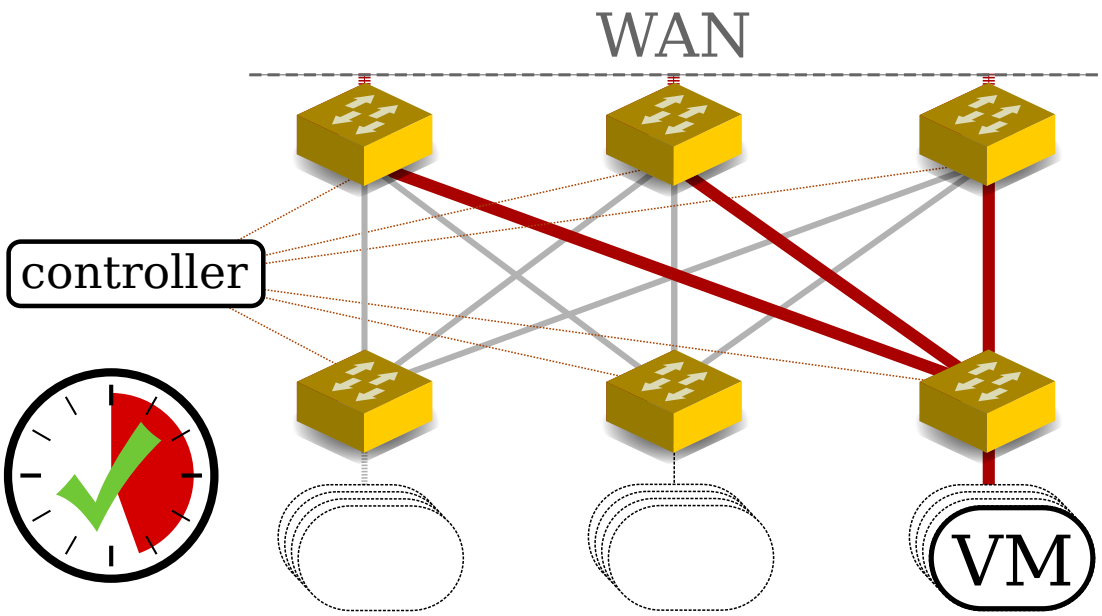
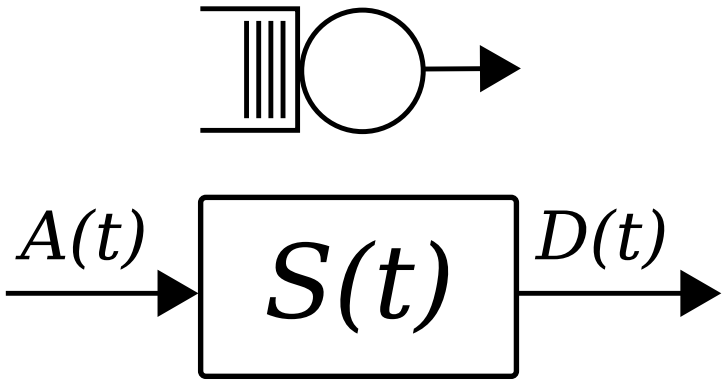
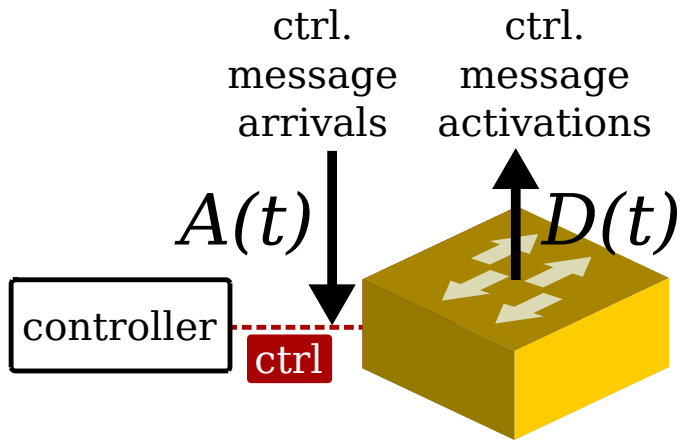


Main causes for flow installation latencies at a switch

- 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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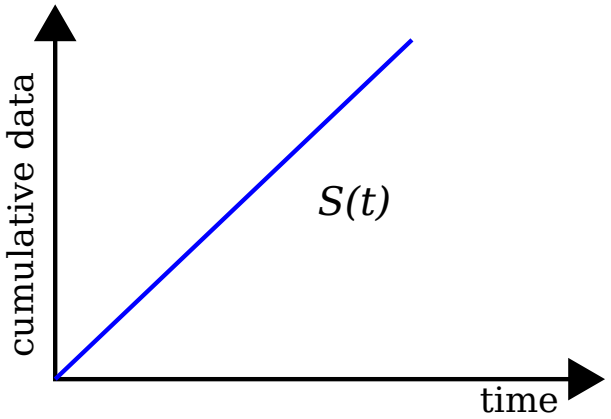

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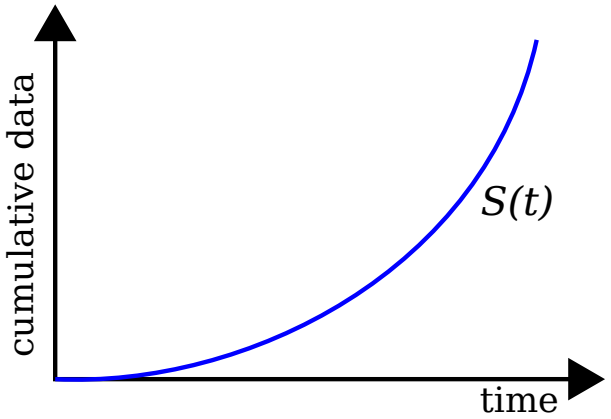

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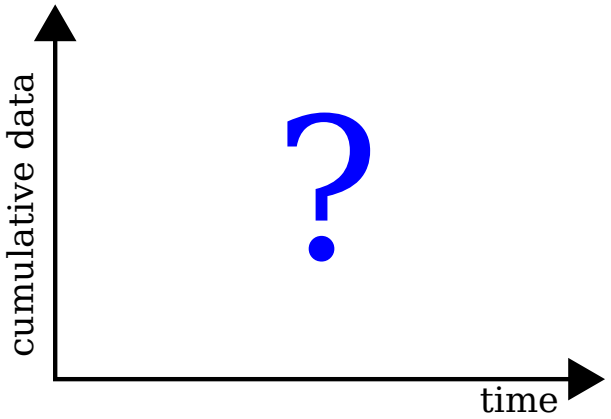

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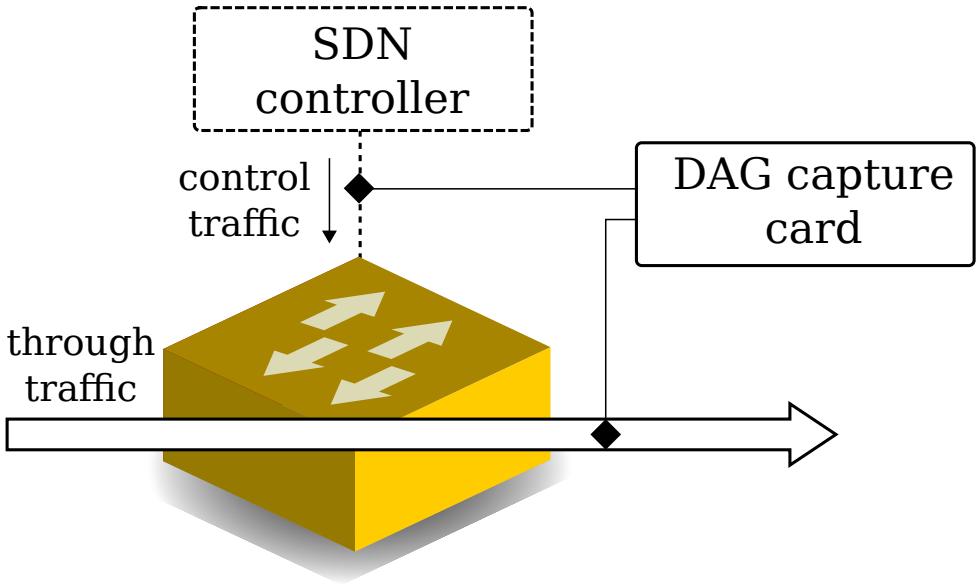
Experimental setup for service curve estimation:

- 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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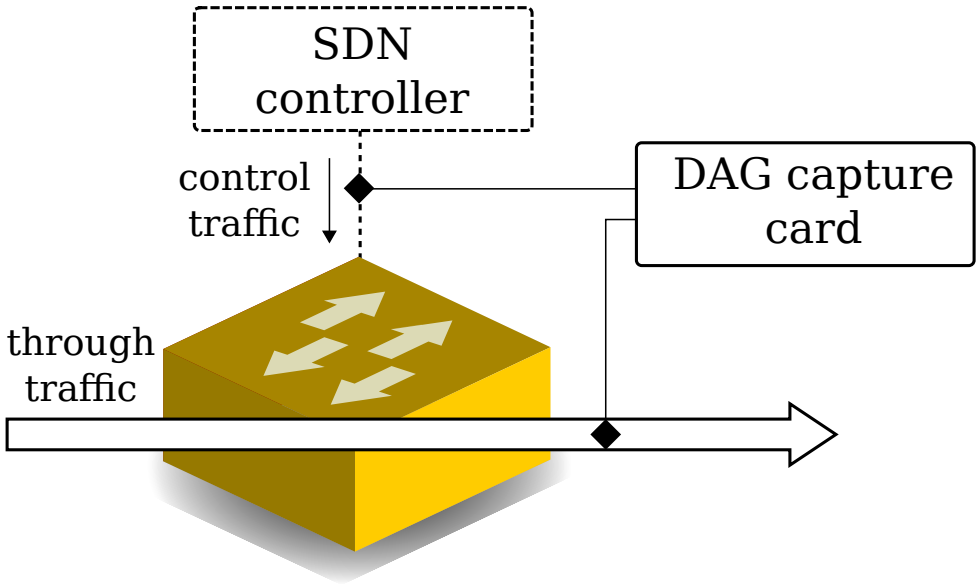

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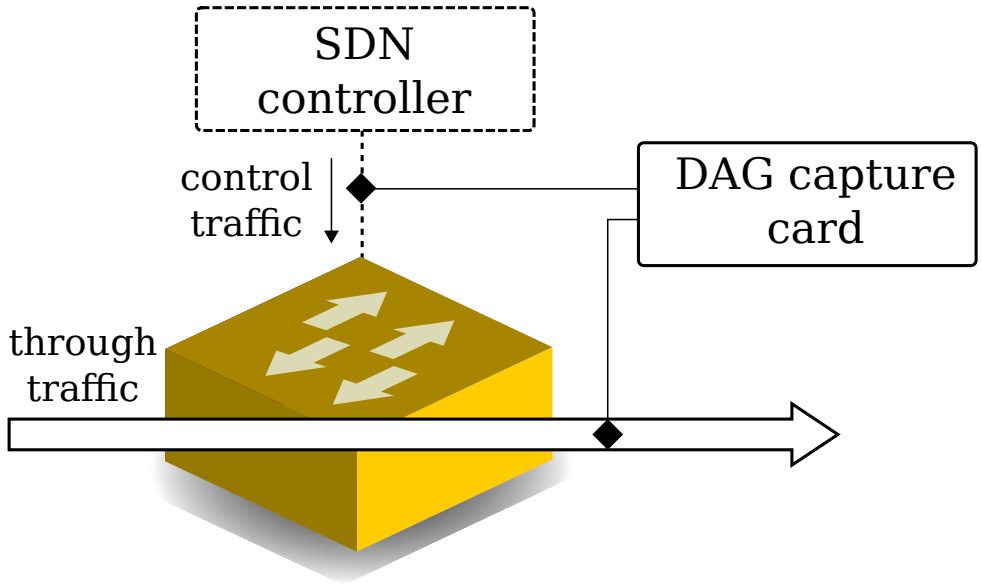

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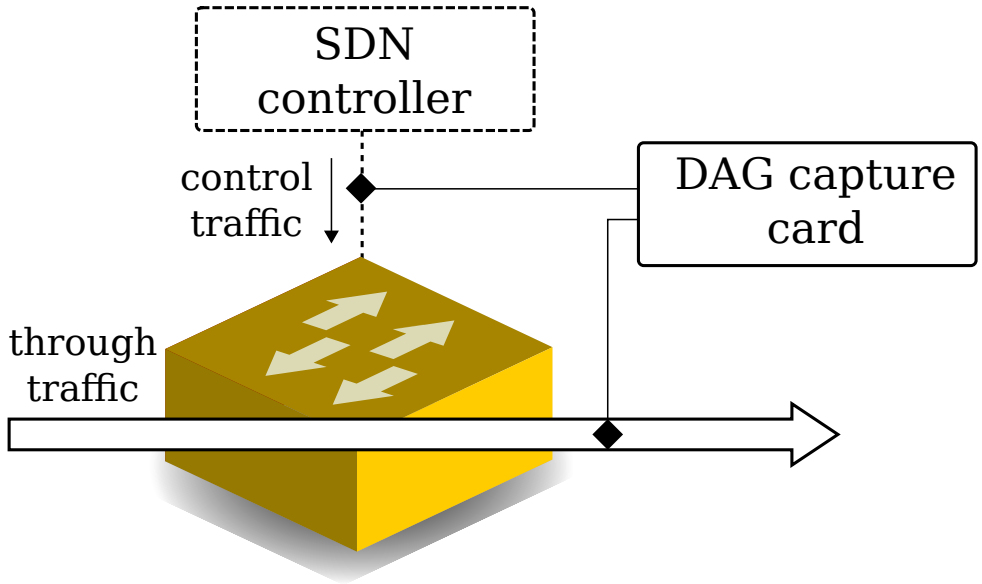

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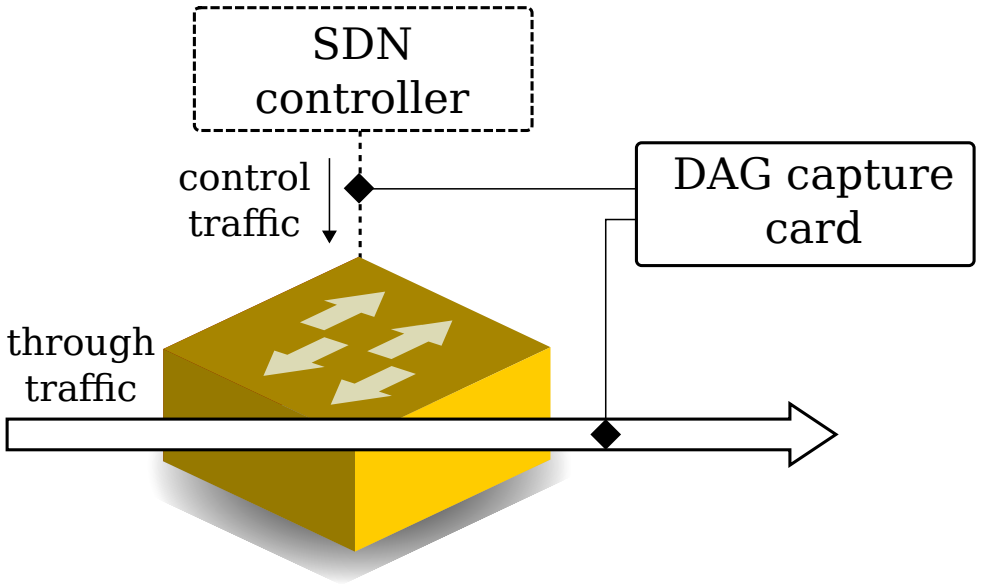

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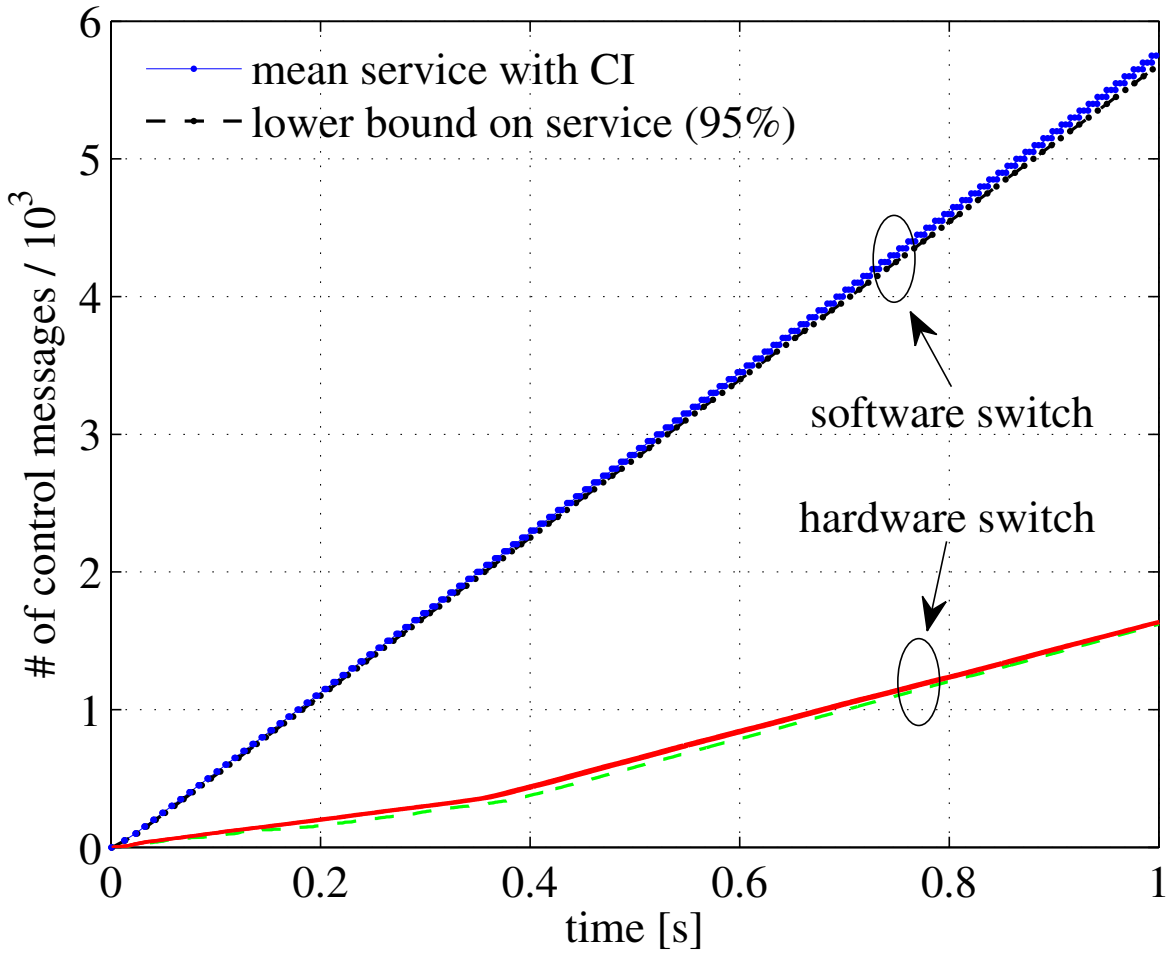
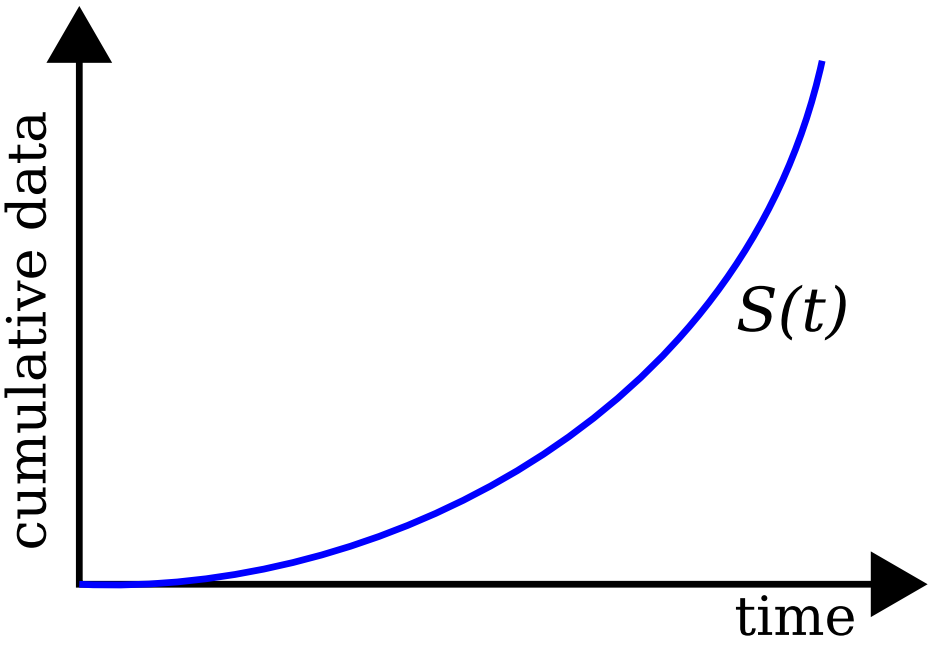

mean service with CI
lower bound on service (95%)
software switch
hardware switch
# of control messages / 10^3
time [s]
0
1
2
3
4
5
6
0
0.2
0.4
0.6
0.8
1

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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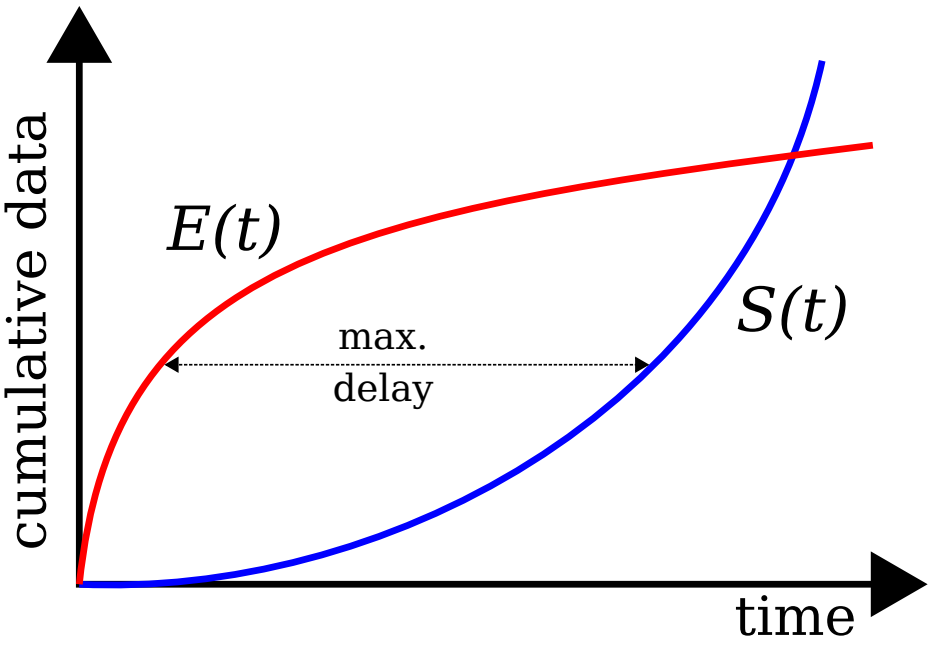

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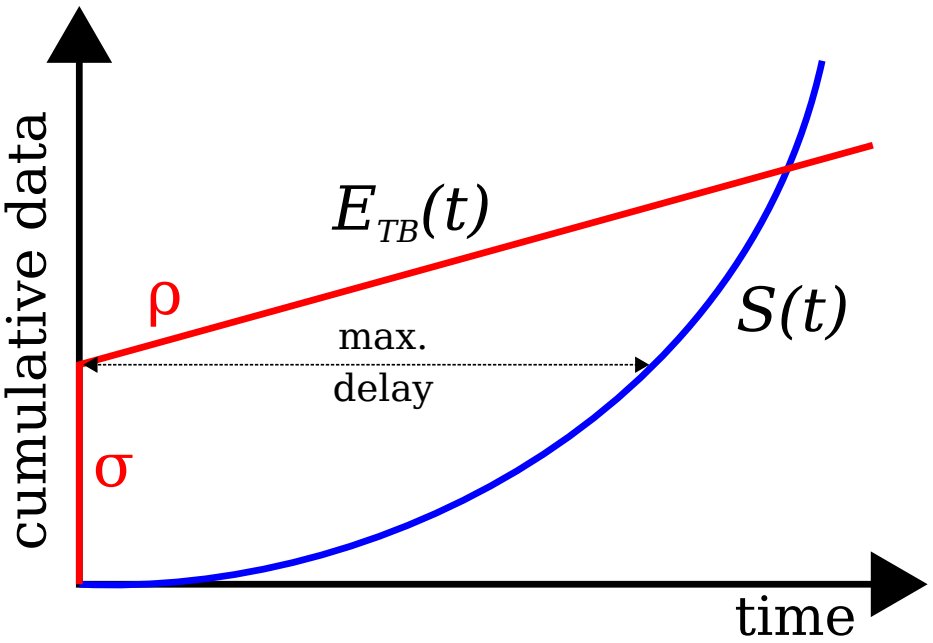
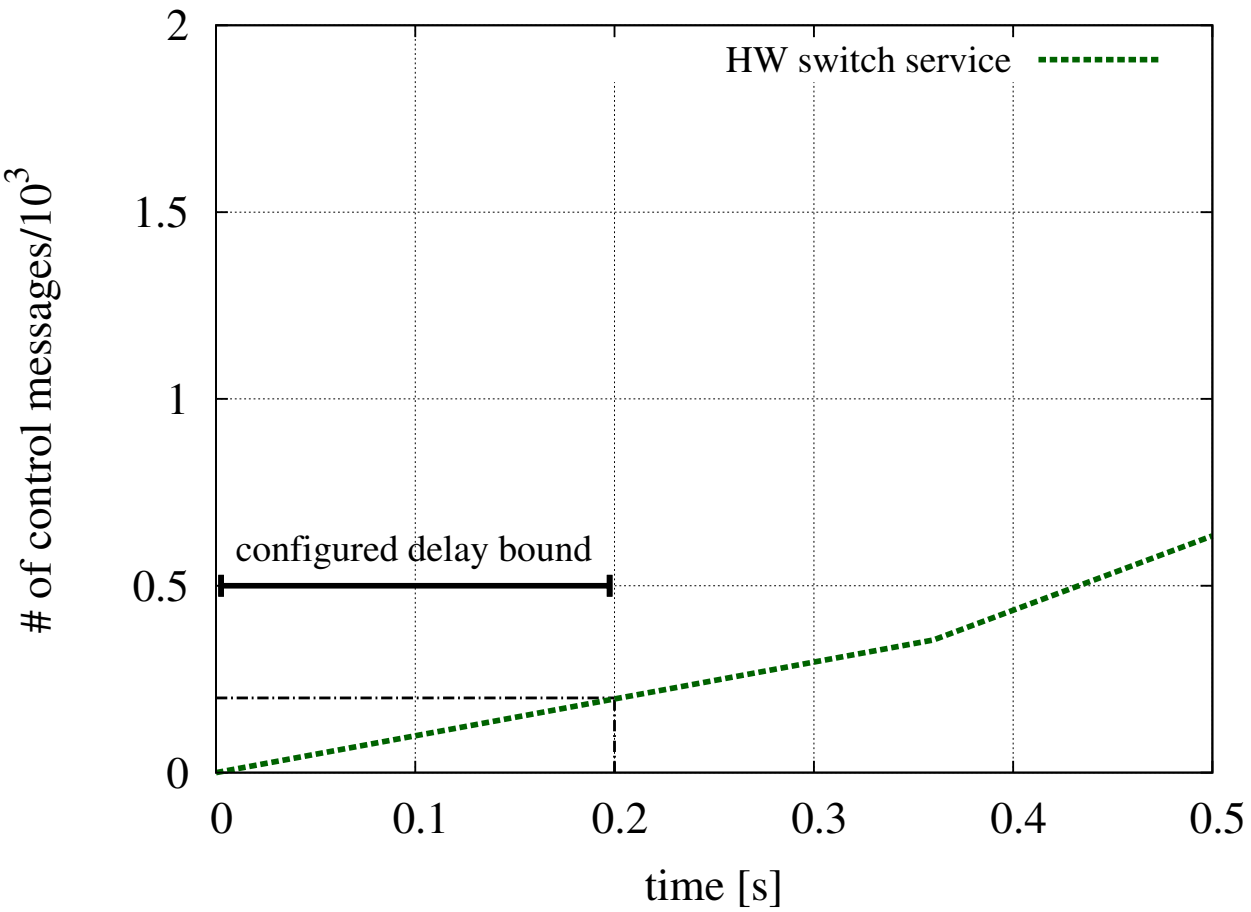


Proposed approach:

- 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



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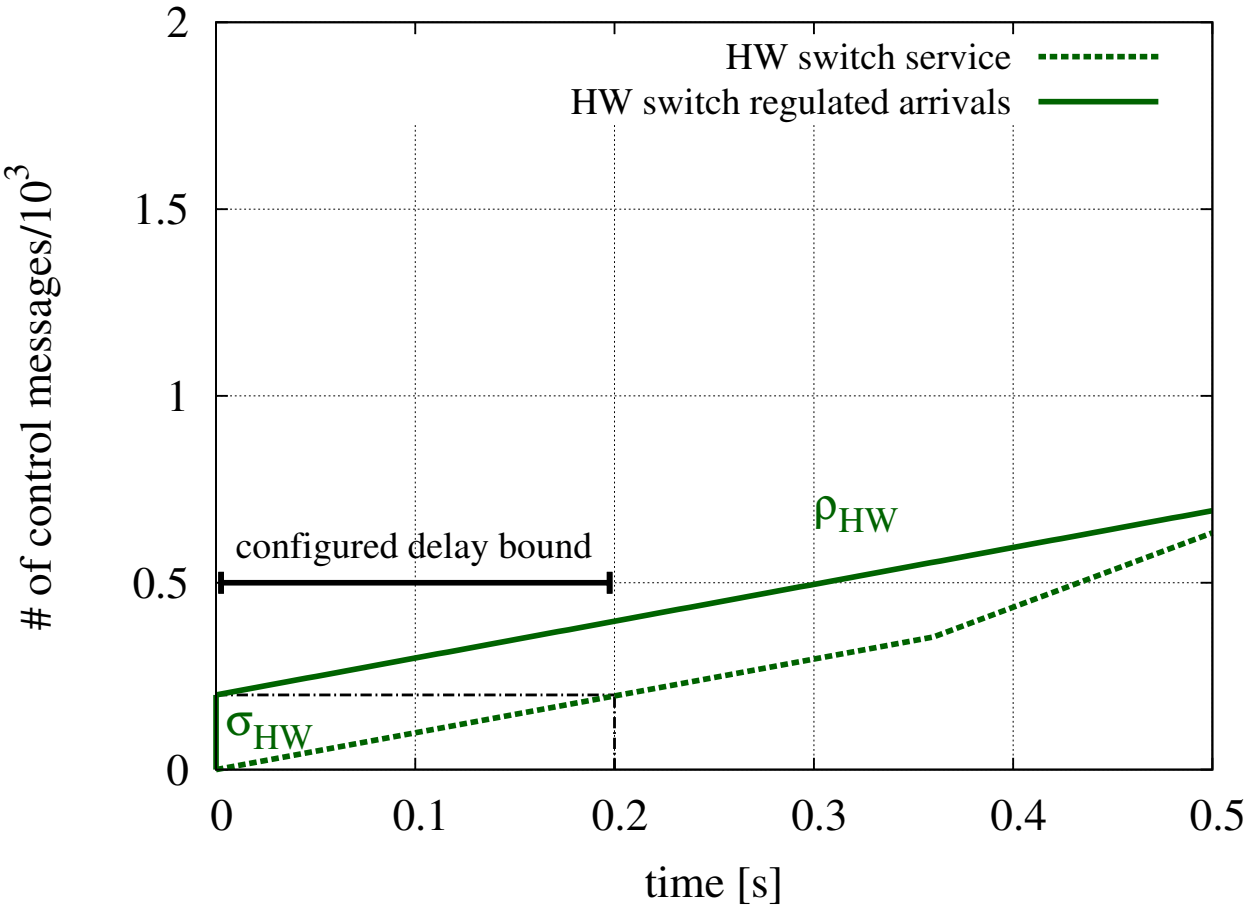

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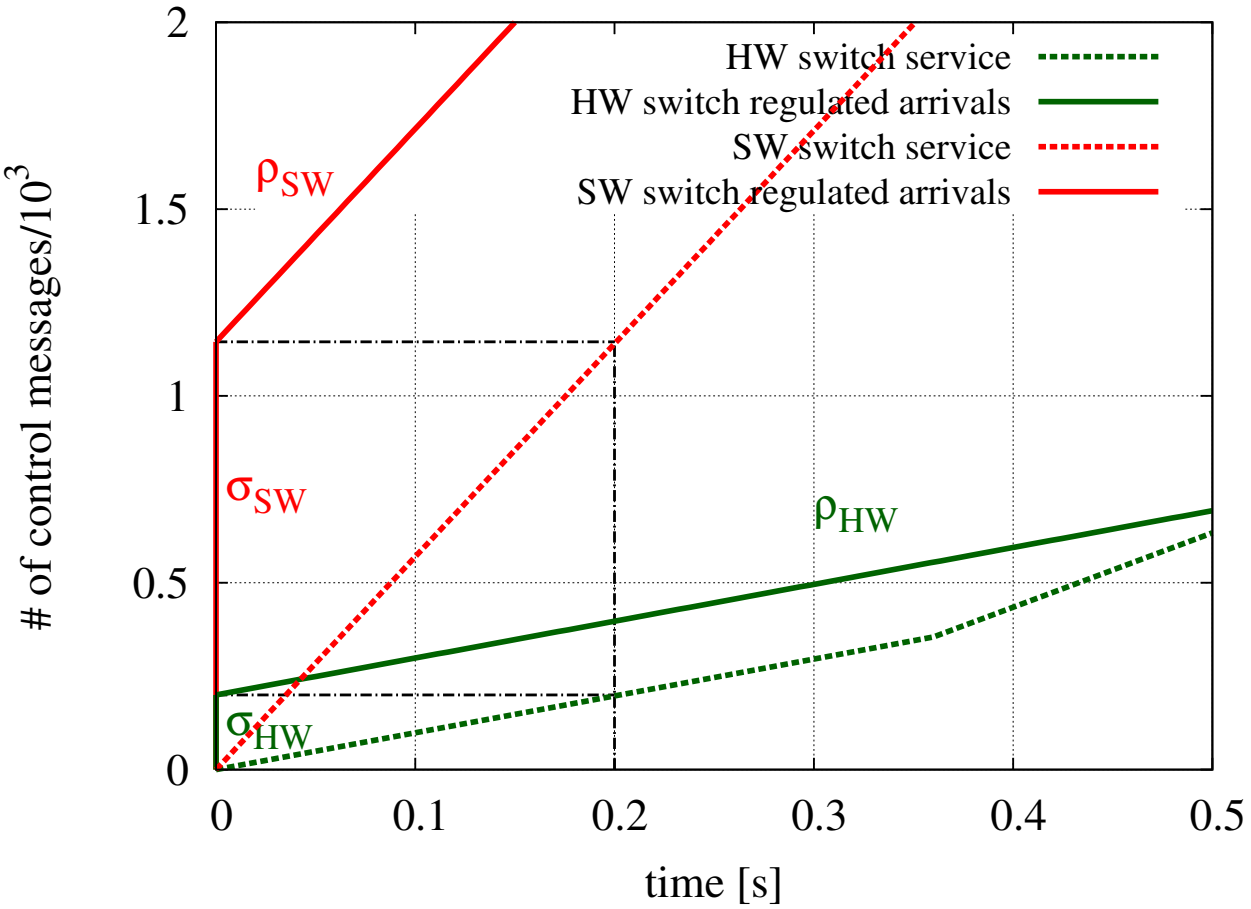

Benefits of our approach

- 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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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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