UMON: Flexible and Fine Grained Traffic Monitoring in Open vSwitch

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NIST
Outline

- Introduction
- UMON design and implementation
- Evaluation
- Summary

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Introduction

- Fine-grained network traffic monitoring is important for effective network management
  - Traffic engineering, anomaly detection, network diagnosis, traffic matrix estimation, DDoS detection and mitigation, etc.

- Scalability has been the main challenge
  - High switching speed
  - Large number of flows
  - Solution: sampling, probabilistic based measurement, hardware enhanced measurement solutions, etc.

- Open vSwitch (OVS) is a popular software switch widely employed by SDN
  - Developed by Nicira as an edge switches for Data center SDN solution
  - Slower switching speed, smaller #flows, access to more CPU and memory resources
  - Similar monitoring tools as hardware switches: Netflow, sFlow, SPAN, RSPAN, flow entry counts
Introduction

- Recent push to use flow entry counts for traffic monitoring

- Challenges in flow entry counts monitoring
  - TCAM space is limited in hardware switches
  - Header fields of interest for packet forwarding may not overlap with those of interest for monitoring
  - Interaction between forwarding and monitoring is not trivial
  - May force SDN to work in reactive mode: constant controller involvement

- Our Idea: leverage software switch to provide user-defined traffic monitoring
Introduction

- **Why software switch?**
  - Slower switching speed
  - Access to more resources (both CPU and memory)
  - Sitting at the edge
  - Open source

- **What UMON likes to achieve?**
  - Monitor arbitrary fields
  - Sub-flow monitoring, e.g., monitor micro/sub-flows of a mega-flow, *without constant controller involvement*
  - Allow to push other management functions, such as anomaly detection, to the switches
UMON: Design and Implementation

- How to instrument the software switch to support UMON?
  - Decoupling monitoring from forwarding
  - Monitoring does not interfere with forwarding

- Design must integrate well with the OVS architecture
  - Two-tiered forwarding architecture
    - User-level: full blown pipelined routing
    - Kernel-level: flow entry caching
UMON: Design and Implementation

- User level decoupling
  - a separate monitoring flow table, where the monitoring rules are stored
UMON: Design and Implementation

- **Kennel level decoupling**
  - Kernel rule does not support priority
  - For a packet, at most one rule matches the header
  - Adding a monitoring table in kernel is ‘heavy’
  - Carefully designed kernel flow rules that satisfy the monitoring requirements
    - *Kernel rule must be ‘finer’ than the monitoring rule*

- Let \((r_f, m_f)\) be the generated kernel flow rule and its mask; 
  \((r_i, m_i), i \in I,\) be the monitoring rule set in the monitoring table

- \(m_f^* \triangleq m_f | \left( \big|_{i \in I_f} m_i \right)\),
  where
  \(I_f \triangleq \{ i \mid r_f \& m_{fi} = r_i \& m_{fi}, i \in I \},\)  
  \(m_{fi} \triangleq m_f \& m_i.\)
UMON: Design and Implementation

- Traffic monitoring of non-routing fields
  - New monitoring actions to collect stats of non-routing fields
  - E.g. SYN Monitoring Action, ACK Monitoring Action, etc.

- Sub-flow monitoring
  - Sub-flows are the fine-grained flows that belong to a mega-flow as defined by the monitoring rule
  - Sub-flow is defined by sub-flow mask $s_i$
  - generate proper kernel flow rules

- Monitoring rule insertion/deletion
  - When removing a monitoring rule => ‘lazy’ approach
  - When a monitoring rule is added => ‘complex’
    - make sure the kernel rule’s granularity is still fine
    - If not, purge the rules. Proper rule will be added when next packet arrives
Evaluation

- **Setting:**
  - Open vSwitch (version 2.3)
  - A standalone machine with 2.67GHz CPU (12 cores), 64G memory, and an Intel NIC of two 10G ports
  - One server, one client
  - Compare performance of UMON, default OVS, and micro-flow enabled OVS
Evaluation

- **UMON overhead evaluation**
  - DECONF trace with 272 hosts and 4432 micro-flows
  - Monitor 150 hosts with micro-flow monitoring on
  - Transmit at 2.2 Gbps

‘Gap’ is due to Generic Receive Offload option (GRO) at NIC
Evaluation

- UMON overhead evaluation

<table>
<thead>
<tr>
<th></th>
<th>Handler</th>
<th>Revalidator</th>
<th>FlowTableSize</th>
<th>MissPktRate</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVS</td>
<td>0.0%</td>
<td>0.60%</td>
<td>295</td>
<td>0</td>
</tr>
<tr>
<td>Microflow OVS</td>
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<td>6.8%</td>
<td>4381</td>
<td>30</td>
</tr>
<tr>
<td>UMON</td>
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<td>9.9%</td>
<td>4301</td>
<td>26</td>
</tr>
</tbody>
</table>

- CPU utilizations are low for all three types of vSwitches
- Revalidator threads consume much more CPU resources than the handler threads due to large flow table size and monitoring activity
Evaluation

- Effect of monitoring rules

Tradeoff between #monitoring-rules, kernel flow table size, and CPU utilization is possible
Conclusions and Future Work

- UMON: decouples monitoring from forwarding, and offers flexible and fine-grained monitoring in OVS
- Design and implement UMON
- Evaluate the prototype

- Design and specify OpenFlow interface for UMON
- Distributed UMON monitoring network for DDoS detection
Backup slides
Evaluation

- Effect of monitoring rules