CARP: Compression Aware Replacement Policies

Electrical & Computer ENGINEERING

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Overview

•Traditional cache replacement and insertion policies mainly focus on block reuse

•Recent literature has proposed cache compression, a promising technique to increase on-chip cache capacity [Pekhimenko et. al., PACT’12]

•In a compressed cache, block size is an additional dimension

•**Observation**: The block most likely to be reused soon may no longer be the best block to keep in the cache

•**Key Idea**: Use compressed block size in making cache replacement decisions

•**Solution**: We propose three mechanisms: Min-LRU, Min-Eviction, and Global Min-Eviction

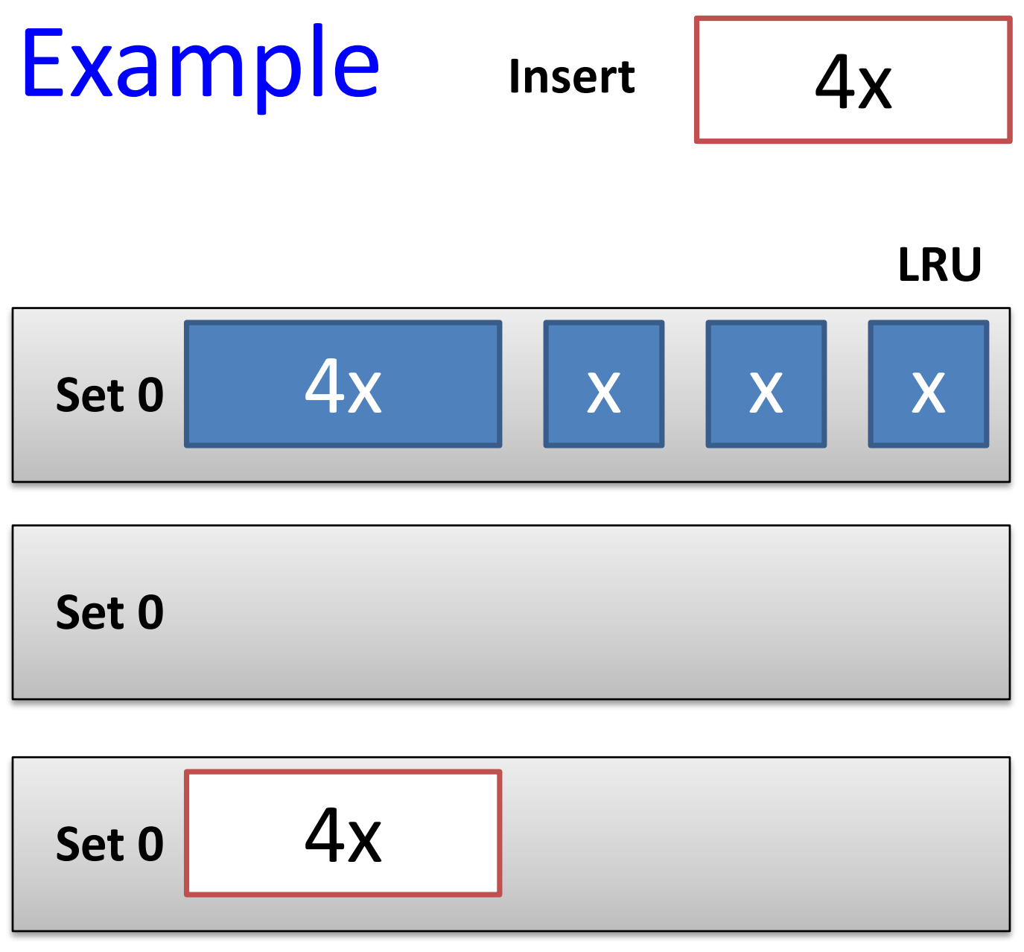
Motivation

Problem: How can we maximize cache performance utilizing both block reuse and size?

• No existing policy considers the many varied block sizes **and** potentials for reuse in making a replacement decision

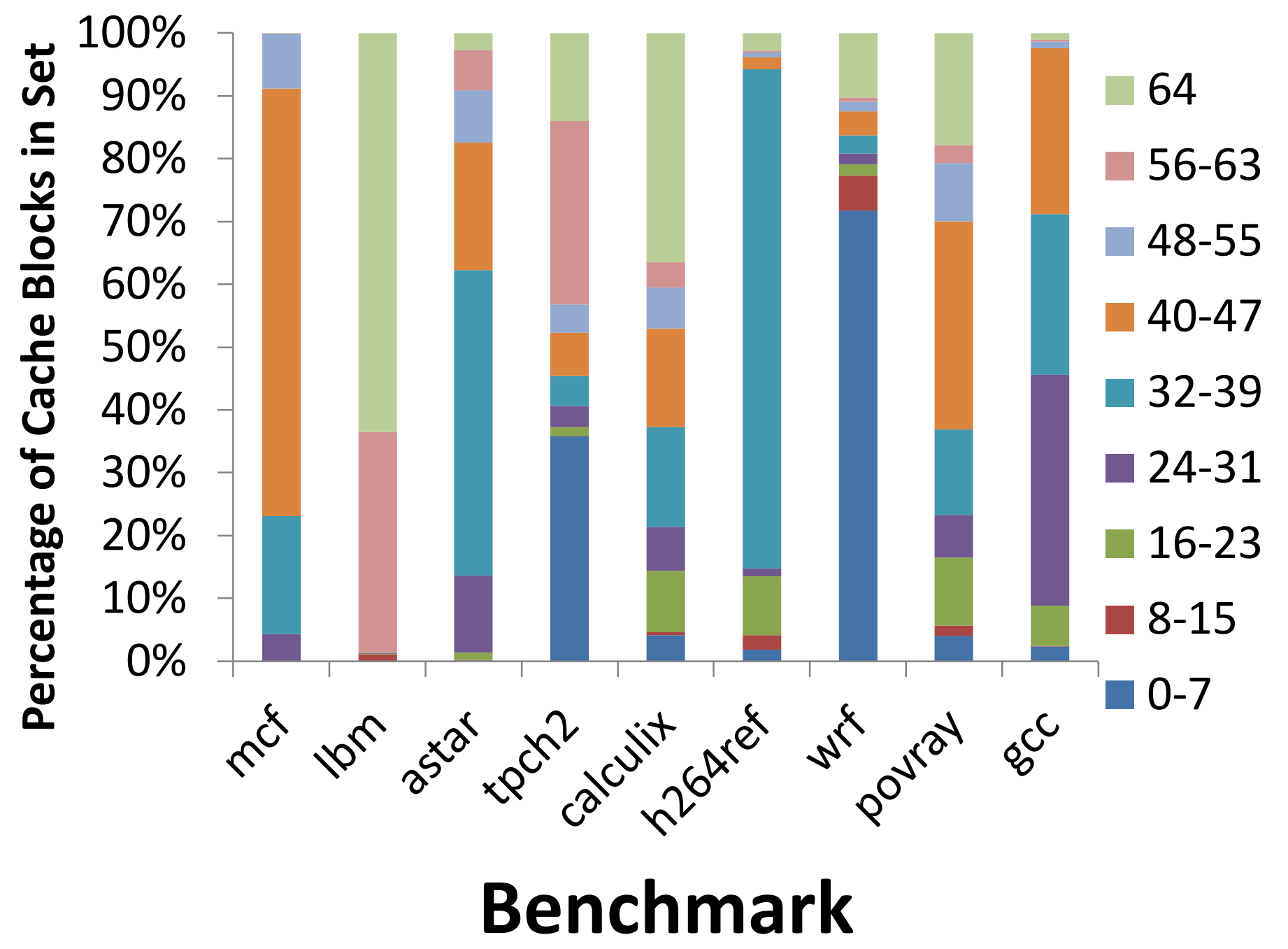
We propose compression aware replacement policies

Example



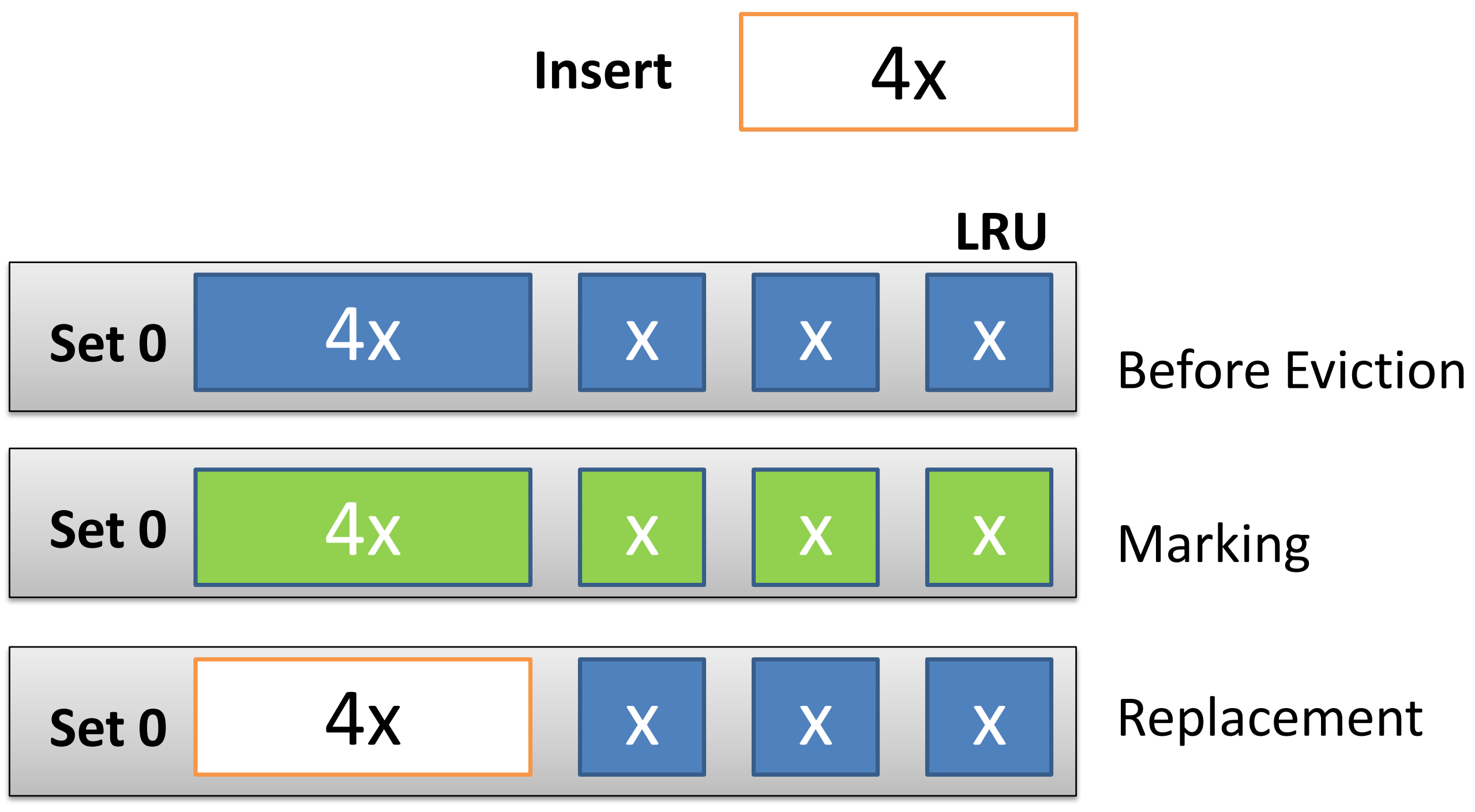
Shortcoming of Traditional LRU

•LRU evicts more than necessary, underutilizing cache capacity



Distribution of Compressed Block Sizes (in bytes): potentially useful to replacement decision

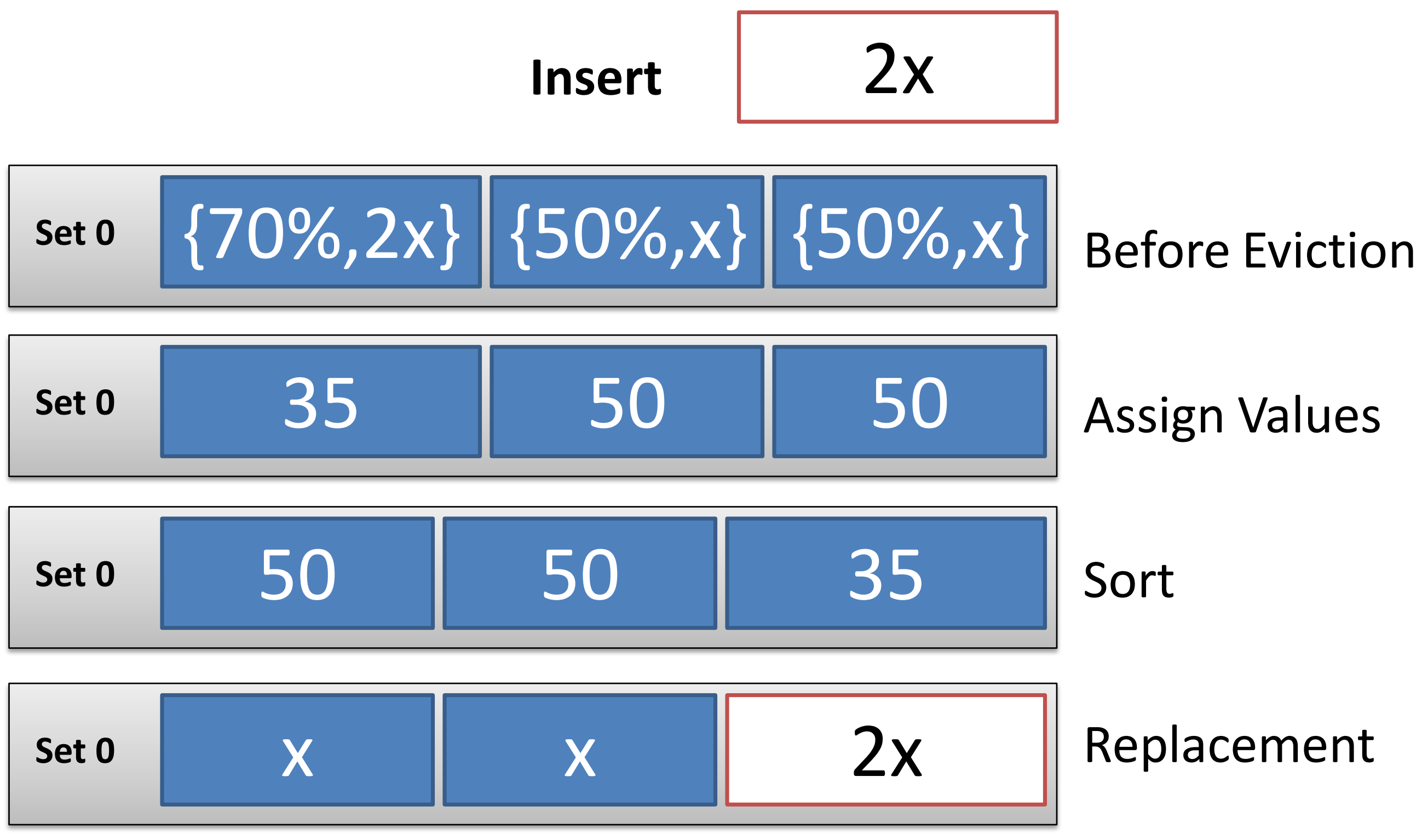
Mechanisms



•Policy 1: Min-LRU

Insight: LRU evicts more blocks than necessary

Key Idea: Evict only the minimum number of LRU blocks



•Policy 2: Min-Eviction

Insight: Keeping multiple compressible blocks with less reuse may be more valuable than a single uncompressible block of higher reuse

Key Idea: Assign a value based on reuse and compressibility to all blocks and on replacement, evict the set of blocks with the least value

Assigning Values to Block

•**Value function: f(block reuse, block size)**

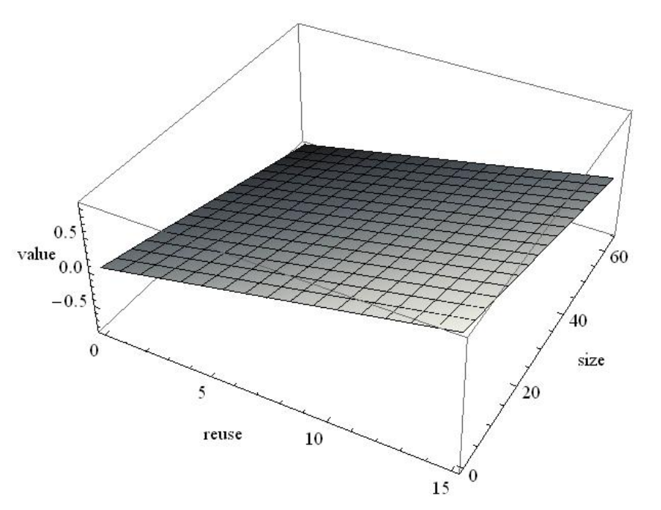
•Monotonically increasing with respect to block reuse

•Monotonically decreasing with respect to block size

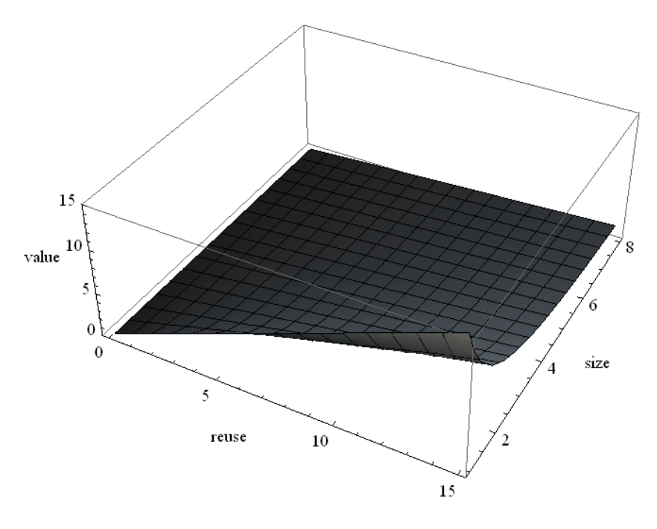
•**Plane** (see figure) achieves these goals, but is complex to implement in hardware

•**Reuse/Size** (see figure) approximates plane and is less complex

•**Probability of reuse predictor: RRIP [Jaleel et. al., ISCA’10] derivative**



3D Plane



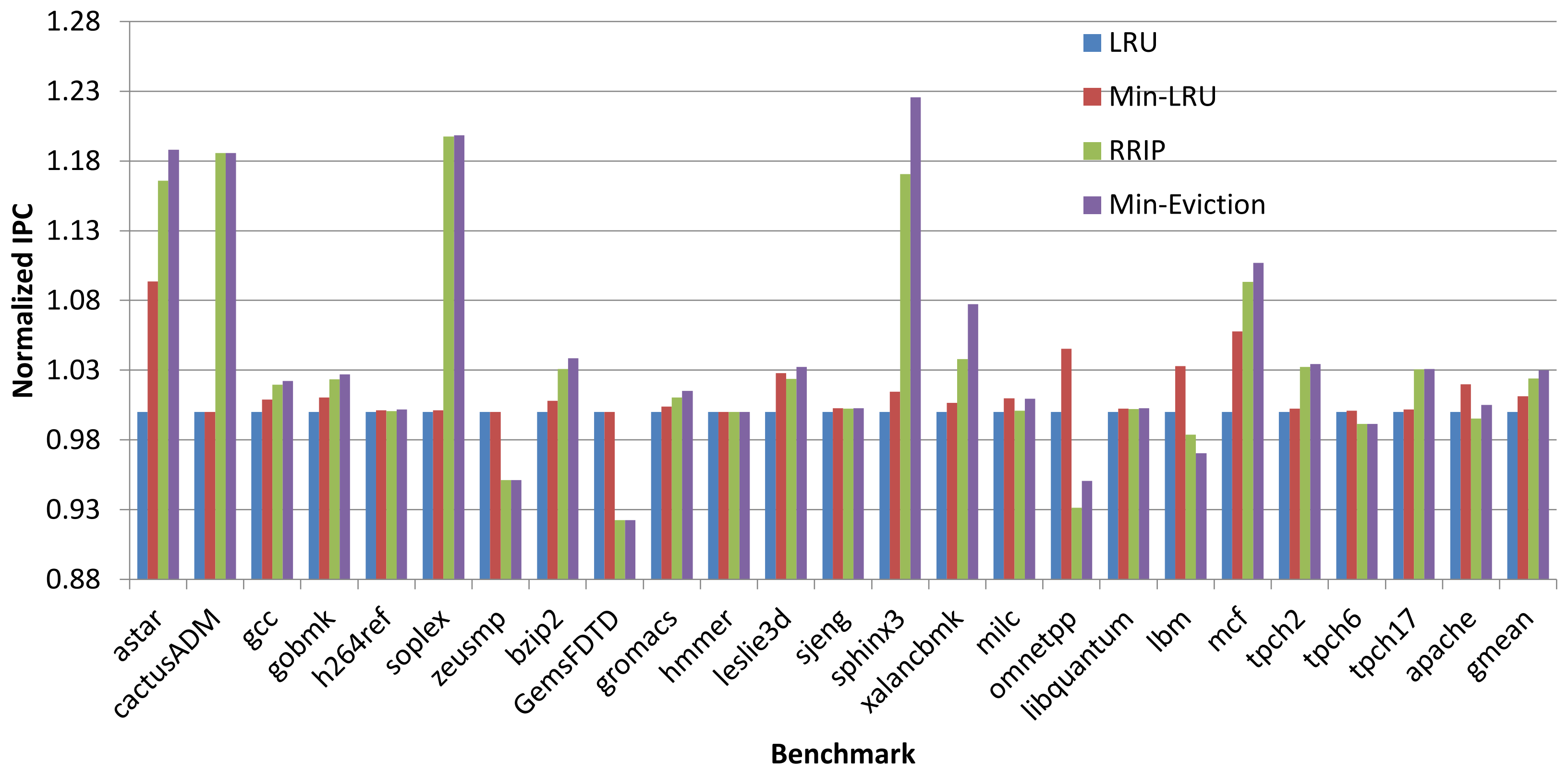
Reuse/Size

Results

•Min-LRU: 1% increase in IPC over LRU

•Min-Eviction: 3% increase in IPC over LRU

•IPC increase due to MPKI decrease



2MB cache size, Base-Delta-Immediate compression scheme, 4Ghz x86 in-order, 1B instructions

Conclusions

Min-Eviction: a novel replacement policy for the compressed cache

- Outperforms current state-of-the-art replacement policies
- First to consider both compressed block size and probability of reuse
- Simple to implement

Further Work:

- **Global Min-Eviction**: a global replacement policy for the compressed decoupled variable way cache that applies similar insight as Min-Eviction
- **Fairness** in compressed cache replacement
- **Multi-core evaluation and analysis** (see paper): 4% increase in normalized weighted speedup over LRU in heterogeneous workloads