Fast Query Processing Using Cooperative Caching for Index Structures

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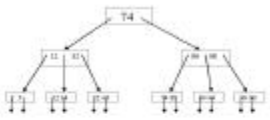
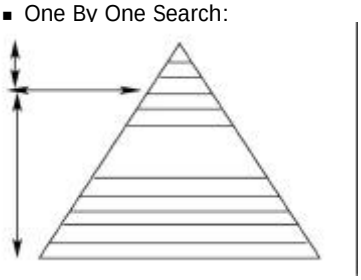
Cooperative Caching for n-ary Tree Lookup

- The Problem:
- There is a static n-ary tree and a huge number of key lookups
- The n-ary tree can fit in memory but not in cache
- High Throughput and Fast Response Time



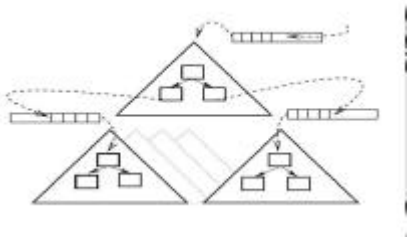
Method A

- One By One Search:



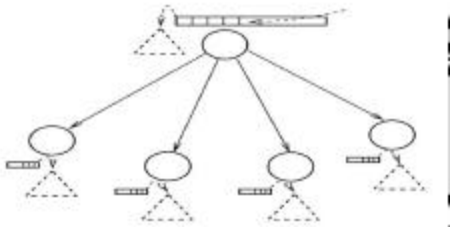
Method B: Buffering Accesses

- Requires >>10^6 keys for efficient batch processing



Method C: Cooperative Caching

- Requires >> 10^4 keys for efficient batch processing.



Design Methods

- A: dominated by memory latency
- B: dominated by memory bandwidth(33%) and CPU speed (67%)
  - need large batches to amortize the cost to load the subtree into the L2 cache.
  - larger batches give long delay and slow response.
- C: dominated by network bandwidth(5%) and CPU speed (95%)
  - Moderated batch to efficiently use network bandwidth and amortize the network latency.
  - Faster response.

Today's Hardware: Boston Univ. Linux cluster (Mariner)

- 4-ary tree size: 3.2MB with 8 levels
- Pentium III
- Myrinet network
  measured vs. ideal bandwidth: 138MB/s vs. 275MB/s
- PC-133 DRAM
  measured vs. ideal bandwidth: 647MB/s vs. 1.06GB/s
- Memory latency: 60ns (measured)
- Cache miss penalty: 110ns (measured)
- L2 cache size: 512KB

Experimental Results

4-ary tree size: 3.2MB
L2 cache size: 512KB
Number of CPUs used: 10
Size of Batch/Msg: 40KB storing 10K keys

Method A	Method B	Method C
95.5ns	76ns	75ns

Comparison

Roughly Caculation :

Method A :

$L_0 \times C_{mar} = 8 \times 110 = 880$

Method B :

$$L_{L2} \times C_{one\_node} + \frac{S_{tree}}{BW_{memory} \times N_{keys\_batch}} = 7 \times 33 + \frac{3.2MB}{647MB/s \times 10000} = 231 + 500 = 731$$

Method C :

$4 / BW_{network} + L_{L2} \times C_{one\_node} \times 2 = 28 + 231 \times 2 = 490$

A fit of the model to the experiment yields
20% error

Future Trends

- Memory latency will not change
- Memory Bandwidth will increase moderately
- CPU speed and network bandwidth will increase dramatically

Predicted Future Results

- Memory latency: 50ns
- Memory bandwidth: 4GB/s
- Network bandwidth: 10Gb/s
- CPU speed: 10GHz

Method A	Method B	Method C
40ns	10ns	5ns

Future Trends

Experimental Results:

Method A	Method B	Method C
95.5ns	76ns	75ns

Predicted Future Results:

Method A	Method B	Method C
40ns	10ns	5ns