Understanding Latency in Software Defined Networks

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Latency in SDN

Time taken to install 100 rules?

Can be as large as 10 seconds!!!
Do applications care about latency?

Latency is critical to many applications

- **MicroTE** routes predictable traffic on time scales of 1-2s
- Limits the applicability of SDN applications
  
  **Latency can undermine MicroTE’s effectiveness**

Applications assume latency is low and constant

- Reroute the affected flows quickly in face of failures
- Longer update time increases congestion and drops
  
  **Latency can inflate failover time by nearly 20s!**
Factors contributing to Latency?

Robust Control Software Design and Distributed Controllers

- Speed of Control Programs and Network Latency
  - Not received much attention
- Latency in network switches
Our Work

Two contributions:

• Systematic experiments to explore latencies in production switches

• Design a framework to overcome the impact of latencies
Outline

• Motivation

• Elements of Latency

• Measurement Methodology

• Inbound Latency

• Outbound Latency
  • Insertion
  • Modification
  • Deletion
Outline

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Elements of Latency

1. Inbound Latency

- **I1:** Send to ASIC SDK
- **I2:** Send to OF Agent
- **I3:** Send to Controller
Elements of Latency

1. Inbound Latency
2. Outbound Latency

**Outbound Latency**

- **O1**: Parse OF Msg
- **O2**: Software schedules the rule
- **O3**: Reordering of rules in table
- **O4**: Rule is updated in table
Outline

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• **Measurement Methodology**
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Latency Measurements - Setup

Switches:
- **POX Controller**
- **Pktgen**
- **Libpcap**

Control Channel:
- Flows IN
- Flows OUT

Openflow Switch

<table>
<thead>
<tr>
<th>Switch</th>
<th>CPU</th>
<th>RAM</th>
<th>Flow table size</th>
<th>Data Plane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vendor A</td>
<td>1 Ghz</td>
<td>1 GB</td>
<td>896</td>
<td>14<em>10Gbps + 4</em>40Gbps</td>
</tr>
<tr>
<td>Vendor B</td>
<td>2 Ghz</td>
<td>2 GB</td>
<td>4096</td>
<td>40<em>10Gbps +4</em>40Gbps</td>
</tr>
</tbody>
</table>
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Inbound Latency

- Increases with flow arrival rate
- CPU Usage is higher for higher flow arrival rates

<table>
<thead>
<tr>
<th>Flow Arrival Rate (packets/sec)</th>
<th>Mean Delay per packet_in (msec)</th>
<th>CPU Usage ( % )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-</td>
<td>7.1</td>
</tr>
<tr>
<td>100</td>
<td>3.32</td>
<td>15.7</td>
</tr>
<tr>
<td>200</td>
<td>8.33</td>
<td>26.5</td>
</tr>
</tbody>
</table>

*vendor A switch*
Inbound Latency

- Increases with interference from outbound msgs

**vendor A switch  200 flows/sec**
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Outbound Latency

• Latency for three different flow_mod operations
  Insertion
  Modification
  Deletion

• Impact of key factors on these latencies
  Table occupancy
  Rule priority structure
Outline

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Insertion Latency – Priority Effects

Vendor B switch

(a) Burst size 100, **same** priority

(b) Burst size 100, **increasing** priority
Insertion Latency – Priority Effects

(a) Burst size 100, **same** priority

(b) Burst size 100, **increasing** priority

Vendor B switch
Insertion Latency – Priority Effects

Vendor B switch

(a) Burst size 100, **same** priority

(b) Burst size 100, **increasing** priority

TCAM

<table>
<thead>
<tr>
<th>100</th>
<th>0x0000</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td></td>
</tr>
<tr>
<td>99</td>
<td></td>
</tr>
</tbody>
</table>
Insertion Latency – Priority Effects

Vendor B switch

(a) Burst size 100, same priority

(b) Burst size 100, increasing priority
Insertion Latency – Priority Effects

Vendor B switch

(a) Burst size 100, **same** priority

(b) Burst size 100, **increasing** priority
Insertion Latency – Priority Effects

(a) Burst size 800, \textit{same} priority

(b) Burst size 800, \textit{decreasing} priority
Insertion Latency – Priority Effects

(a) Burst size 800, **same** priority

(b) Burst size 800, **decreasing** priority

**Vendor A switch**

0x0000

TCAM
Insertion Latency – Priority Effects

(a) Burst size 800, same priority
(b) Burst size 800, decreasing priority

Vendor A switch

TCAM

0x0000

100
101
102
103
104
Insertion Latency – Priority Effects

Vendor A switch

(a) Burst size 800, same priority

(b) Burst size 800, decreasing priority

TCAM
Insertion Latency – Priority Effects

(a) Burst size 800, **same** priority

(b) Burst size 800, **decreasing** priority

Vendor A switch

TCAM

0x0000

99

100

101

102

103

104
Insertion Latency – Priority Effects

(a) Burst size 800, **same** priority

(b) Burst size 800, **decreasing** priority

Vendor A switch

<table>
<thead>
<tr>
<th>Rule #</th>
<th>0x0000</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>99</td>
</tr>
<tr>
<td>101</td>
<td></td>
</tr>
<tr>
<td>102</td>
<td></td>
</tr>
<tr>
<td>103</td>
<td></td>
</tr>
</tbody>
</table>

TCAM

104
Insertion Latency – Table occupancy Effects

- **Rule Priority Structure and Table Occupancy**
- **TCAM Organization and # Of Slices**
- **Switch Software Overhead**

(a) low priority rules into a table with **high priority** existing rules

(b) high priority rules into a table with **low priority** existing rules

Vendor B switch
Outline

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  • **Modification**
  • Deletion
Modification Latency

- Higher than Insertion latency for vendor B
- Not affected by rule priority but affected by table occupancy

![Graphs showing modification latency for Vendor B switches with 100 and 200 rules in the table.](image-url)
Outline

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• **Outbound Latency**
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  • Modification
  • Deletion
Deletion Latency

• Higher than Insertion latency for both vendor A and B
• Not affected by rule priority but affected by table occupancy
Deletion Latency

- Higher than Insertion latency for both vendor A and B
- Not affected by rule priority but affected by table occupancy

![Graph showing Deletion Latency](image)

Deletion is causing TCAM Reorganization

Vendor A switch
Summary

• Latency in SDN is *critical* to many applications

• Assumption: Latency is *small or constant*

• Latency is high and variable

• Varies with Platforms, Type of operations, Rule priorities, Table occupancy, Concurrent operations

• Key Factors: *TCAM Organization, Switch CPU* and *inefficient Software Implementation*
Summary

- Latency in SDN is *critical* to many applications
- Assumption: *Latency is small or constant*
- Latency is high and variable
- Varies with Platforms, Type of operations, Rule priorities, Table occupancy, Concurrent operations
- Key Factors: *TCAM Organization, Switch CPU* and *inefficient Software Implementation*
Backup Slides
Impact of Concurrent CPU jobs

• Impacts insertion delay. E.g. *Polling Statistics*
• Polling stats impacts more when table occupancy is higher

![Low Power CPU delays concurrent jobs](chart)

Vendor B