R2-D2: Filter Rule set Decomposition and Distribution in Software Defined Networks
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**Background and Motivation**

**Context**
- Large number of filtering rules due to the increasing number of hosts and applications.
- Increase in number of attacks that affect entries in access-control lists (ACL).
- Expensive and power-hungry ternary content-addressable memory (TCAM).

**Research question**
How to decompose and distribute filtering rules on a set of limited size switch tables?

**Overview of Longest prefix matching (LPM) representation**

<table>
<thead>
<tr>
<th>Rule</th>
<th>Address field</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 0 * *</td>
<td>A₁</td>
</tr>
<tr>
<td>2</td>
<td>0 0 0 *</td>
<td>A₂</td>
</tr>
</tbody>
</table>

Table: Example of a rule set in a switch table.

If a switch receives a packet with 0001 as address

- **Prioritized list strategy**: Rule 1 is first, A₁ is applied.
- **LPM strategy**: Rule 2 is most specific, A₂ is applied.

**Rule Representation**
- Single field filtering.
- Sufficient for blacklists.
- Rules represented in a binary tree.
- One rule at most on each tree node.

**Decomposition Algorithm**
- Input a set of rules and switches.
- Search the binary tree in order to find the best candidates.
- All rules present in the chosen node and all nodes below it, will be added to the switch.
- Minimize the number of generated rules by merging old forward rules with the ones from the best candidates.
- No rule duplication.

**Forward Rule Generation**
- Forward rules avoid processing packets filtered by previous switches multiple times.
- Rules with deny action does not require a forward rule to be generated.

**Decomposition over a graph**
- Series-parallels graphs.
- Build the binary tree from a parallel and series composition.
- Simplify the binary tree using S-components.
- Packets with different sources will be processed by the same rule table of an intersection switch.

**Evaluation**
- 12 sets of data generated using ClassBench.
- Percentage of forward action field between 0 and 100%.
- Rules with same action type have zero overhead.
- Around 15% overhead on 8 switches path length.

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