Flash Memory & Data Structures: What they don't want you to know

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Flash 101

aka Flash memory is the future.

1. **Advantages:** Increased Throughput, Increased Robustness, Reduced Latency
2. **Characteristics:** Erase before write, Out-of-place update, Weariness, Garbage collection
3. **Used as:** Raw flash and SSDs in Cache, primary tier
4. **Problems:** Slow random writes, Expensive

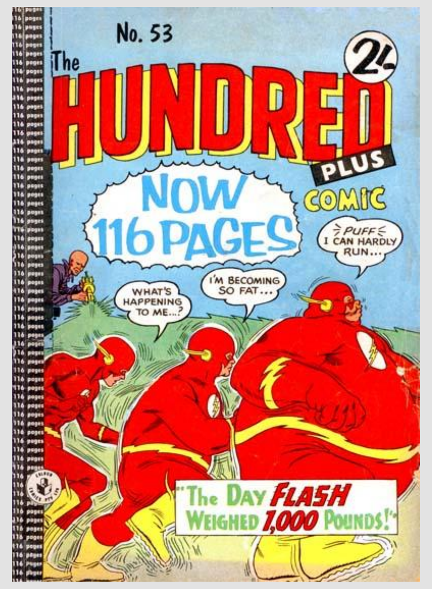


Figure 1. Flash getting fat [AusReprints.com]

Indexing problem on flash memory

Standard B+-tree sucks: Write-amplification, faster usage of flash disk.

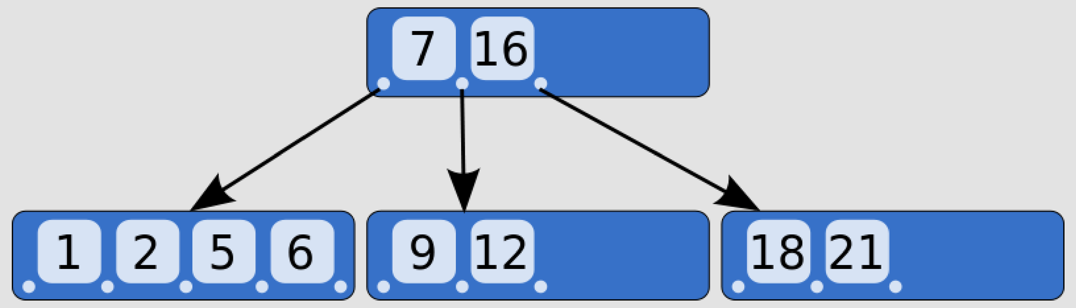


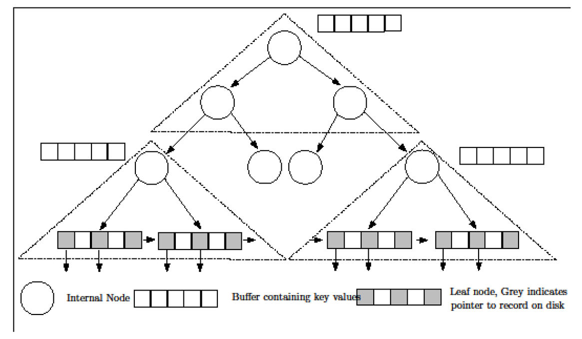
Figure 2. Sample B-tree [wikimedia.org]

How to construct and evaluate new data structures to choose the best?

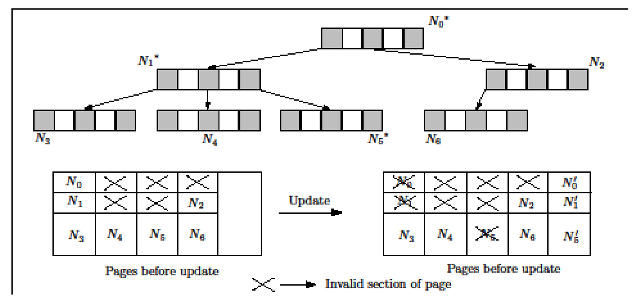
Cost analysis

We theoretically evaluate the performance for insert, delete and modify operations.

Use general-cost flash memory model [2].



LA-tree [1]: Periodic buffering of I/O operations in the tree



μ-tree [4]: Variable-sized nodes

FD-tree [5]: Converts random writes to sequential writes

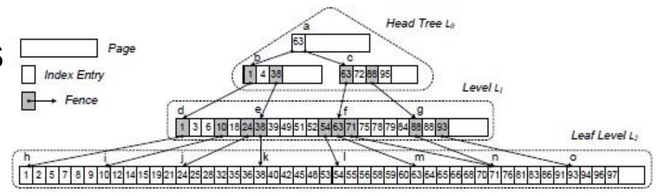


Figure 3. Proposed indexing structures

Further trends:
1. Block-aware layout
2. Self-tuning structure of the node
3. *Intelligent* FTL

Comparison results

Table 1: Complexity of operations in various data structures in the general-cost model. (h = height of the tree)

Data Structure	Search cost (read I/Os)	Update cost (write I/Os)	Reference
B^+-tree (FTL)	$O(\log_{B\_R} N)$	$O(1)$	[3]
LA-tree	$O((1 + \frac{B_U}{k\,B_R}) \log_{B\_R} N)$	$O(\frac{\log_{B\_R} N}{k})$	[1]
FD-tree	$O(\log_{B\_R} N)$	$O(\frac{B_R}{B_W} \log_{B\_R} N)$	[5]
μ-tree	$O(h)$	$O(1)$	[4]

N = Number of elements in tree
B_R = Read block size
B_W = Read block size
B_U = Size of buffer

Conclusions

1. FTL is useful but causes space and time overhead
2. Data structures like FD-tree can reduce write-amplification even without FTL, but are complex to implement
3. Simple workload-aware data structures (like FlashDB) can be very useful

Recommendations

- Need for developing more flash-aware algorithms
- Standardize performance claims over common workloads

Literature cited

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