Non-uniform cache architecture (NUCA)

Arkaprava Basu

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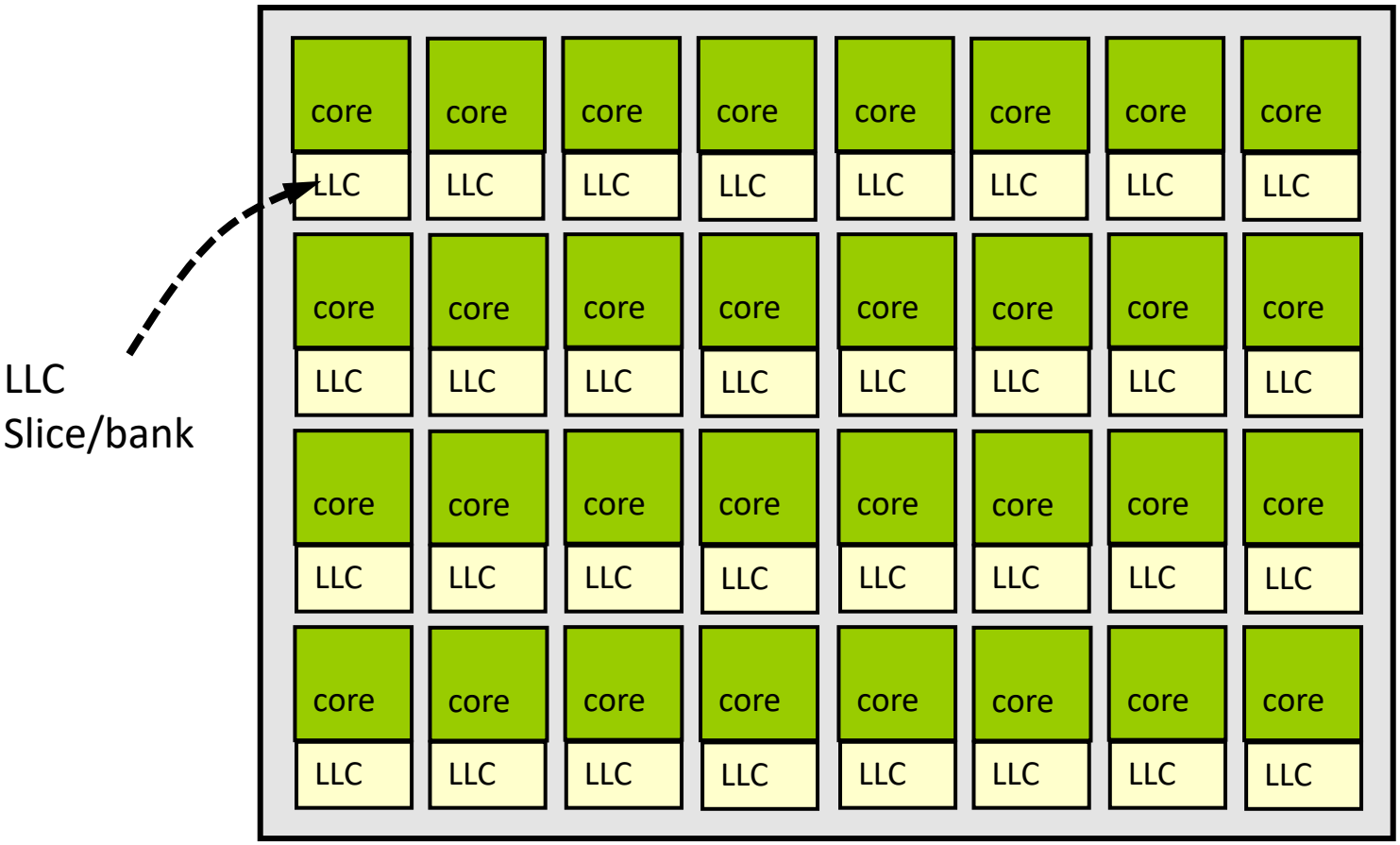
- **Non Uniform Cache Architecture**

Non-Uniform Cache Architecture (NUCA)



Picture modified from Hardavellas's talk

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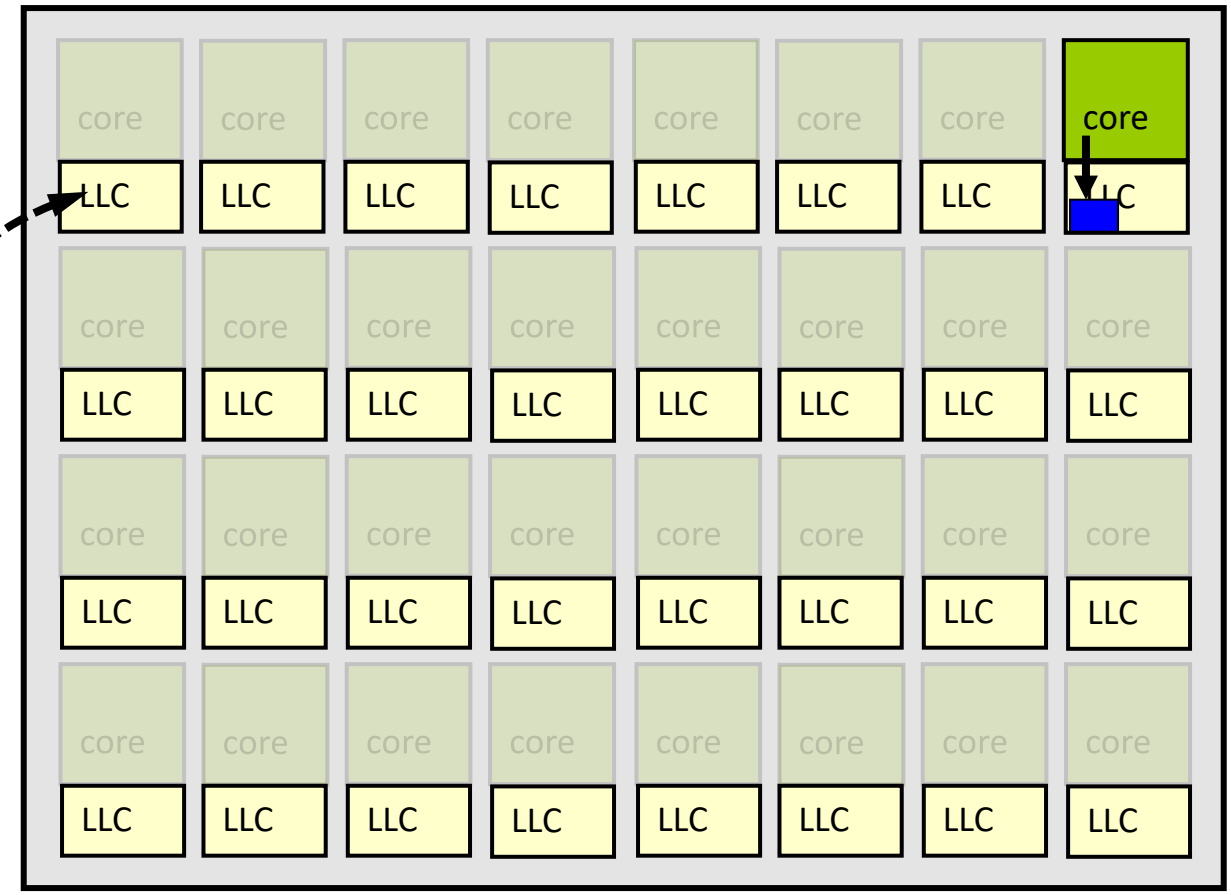

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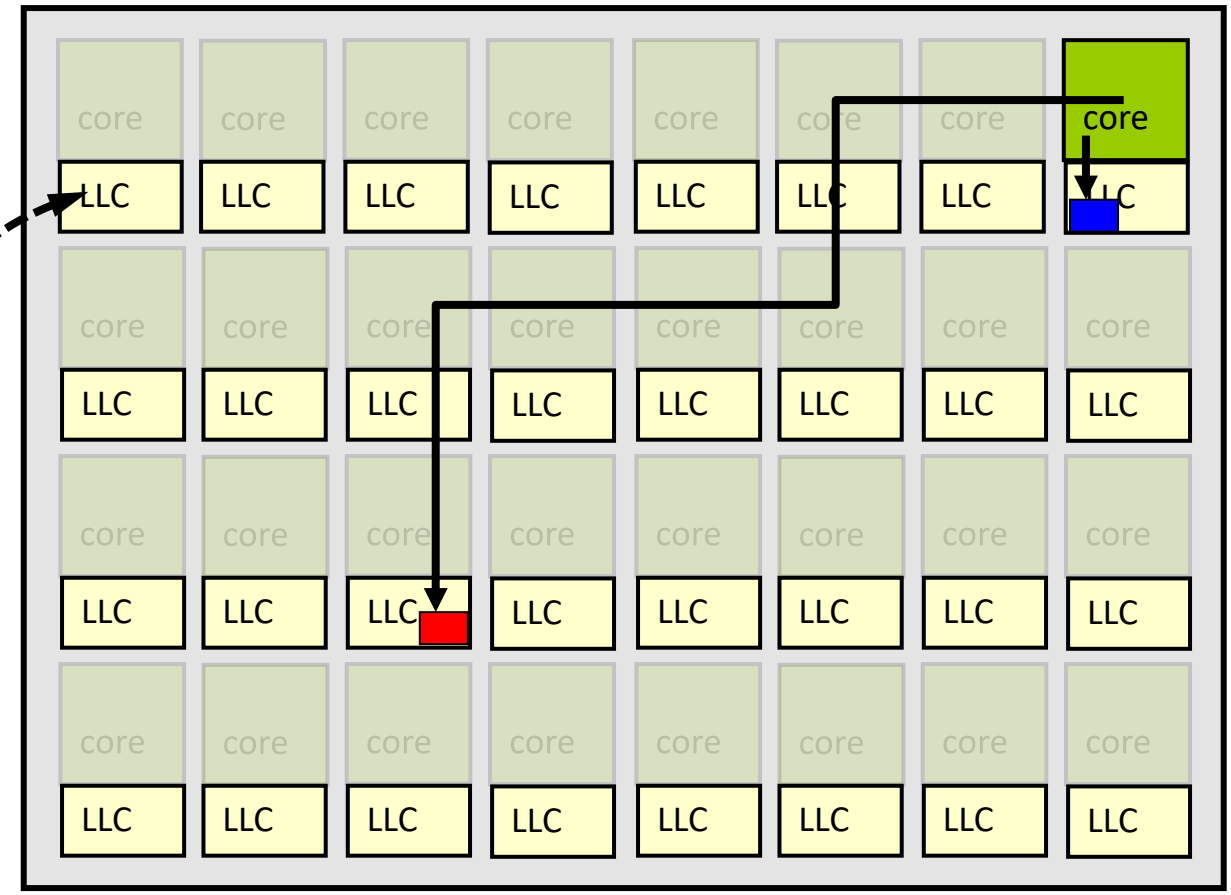

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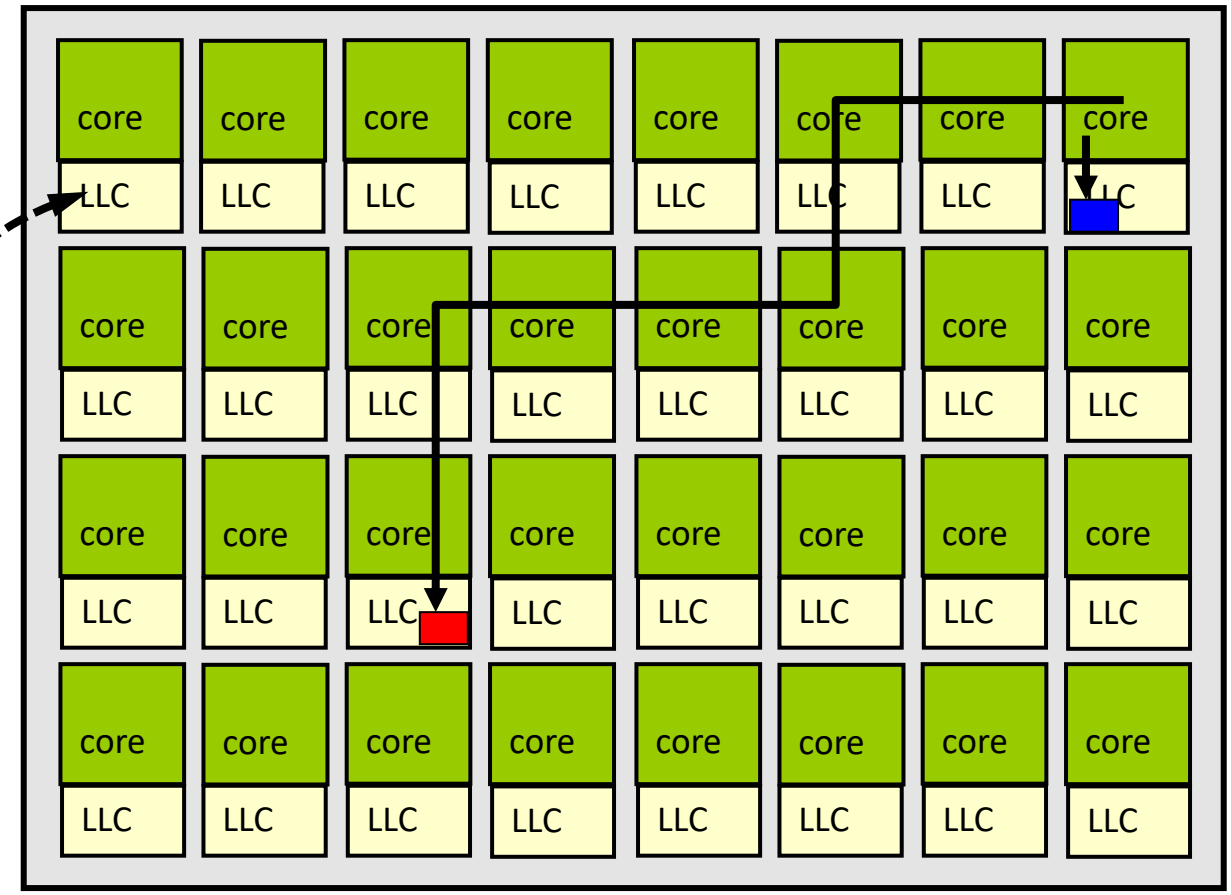
NUCA as Private LLC



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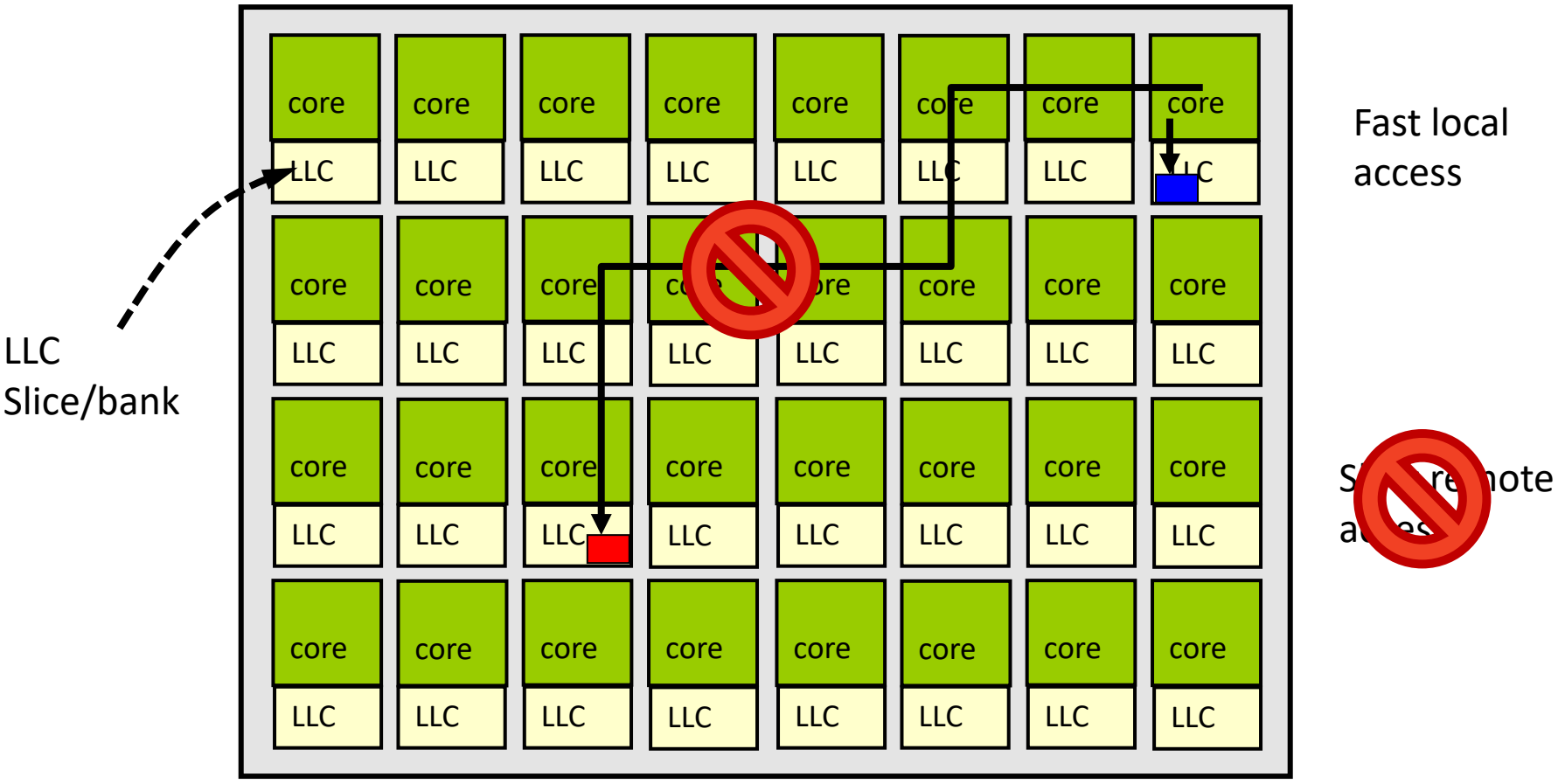
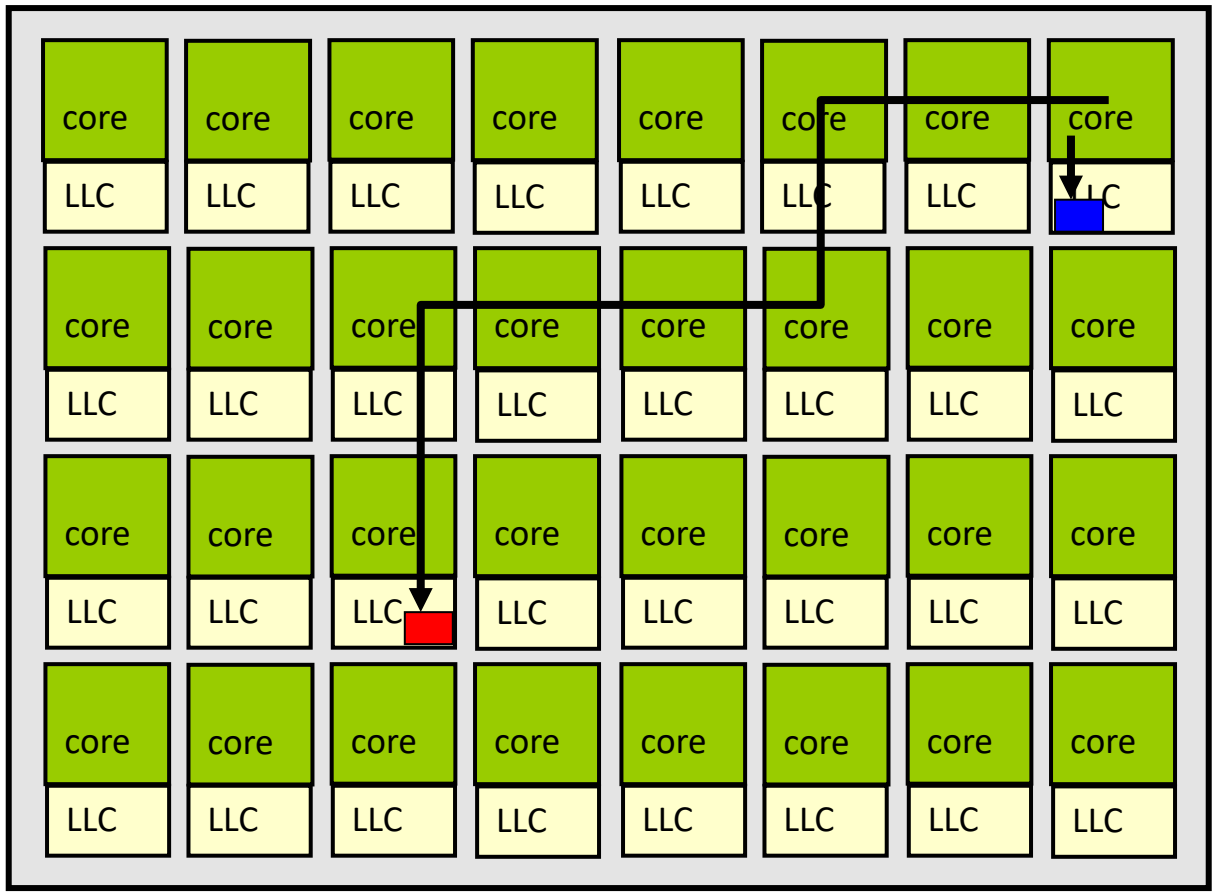


- (+) Low access latency, less interconnect traffic
- (-) Duplication, possible under-utilization of capacity, coherence

NUCA as shared LLC (Static NUCA)

Physical address bit decides "home" slice/bank



- (+) No duplication, no coherence, full capacity utilization
- (-) High remote access latency, interconnect traffic

Can we get the best of both worlds?

- Low avg. hit latency of private caches
- Low LLC miss rate of shared caches

Cooperative Caching (Chang et. al. 2006)

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    - On a miss at local private cache slice, coherence protocol determines if there exists another copy
  - Randomly choose which cache slice to spill to with higher probably of choosing the neighboring slice
    - Spill probability to decide whether to cooperate or not

Cooperative Caching (Chang et. al. 2006)

- Controlling replication:
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- Problem with Cooperative caching:
  - Coherence among the private LLC slices!

Reactive NUCA (ISCA'09)

- Observation: Not all cache blocks are equal

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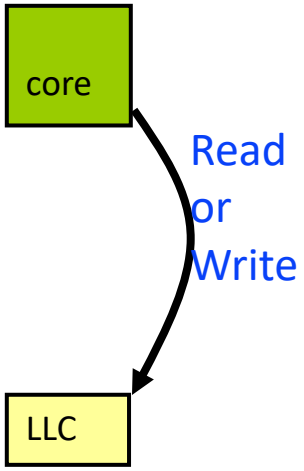
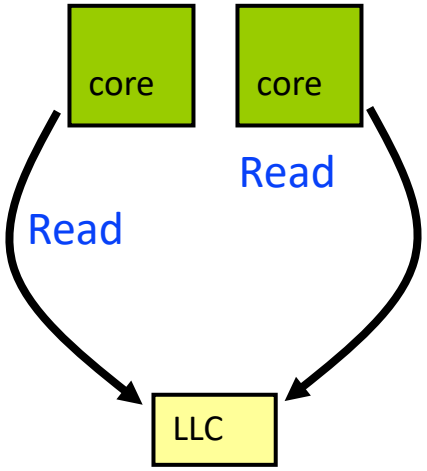
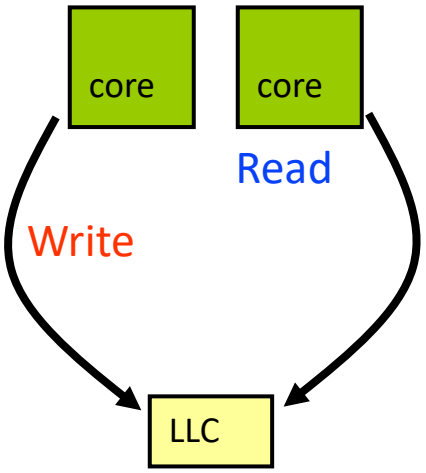


Private
(Read-only or
Read-Write)



Shared
Read-Only
(Often instructions)



Shared
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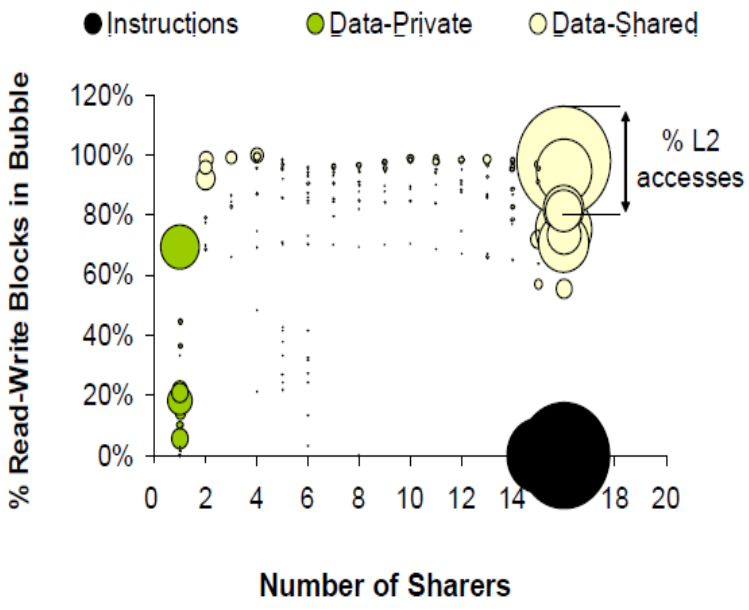
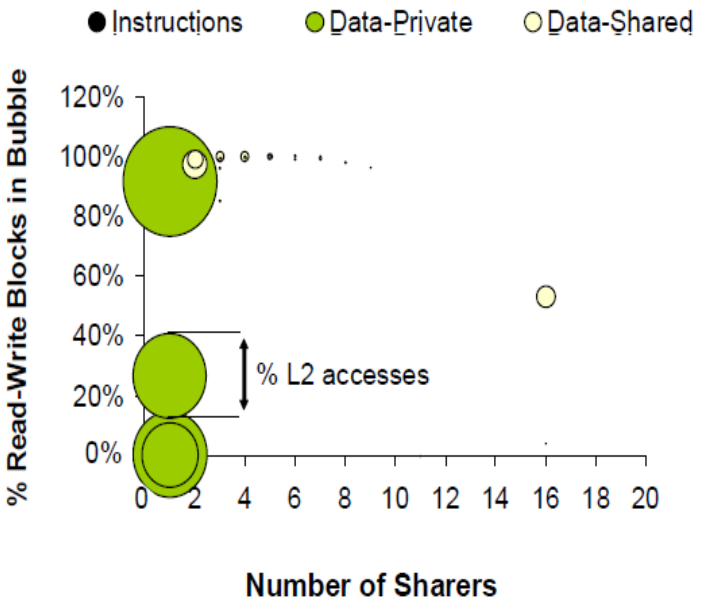
Characterization of LLC accesses



(a) Server Workloads

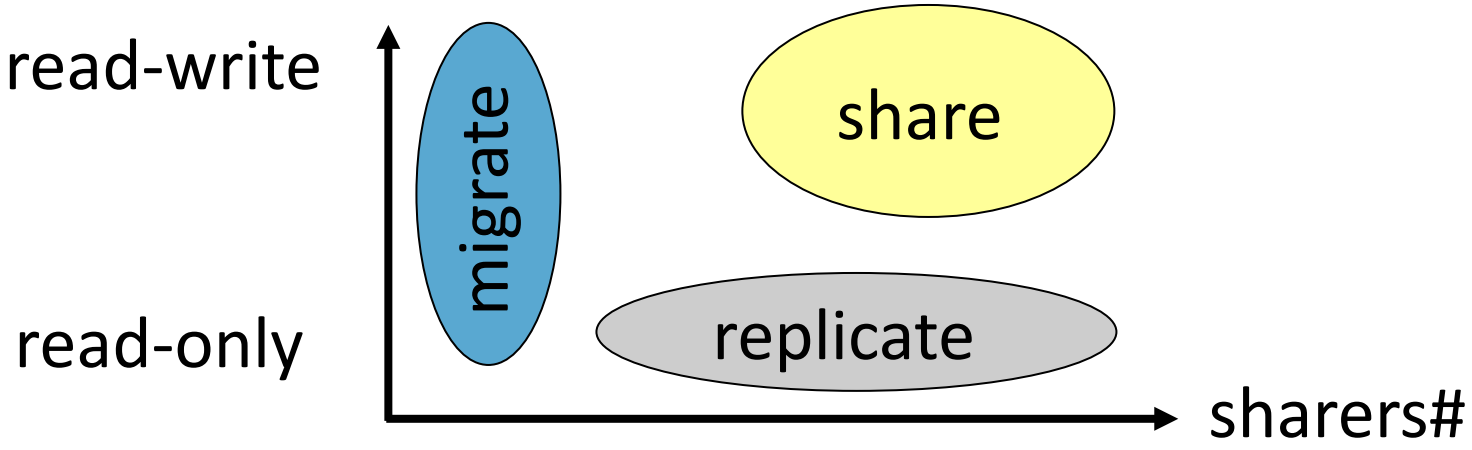


(b) Scientific and Multi-programmed Workloads

- Not all types of workloads are equal either !

Picture modified from R-NUCA paper

Where to place what type of content?



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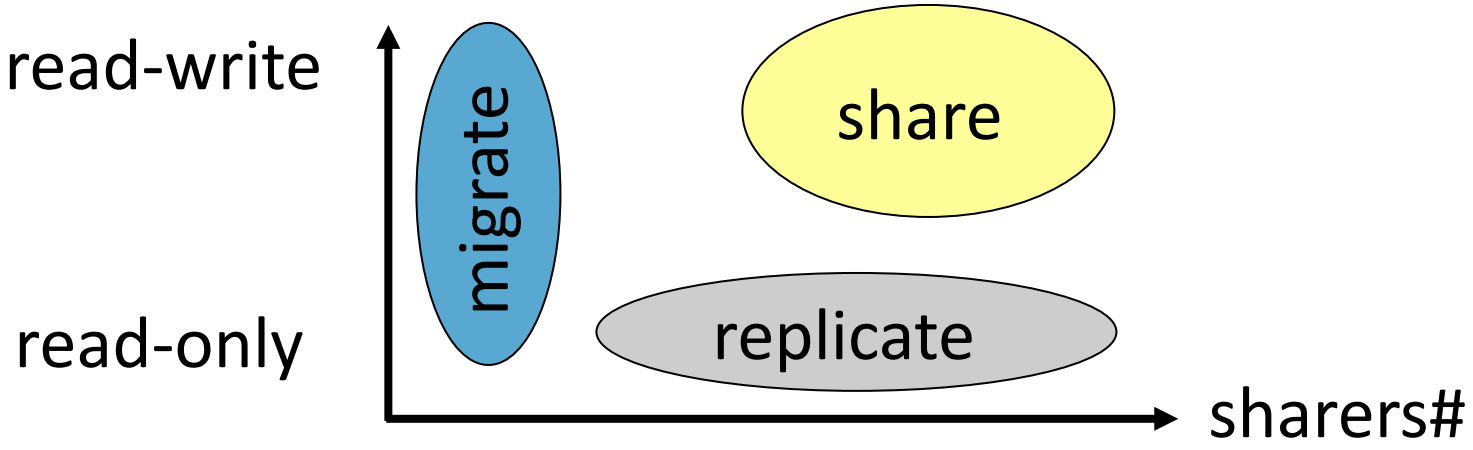

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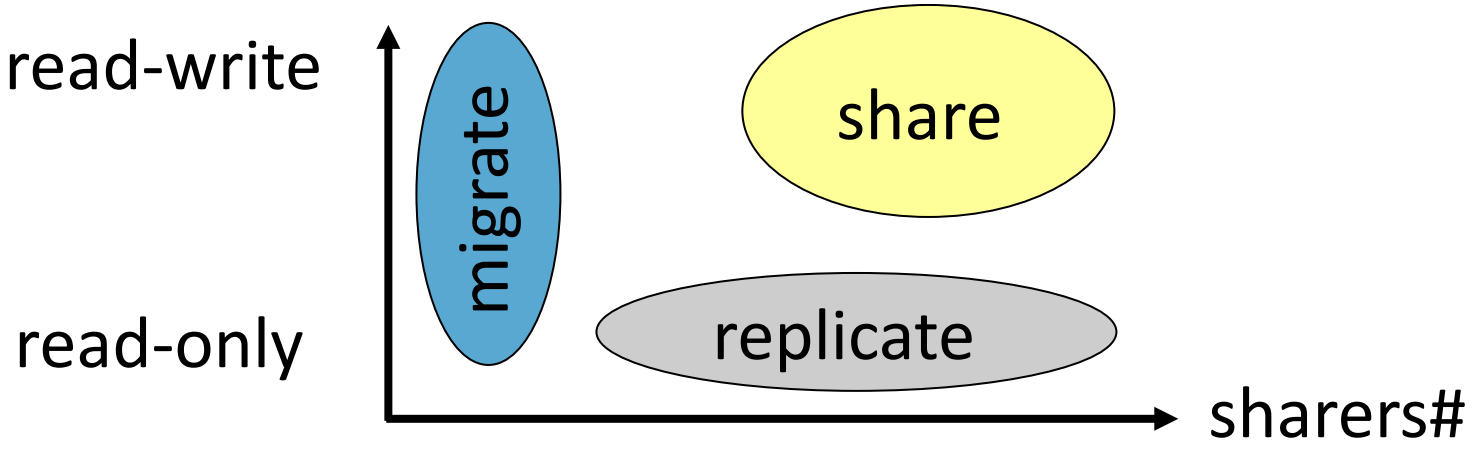

- Private and replicated read-only content no need to worry about coherence
- Shared read-write data can be placed in "home" bank/slice based on address (like S-NUCA) → no coherence

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- What happens on a miss-classification?
  - e.g., a page classified read-only is being written to

Putting it together: R-NUCA

- OS helps classify type of content at page granularity
- TLB entries keep this classification information
- A cache block is replicated (shared read-only) migrated (private read-only, read-write) or kept at "home" bank/slice (shared read-write), based on the classification