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Elastic Cooperative Caching:

An Autonomous Dynamically Adaptive Memory Hierarchy for Chip Multiprocessors

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Outline

- Motivation
- Related Work
- Elastic Cooperative Caching
- Evaluation
- Conclusions

Motivation

- Find optimal cache organization for tiled microarchitectures
- Desired behavior
  - Scalable
  - Minimize access latency
  - Minimize inter-thread interference
  - Minimize off-chip misses

Avoid centralized structures.

Data placement based on proximity.

→ Private cache partitions.

→ Dynamic cache allocation.

Motivation

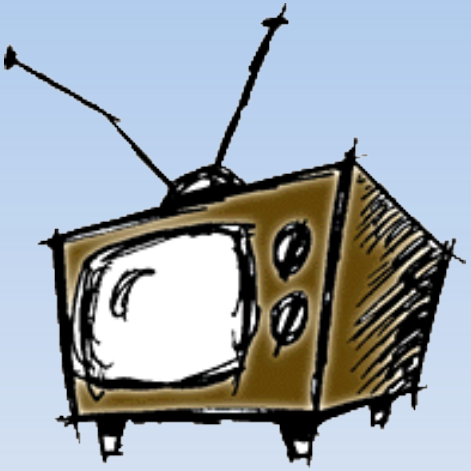
- Application Taxonomy
  - Saturating Utility
  - Low Utility
  - Shared High Utility
  - Private High Utility

Extended classification from Qureshi et al. [MICRO'06]

Related Work

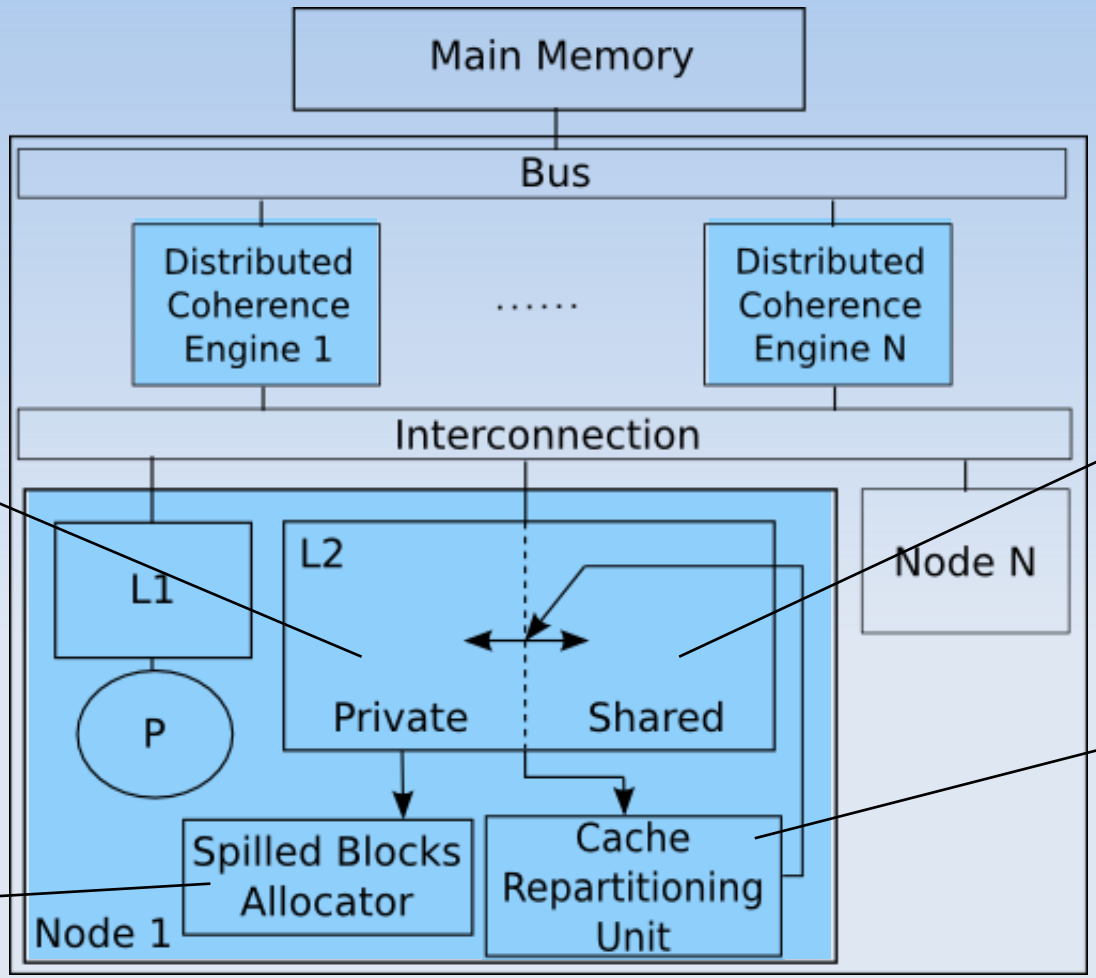
- Reactive NUCA [ISCA'09]
- Adaptive Selective Replication [MICRO'06]
- Adaptive Shared/Private NUCA [HPCA'07]

  - OS-page granularity.
  - Software based.
  - Common shared cache space.
  - Adjusts replication but not amount of cache per node.
  - Centralized structures.



More: Athena Award Lecture Mary Jane Irwin

Elastic Cooperative Caching – Structure



Herrero et al. [PACT'08]

Only local core can allocate

Allocates evicted blocks from all private regions

Every N cycles repartitions cache based on LRU hits in S&P partitions.

Distributes evicted blocks from private partition among nodes.

Elastic Cooperative Caching – Adaptive Spilling

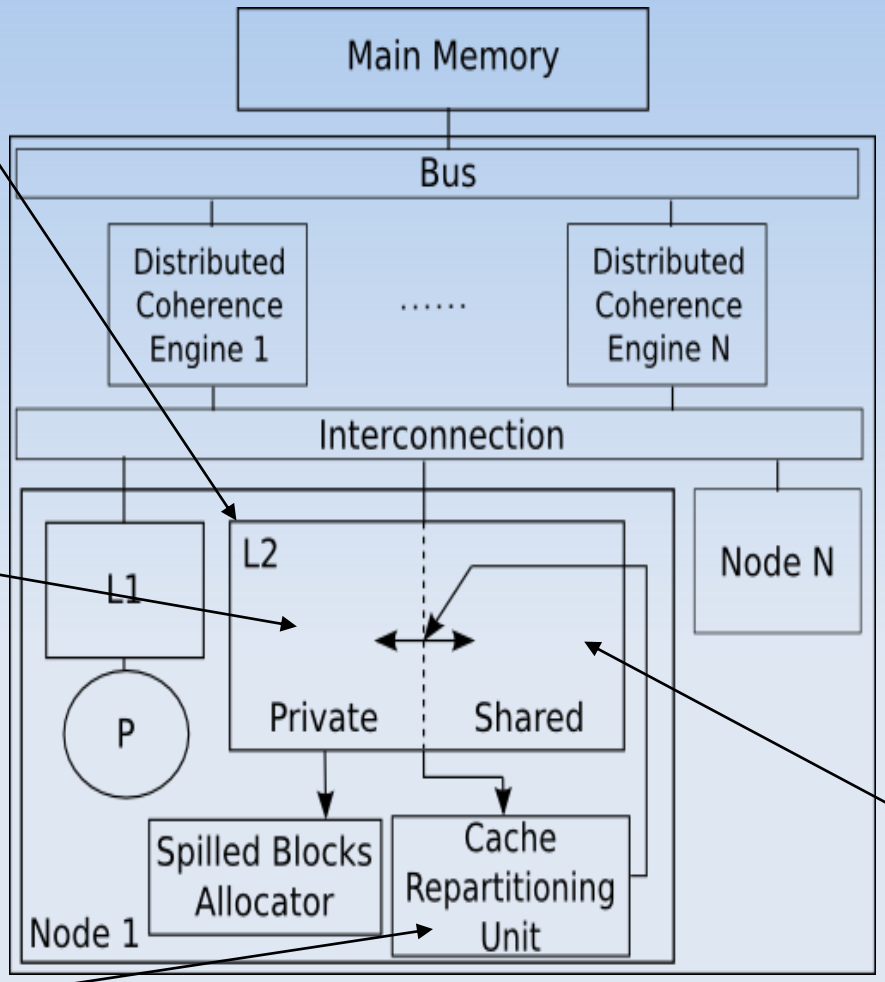
- ElasticCC oportunity: Not only repartition but also decide which nodes can use shared partitions.

Type	Working Set Size	Sharing	Local Reuse	Private Cache Size	Spilling
Saturating Utility	Small/ Medium	H/L	H/L	Small/ Medium	No
Low Utility	Big	Low	Low	Small	No
Shared High Utility	Big	High	H/L	Small	Yes
Private High Utility	Big	Low	High	Big	Yes

Spill shared blocks or blocks fromcaches with 75% or more private cache space

Elastic Cooperative Caching – Structure

Distributed cache among nodes. Local allocation.



Private Regions.

Independent local repartitioning units.

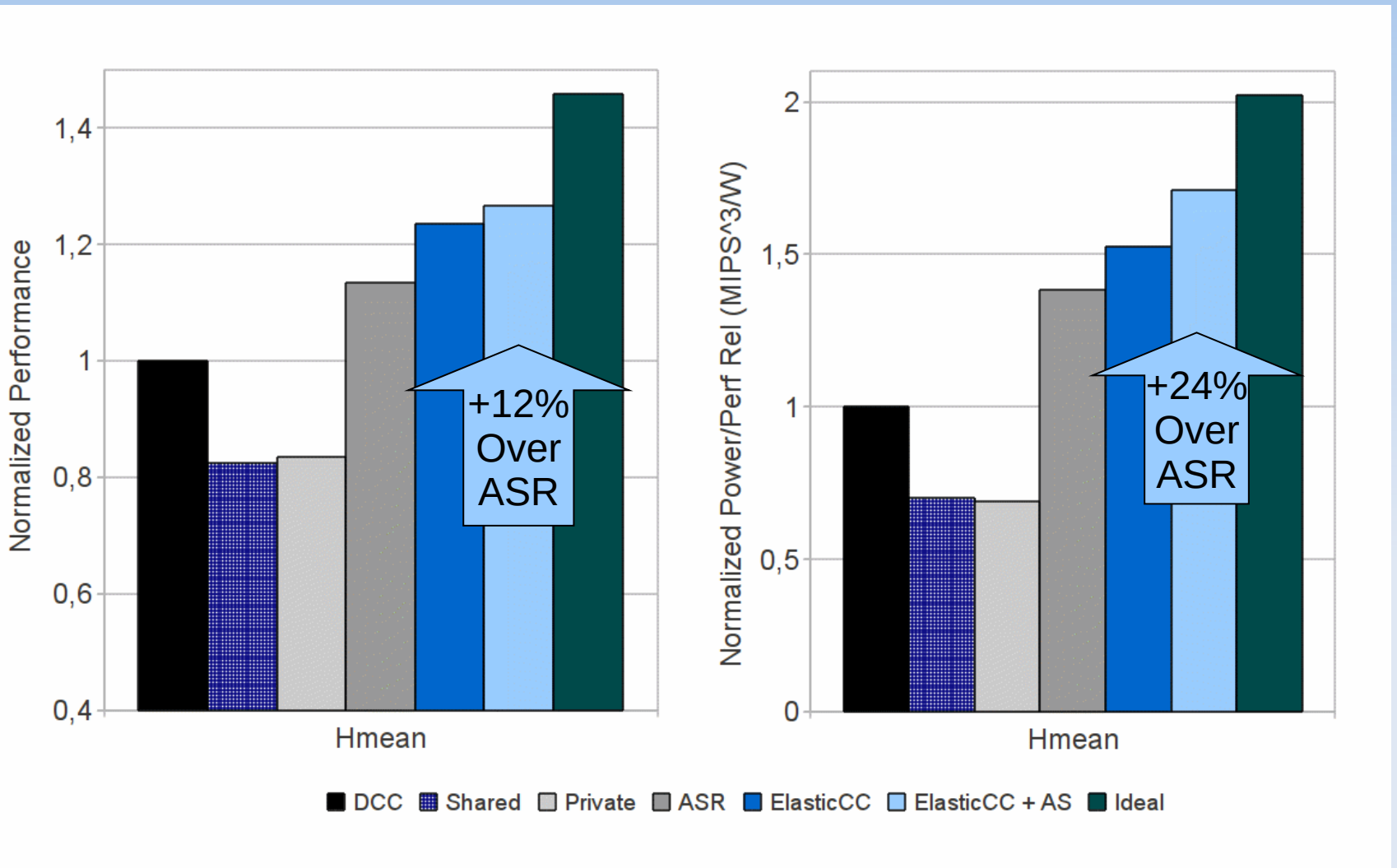
Cache Partitioning. Dynamic Cache Allocation.

- Desired behavior
  - Scalable
  - Minimize access latency
  - Minimize inter-thread interference
  - Minimize off-chip misses

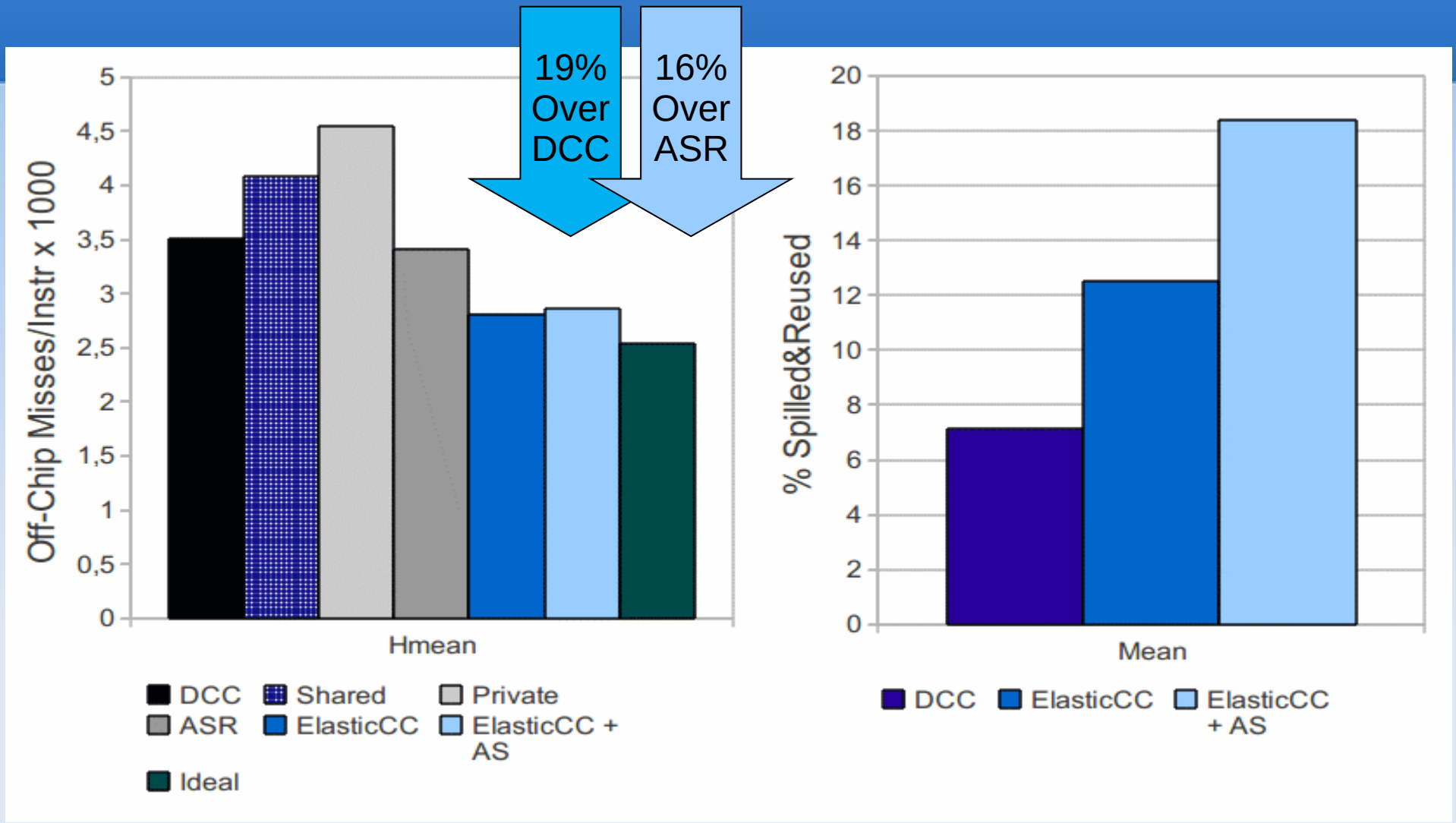
Evaluation – Studied Configurations

- **16 Processors**
- **Pairs of SPEC OMP'01 benchmarks of each of previous categories.**
- **Configurations**
  - **Shared Memory**
  - **Private Memory**
  - **Distributed Cooperative Caching** (DCC)
  - **Adaptive Selective Replication** (ASR)
  - **Elastic Cooperative Caching**
  - **ElasticCC + Adaptive Spilling**
  - **Ideal**: Fixed Half Private/Half Shared 2xL2

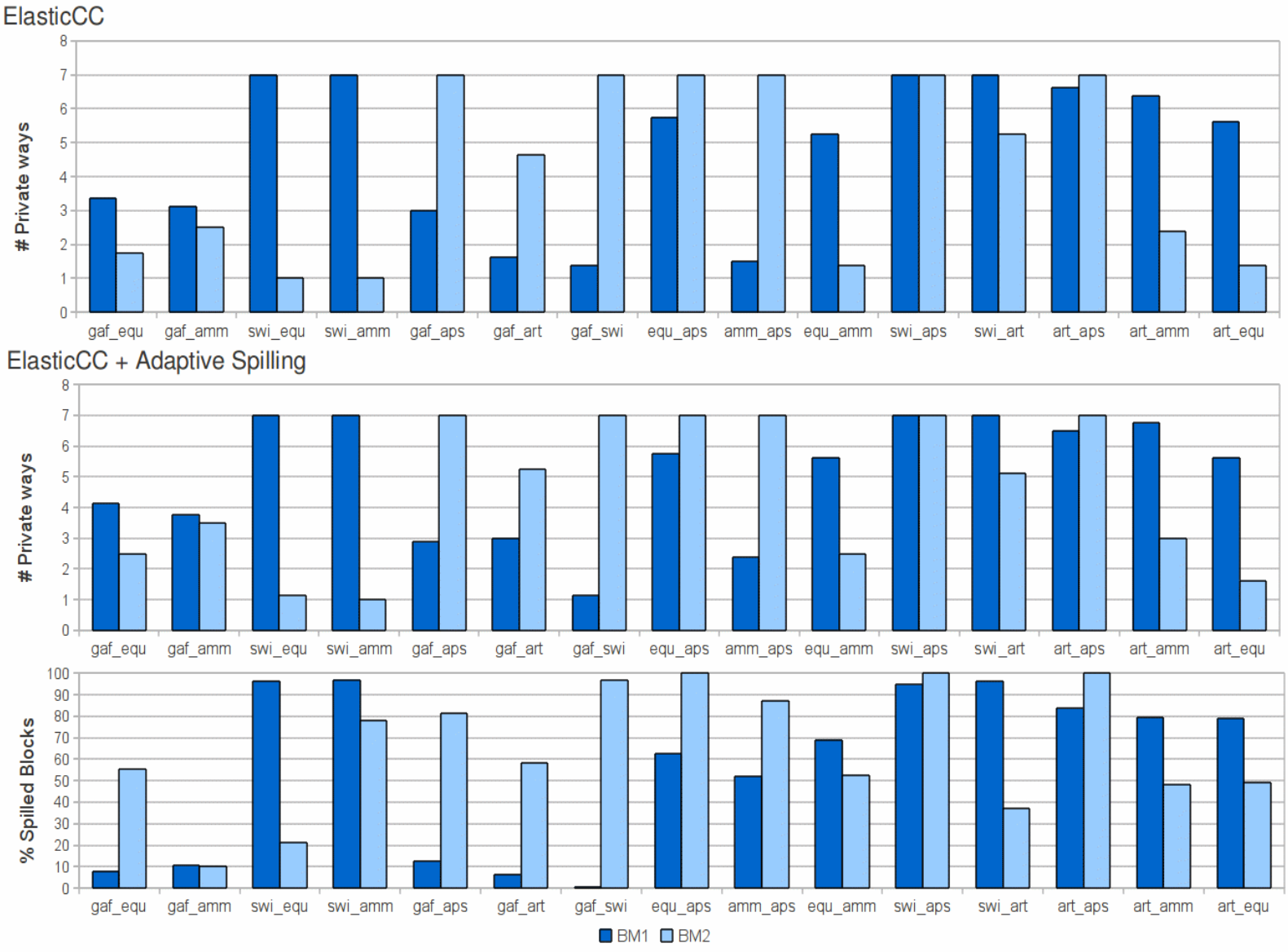
Evaluation – Performance & Efficiency



Evaluation – Off-Chip Misses & Reuse



Evaluation – Cache Behavior



Gafort – Low Utility

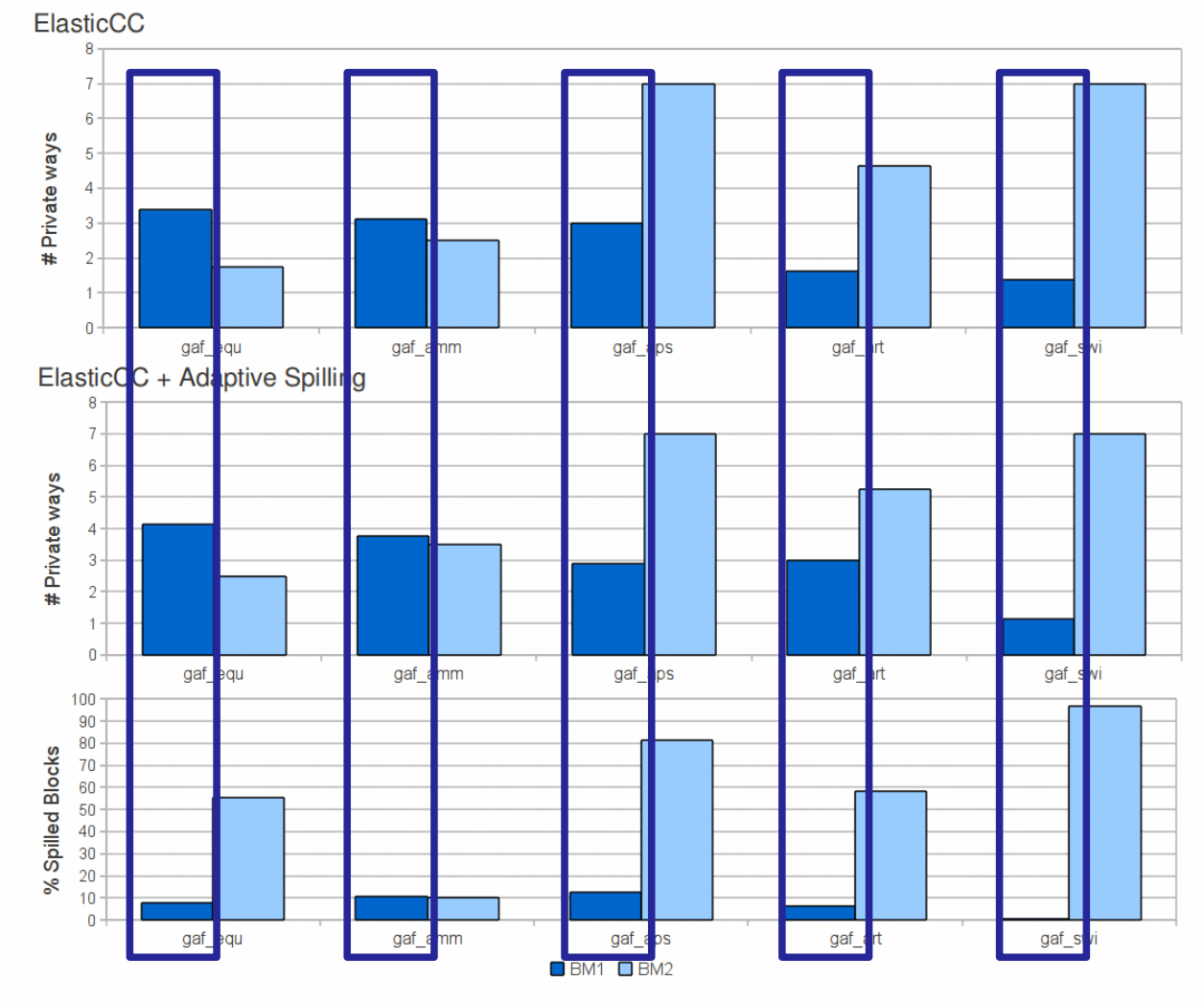
Apsi, Art, Equake – Saturating Utility

Ammp – Shared High Utility

Swim – Private High Utility

UPC

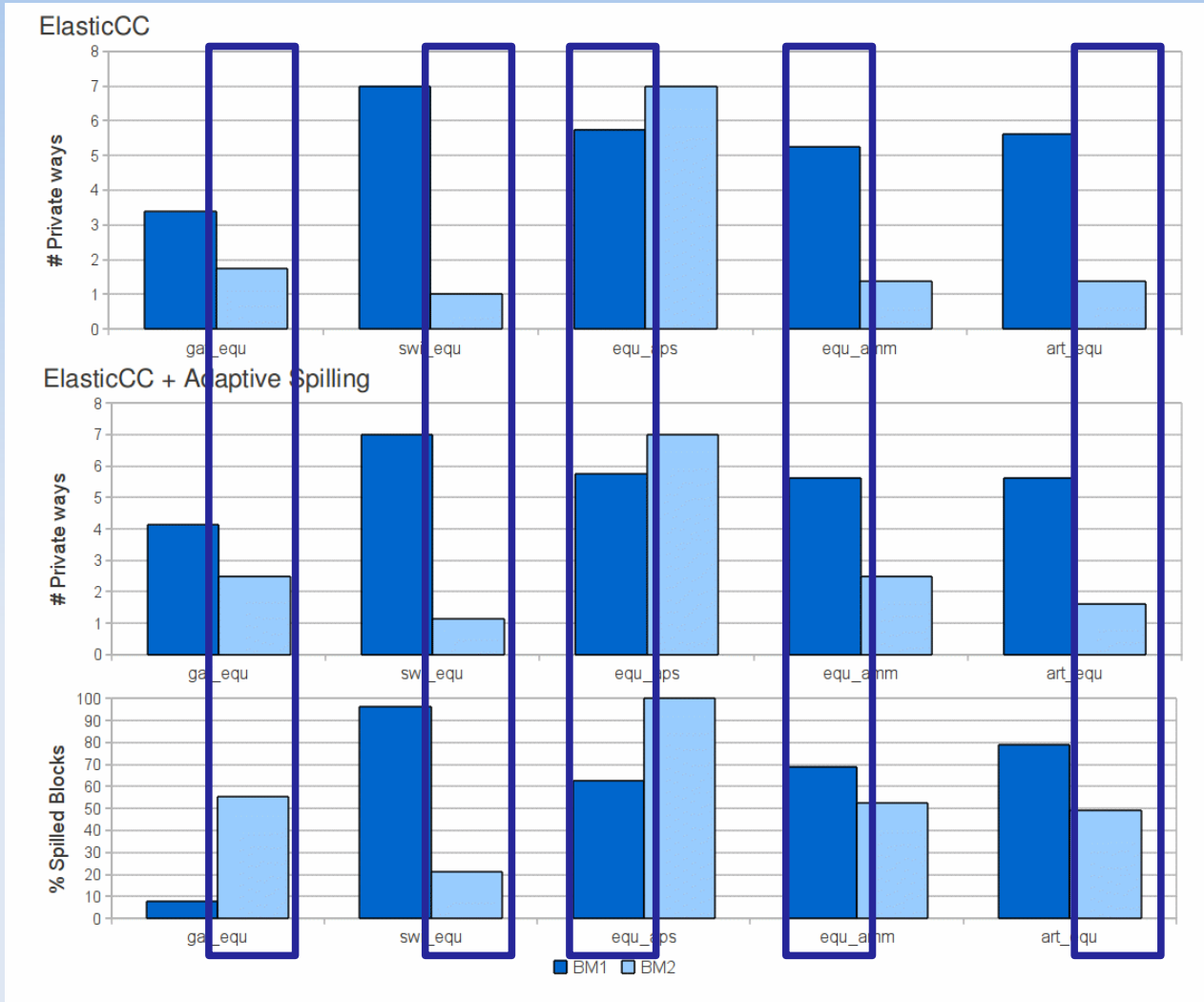
Evaluation – Cache Behavior

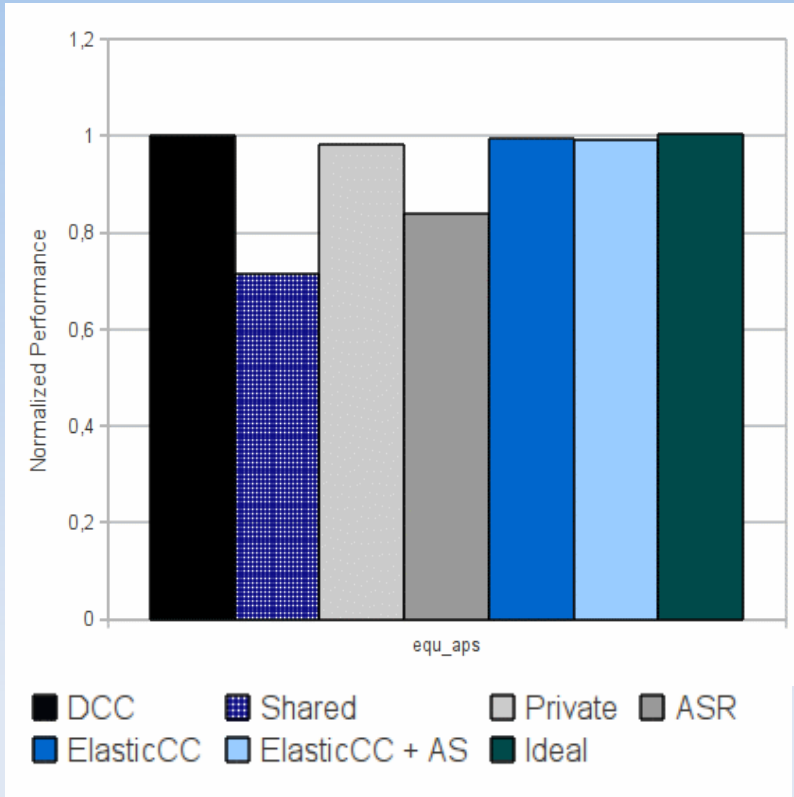


Gafort –
Low Utility

No reuse, does not benefit from caches.

Evaluation – Cache Behavior

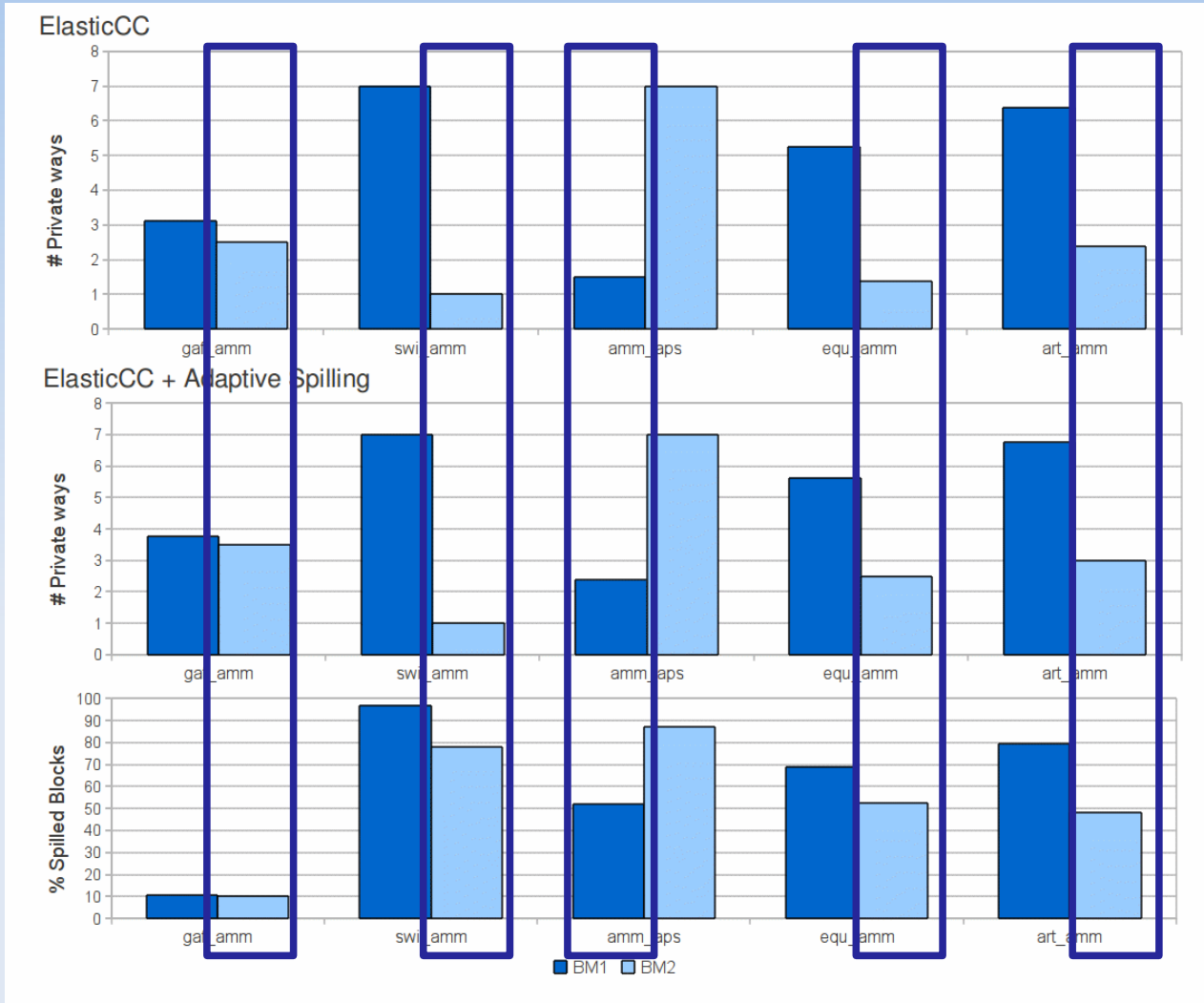


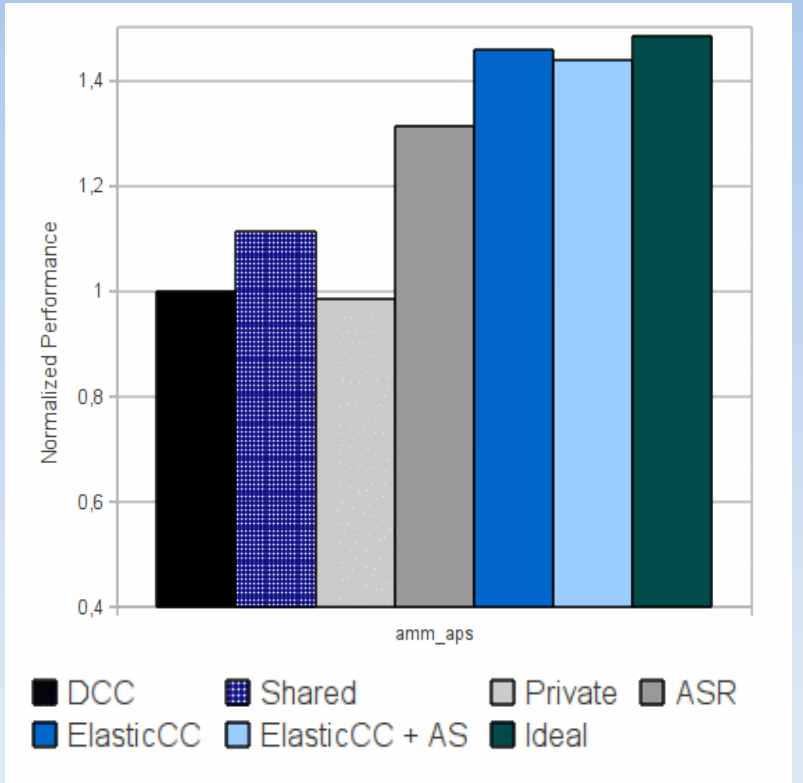


Apsi, Art, Equake – **Saturating Utility**

Benefits from a given ammount of extra cache

Evaluation – Cache Behavior

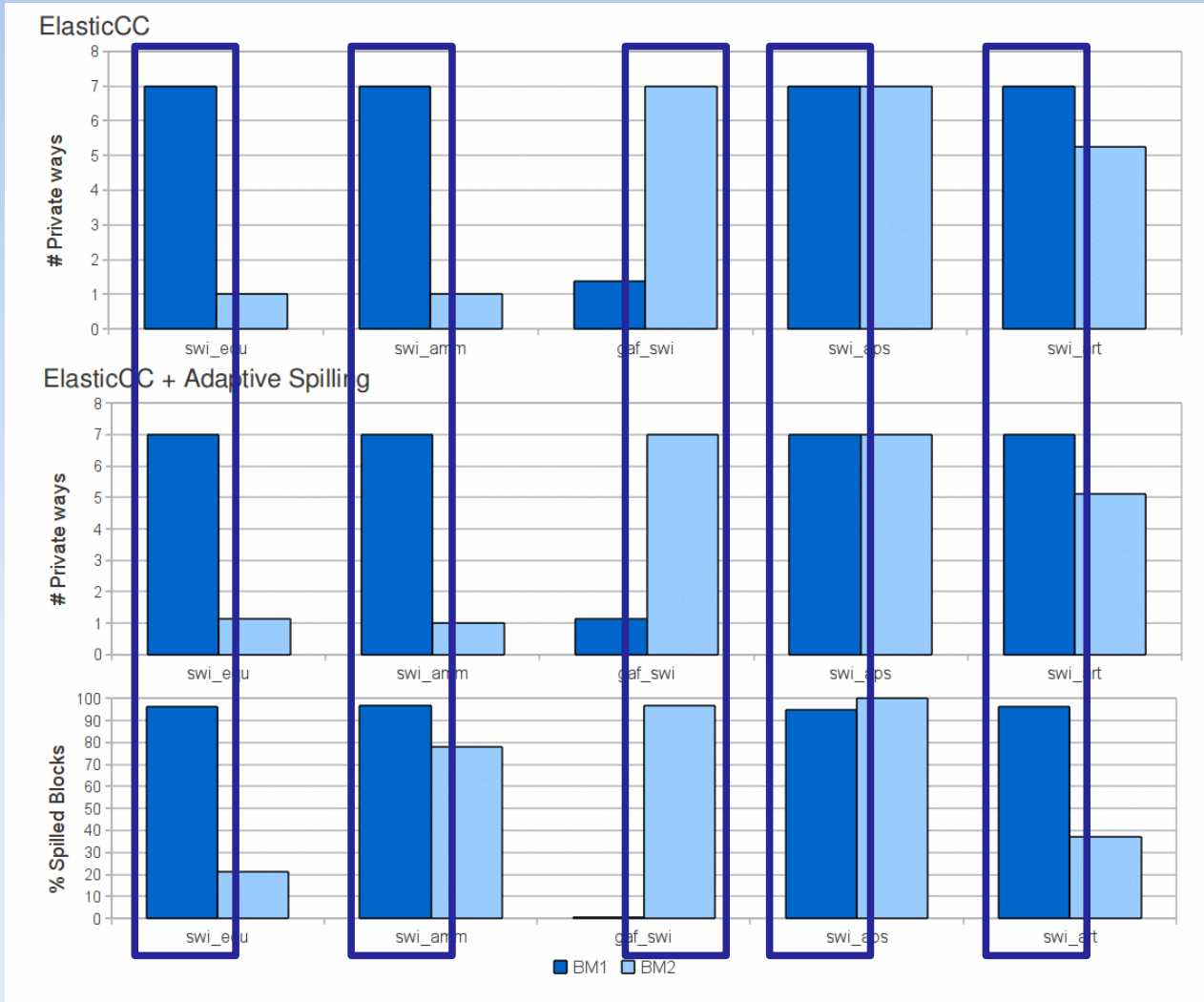


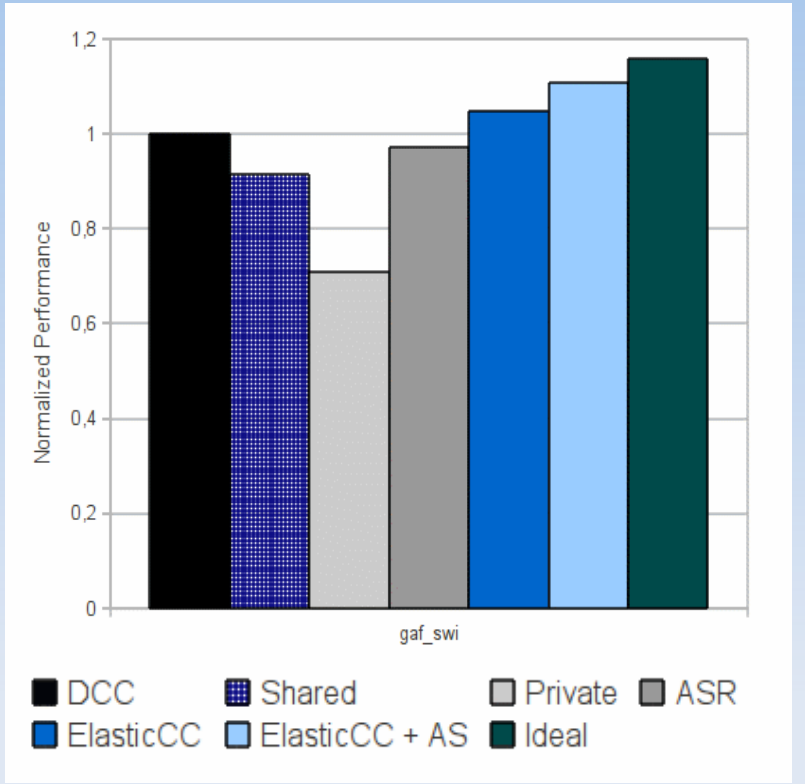


Ammp –
Shared High Utility

Benefits from shared cache space.

Evaluation – Cache Behavior

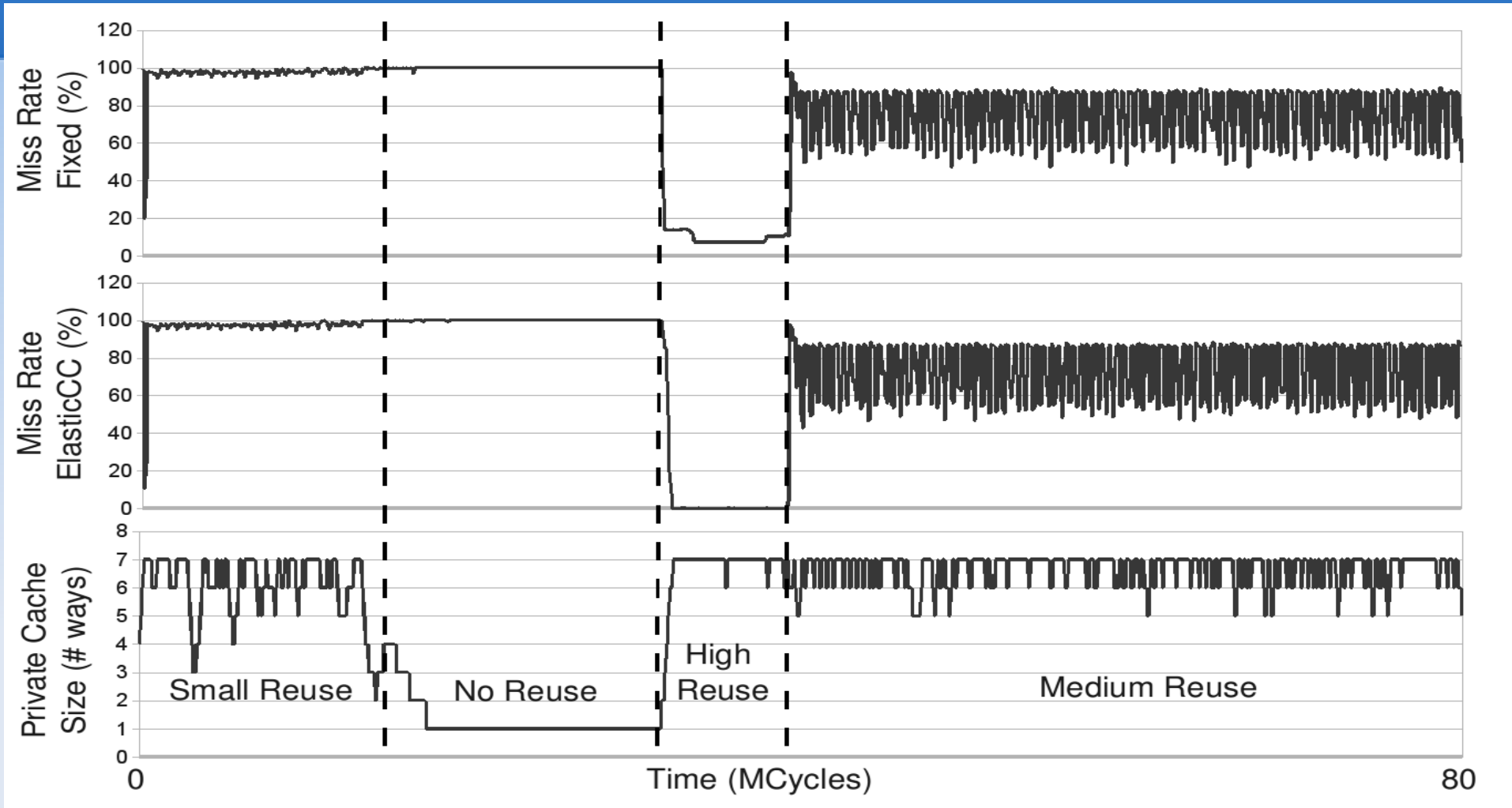




Swim –
Private High Utility

Always benefits from extra cache

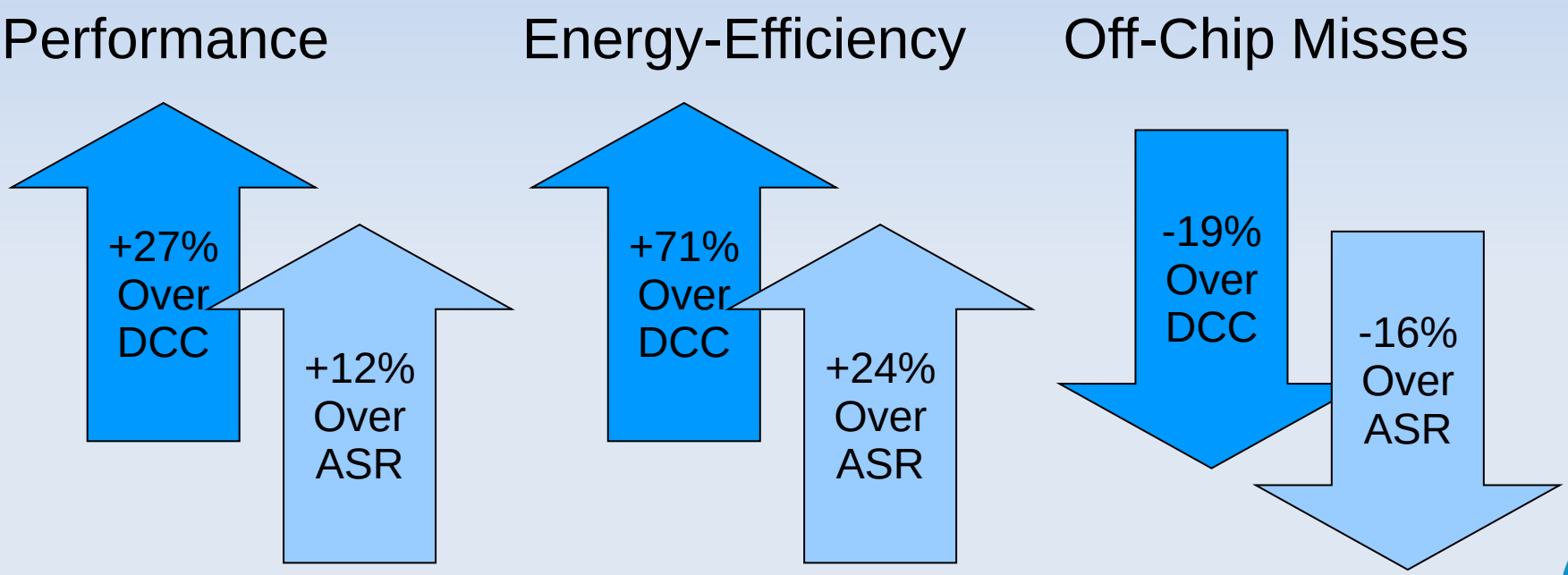
Evaluation - Temporal Cache Behavior



Gafort-Equake execution, Equake Thread 1

Conclusions

- Elastic Cooperative Caching
  - Distributed organization
  - Adaptive behavior to application requirements



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