ASPIRE

Exploiting ***As***ynchronous ***P***arallelism in ***I***terative Algorithms using a ***Re***laxed Consistency based DSM

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Motivation

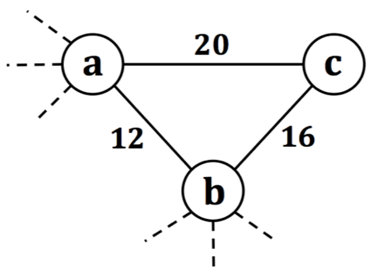
- Iterative algorithms
  - PDE Solvers: Heat Simulation
  - Graph Analysis: PageRank, Community Detection
- Real-world datasets are typically large
  - Social Networks, Genome Graphs
- Processing on distributed memory machines
  - Performance
  - Programmability

Outline

- Iterative Algorithms
- Overview of ASPIRE
- Existing Weak Memory Models
- Relaxed Consistency Protocol
- Evaluation
- Conclusion

Iterative Algorithms

- Data Centric
  - Computation written for a single element
  - Terminate when values converge
  - Highly parallel execution
- Network Bound
  - Computation is simple



Fetch(c)
Fetch(a)
Fetch(b)
c’ = f (c, a, b)
Store(c, c’)

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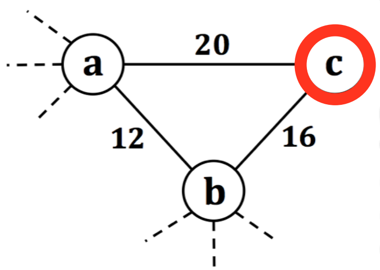

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Execution Models

- Bulk Synchronous Parallel (BSP) [CACM'90]
  - Disjoint computation and communication
  - Computation based on previous iteration
- Asynchronous Parallelism [Baudet 1978]
  - Overlap computation and communication
  - Computation based on current iteration
  - Known to be faster than BSP

ASPIRE

- Improve asynchronous execution
  - Make them faster
- Tolerate network latencies
  - Tardis: remote fetch is ~2.3 times of local fetch
- Relaxing consistency
  - Allow use of stale values
- Without affecting convergence
  - Minimize use of stale values

ASPIRE

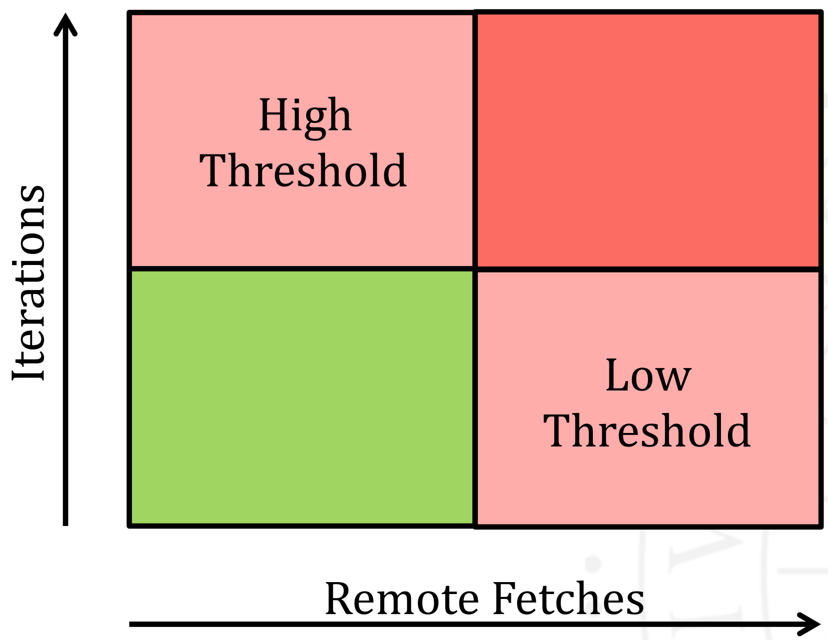
- Improve asynchronous execution
  - Make them faster

Challenge: Relax consistency without delaying convergence

- Relaxing consistency
  - Allow use of stale values
- Without affecting convergence
  - Minimize use of stale values

Weak Memory Models

- Delta Consistency [SPAA'97] [PPoPP'03]
  - Controls staleness using static threshold



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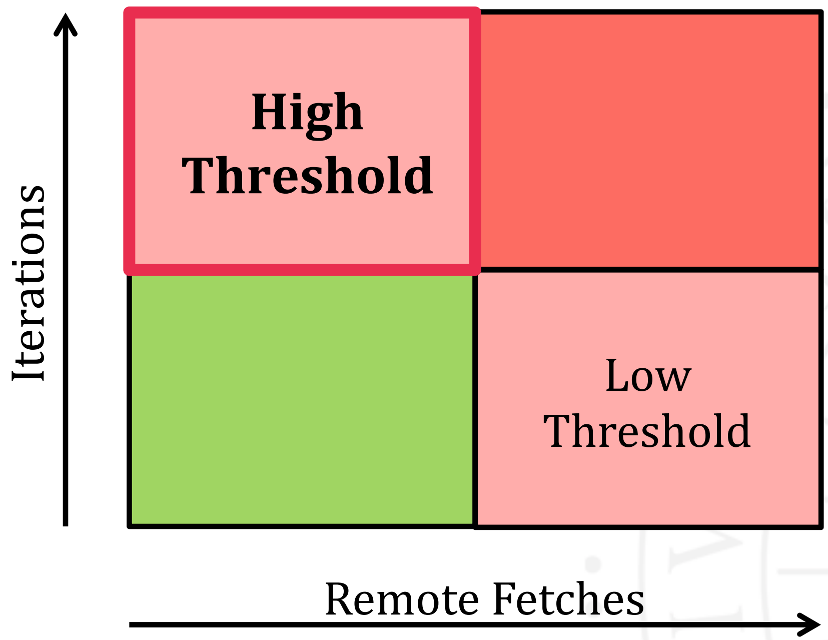

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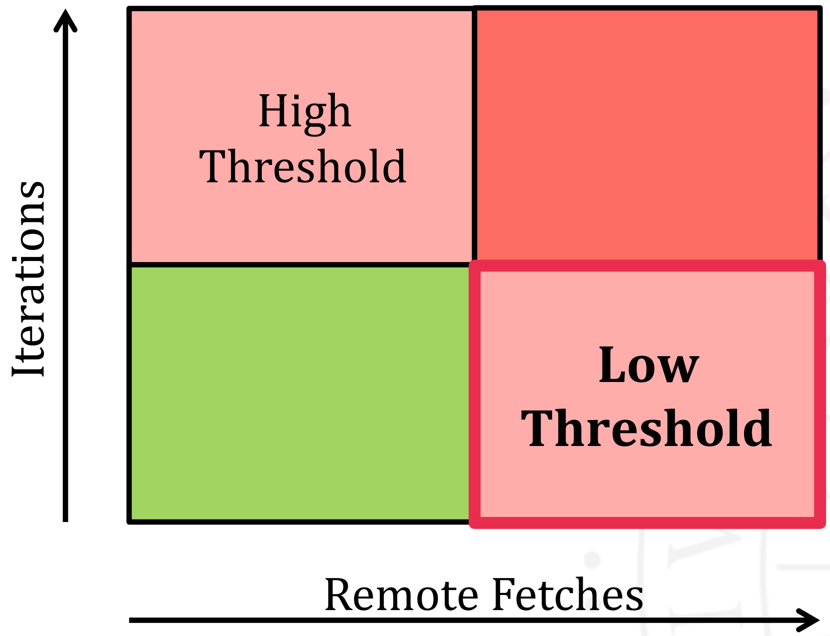

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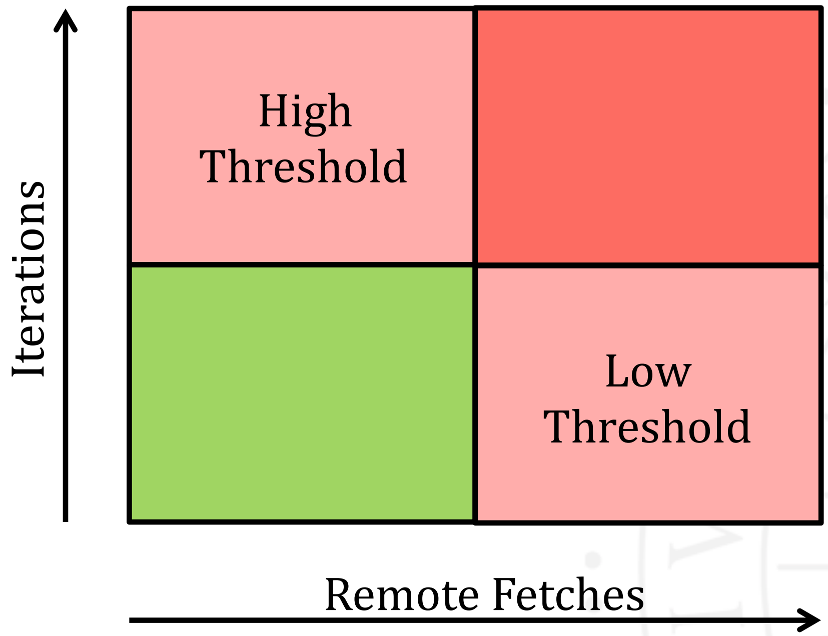

Delayed updates affect convergence

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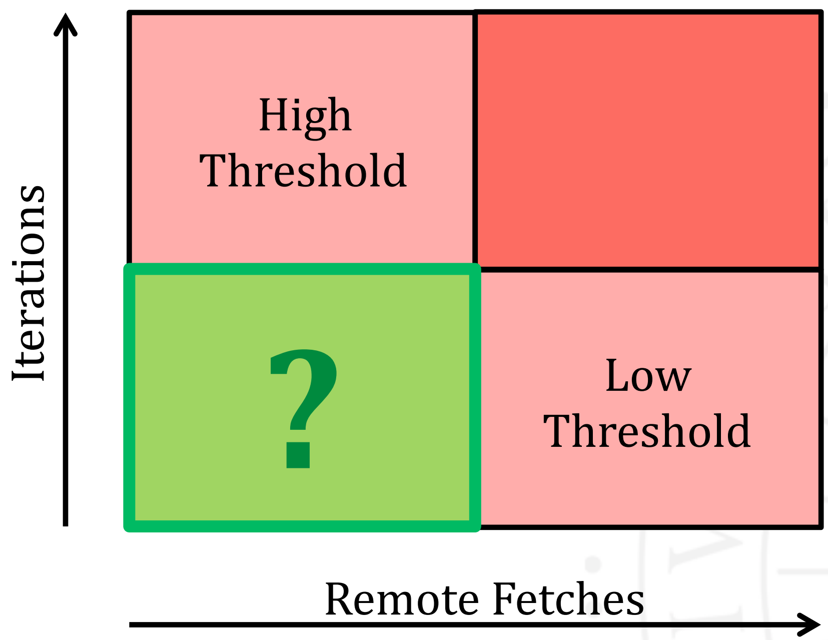

Delayed updates affect convergence

Relaxed Consistency Protocol

- Tracks staleness to exploit it
  - Cached objects have a staleness value
- Best efforts to minimize stale objects
  - Refresh cached objects based on access pattern

- Provides programming support
  - Local writes must be immediately visible
  - Once an object is read by a thread, no earlier writes to it can be read by the same thread

Relaxed Consistency Protocol

- Current-hit
  - object in cache; staleness = 0
- Stale-hit
  - object in cache; 0 < staleness <= t
- Stale-miss
  - object in cache; staleness > t
- Cache-miss
  - object not in cache

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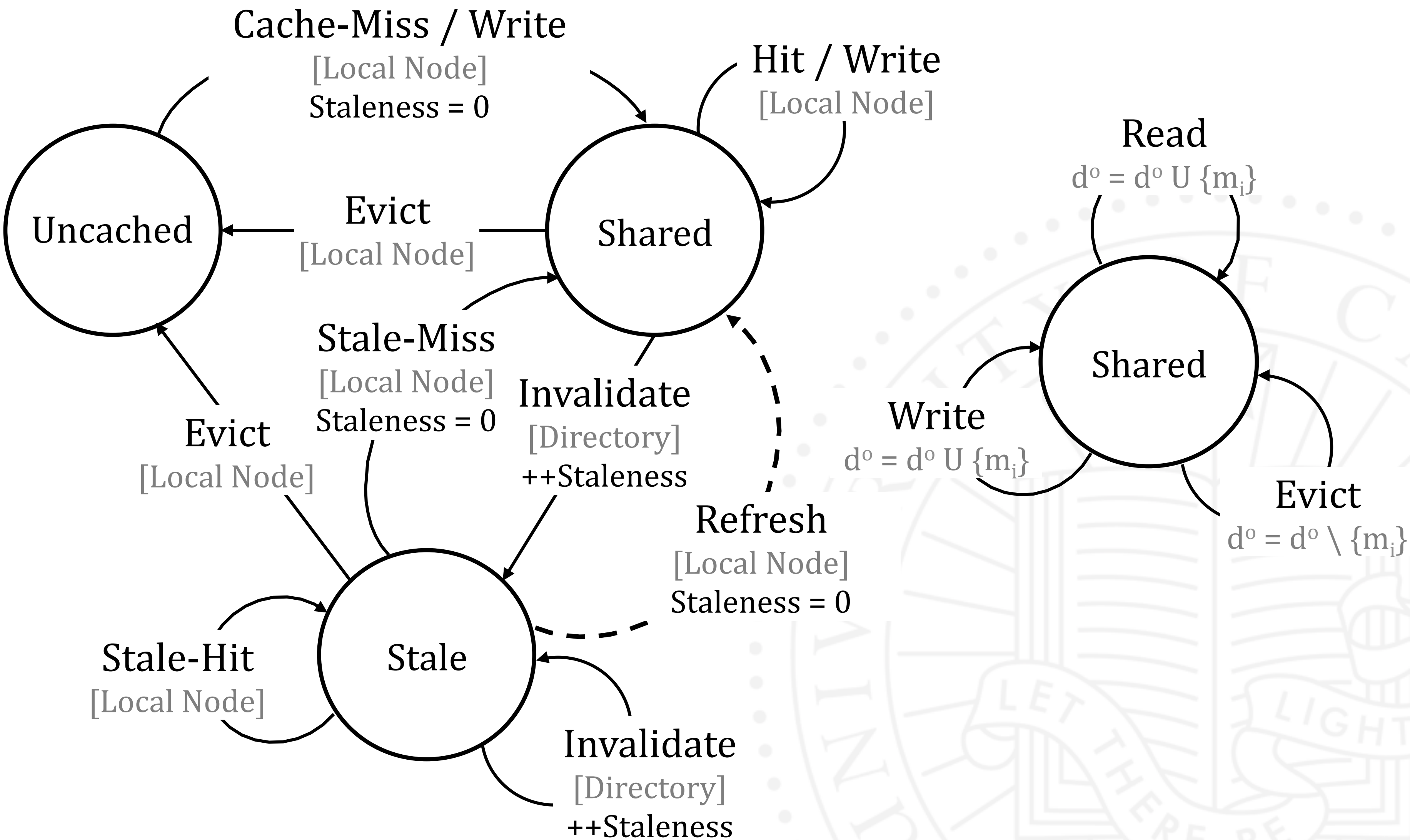

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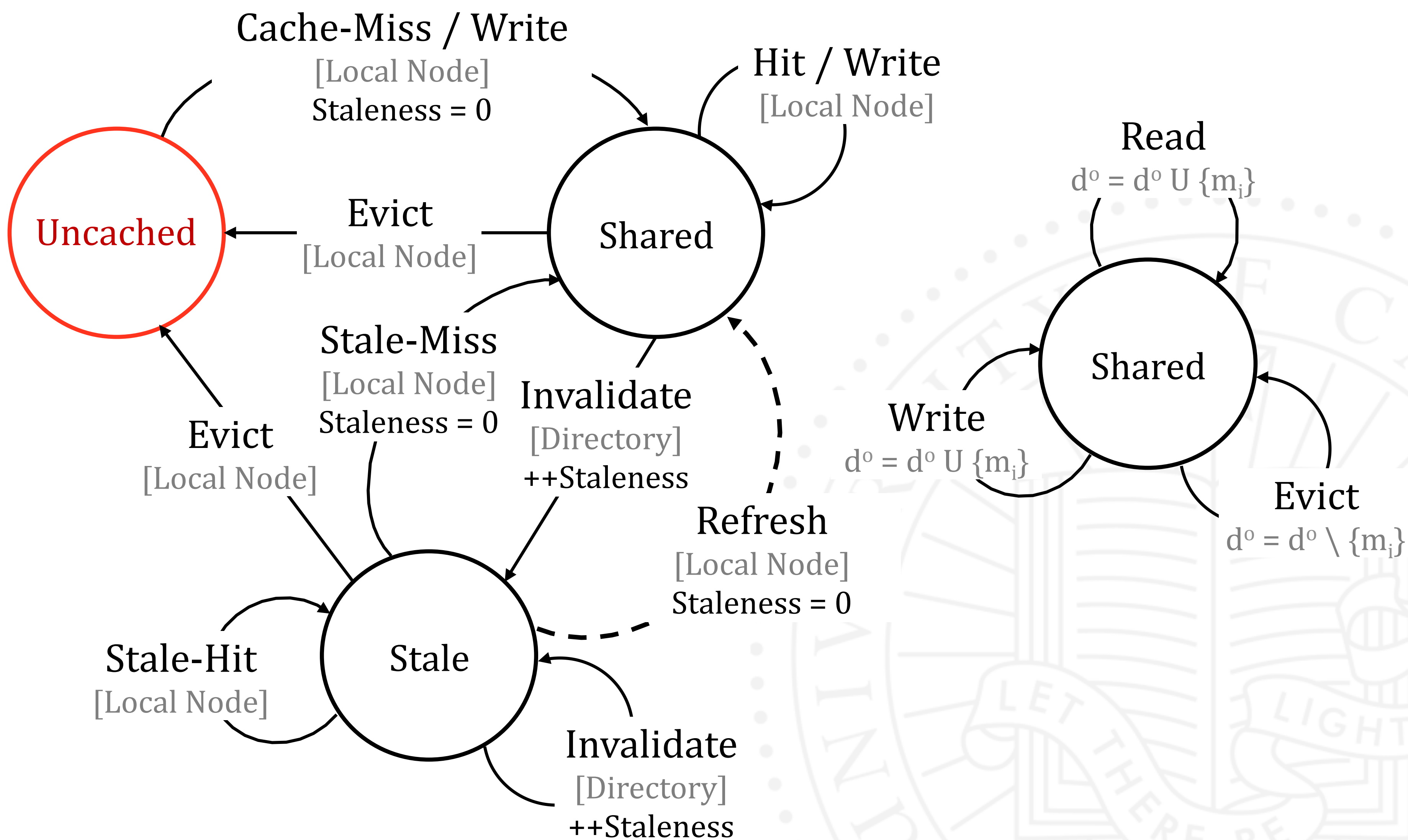

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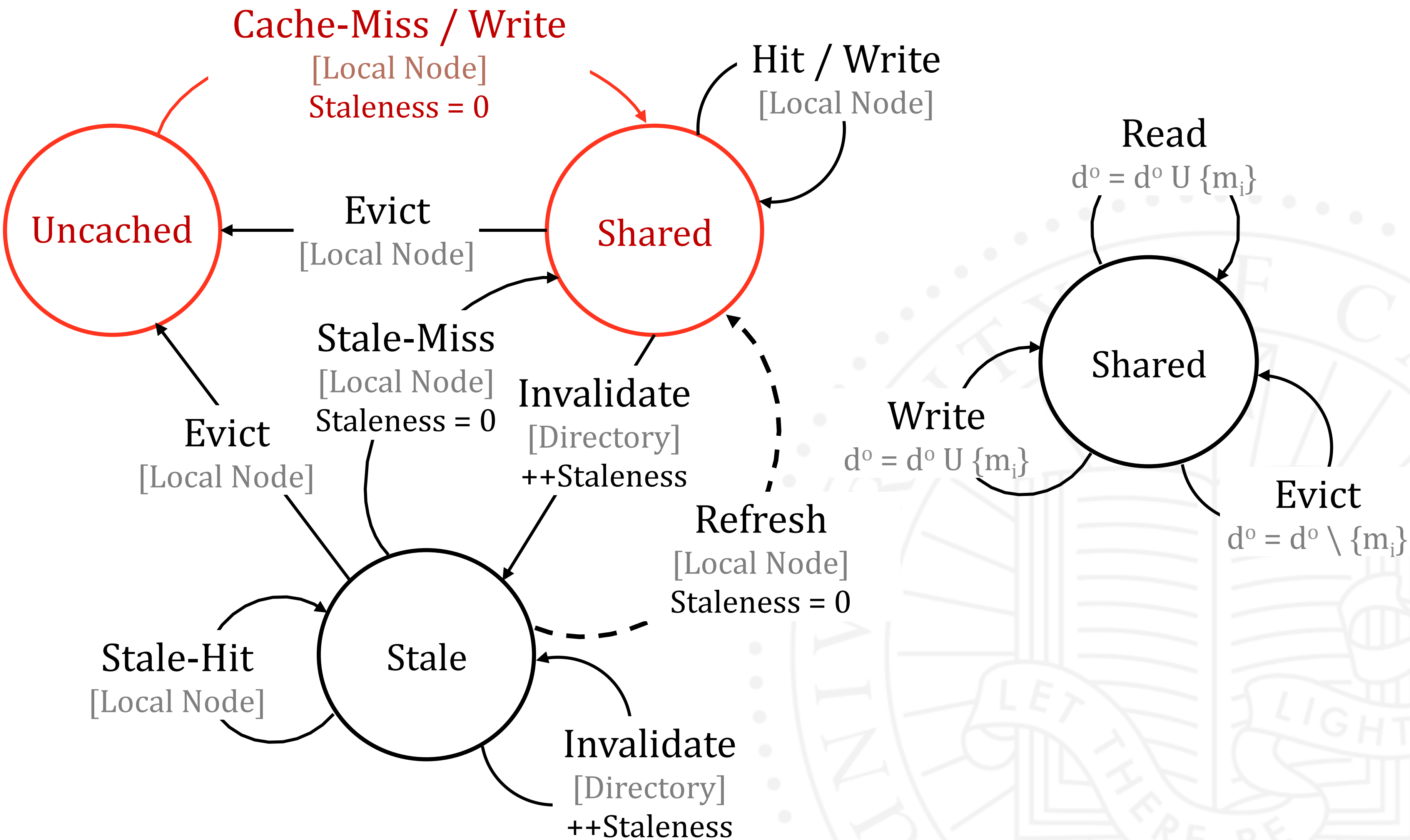

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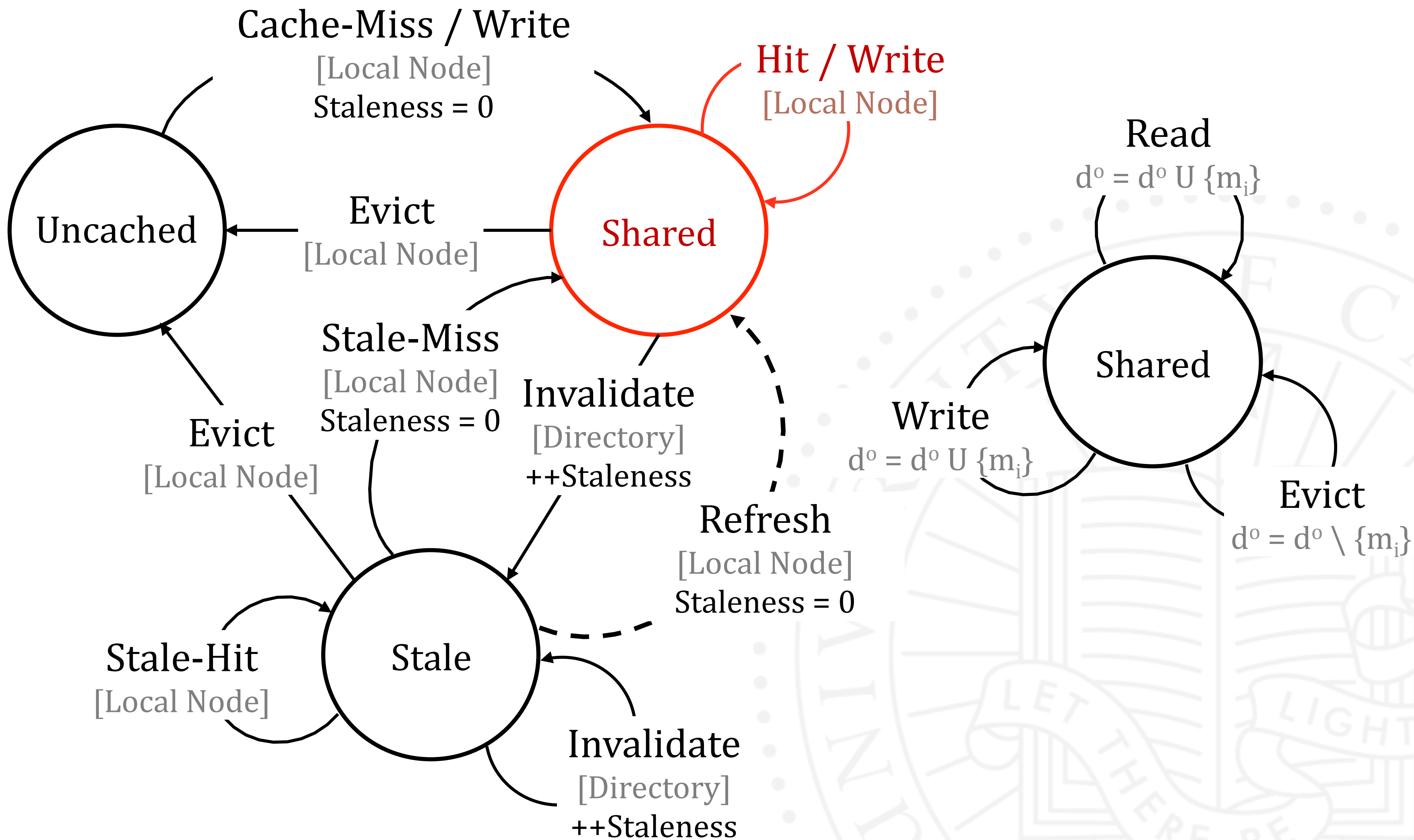

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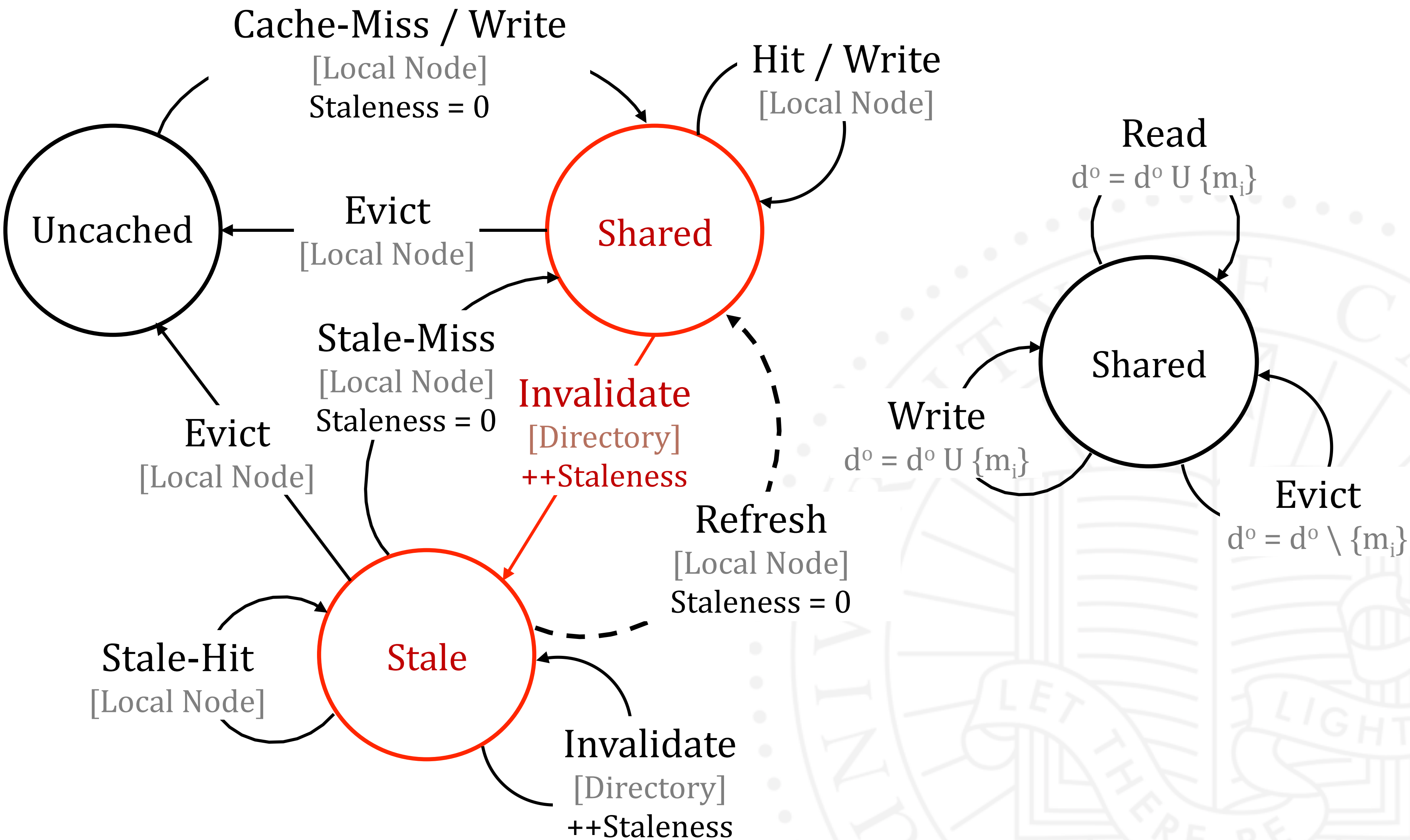

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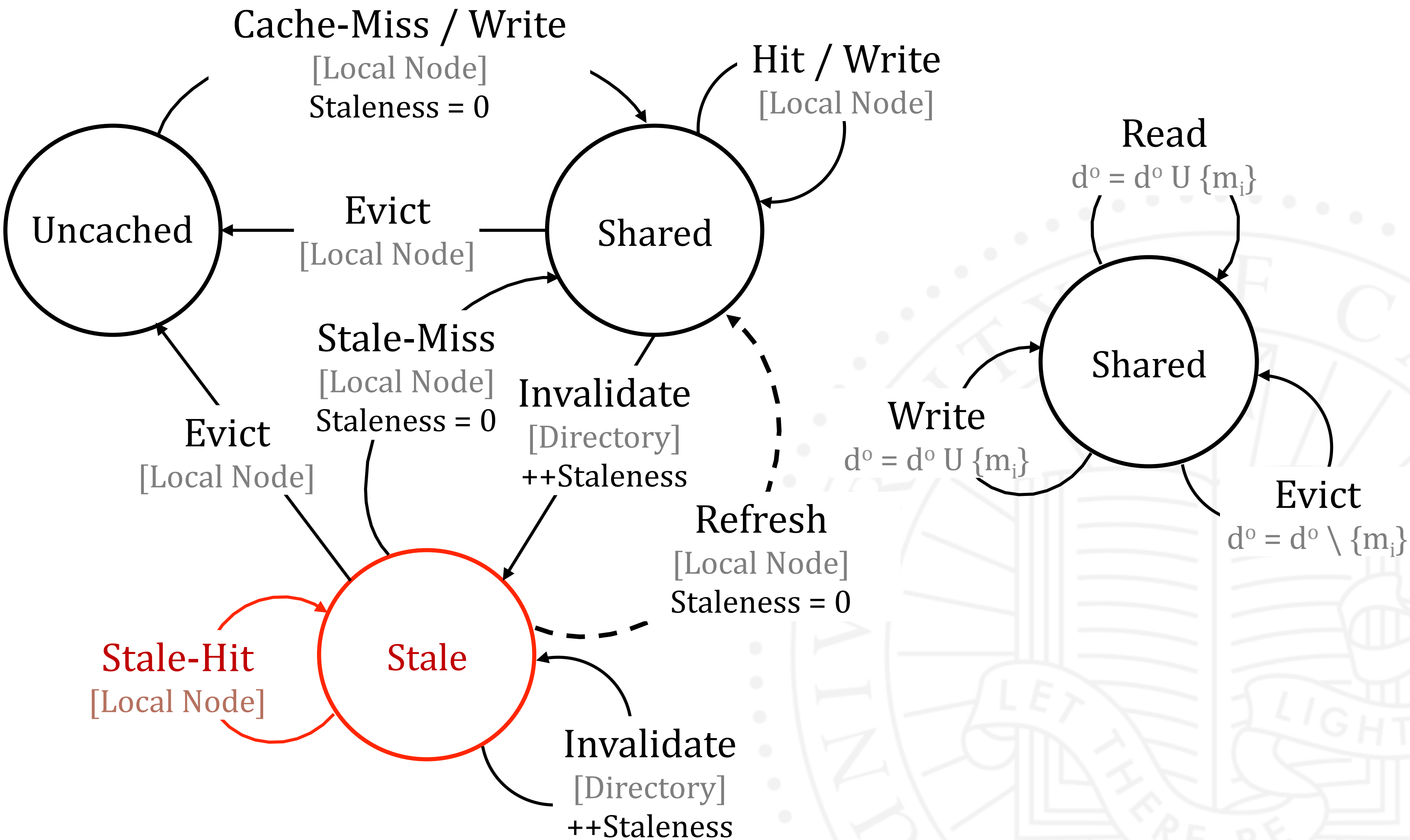

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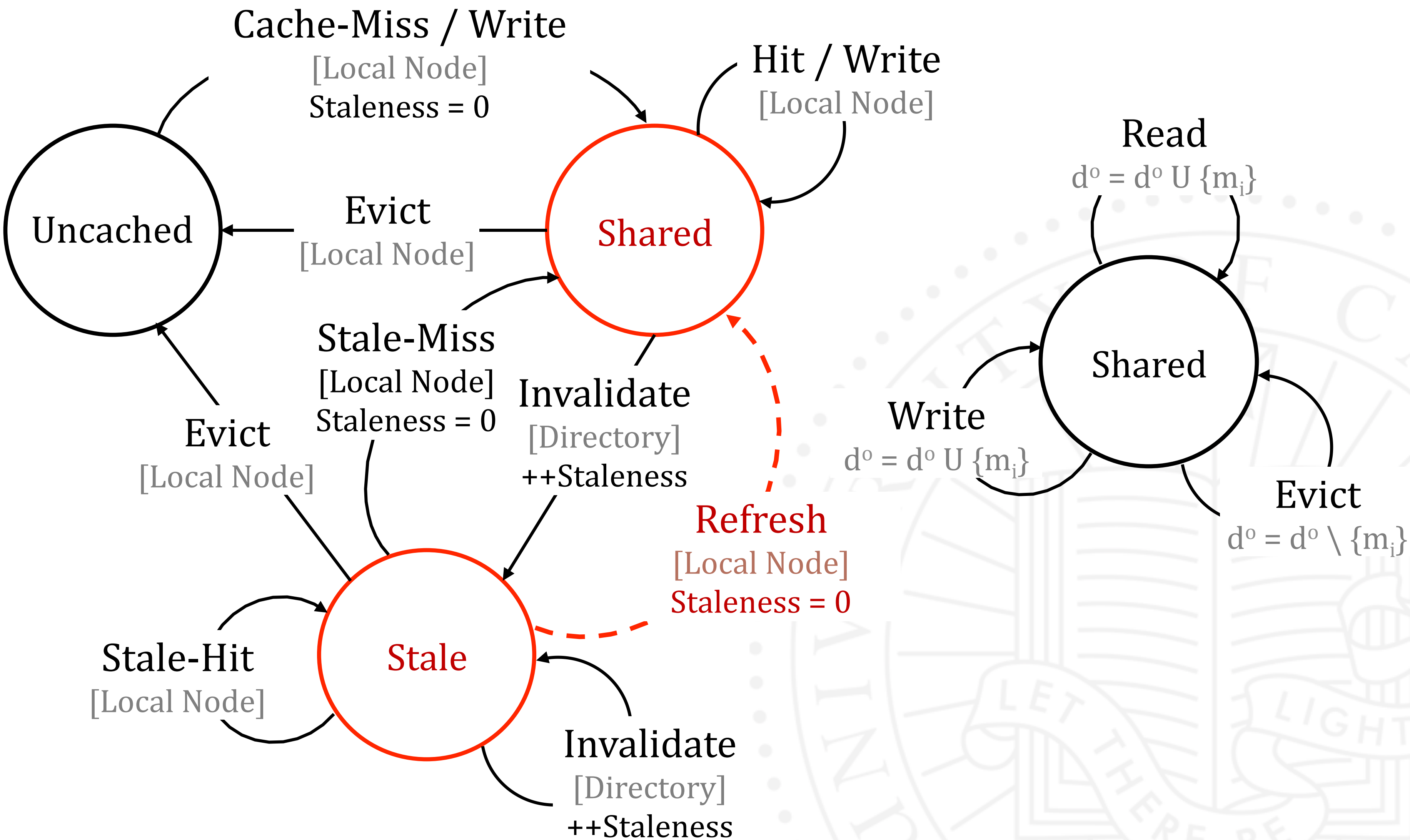

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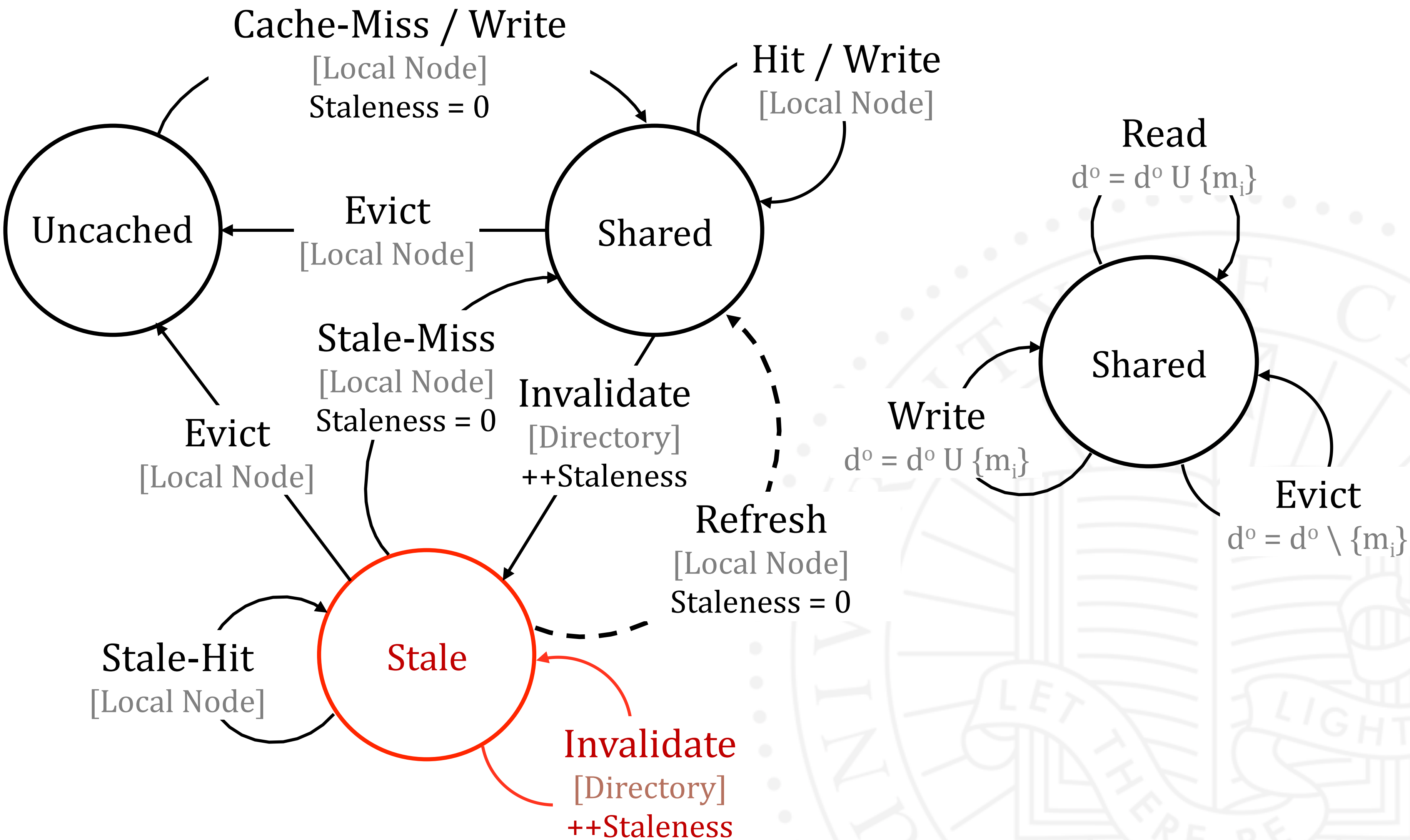

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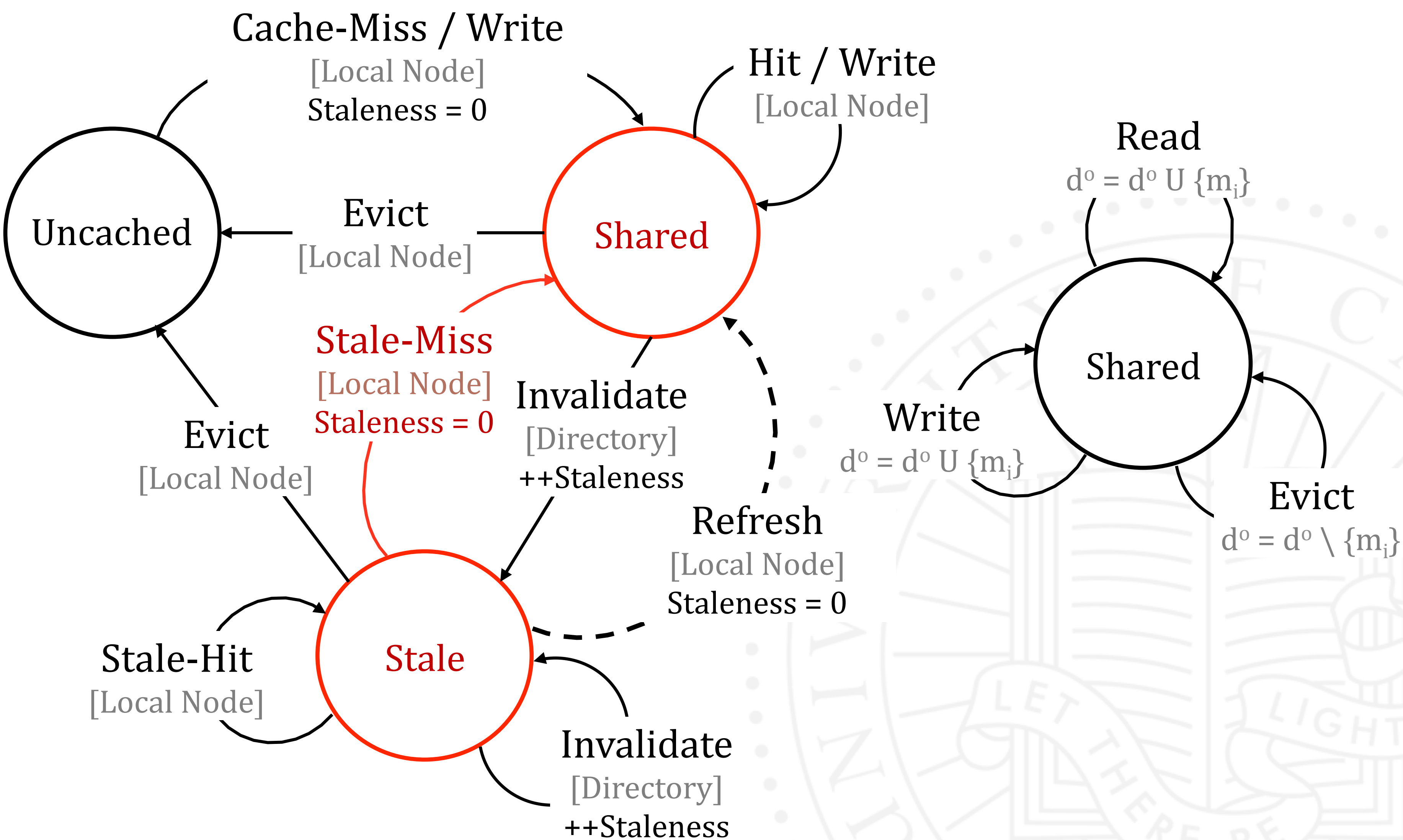

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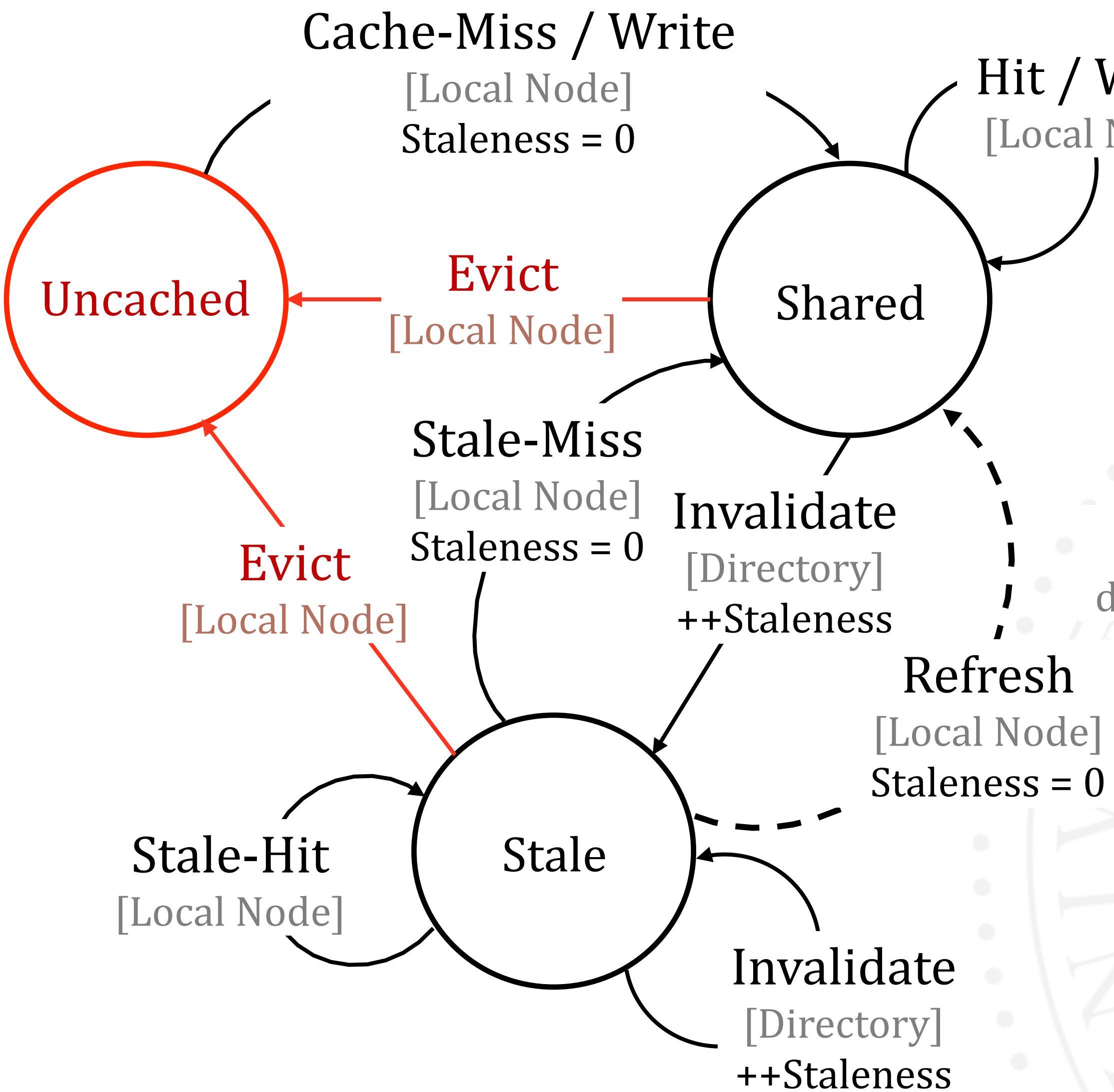

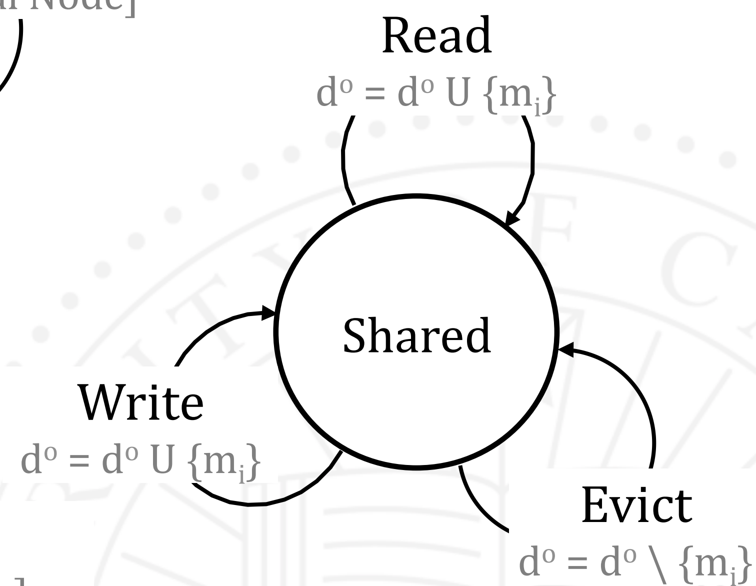

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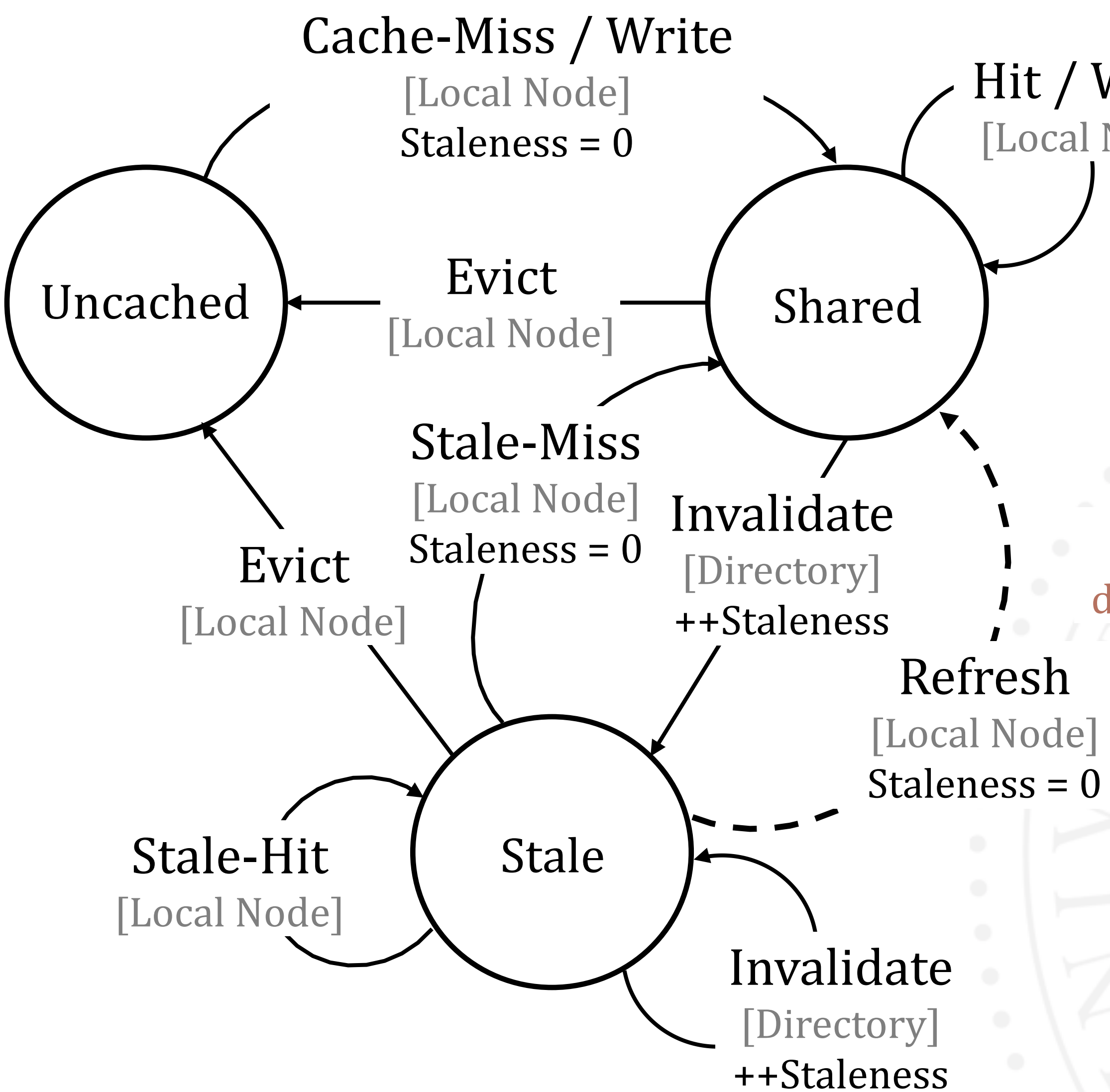

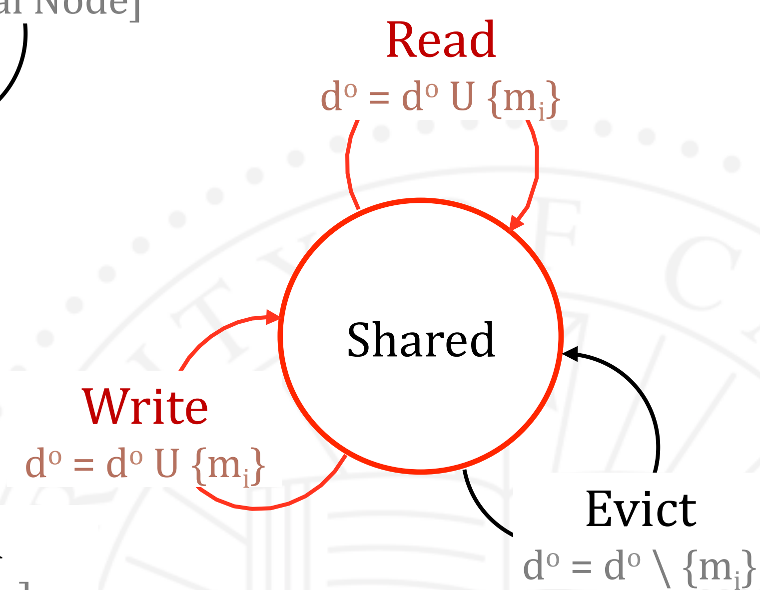

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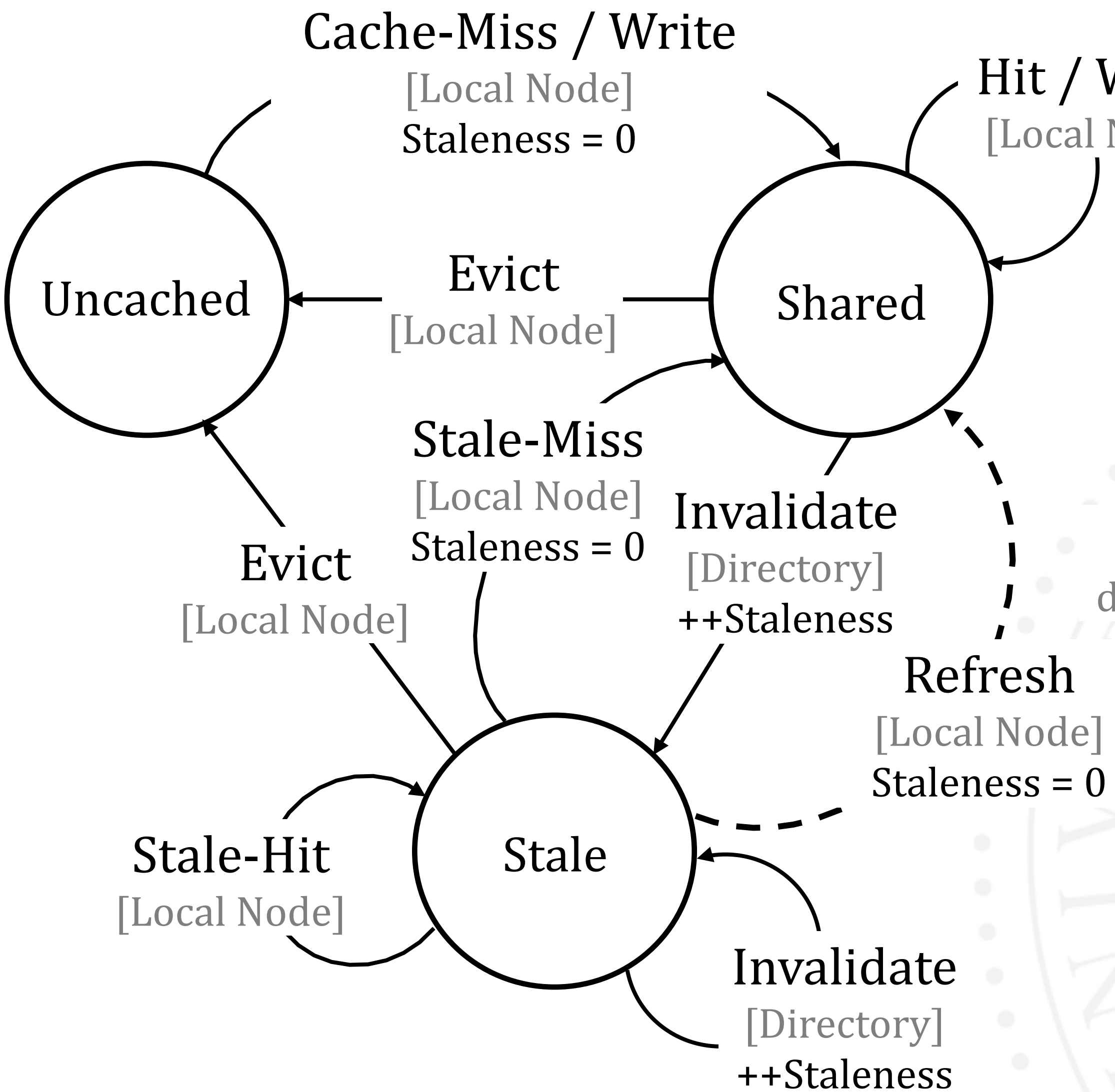
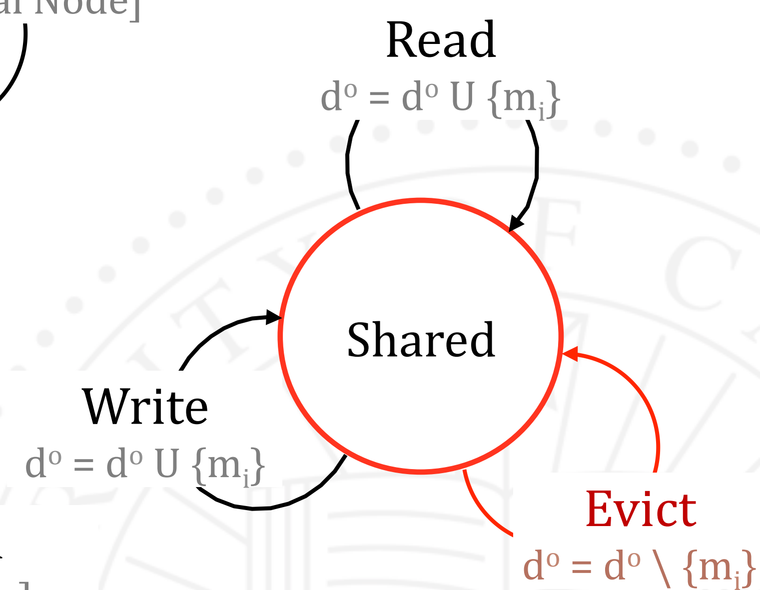




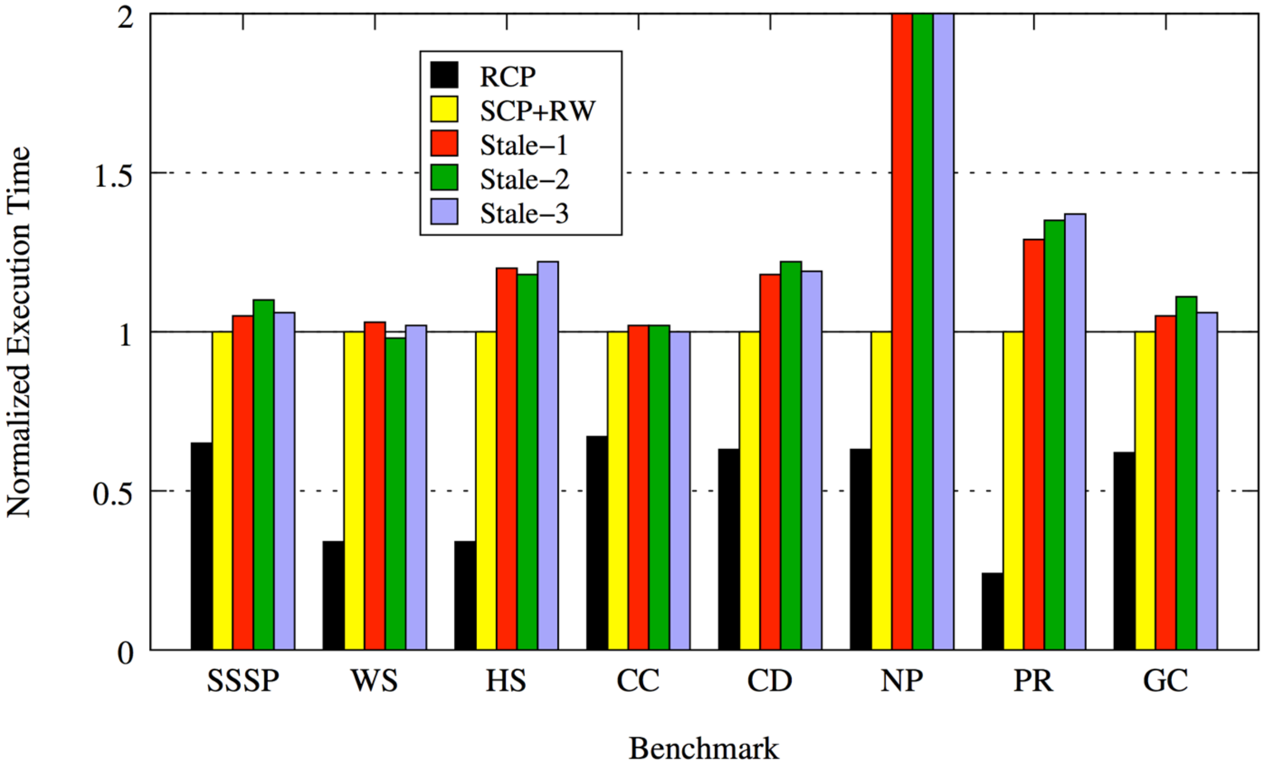
Implementation

- Similar to dyDSM [Koduru et al. 2013]
  - Object based
  - Protocol relaxes strict consistency
  - Graphs are distributed using METIS [SISC 99]
- Runtime
  - Single Writer Model
  - Refresh strategy using producer-consumer model
  - Termination semantics

Experimental Setup

- Tardis @ UCR
  - 16-node cluster running CentOS 6.3
- 8 benchmarks
  - WS, HS, PR, SSSP, CC, CD, NP, GC
- 10 real-world inputs
  - SNAP dataset collection
  - UFL sparse matrix collection

Execution Time

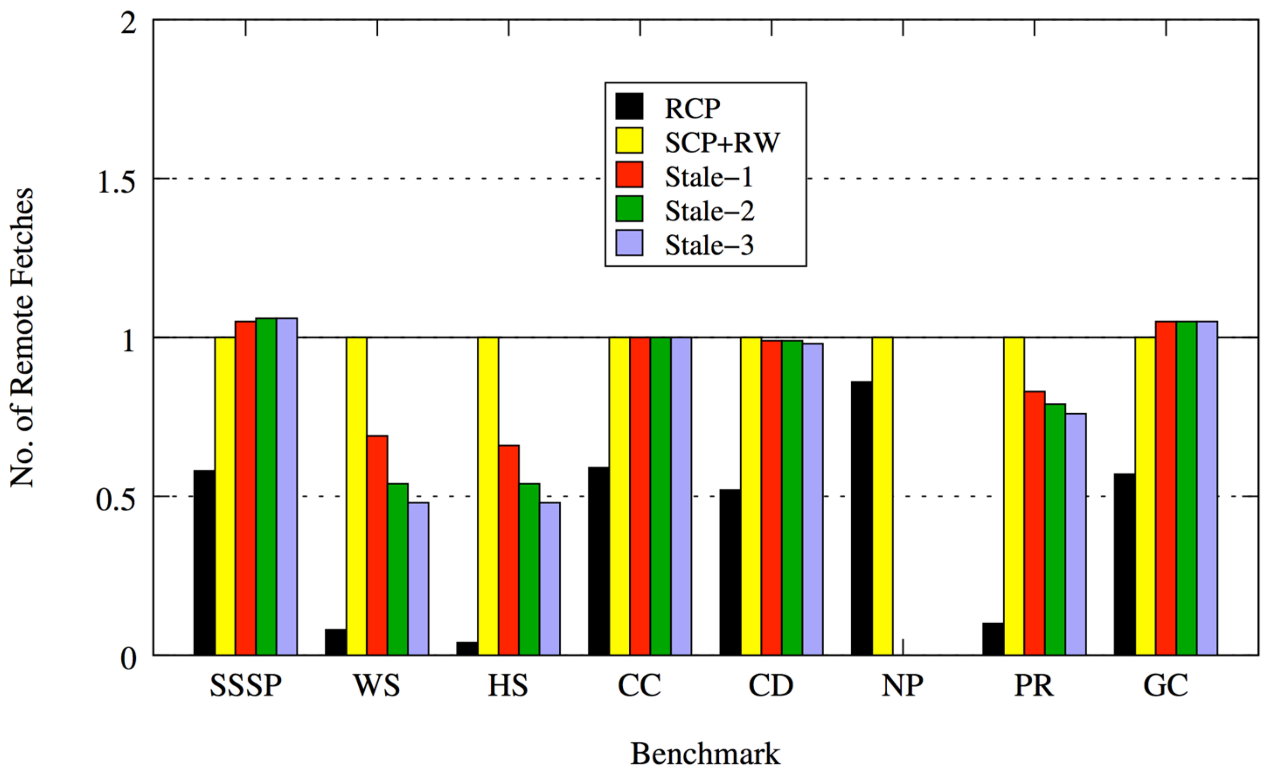


Pokec:
30M edges
1.6M vertices

AtmosModl:
10M edges
1.4M vertices

RCP 48.7% faster than SCP+RW and 56% faster than best Stale-n

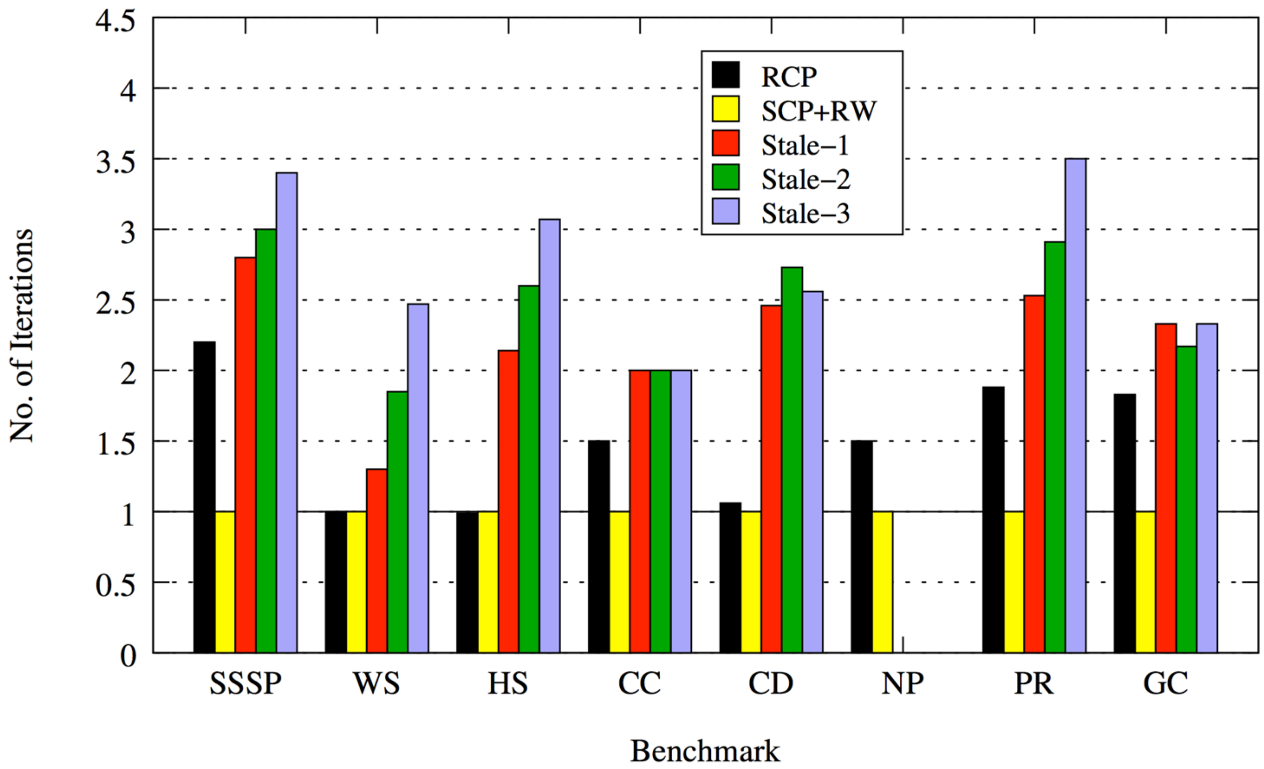
Remote Fetches



RCP blocks on 41.8% of remote fetches (7.5% for PR, WS & HS)

Best Stale-n blocks on 85.6% of remote fetches

Iterations

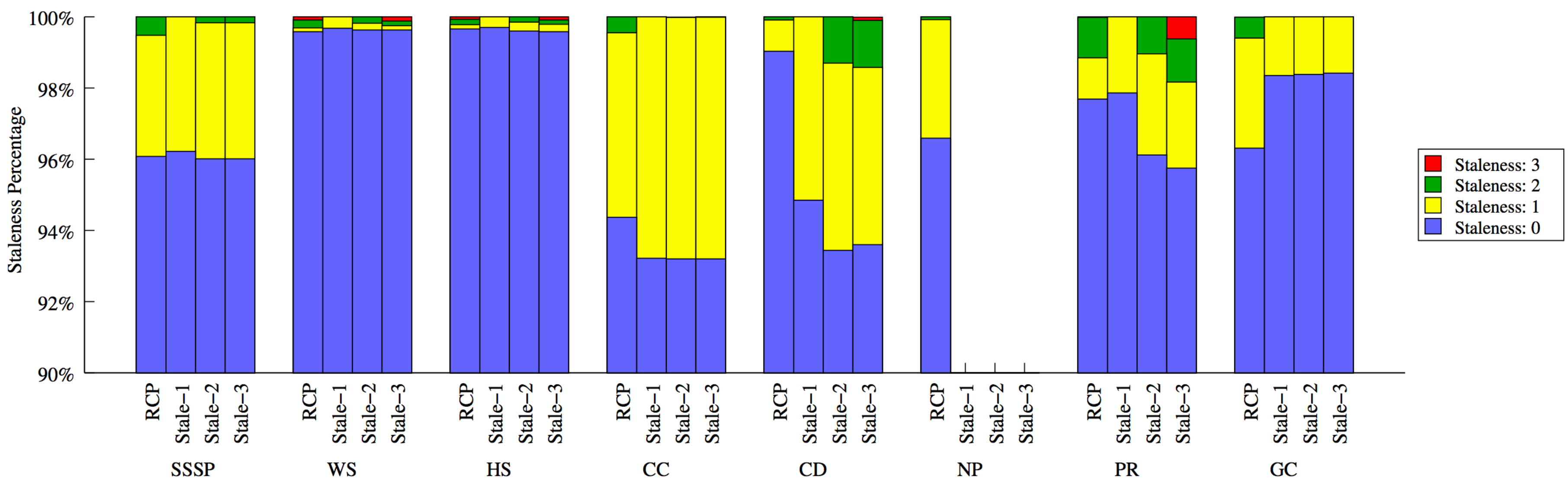


RCP requires 49.5% more iterations

Stale-2/Stale-3 require 146/176% more iterations

Staleness Percentage

97.4% of values have staleness 0; 2.2% of values have staleness 1



Graph Processing Frameworks

- Distributed memory
  - GraphLab [VLDB’12], Pregel [SIGMOD’10], PowerGraph [OSDI’12]
- Shared memory
  - Ligra [PPoPP’13], Grace [CIDR’13], Galois[PLDI’07]
- Out-of-core
  - GraphChi [OSDI’12], X-Stream [SOSP’13]

GraphLab

		SSSP	PR	GC	CC	NP
Orkut	**RCP**	161.88	822.95	92.79	90.31	2.35
	GraphLab	239.4	829.3	248.66	102.02	140.5
LiveJournal	**RCP**	21.73	343.96	17.44	22.09	133.43
	GraphLab	15.7	295.1	X	66.99	150.2
Pokec	**RCP**	9.47	169.47	8.81	7.1	1.74
	GraphLab	8.7	159.9	173.47	40.52	76.4
HiggsTwitter	**RCP**	2.5	15.64	3.59	4.1	0.48
	GraphLab	5.5	X	263.45	16.21	32.5
RoadNetCA	**RCP**	49.47	7.70	0.93	56.96	16.51
	GraphLab	60.3	88.4	50.22	220.9	37.4
RoadNetTX	**RCP**	44.21	5.05	0.53	50.94	15.83
	GraphLab	18.3	78	60.76	115.6	X

- RCP compares favorably with GraphLab
- RCP is orthogonal to these frameworks
  - Can be used in their asynchronous engines

Other Experiments

- Different inputs
- Overhead study
- Design choices
    - Invalidates v/s updates
    - Sensitivity to object size
    - Sensitivity to writes
    - Sensitivity to communication delay
- Different cluster sizes

Conclusion

- Relaxing consistency is useful
  - With controlled use of staleness
  - Using refresh strategy
- Efficient than prior DSMs based on
  - Strict consistency
  - Delta consistency
- Processing Frameworks
  - Easier to code (Pregel)
  - Compares favorably (GraphLab)

Thanks

- GRASP
  - http://grasp.cs.ucr.edu
- Acknowledgements