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Kommunikationsnetze

A Software-Defined Firewall Bypass for Congestion Offloading

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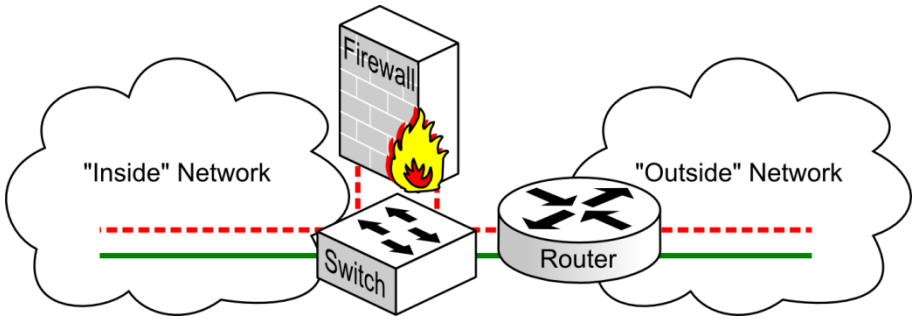
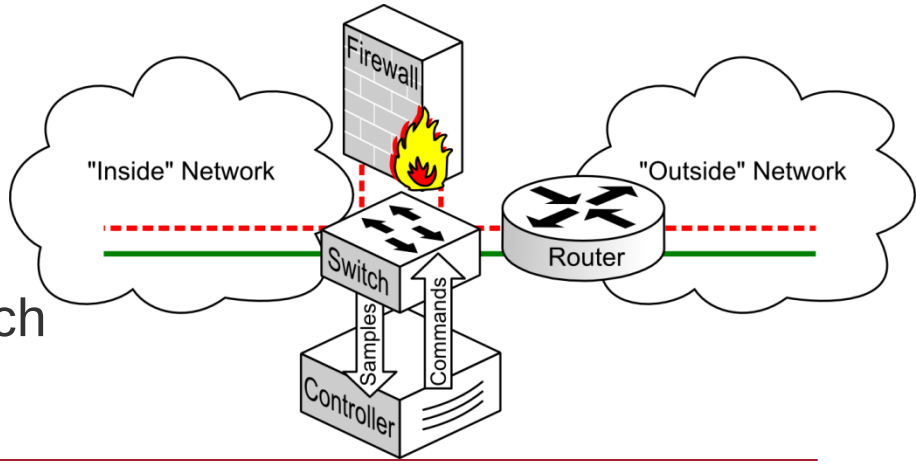
Motivation

- Increasing network bandwidth
  - 1 Gb/s access ports, ≥ 10 Gb/s backbones
- Packet filtering at network perimeter
  - Stateful firewall
    - Advanced filtering capabilities
    - Can handle large numbers of flows
    - Limited throughput
  - SDN switch
    - Limited filtering capabilities
    - Limited number of flows
    - High throughput
- Idea
  - Selective bypassing of stateful firewall using SDN switch

Firewall Bypass

- Firewall bypass
  - Relieve congestion pressure
  - Divert trusted flows around firewall using switch
- Static Bypass
  - Whitelist or blacklisting using switch ACLs
- Dynamic Bypass
  - Detect accepted flows by sampling outgoing packets at firewall
  - Use SDN to install rules at switch

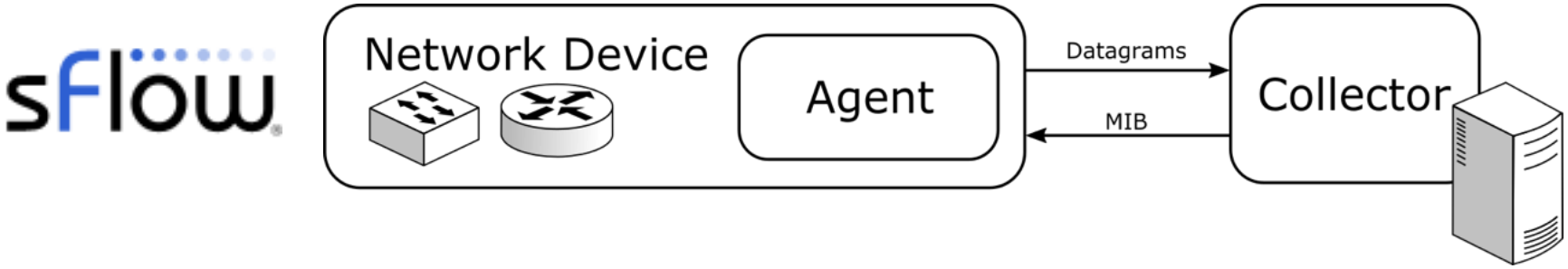




Dealing with Limited Flow Tables

- Problem with dynamic bypass approach
  - Per-flow rules required for bypassing
    - E.g. 2 rules per TCP connection
  - Limited size of hardware flow tables in commodity SDN switches
    - Number of usable rules: $2000 < n_r < 20000$
  - Detecting connection teardown not possible in OpenFlow < v1.5
    - Rules cannot be reused immediately after connection is terminated
- Strategy
  - Adapt bypass usage to firewall load
  - Preferentially bypass large flows
- Challenges
  - Measure traffic rate and detect overload
  - Determine offloading rate and select appropriate flows

Detecting Congestion



- Packet flow sampling using sFlow
  - Random sampling of every n^{th} outgoing packet
- Trade-off for *n*
  - Needs to be small enough to allow for exact measurement
  - Must be large enough so that agent can comply with rate
- Export raw packet headers to sFlow collector
- Estimate packet rate and byte rate

- High-load threshold: 80% of bottleneck capacity

Offloading Rate and Flow Selection

- Determine offloading rate
  - Objective: prevent rule exhaustion
  - Do not install rules faster than they can be reclaimed
  - Make sure that remaining rules suffice for a minimum time at current rate

- Flow selection
  - Objective: prefer large flows
  - Random offloading (ROff)
    - Select flows for offloading randomly based on sampled packets
    - Larger flows → larger sampling probability
  - Intelligent offloading (IOff)
    - Stronger preference of large flows compared to ROff
    - Count packets received for a flow
    - Increase offloading probability for flows with higher packet count

Proof-of-Concept Implementation

- Proof-of-Concept Implementation based on Ryu
  - Python SDN controller framework
  - OpenFlow 1.3, sFlow v5

- Hardware
  - OpenFlow-capable switch: HP ProCurve 5412zl
  - Stateful firewall: Cisco ASA 5550 (transparent mode)

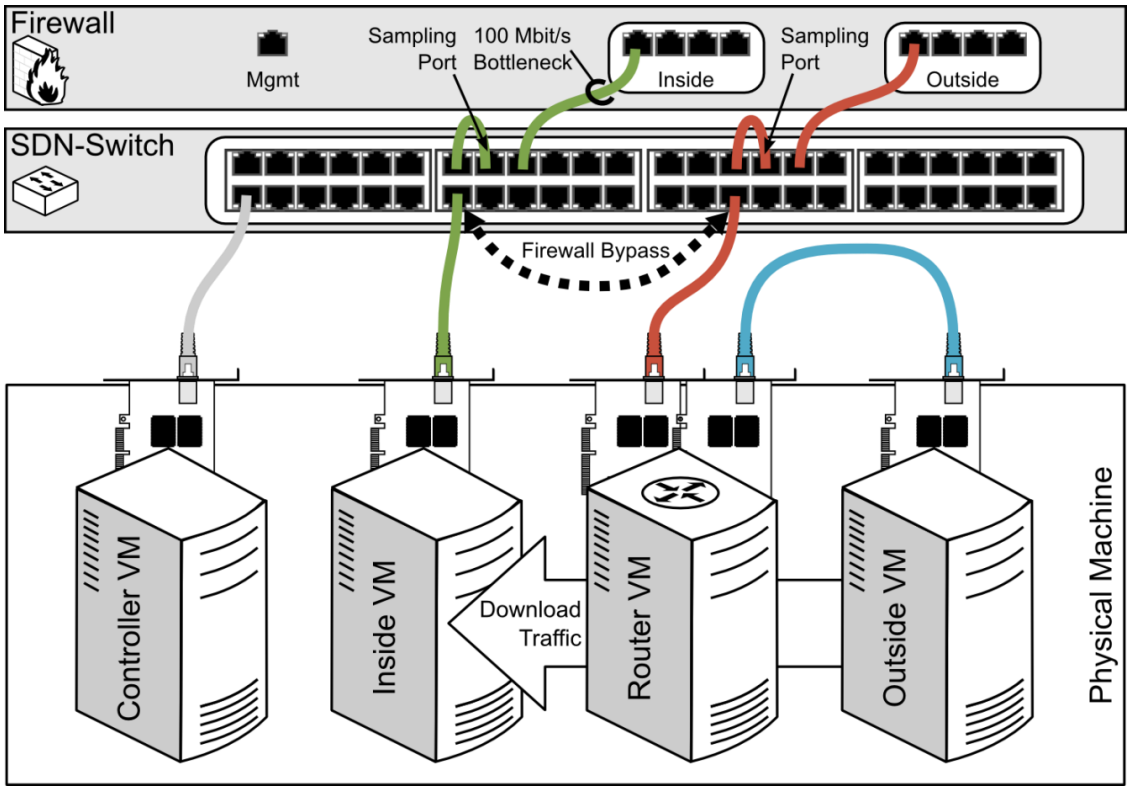
sFlow

- Virtual Machines (VMs)
  - Inside (HTTP Client)
  - Outside (nginx web server)
  - Router
  - Controller

- Linux/KVM virtualization with dedicated physical NICs for VMs

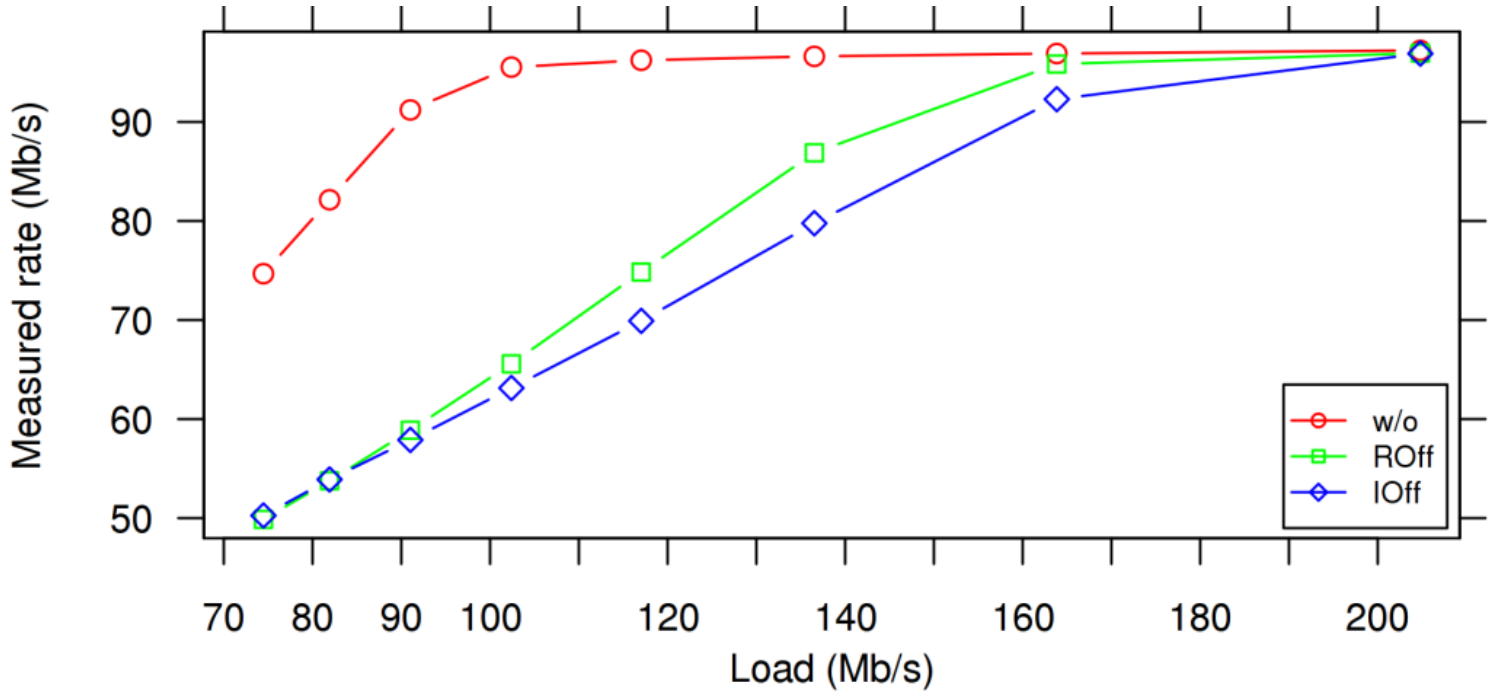
Experiment Setup

- No 10 Gb/s modules
  - 100 Mb/s bottleneck
- sFlow only samples outgoing packets
  - Extra sampling ports
- Traffic
  - Parallel HTTP file downloads
  - Poisson process
  - Mean size: 1 MB
  - $c_{var} = 3$

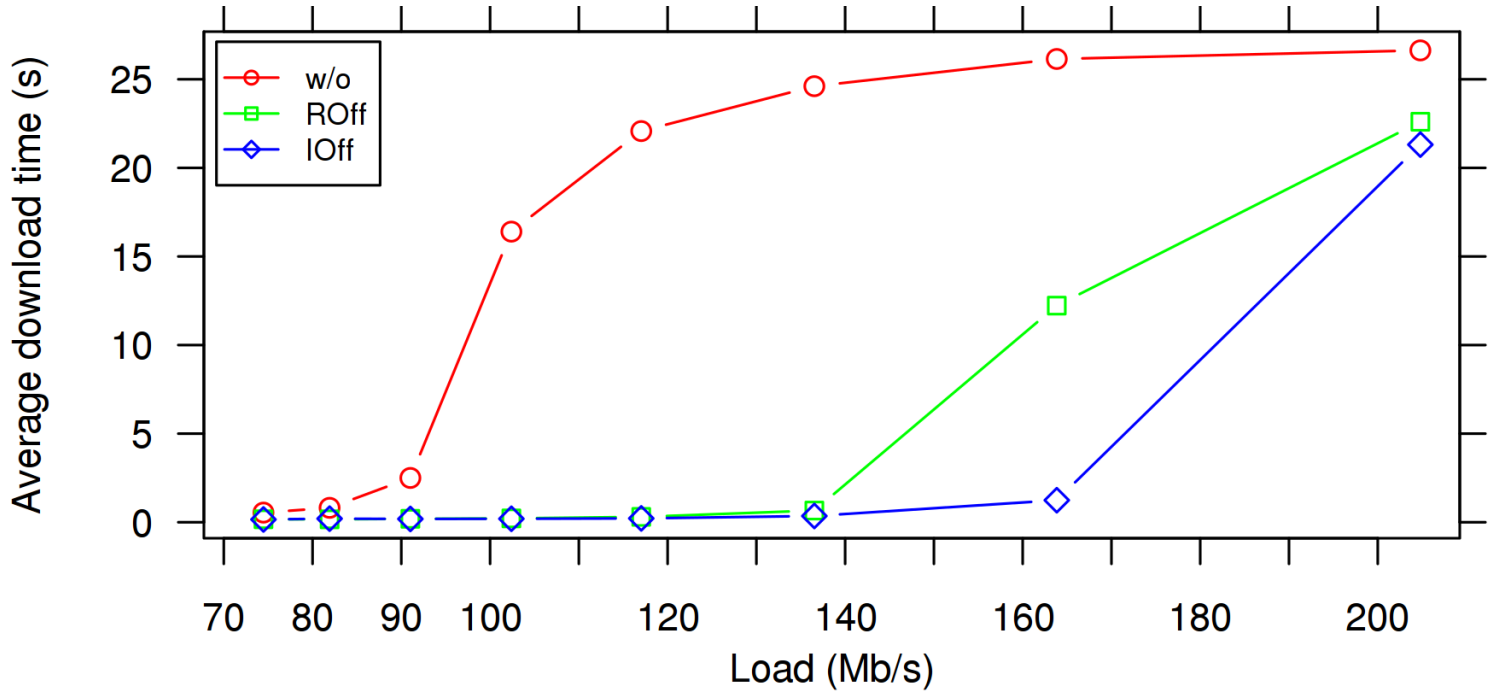


- Experiment parameters
  - 2000 flow rules (= 1000 bypasses for TCP connections)
  - 300 s timeout

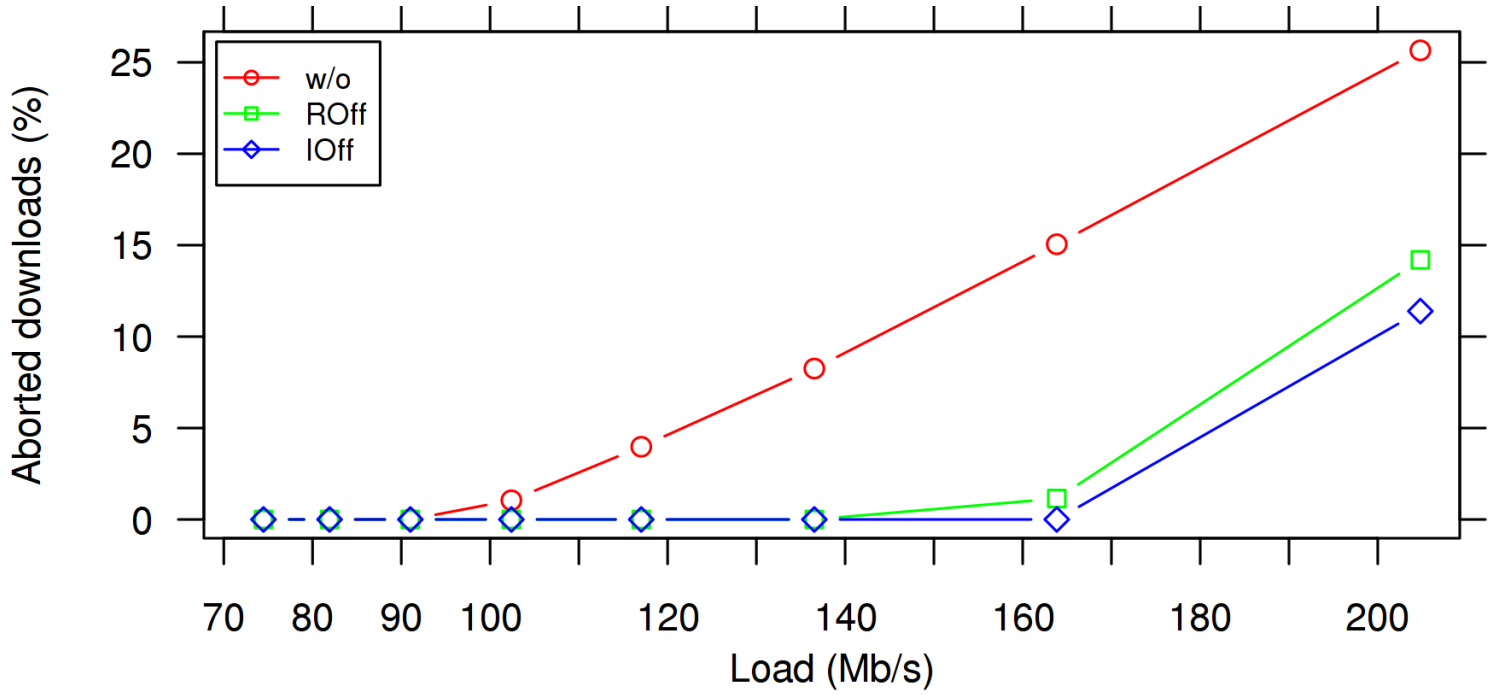
Measured Rate on Firewall



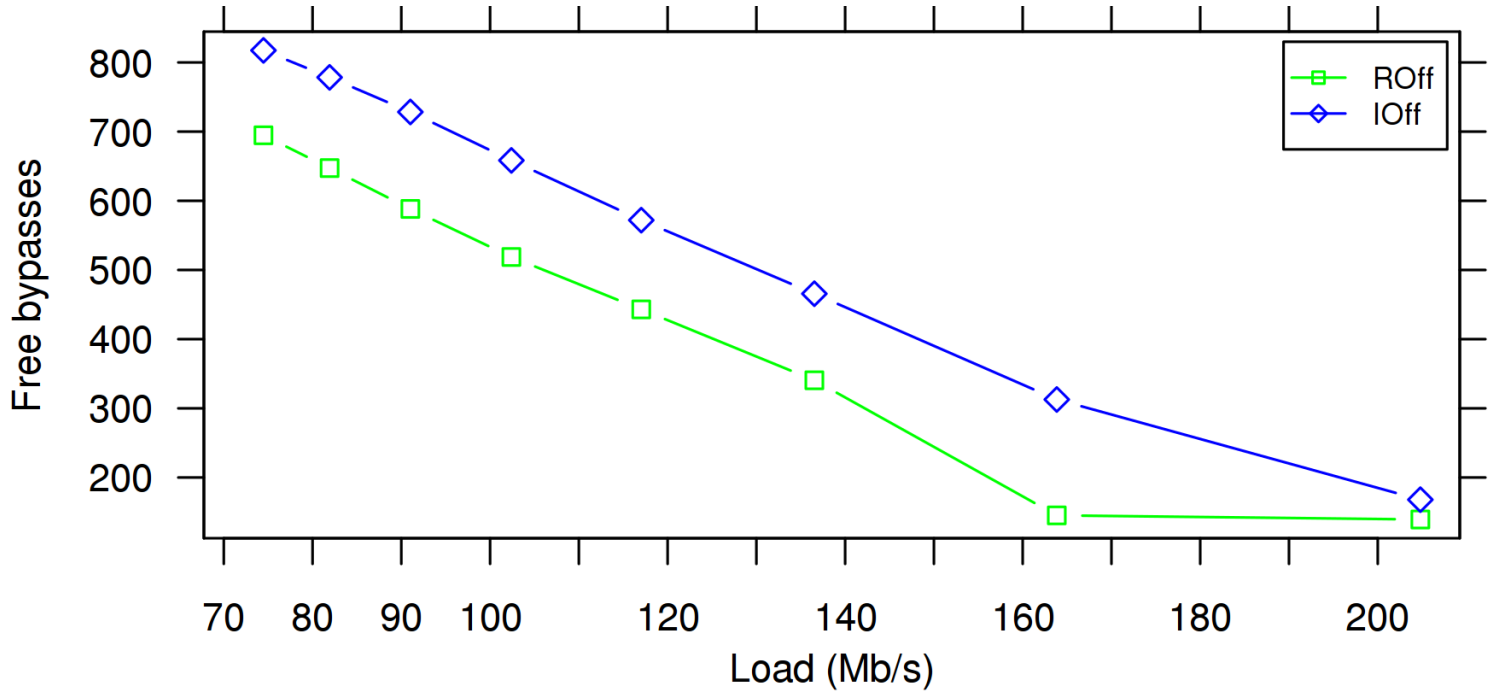
Average Download Time



Aborted Downloads

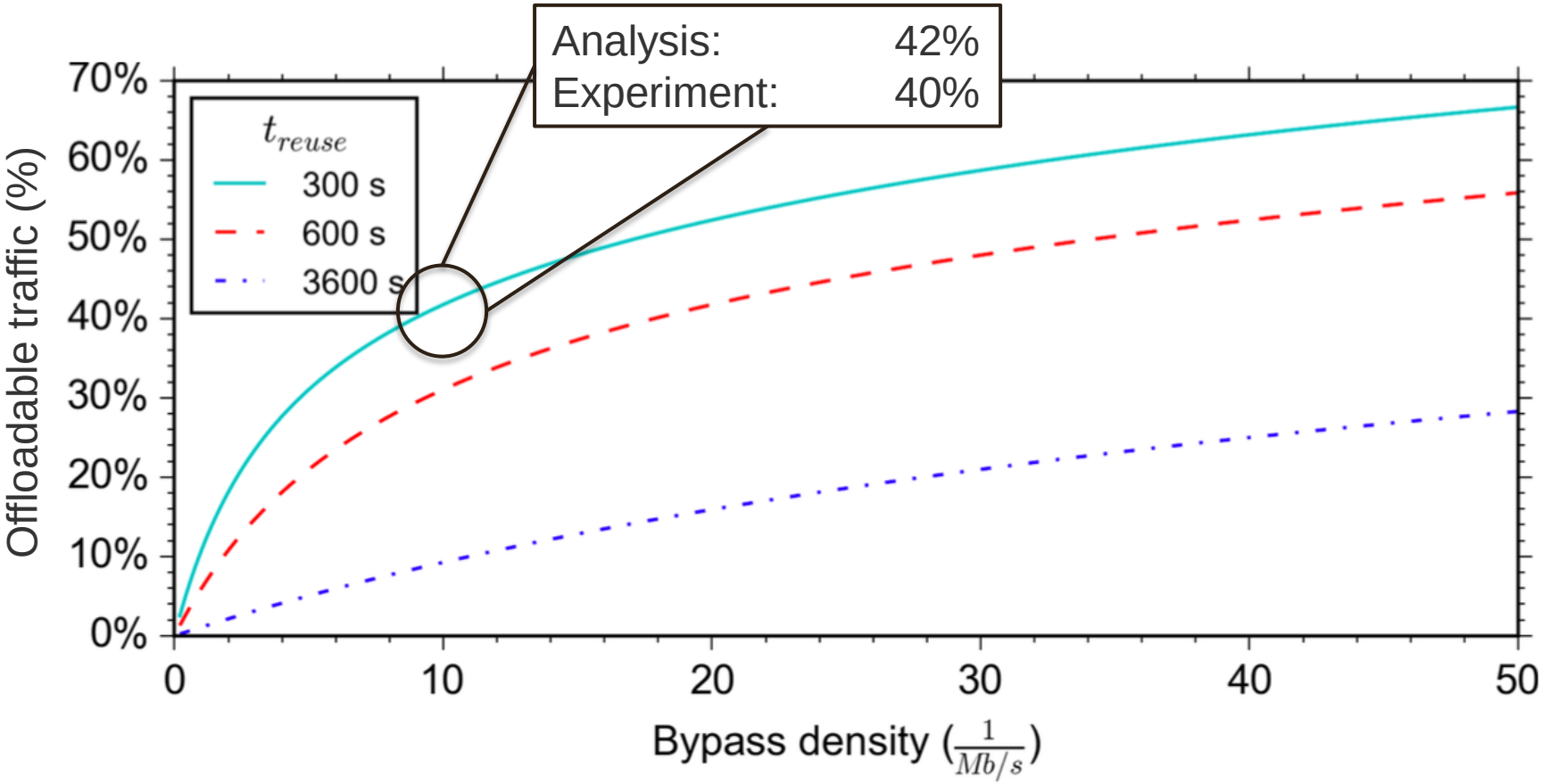


Rule Usage


Free bypasses
800
700
600
500
400
300
200
70
80
90
100
120
140
160
180
200
Load (Mb/s)
ROff
IOff

Analytic Model & Results

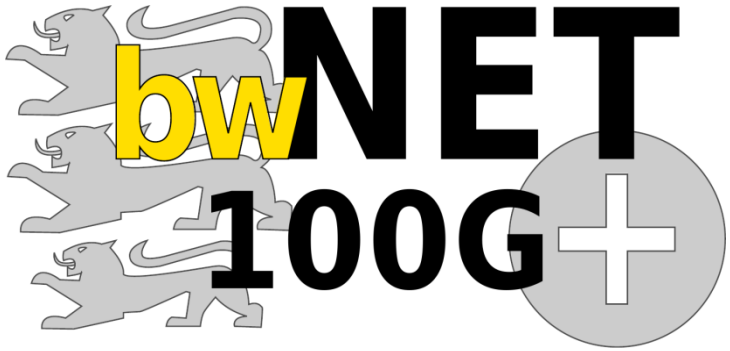
- Bypass density: ratio of no. bypasses to firewall capacity: $\frac{n_{by}}{C}$
- t_{reuse}: time after which flow rule can be reused (dominated by timeout)



Summary

- Dynamic bypass: offloads flows accepted by firewall
  - Controller samples traffic from firewall using sFlow
  - Detects congestion and possibly offloads accepted flows using OF
  - Proof-of-concept implementation
- Performance evaluation of dynamic firewall bypass
  - Problem: only few flow rules supported on switches
  - Effective offloading in downscaled experiment
- Theoretical model to predict offloadable traffic
  - Validated by experimental results
  - Switches w/ many flow rules needed for effective offloading
- Accepted at CNSM'17, Tokyo, Japan, Nov. 2017

- Questions?



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