EE 691: R&D Project

# Secure LLC

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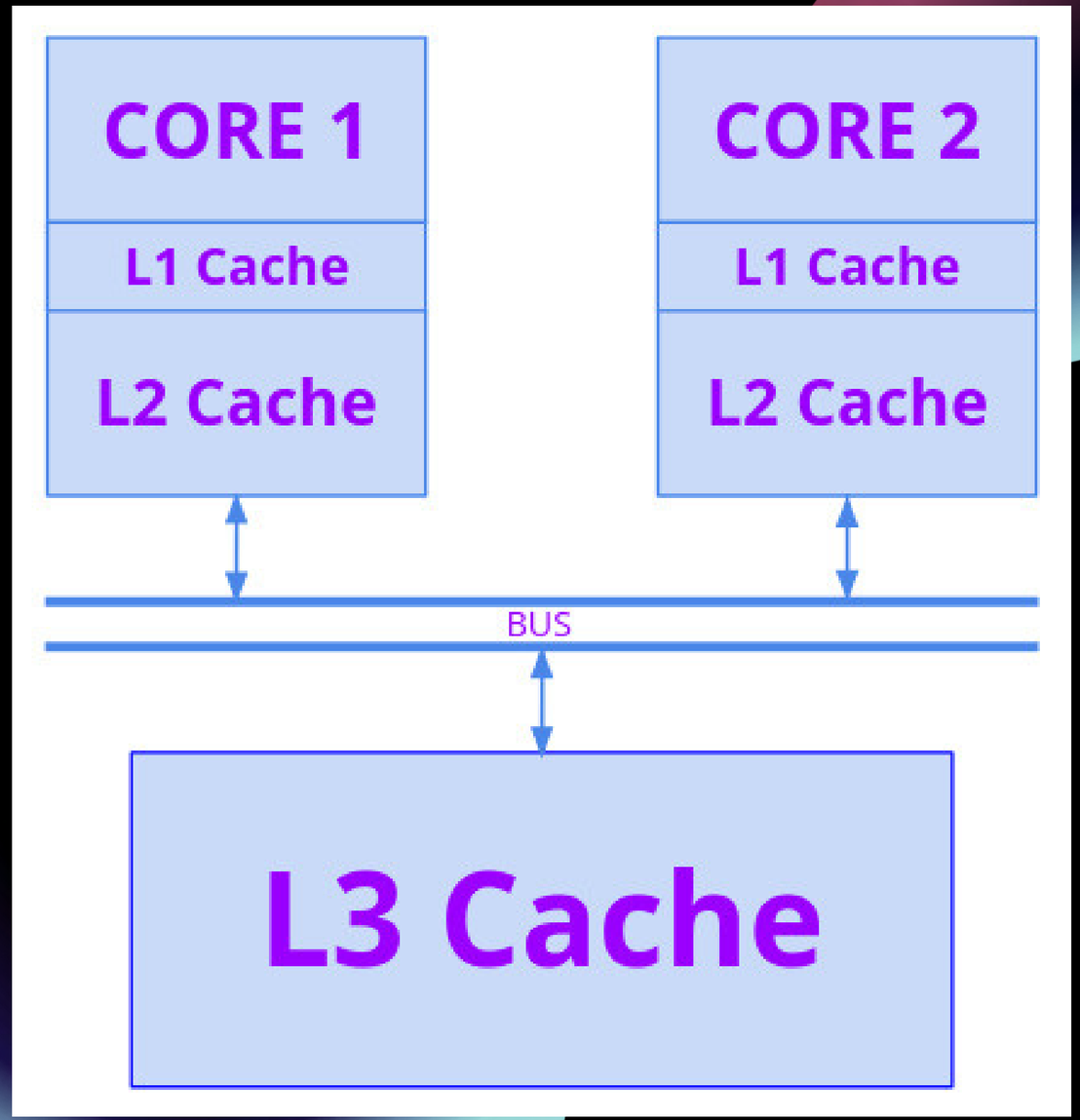
# Outline

- Introduction
- Literature Survey
- Proposed Idea
- Simulation Results
- Conclusion
- Future Work
- Refernces

# Introduction

- The primary benefit of cache partitioning is that it provides protection from one core evicting another



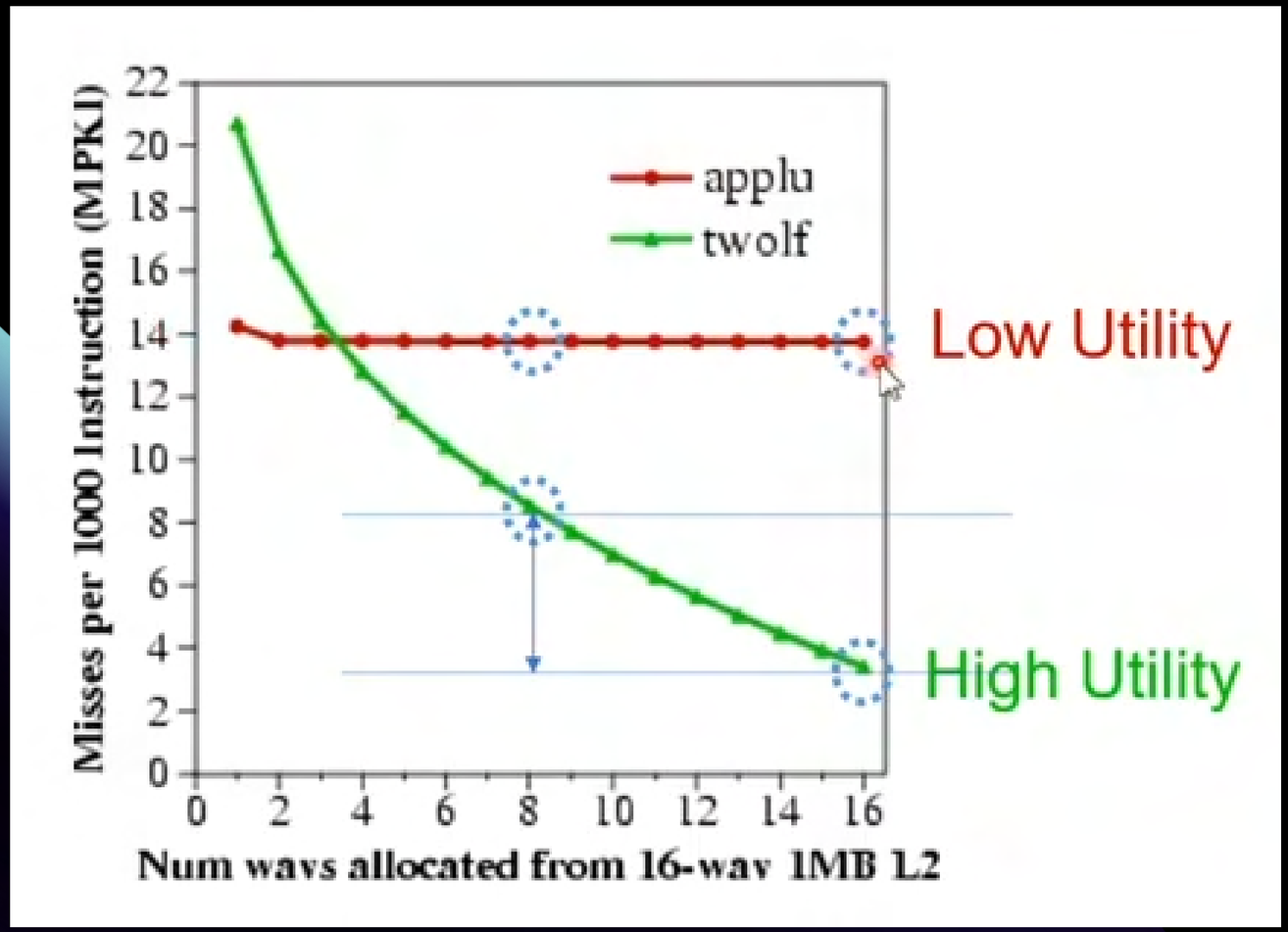
# Introduction

- Static Partitioning divides it equally between each core once and never again.
- UCP is an algorithm that dynamically partitions the cache based on their utility
- This creates side channels and the risk of hardware attacks

# Literature Survey

## UCP

A core with demand greater than another is given an extra line takenthe other core.

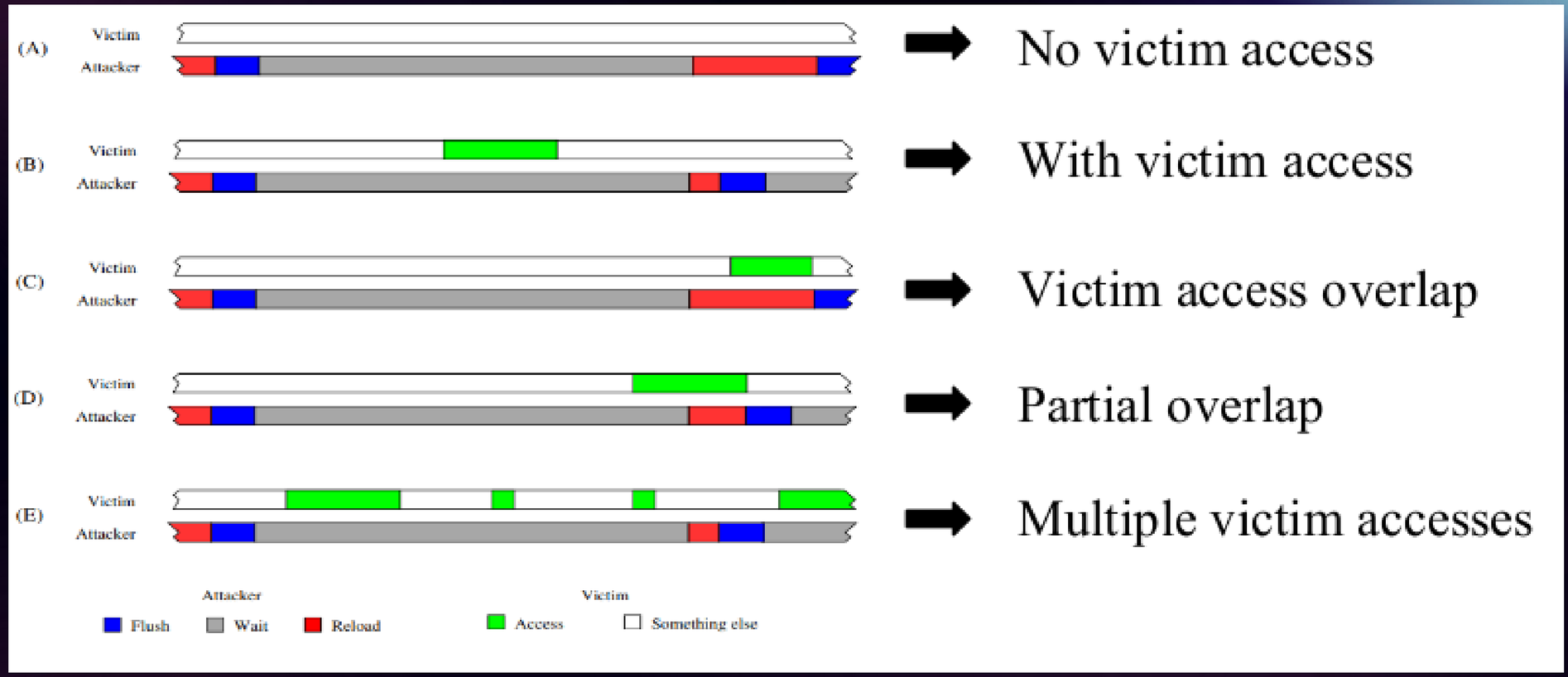



M. K. Qureshi and Y. N. Patt, "Utility-Based Cache Partitioning: A Low-Overhead, High-Performance, Runtime Mechanism to Partition Shared Caches," 2006 39th Annual IEEE/ACM International Symposium on Microarchitecture (MICRO'06), 2006, pp. 423-432, doi: 10.1109/MICRO.2006.49.

# UCP vs Static

- Utiltiy-based partitioning performs significantly better
- This however introduces the risk of hardware attacks
- A line reallocated from one core to another, provides information
- Several attacks have target the side channel so formed

# Flush + Reload




Y. Yarom and K. Falkner, “Flush+reload: A high resolution, low noise, l3 cache side-channel attack,” in Proceedings of the 23rd USENIX Conference on Security Symposium, SEC’14, (USA), p. 719–732, USENIX Association, 2014

# Prime + Probe

- The attacker fills cache sets with its own data
- It then waits for a time interval while the victim executes and utilizes the cache.
- The attacker continues execution and measures the time to load each set of his data

F. Liu, Y. Yarom, Q. Ge, G. Heiser, and R. B. Lee, “Last-level cache side-channel attacks are practical,” in 2015 IEEE Symposium on Security and Privacy, pp. 605–622, 2015.

# Mitigations

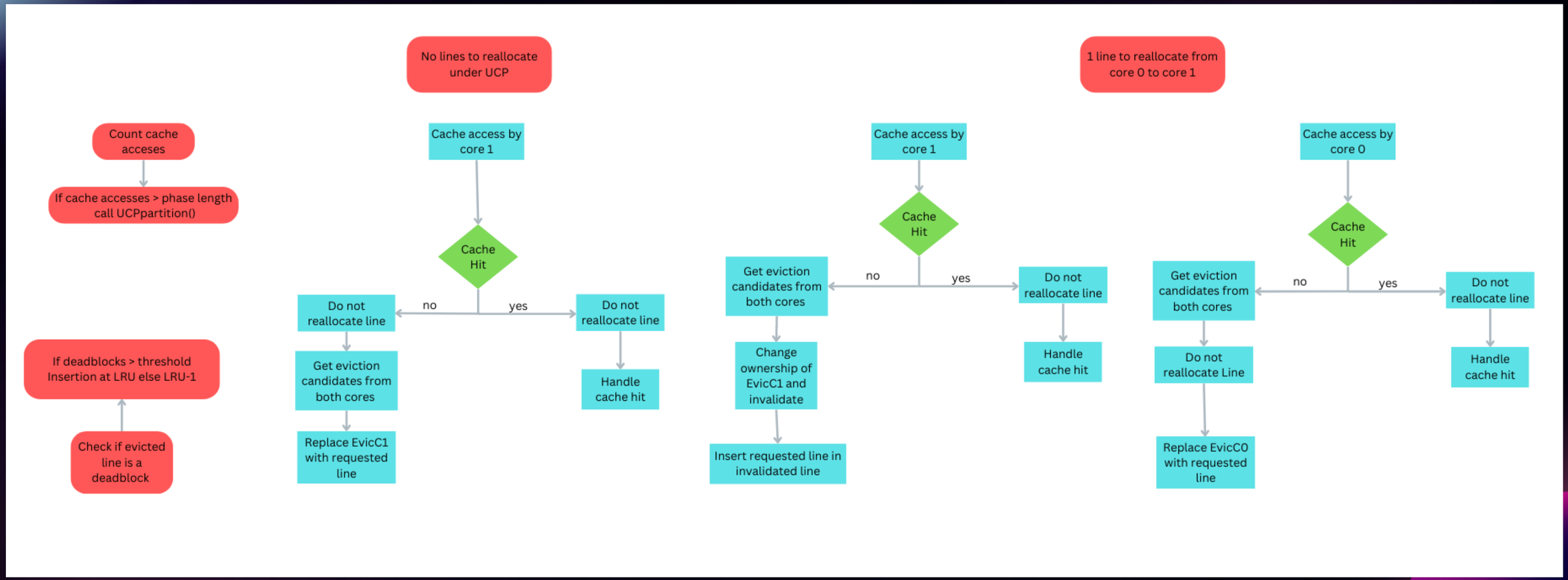
- These attacks which target the LLC side channel need to be mitigated
- One way is to revert back to static partitioning
- This however decreases performance
- Another could be to implement the PASS-P algorithm

# PASS-P

- It mitigates attacks where the attacker tries to analyze the memory accesses made by the victim
- PASS-P invalidates all cache lines that are reallocated from one process to another.

N. Boran, P. Joshi, and V. Singh, “Pass-p: Performance and security sensitive dynamic cache partitioning,” in Proceedings of the 19th International Conference on Security and Cryptography - Volume 1: SECRYPT,, pp. 443–450, INSTICC, SciTePress, 2022.

# Proposed Idea



# Proposed Idea

- Partitioning could be calculated independently for each set or done globally
- We refer independent partitioning to as local partitioning and the latter as global partitioning
- The former results in each set having a different partition

# Simulation Results

# Simulation Setup

- **Simulator**: Sniper Multicore Simulator
- **Baseline Processor**: x86 Nehalem microarchitecture, 2.67 GHz, 4-wide fetch,128-entry ROB
- **Main Memory Access Latency**: 175 cycles

# Simulation Setup

- **Memory Organization:** Private L1, L2 caches and shared L3 cache
- **LLC Size**: 4MB
- **Cores:** 2 core

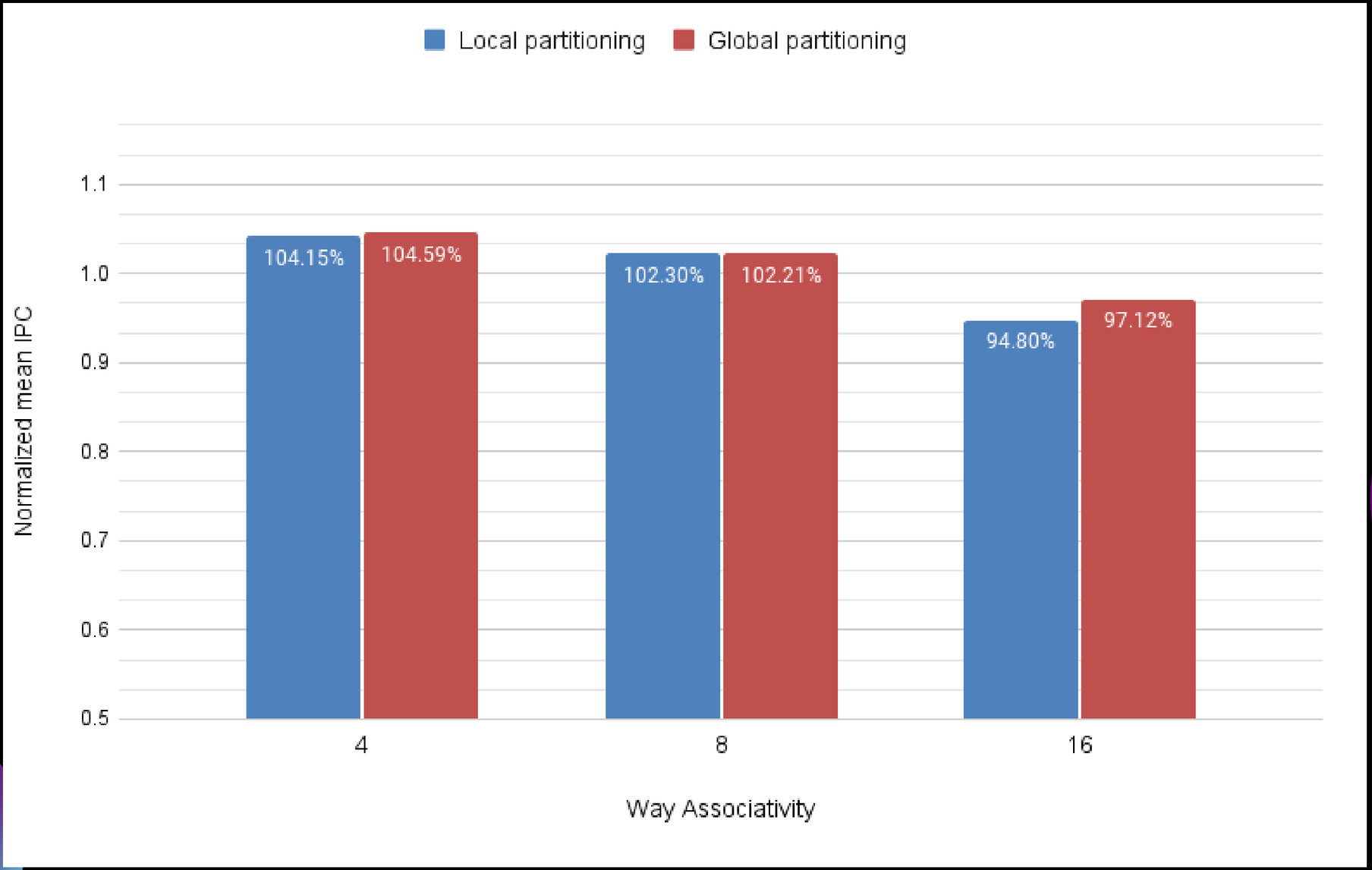
# Simulation Setup

- **Benchmarks:** 25 pairs of SPEC* 2006 benchmarks, categorized as memory-memory intensive (18) and memory-compute intensive(7)

- IPC normalized with respect to static partitioning

John L. Henning. 2006. SPEC CPU2006 benchmark descriptions. SIGARCH Comput. Archit. News 34, 4 (September 2006), 1–17. https://doi.org/10.1145/1186736.1186737

# IPC comparison for different partitioning



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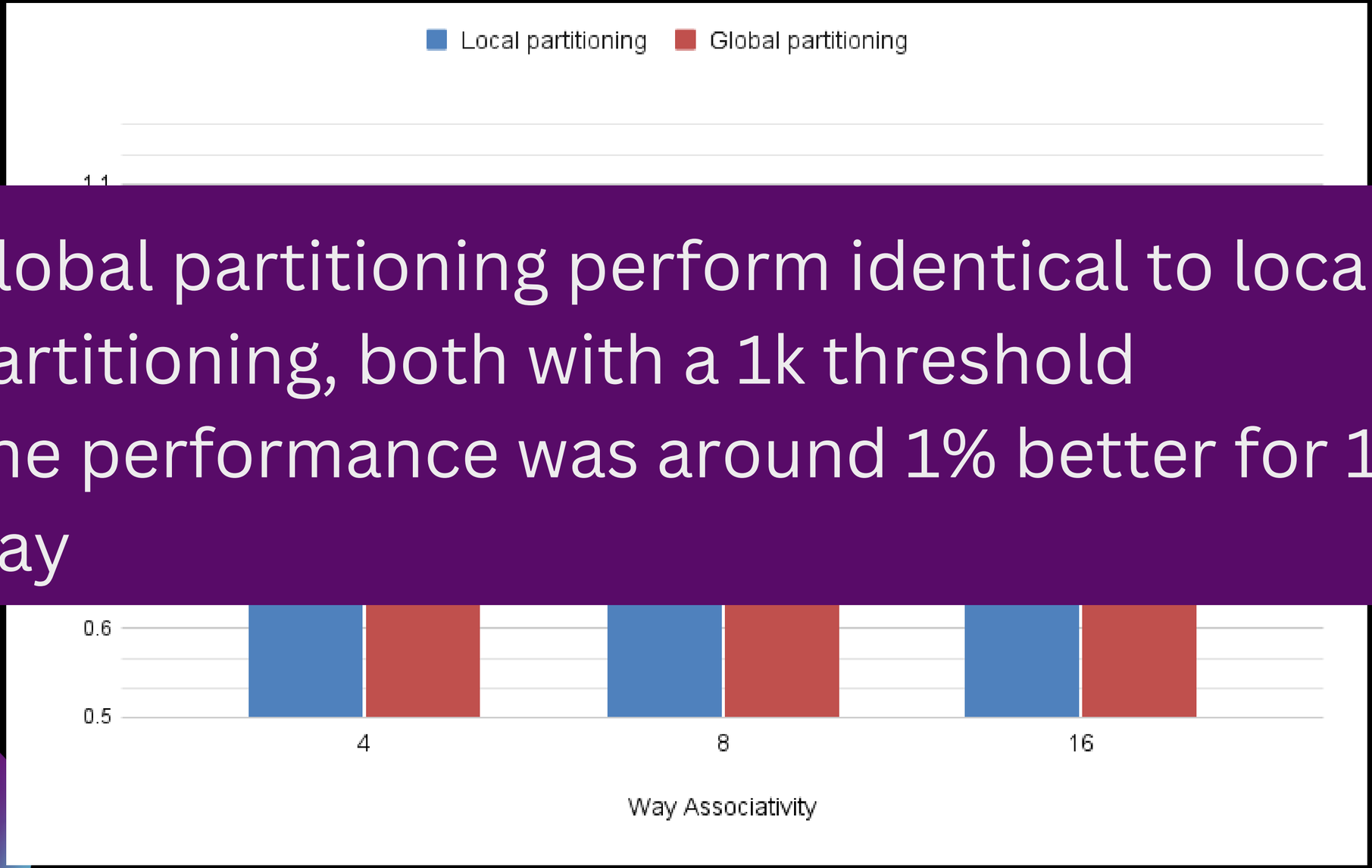



- Global partitioning perform identical to local partitioning, both with a 1k threshold
- The performance was around 1% better for 16 way

# IPC comparison for different partitioning

- This could be due to
  - considerably larger computation associated with local partitioning
  - Each set is partitioned a lesser number of times
  - This leads to each set incorrectly modeling the utility

# IPC comparison for different set associativies

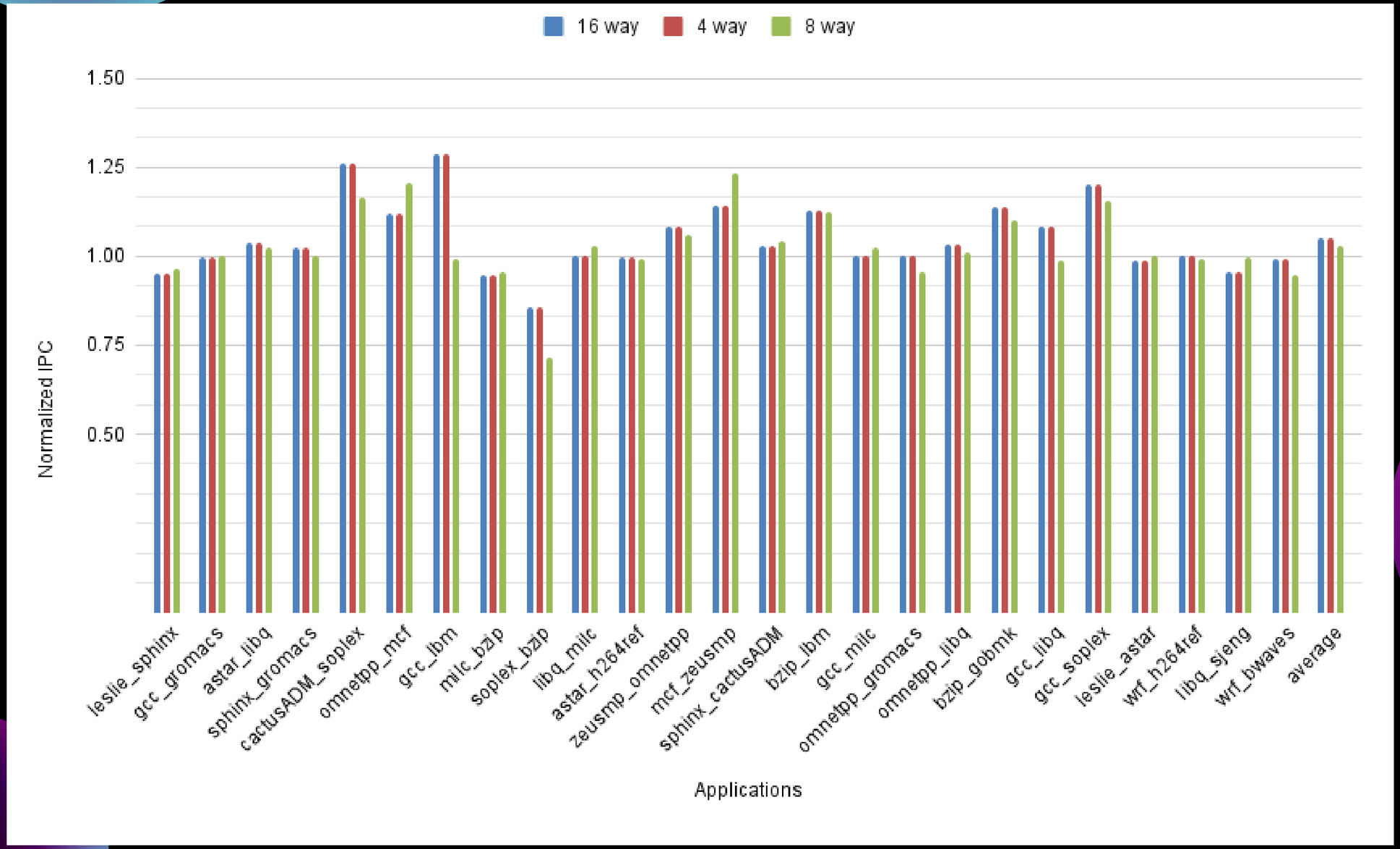
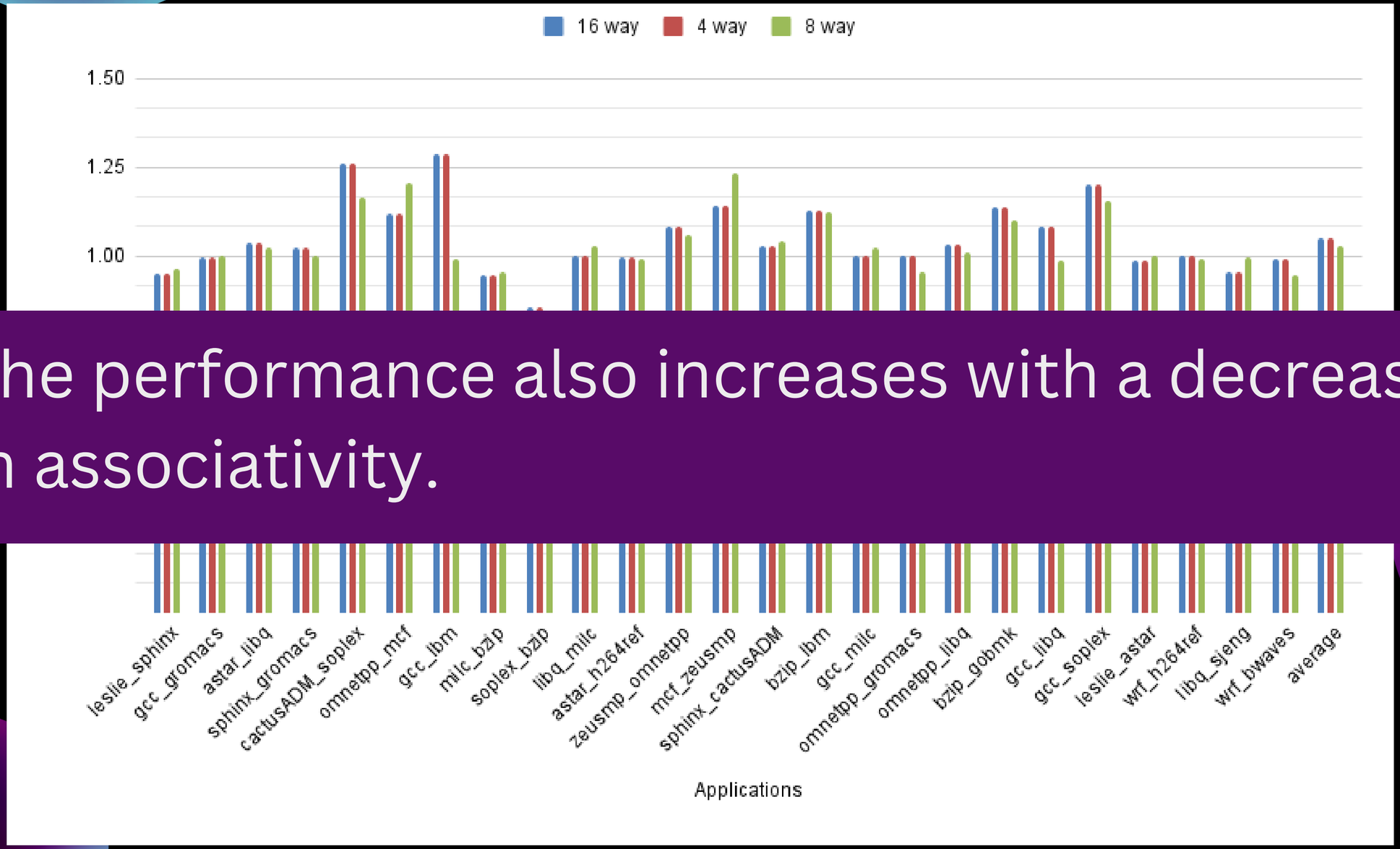



Fig: IPC comparison for **global** partitioning with different set associativites

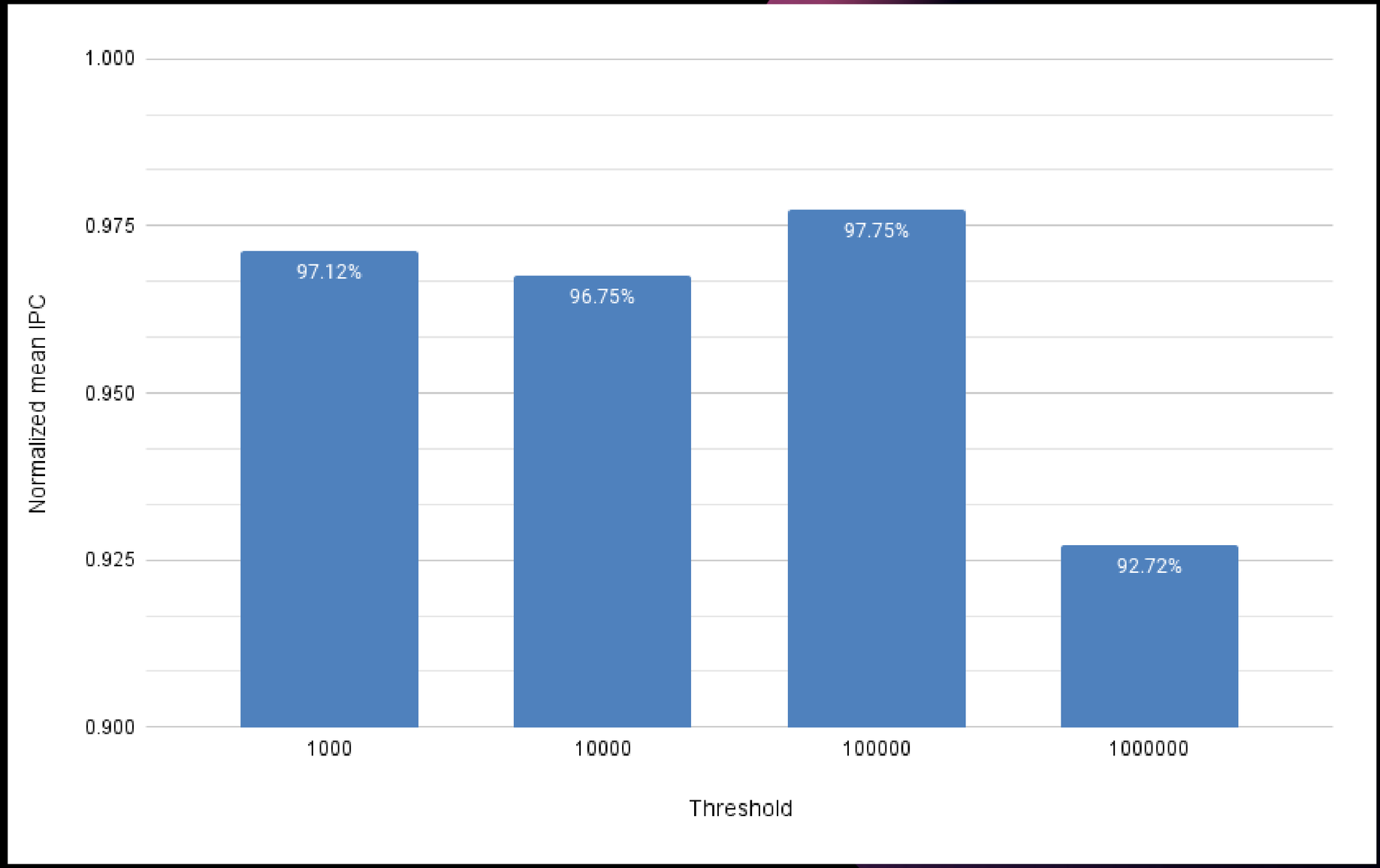
# IPC comparison for different set associativies



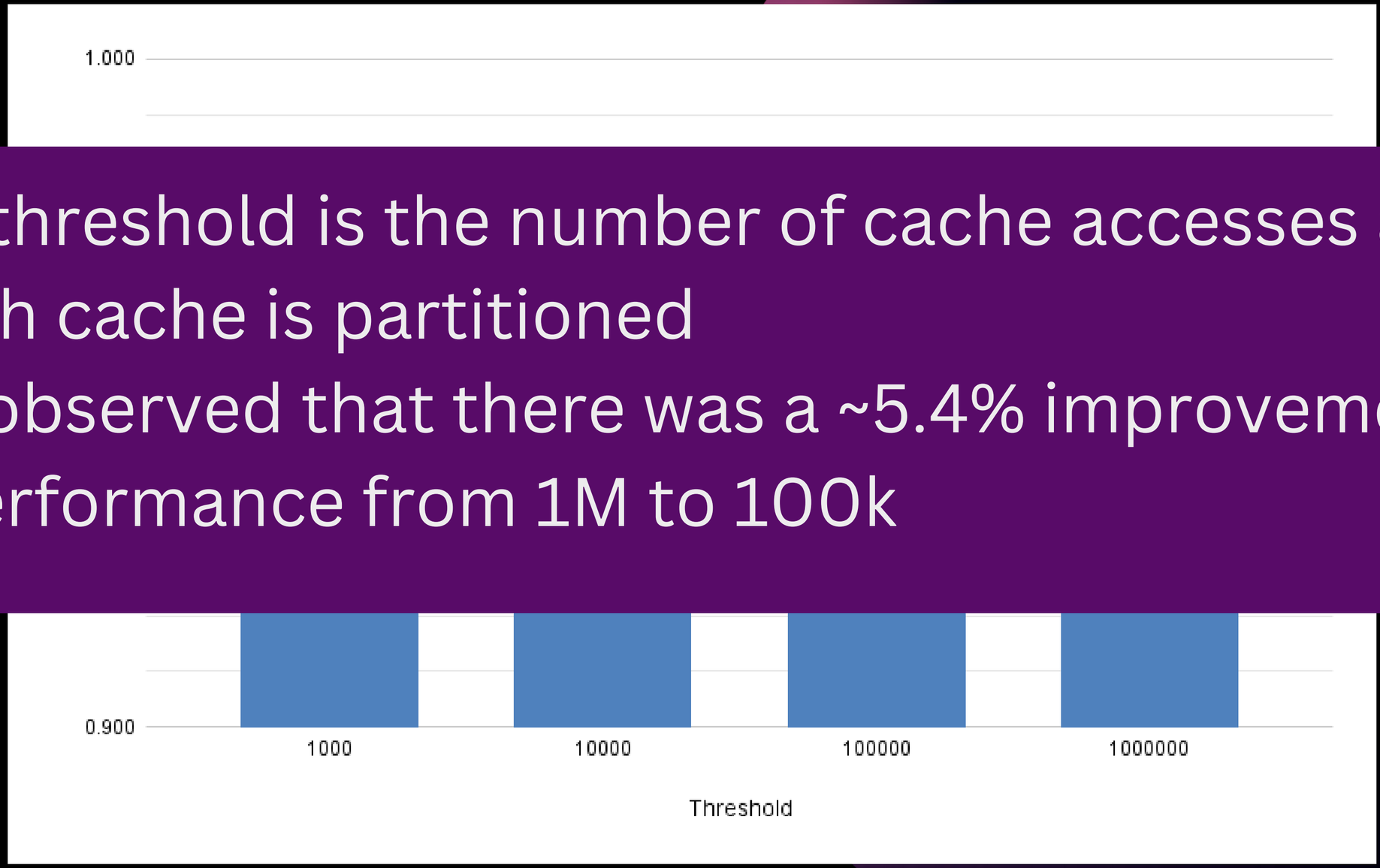

- The performance also increases with a decrease in associativity.

Fig: IPC comparison for **global** partitioning with different set associativites

# IPC comparison for different thresholds

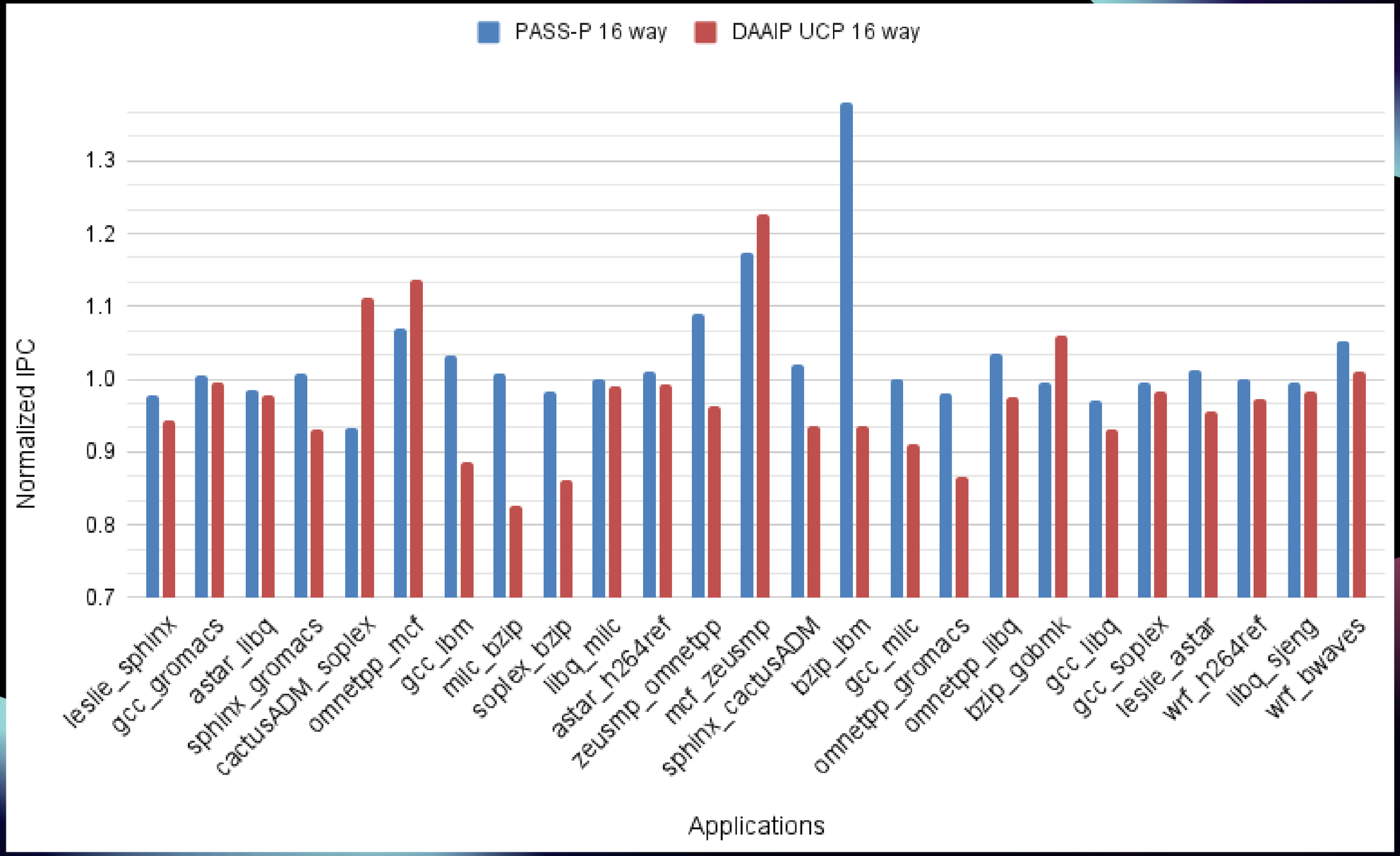


# IPC comparison for different thresholds




- The threshold is the number of cache accesses after which cache is partitioned
- It is observed that there was a ~5.4% improvement in performance from 1M to 100k

# Comparison with PASS-P



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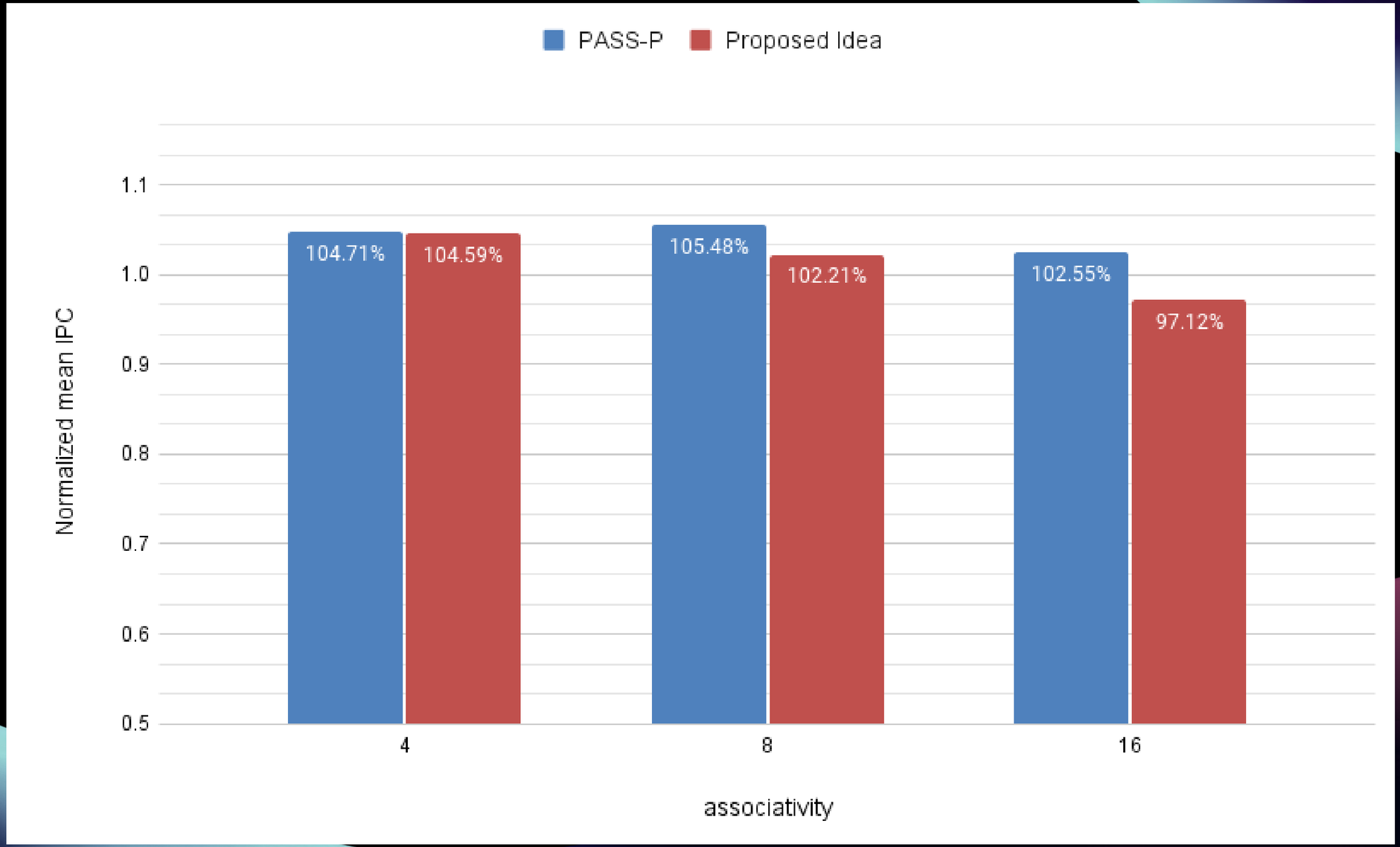
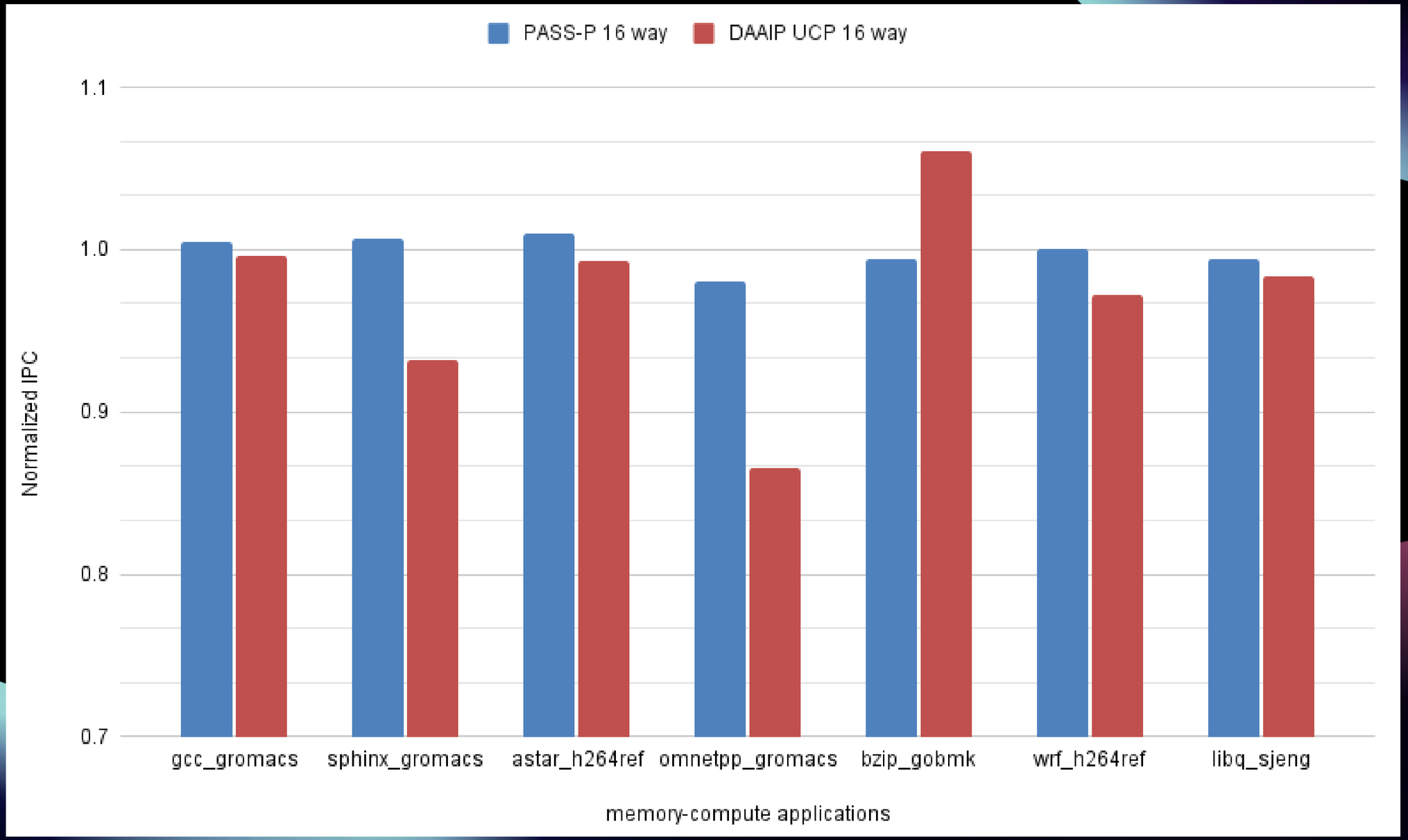


# Comparison with PASS-P

- PASS-P showed a ~5% better performance with 16 way, ~3% for 8 way and ~0.2% for 4 way
- This could arise due to PASS-P selectively reallocating clean lines
- ~41% of the lines evicted or reallocated were dirty
- Thus selecting only clean lines could avoid latencies due to writeback

# Comparison with PASS-P



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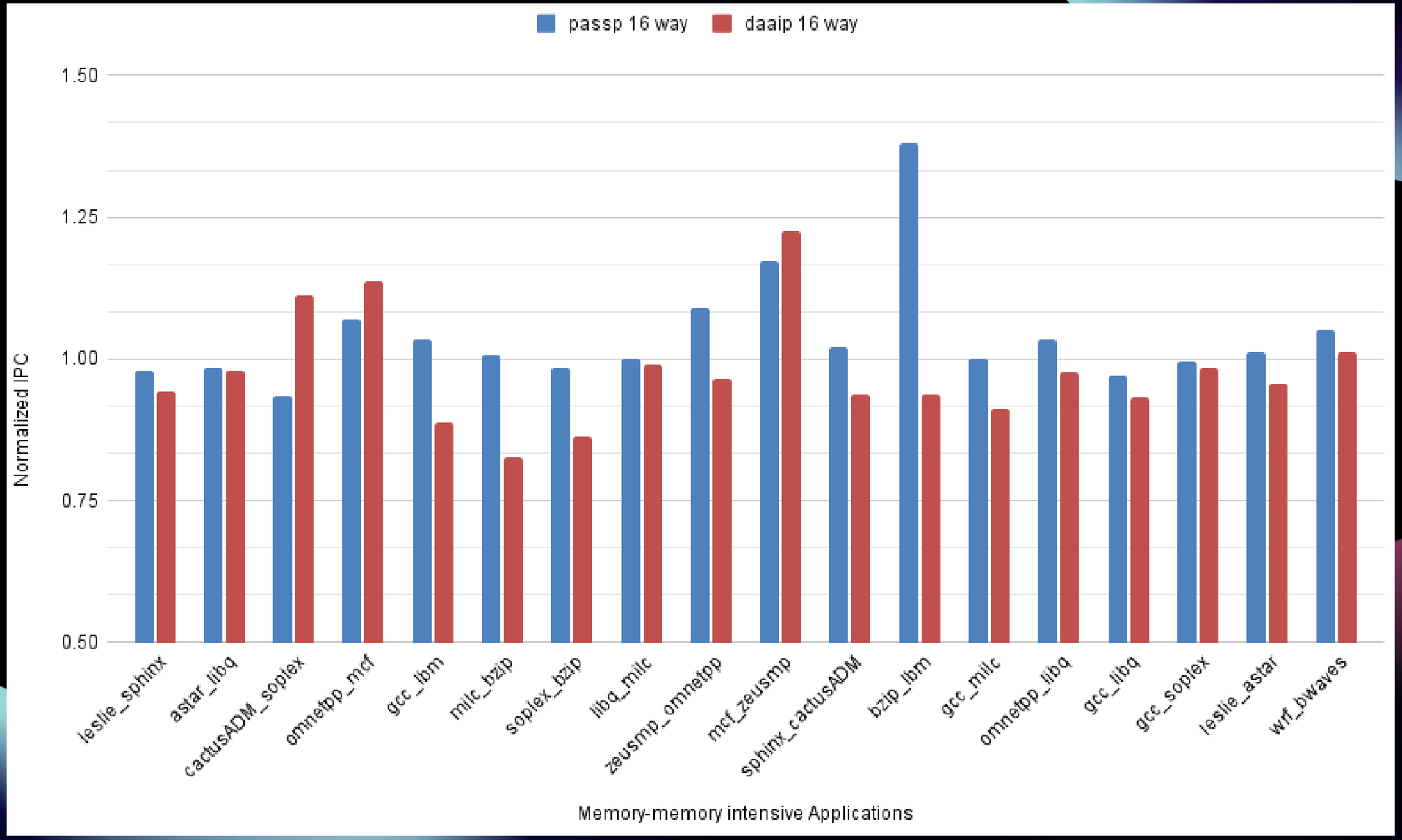

# Future Work

- Extend the proposed idea to invalidate only clean lines
- Incorporate replacement policies like Mockingjay that have high prediction accuracy.

# Conclusion

- A partition that closely models the core's utility can improve performance by ~10%
- The hardware overhead for the proposed idea is only 256kB and 3 counters above SRRIP
- The proposed idea did not perform better than PASS-P as expected

# DAAIP

- It is a cache replacement algorithm that dynamically updates the insertion policy
- Based on the number of deadblocks encountered, new lines are inserted at LRU or LRU-1.

Newton, S. K. Mahto, S. Pai, and V. Singh, “Daaip: Deadblock aware adaptive insertion policy for high performance caching,” in 2017 IEEE International Conference on Computer Design (ICCD), pp. 345–352, 2017.

# References


1. N. Boran, P. Joshi, and V. Singh, “Pass-p: Performance and security sensitive dynamic cache partitioning,” in Proceedings of the 19th International Conference on Security and Cryptography - Volume 1: SECRYPT,, pp. 443–450, INSTICC, SciTePress, 2022.
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# THANK YOU!