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# ELB-trees - Efficient Lock-free B+trees

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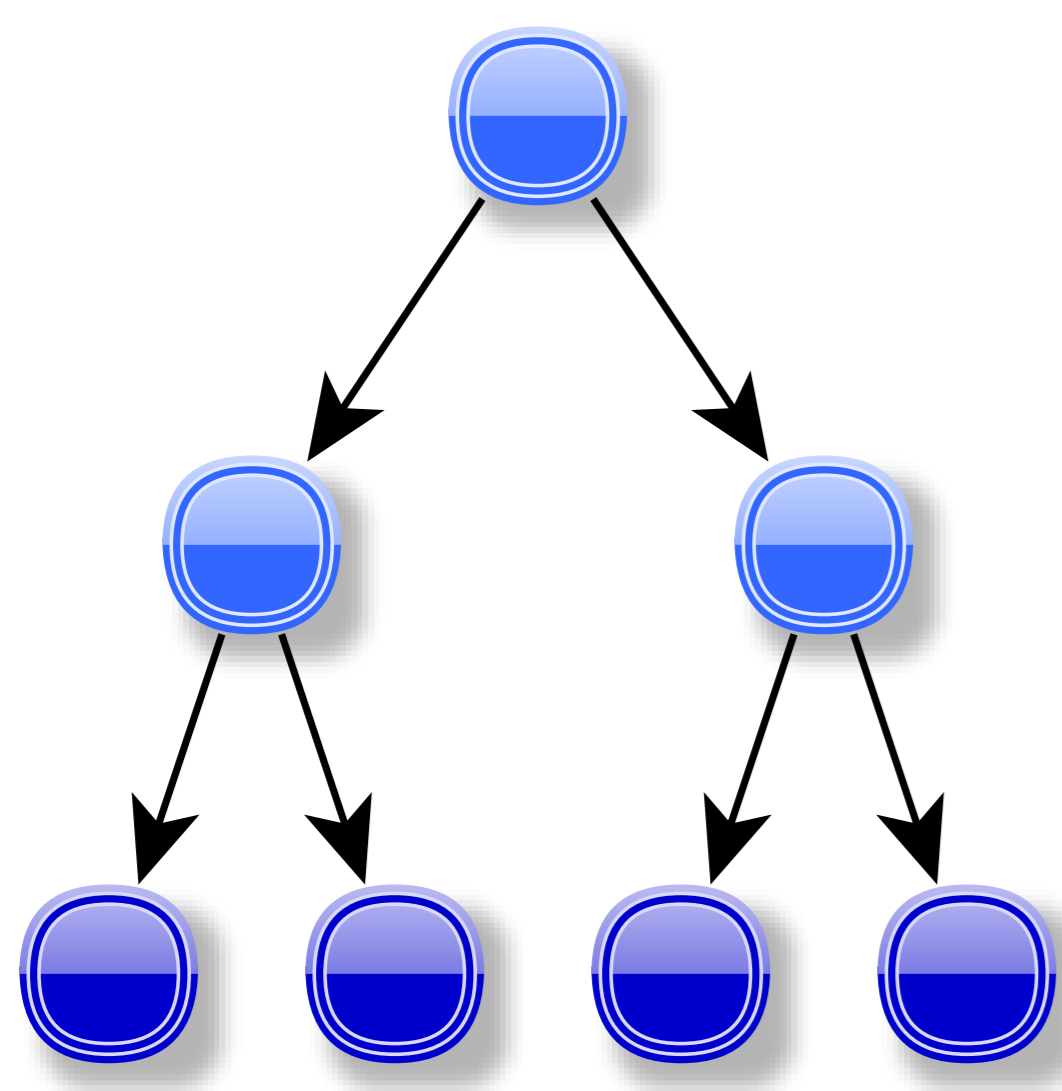
## Motivation

- ▶ Processors are increasingly parallel
- ▶ We need scalable, efficient, and thread safe data structures
- ▶ Lock based solutions scale poorly
- ▶ Lock-free solutions avoid deadlocks and scheduling issues

## Contributions

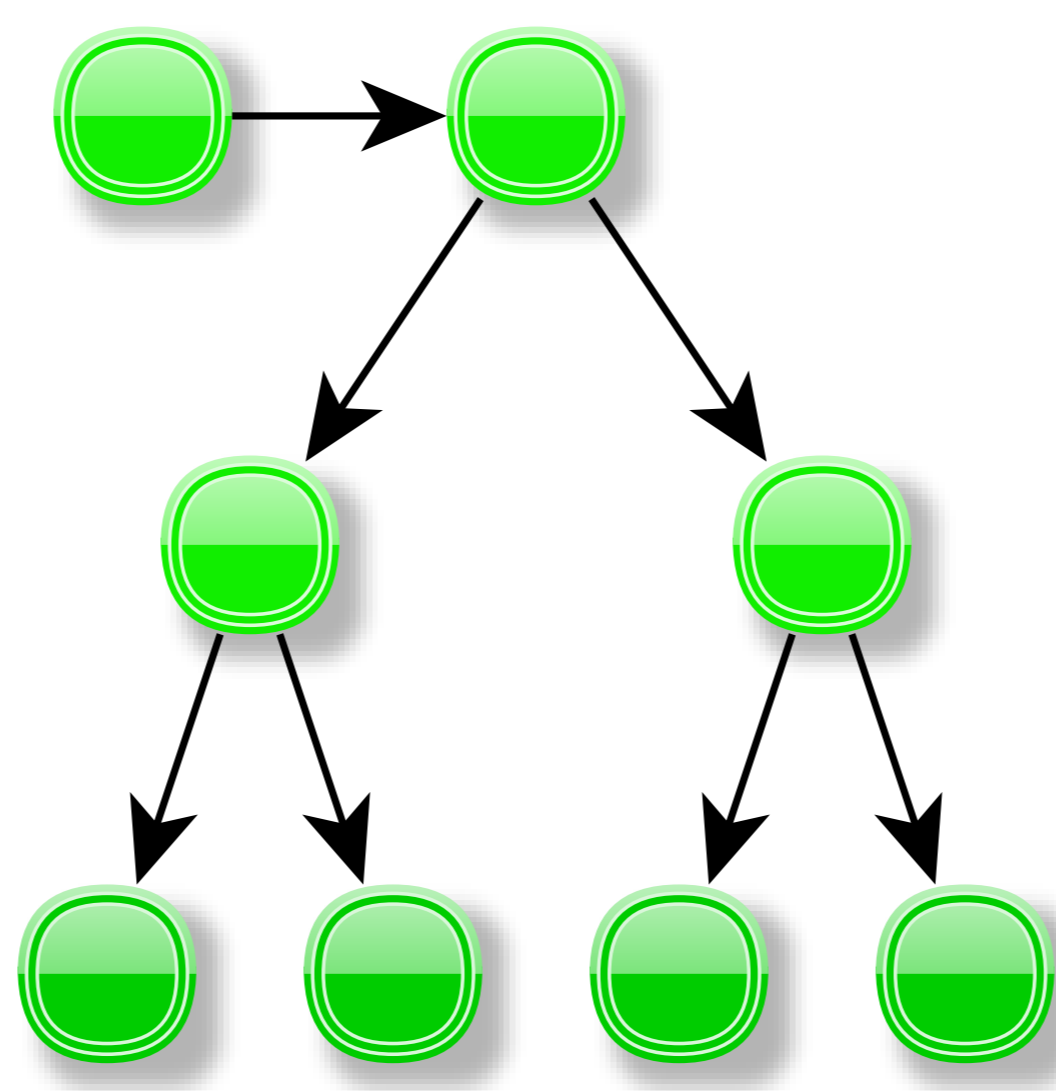
- ▶ An efficient lock-free balanced search tree (ELB-tree)
- ▶ Uses a single synchronization (CAS) per operation, in the common case
- ▶ Not dependent on reference counting or automatic garbage collection
- ▶ Almost 30 times faster than left-leaning red-black trees at 30 threads

## B+trees (Inspiration)



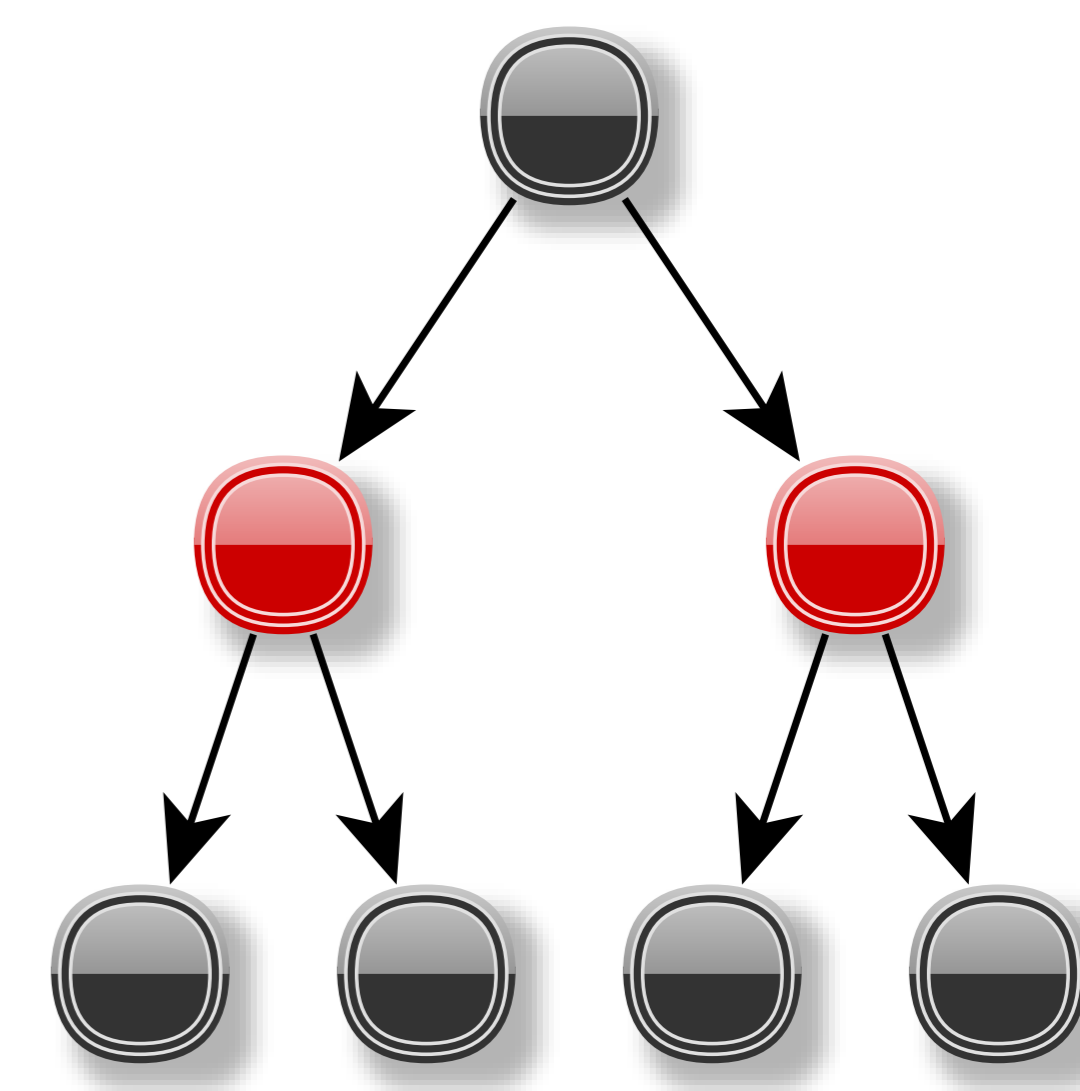
- ▶ Leaf oriented wide search tree
- ▶ Nodes at least 50% full
- ▶ Rebalance by merging, splitting, or stealing
- ▶ Optimized for space and storage on media

## ELB-trees (New)



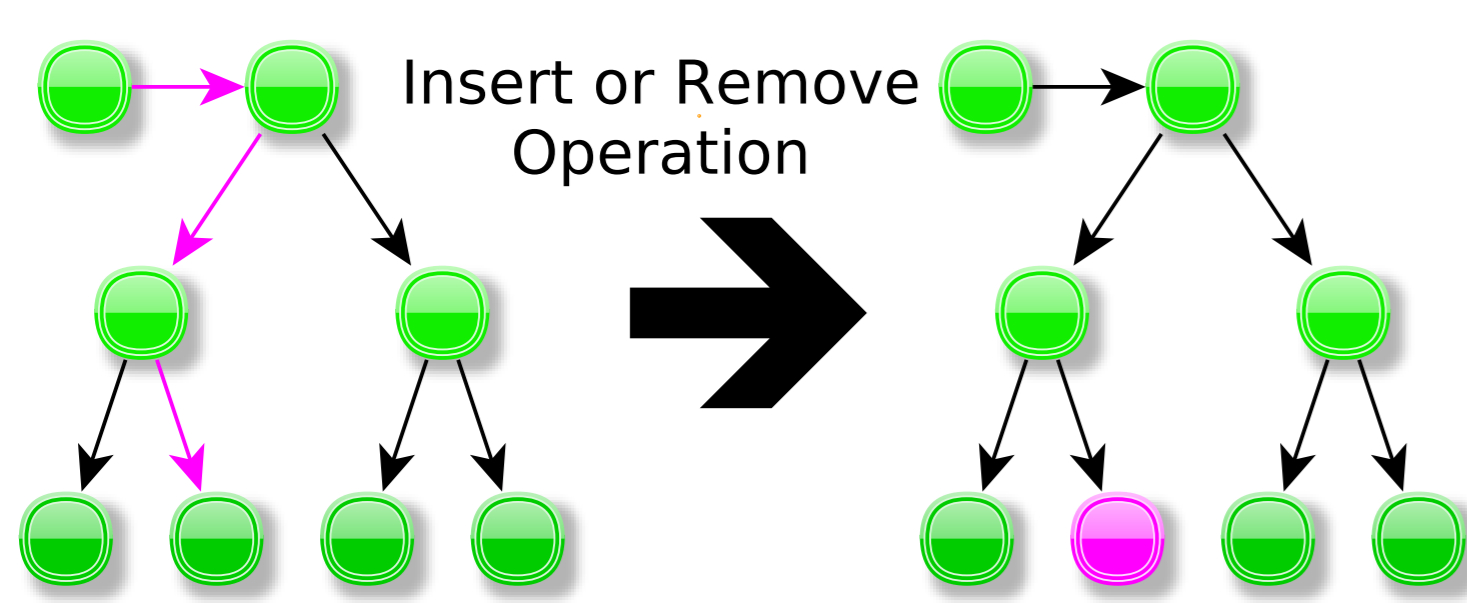
- ▶ Leaf oriented wide search tree with fake root
- ▶ Nodes at least  $k^{-1}$ ,  $k > 2$  full
- ▶ Rebalance by replacing parent node
- ▶ Optimized for parallel speed and RAM storage

## Left-leaning red-black trees

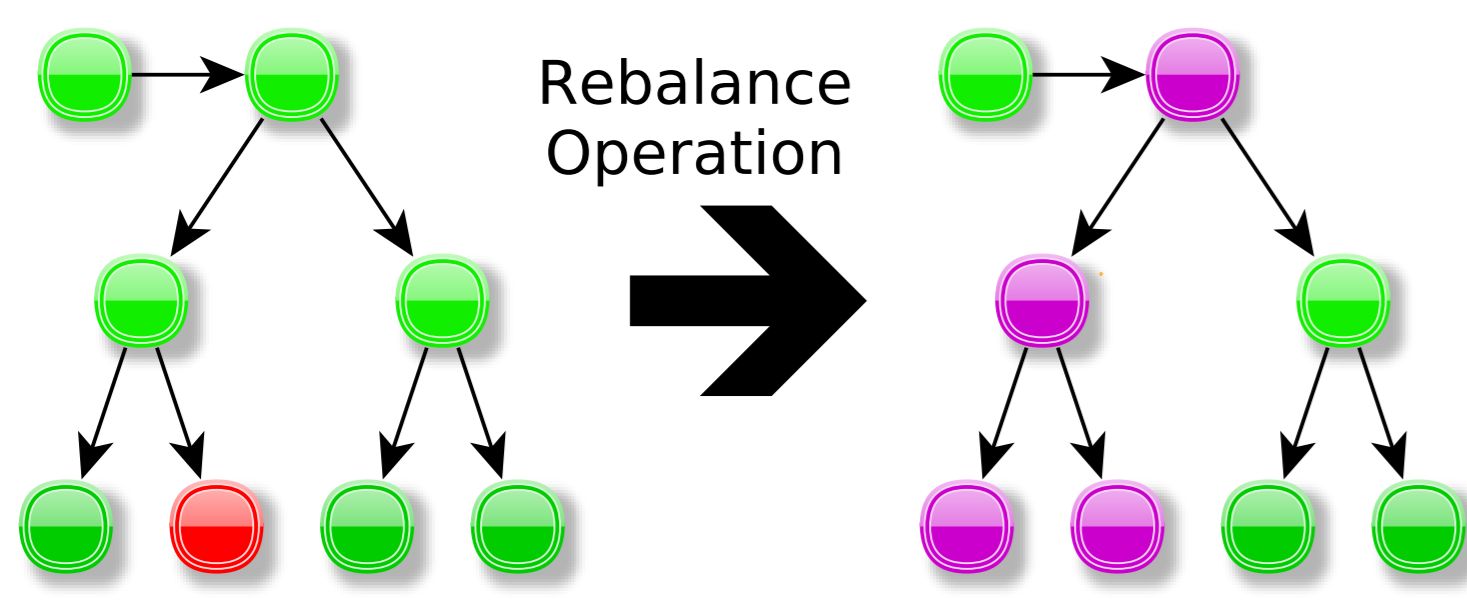


- ▶ State of the art binary search tree
- ▶ No empty nodes
- ▶ Local rebalance frequently
- ▶ Optimized for speed and RAM storage

## Approach



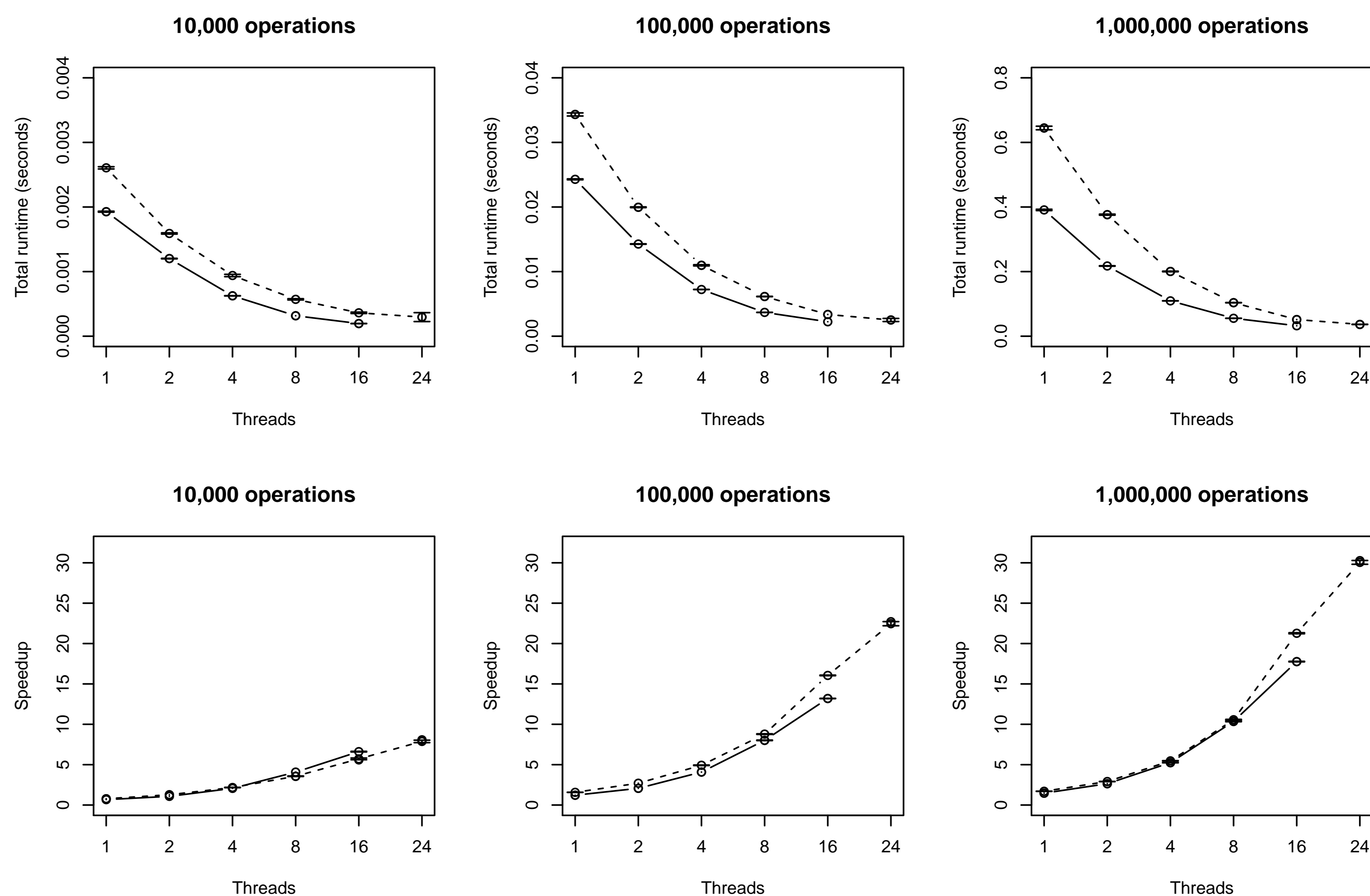
- ▶ Insert/remove: Find the relevant leaf and write with a CAS operation



- ▶ Rebalance: prevent changes to related nodes (in purple), replace the parent, and permit modification of grandparent

## Evaluation

- ▶ Perform 10,000, 100,000, or 1,000,000 operations on tree of size 10,000, 100,000, or 1,000,000
- ▶ 20% of the operations are insert, 20% are remove, and the last 60% are search operations
- ▶ Uniformly distributed keys and values
- ▶ Measure runtime and speedups relative to single threaded left-leaning red-black tree
- ▶ Solid line is 2x 4 Core Intel Xeon, dashed line is 2x 16 core AMD Opteron



- ▶ Better speedup for large than small trees, due to:
  - ▶ Spatial locality more significant, lower node contention, lower relative overhead for leaf processing

## Limitations

- ▶ Limited to 32 bit keys and values
- ▶ Operations not linearizable
- ▶ Requires 128 bit CAS operations

## Related Work

- ▶ Ellen *et al.* A Lock-Free B+tree. In *PODC'10*.
- ▶ Braginsky *et al.* A Lock-Free B+tree. In *SPAA'12*.
- ▶ Bonnichsen *et al.* ELB-trees. In *MuCoCoS'13*.

## Conclusion

- ▶ Introduced a scalable, efficient, and thread safe dictionary
- ▶ Comparable sequential performance to left-leaning red-black trees
- ▶ Highly scalable, especially for large data sets