Sorting and Searching using Ternary-CAMs

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Sorting & Searching in Hardware

• TCAMs: primarily used for forwarding.
• Sorting and searching are classical operations.
  – May be required at high speeds.
• Range search applications.
  – Address range locking
  – Virtual to physical address mapping
  – Port number search
• Priority queues, Sorted lists are common data structures.
  – Special purpose chips are available
Our Results

- We present two stage pipeline using TCAMs
  - for range search, sorting, priority queues
  - $O(1)$ time, for search/update operations.
  - $O(1)$ space for each entry

Disjoint Range Search

- Numbers are $w = 32$ bit long
- query point $q$
- Naïve approach : use upto $(2w-2) = 60$ prefixes per range
  - A prefix is a special kind of range
  - We do it in 2 prefixes per range with two concurrent lookups
Use Longest Common Prefix

- LCP(x, y) : easy to compute by bit operations
  - e.g., LCP(34, 55) is 001****
  - 34 is 00100010 in binary; 55 is 00110111
- LCP is same as lowest common ancestor
- If q is in a range, q matches LCP of its endpoints

Store LCPs in TCAM

- Doesn’t work. Matching range may not be longest prefix
Why LCPs don’t work

Store Extended LCPs in TCAM

• Only the range i and range j can potentially match q
Store Extended LCPs in TCAM

TCAM

<table>
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<tr>
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<th>LCP₁₀</th>
<th>LCP₁₁</th>
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<td>000·0*</td>
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<td>LCP₄·0</td>
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q → LCP₁₀

q → LCP₁₁

• Only the range i and range j can potentially match q

Proof

• Theorem: If q is in the range [s, t], then either LCP.0 or LCP.1 is longest matching prefix in its TCAM
  – where LCP = longest common prefix of (s, t)
• Proof:
  – Assume otherwise
  – Find that the ranges overlap
  – contradiction.
Results

- Search: two parallel lookups, followed by two parallel compares: $O(1)$
- Updates: insert 2 Extended LCP of endpoints: $O(1)$
- Can be extended to overlapping ranges
- Sorting: special case of disjoint range search. Updates to a sorted list is fast: $O(1)$
- Priority queue (findmin): special case of sorting
- Range intersection (useful for locking)
Applications

• High speed sorting in O(n)
• Virtual to physical address translation
  – TLB can be compressed by viewing it as range search and using a TCAM
  – storage networks
• Locking, memory protection
• Graphics co-processors