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

Rule	Address field	*Action*
1	0 0 * *	A_1
2	0 0 0 *	A_2

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, A_1 is applied.
LPM **strategy** : Rule 2 is most specific, A_2 is applied.

Rule Representation

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

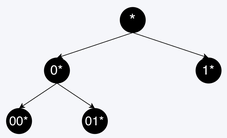
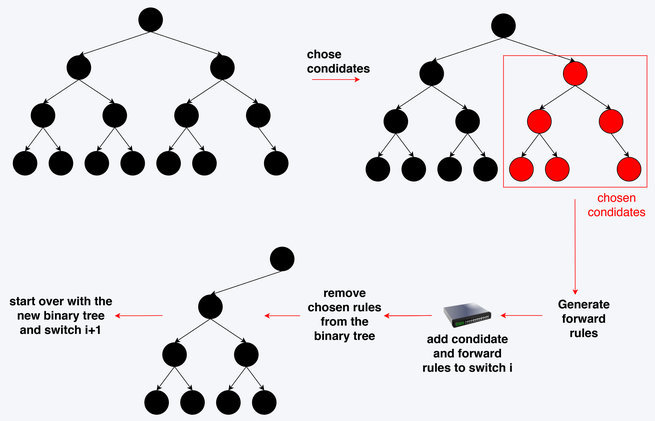


Figure: Compact representation of rules prefixes (00*,01*,0*,1*,0*) in a binary tree.

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.

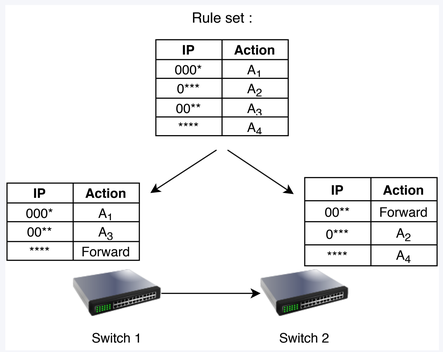


Figure: Illustration of forward rule generation with a rule set and two successive switches.

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.

Figure: S-component.

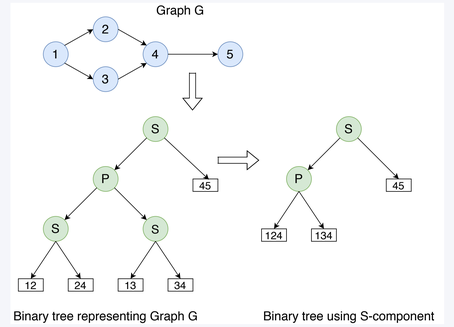
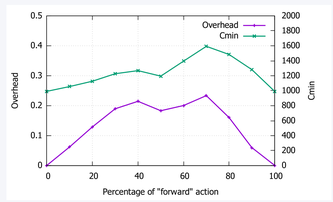


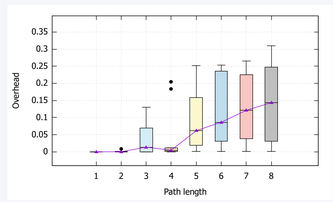
Figure: Tree representation of a series-parallel graph.

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.



(a) Effect of action field on overhead OH and C_{min} using acl1 rule set.



(b) Rule space overhead while distributing a rule set with a 50% of rules having Forward actions.

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