Minimization of ACL Storage by Adding Minimal Hardware of Range Matching and Logical Gates to TCAM

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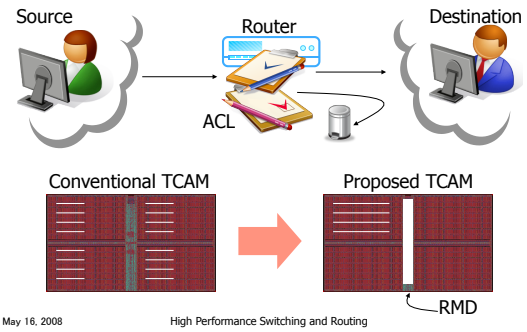
Outline

- Introduction
  - Access Control List (ACL)
  - Ternary Content Addressable Memory (TCAM)
  - Prefix Expansion
- Proposal & Contribution
  - Range Matching Device (RMD)
  - Optimization of Prefix Expansion (PE-MIN)
  - Managing TCAM (RMD + PE-MIN)
- Evaluation
- Conclusion

Sketch of Proposal



Access Control List (ACL)


```
access-list 101 permit tcp host 10.1.1.2 host 172.16.1.1 eq telnet
access-list 102 deny tcp any range 137 139 any
access-list 101 permit ip 10.1.1.0 0.0.0.255 172.16.1.0 0.0.0.255
access-list 111 deny icmp any 10.1.1.0 0.0.0.255 echo
access-list 191 permit udp any any range 16384 16483
```

- List in routers for packet classification (permit/deny)
- Entries consist of source and destination IP address, source and destination port number, and protocol number
- Storage in TCAM

Ternary CAM

- Searches using the content of memory, returns the memory address
- Cell representation: 0 / 1 / *

Cons

- High power consumption
- Large chip area
- Expensive inter chip communication cost

Pros

- Fast search speed
- Excellent performance in longest prefix match
- Simple and standardized structure

Motivation

- Writing ACL in TCAM
  - Issue of expressing port numbers in ranges

  Q. How do we write "ranges" in memory?

  Q. How do we restrain the growth of expensive TCAM entry?
- Possible storage of ranges
  - Full expansion: writing every single number to exactly match the entire range
  - Prefix expansion: writing least significant bits as don't care bits

Example Prefix Expansion

- For a port range of "1024 ~ 65535",
  - Full Expansion: 64512 entries
  - Prefix Expansion: 6 entries

```
1***************   32768 - 65535
01**************   16384 - 32767
001*************   8192 - 16383
0001************   4096 - 8191
00001***********   2048 - 4095
000001**********   1024 - 2047
```

Good performance of ranges in units of 2^i

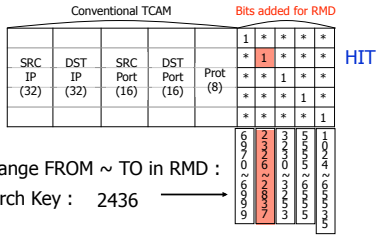
- For a port range of "16385 ~ 65534",
  - Full Expansion: 49150 entries
  - Prefix Expansion: 29 entries

Research Purpose

- Minimize memory usage by integrating additional device within the TCAM
- Decrease worst case by optimizing prefix expansion algorithm

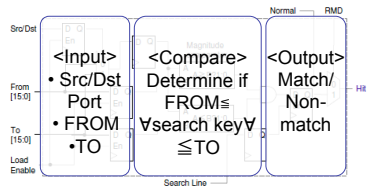
Reduce TCAM's memory consumption by using Range Matching Device and optimized prefix expansion

Range Matching Device (RMD)



- Additional bits to the conventional TCAM, reserved to express pre-written ranges

Logical Circuit of RMD

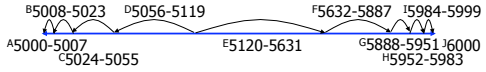


- Write the range FROM ~ TO in the memory
- Determine if the search key (port #) is within FROM ~ TO

Prefix Expansion Algorithms

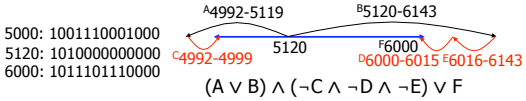
Prefix expansion of range "5000 ~ 6000"

- PE-OR: Conventional prefix expansion



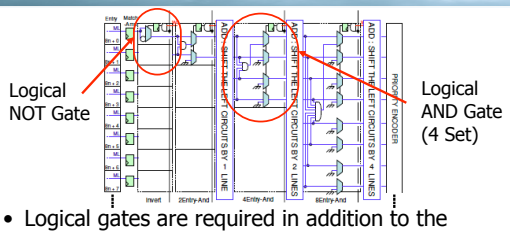
A ∨ B ∨ C ∨ D ∨ E ∨ F ∨ G ∨ H ∨ I ∨ J

- PE-MIN: Proposed prefix expansion



(A ∨ B) ∧ (¬C ∧ ¬D ∧ ¬E) ∨ F

Logical NOT/AND Gates in TCAM



- Logical gates are required in addition to the conventional TCAM to express the result of PE-MIN
- Gain: Tradeoff between the additional gates and the reduced line

RMD Policy

Proposal

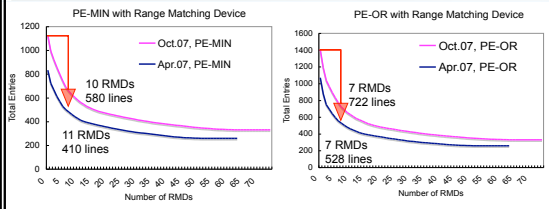
- Weight of each range determines the order to be written in the RMD

(Lines after PE - 1) x (Number of ACLs referring this range)

Range	PE-MIN lines	# of Ranges	PE-MIN x # of Ranges	Weight
2326 ~ 2837	8	16	128	112
6970 ~ 6999	4	18	72	54
5555 ~ 6555	10	6	60	54
5555 ~ 5587	5	11	55	44
3230 ~ 3253	4	14	56	42

Entry Reduction using RMD

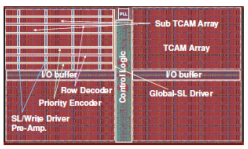
Evaluation



- PE-MIN: 50% of reduction with 10~11 RMDs
- PE-OR: 50% of reduction with 7 RMDs
- With only 2~3 additional RMDs, the reduction level of PE-MIN can be achieved in case of PE-OR

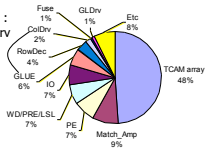
Overhead Cost Estimation 1

Evaluation



<TCAM VLSI in 90nm Technology>

Control Logic : GLUE + ColDrv = 8% 305K Gates (Priori)

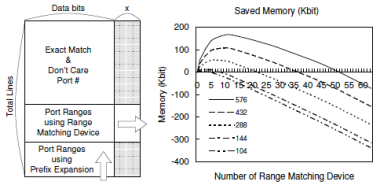


RMD: 580 Gates x 20 RMDs = 11.6K Gates
Current TCAM : TCAM with RMD = 100 : 100.3

- Inserting 20 RMD to current TCAM
  ⇒ 0.3% increase in manufacturing cost

Overhead Cost Estimation 2

Evaluation



(a) Reduced and Increased Memory Space (b) Saved Memory Space

Ex.
Data bits: 576
RMDs : 11
→Saves 170Kbit
(Around 300 entries.
30% reduction)

- Tradeoff in vertical and horizontal bit lengths
- Gain/loss tradeoff depends on data bit length

Conclusion & Future Work

- Proposed new TCAM architecture by integrating Range Matching Device and using optimized prefix expansion algorithm
- Evaluated using actual ACL data
- Future work
  - Analysis of the proposed method using other ACLs to achieve a general purpose TCAM
  - Implementation of the proposed TCAM in the network processor to investigate further performance characteristics (i.e. power consumption)

Thank you