The Bw-Tree: A B-tree for New Hardware Platforms

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An Alternate Title

“The BW-Tree: A Latch-free, Log-structured B-tree for Multi-core Machines with Large Main Memories and Flash Storage”

BW = “Buzz Word”
The Buzz Words (1)

**B-tree**

Key-ordered access to records
Efficient point and range lookups
Self balancing
B-link variant (side pointers at each level)
The Buzz Words (2)

Multi-core + large main memories

- Latch (lock) free
  - Worker threads do not set latches for any reason
  - Threads never block
  - No data partitioning
- No updates in place
  - “Delta” updates
  - Reduces cache invalidation

Flash storage

- Good at random reads and sequential reads/writes
- Bad at random writes
- Use flash as append log
- Implements novel log-structured storage layer over flash
Focus of this talk

- Create-Read-Update-Delete ("CRUD") API
- B-tree search/update logic
- In-memory pages only

- Logical page abstraction for B-tree layer
- Brings pages from flash to RAM as necessary

- Sequential writes to log-structured storage
- Flash garbage collection
Multiple Deployment Scenarios

In-memory latch-free B-tree (Hekaton)

High-performance standalone atomic record store (e.g., LevelDB)

Data component (DC) in a decoupled “Deuteronomy” style transactional system

http://research.microsoft.com/deuteronomy/
Bw-Tree Latch Freedom
Mapping Table and Logical Pages

Mapping table translates logical page id to physical location
Important for latch-free behavior and log structuring
Isolates updates to a single page
Delta Updates

Each update to a page produces a new address (the delta)
Delta physically points to existing “root” of the page
Install delta address in the mapping table using compare and swap
Delta consolidation

Long delta chains degrade search performance
Delta consolidation creates new search-optimized page
Consolidation piggybacked onto regular operations
Old page state becomes garbage (protected by epochs)
Latch-Free Node Splits

B-link structure allows us to “half split” without latching
Splitting requires two atomic steps

1. Install split at child level by creating new page
2. Install index term for new page at the parent
Performance Highlights
Performance Highlights

Experimented against
- BerkeleyDB standalone B-tree (no transactions)
- Latch-free skiplist

Workloads

XBOX
- 27M get/set operations from XBox Live Primetime
- 94 bytes keys, 1200 byte payloads, read/write ratio of 7:1

Enterprise storage deduplication
- 27M deduplication chunks from real enterprise trace
- 20-byte keys (SHA-1 hash), 44-byte payload, read-write ratio of 2.2:1

Synthetic
- 42M operations with keys randomly generated
- 8-byte keys, 8-byte payloads, read-write ratio of 5:1
vs BerkeleyDB

- **Xbox**: 10.40 M
- **Synthetic**: 3.83 M
- **Deduplication**: 2.84 M

Bar chart comparing operations/sec (M) for BW-Tree and BerkeleyDB.
vs Skiplists

<table>
<thead>
<tr>
<th>Synthetic workload</th>
<th>Bw-Tree</th>
<th>Skiplist</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.83M Ops/Sec</td>
<td>3.83M Ops/Sec</td>
<td>1.02 M Ops/Sec</td>
</tr>
</tbody>
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![Graph showing L1 hits, L2 hits, L3 hits, and RAM for Bw-tree and Skiplist operations.]