

# A Rule Grouping Technique for Weight-Based TCAM Coprocessors

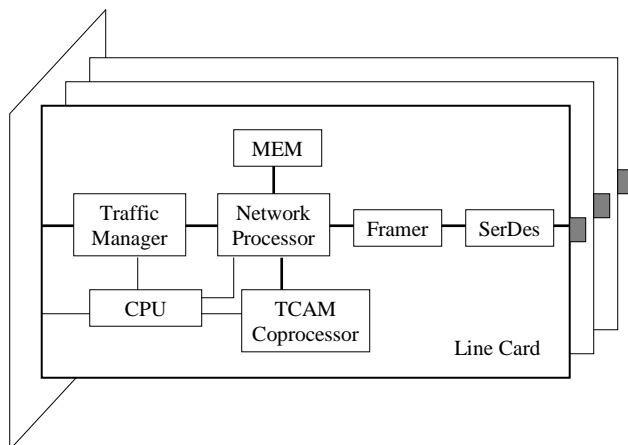
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## Outline

- Background
- Problem
- Solution
- Future Work

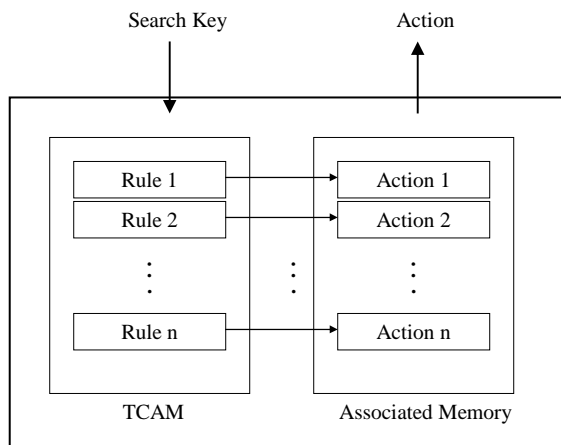
## TCAM Coprocessor

- A popular solution for offloading *packet classification* tasks from a network processor



## TCAM Coprocessor

- Memory Structure:



## An example

- Consider a five-tuple policy table
  - A policy filter may state: “all the traffic from network  $11.22.xx.xx/16$  to network  $22.33.44.xx/24$  should be blocked”, where “x” denotes 8 consecutive wildcarded bits.  
↓
  - A five-tuple rule:  $\{11.22.xx.xx, 22.33.44.xx, xx, xx, x\}$
  - Action: “drop” the packet matching the above rule

## TCAM Coprocessor

- How to break the ties if a search key matches multiple rule entries?
    - E.g.: search key  $\{11.22.25.32, 22.33.44.11, 16, 1025, 6\}$  matches
      - $r1 = \{11.22.xx.xx, xx.xx.xx.xx, xx, xx, x\}$
      - $r2 = \{11.22.xx.xx, 22.33.44.xx, xx, xx, x\}$
      - $r3 = \{xx.xx.xx.xx, 22.33.44.xx, 16, xx, x\}$

↓ Increasing Match Priority
- r1 \_\_\_\_\_  
r2 \_\_\_\_\_  
r3 \_\_\_\_\_

## TCAM Coprocessor

Two hardware solutions:

– Ordered TCAM (OTCAM) Coprocessor



– Weighted TCAM (WEITCAM) Coprocessor



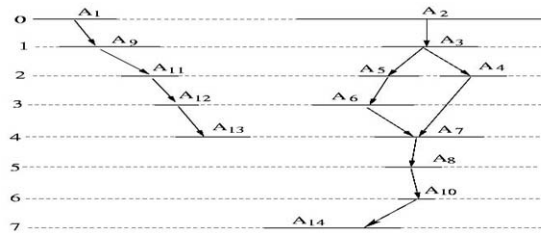
## WEITCAM Coprocessor

- Easier to manage than OTCAM coprocessor
- Consuming more memory resource than OTCAM: a  $w$ -bit weight sub-field per  $l$ -bit slot, e.g., about 16% for  $w = 10$  and  $l = 64$
- To reduce memory overhead, a WEITCAM with small  $w$  is preferred
- A key issue: run out of weights – **Weight Depletion**

## Weight Depletion Problem

Define:

- Connected Rule Group (CRG):  
CRG-1 = {A1, A9, A11, A12, A13}  
CRG-2 = {A2, A3, A4, A5, A6, A7, A8, A10, A14}
- Multiple Match Group (MMG):  
MMG-1 = {A1, A9, A11, A12, A13}  $\square$  CRG-1  
MMG-2 = {A2, A3, A5, A6, A7, A8, A10, A14}  $\square$  CRG-2  
MMG-3 = {A2, A3, A4, A7, A8, A10, A14}  $\square$  CRG-2



## Weight Depletion Problem

Two observations:

1. The weight space can be reused by different CRGs
2. The minimum number of weights required by a CRG is lower bounded by the size of the largest MMG in that CRG

Conclusion:

**Weight depletion occurs if there is at least one MMG of size larger than the weight space size  $2^w$**

## An Example

$MMG-A = \{A1, A2, A3\}$

$A1 = \{11.xx.xx.xx, xx.xx.xx.xx, xx, xx, x\}$

$A2 = \{11.22.xx.xx, xx.xx.xx.xx, xx, xx, x\}$

$A3 = \{11.22.33.xx, xx.xx.xx.xx, xx, xx, x\}$

$MMG-B = \{B1, B2, B3\}$

$B1 = \{33.xx.xx.xx, xx.xx.xx.xx, xx, xx, x\}$

$B2 = \{33.44.xx.xx, xx.xx.xx.xx, xx, xx, x\}$

$B3 = \{33.44.55.xx, xx.xx.xx.xx, xx, xx, x\}$

Adding  $C = \{xx.xx.xx.xx, xx.xx.xx.xx, xx, xx, 1\}$  with match priority higher than rules in MMG-A but lower than rules in MMG-B



$MMG-A-C-B = \{A1, A2, A3, C, B1, B2, B3\}$

- Small MMGs can be chained together to form a large MMG, causing weight depletion
- Theoretically, the largest MMG size one may build from 104-bit five-tuple rules is on the order of  $3^{104}$

## A Solution

### A Key TCAM Property:

**When a search key matches multiple rules with the same highest weight value, the action associated with one of the matched rules is returned. However, exactly which one is returned cannot be determined**

## A Solution

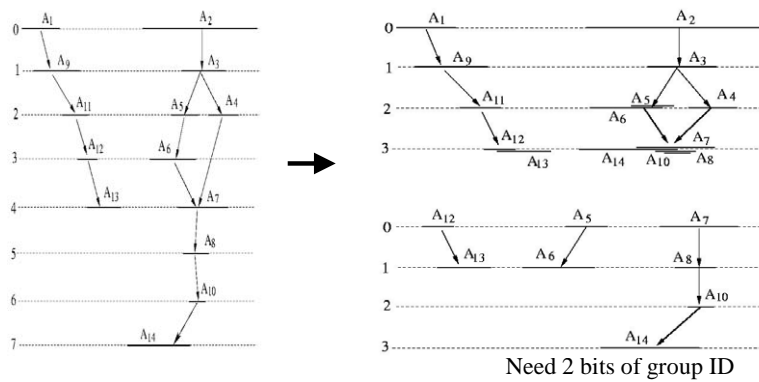
### A Rule Grouping Technique:

**Allow multiple rules in an oversized MMG to be assigned the same weight value to reduce weight consumption, and break ties through a second TCAM table lookup**

## A Solution

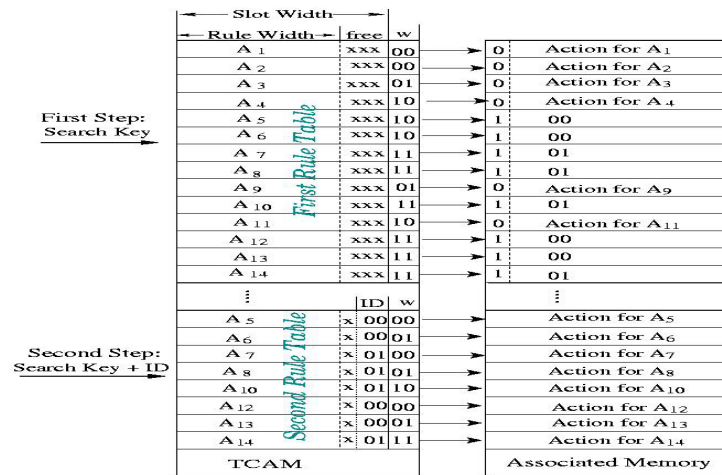
### A Rule Grouping Technique:

(Assume  $w = 2$ , or weight space size = 4)



# A Solution

Table formats:

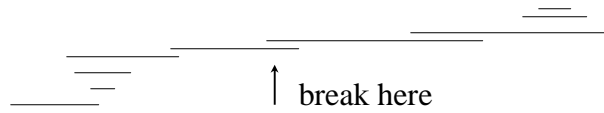


## Scalability of the Solution

- MMG size as large as  $2^{2w}$  can be supported, e.g.,
  - 16 K, for  $w = 7$
  - 1 M, for  $w = 10$
- Generalized version: with  $n$  TCAM table lookups, MMG size as large as  $2^{wn}$  can be supported
- Rule structure independent
- Drawbacks
  - At least an extra  $w$ -bit ID sub-field per slot
  - Multiple TCAM lookups

## Future Work

- Exploring rule structure: Breaking a large MMG into smaller ones



- Impact on database update