Load Value Approximation

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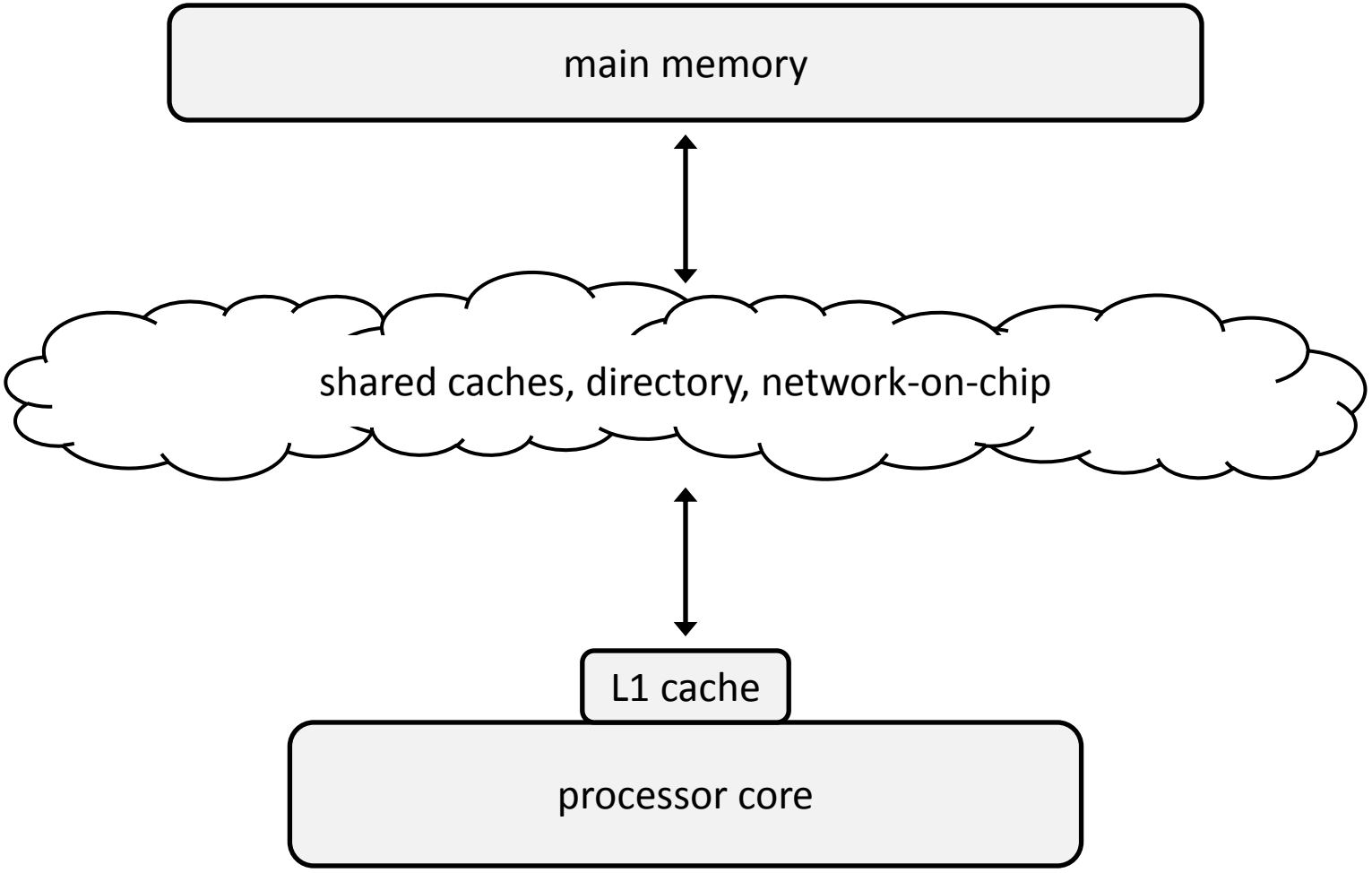
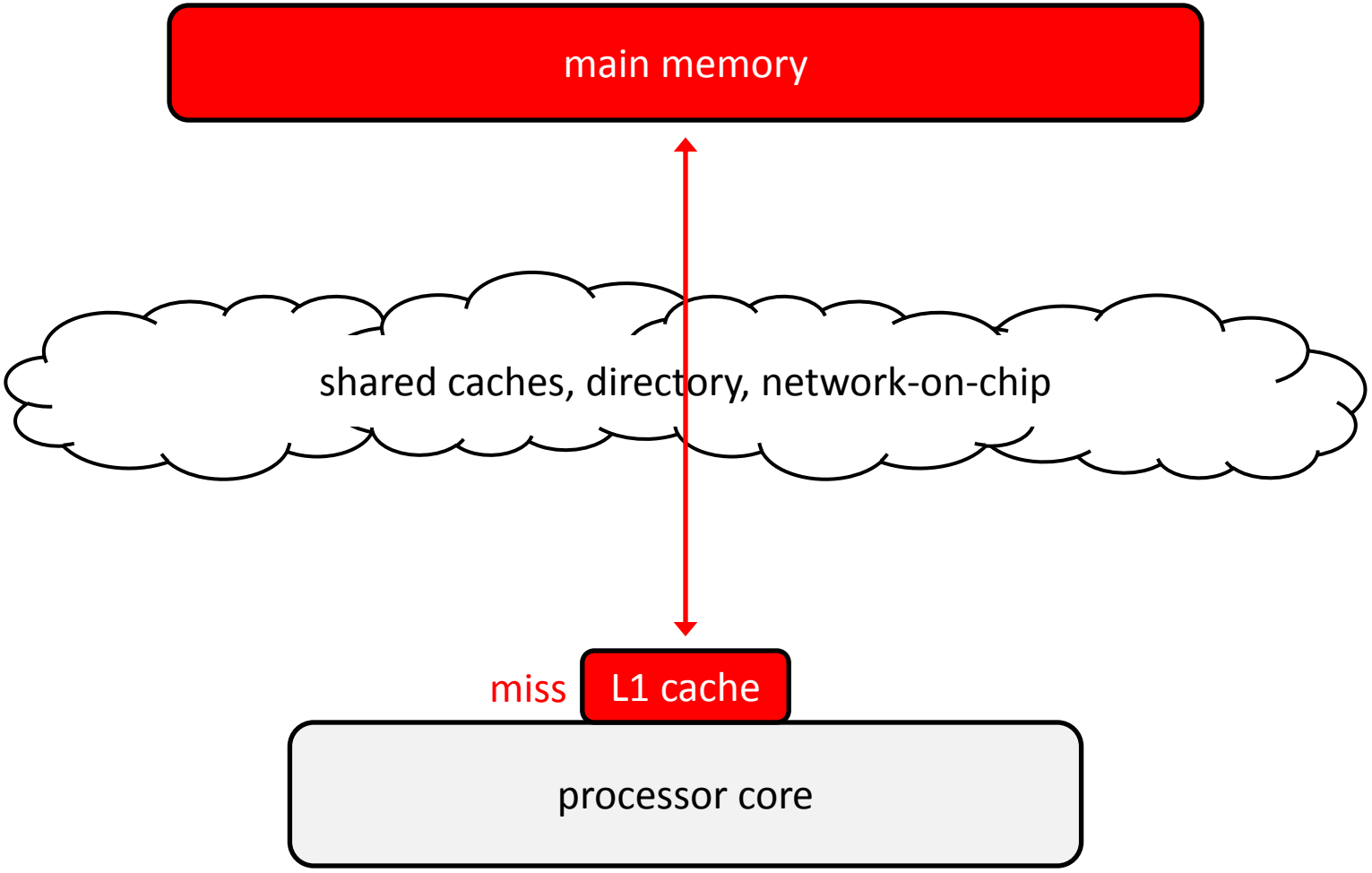
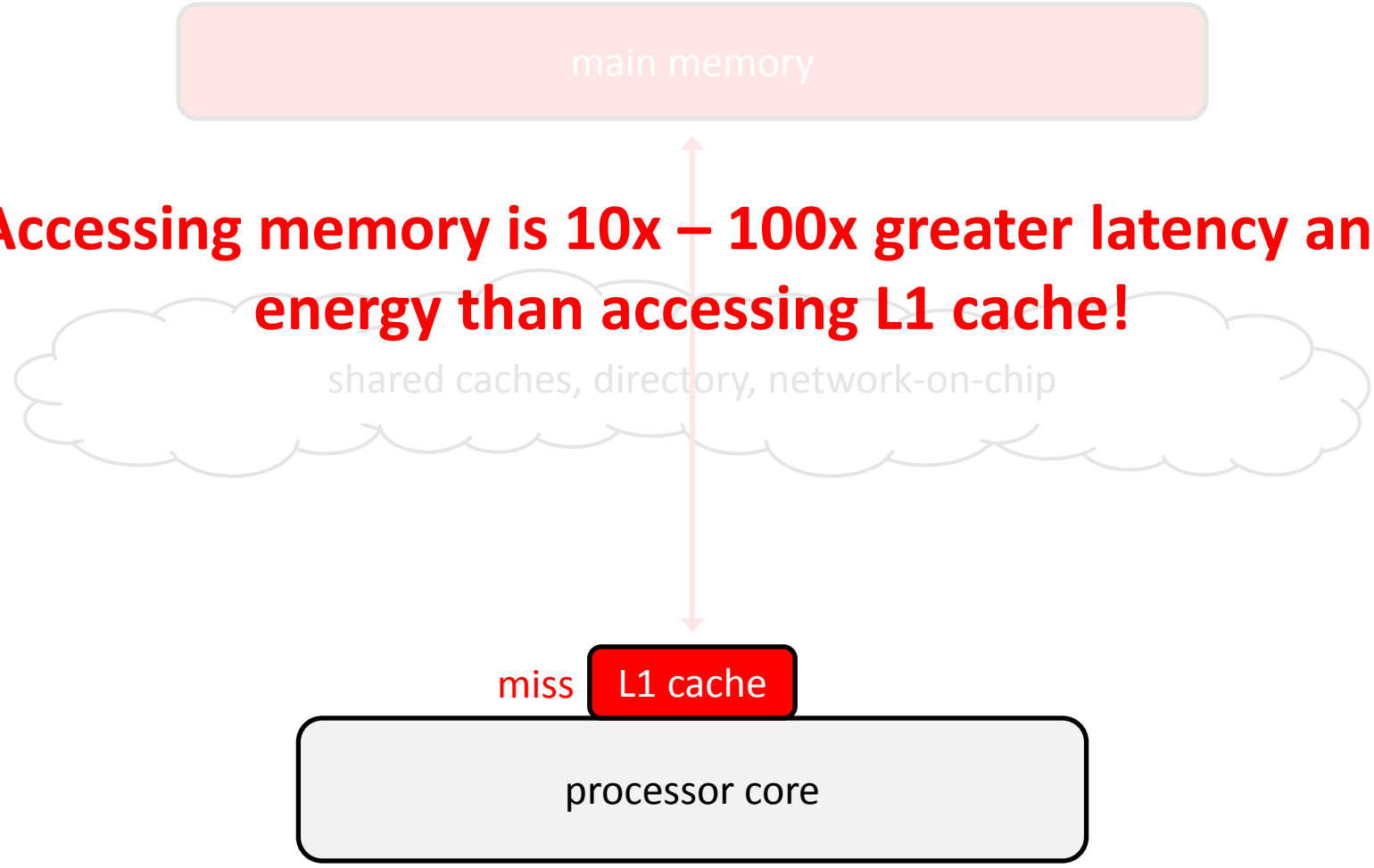
Accessing Memory



Accessing Memory



Accessing Memory



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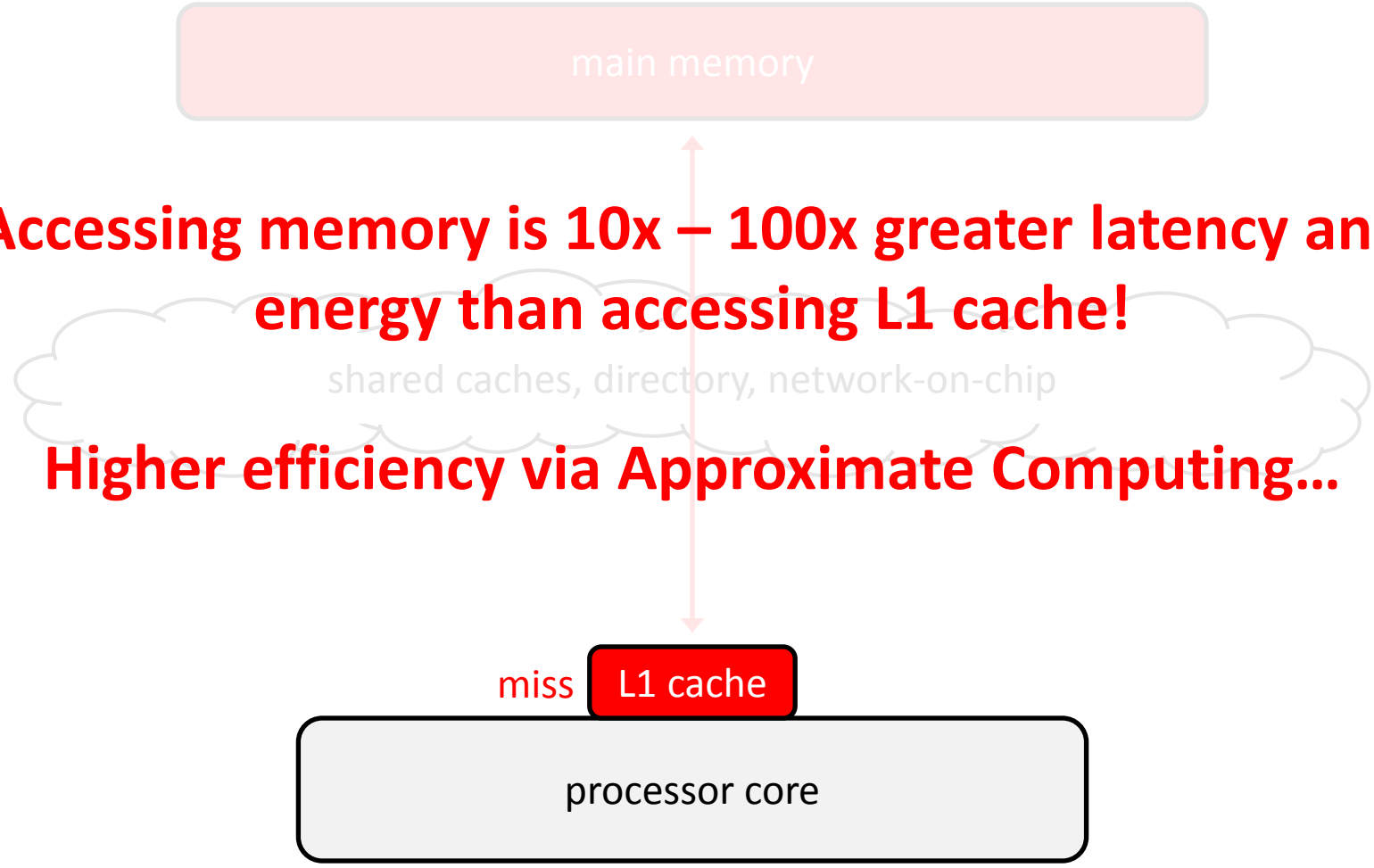
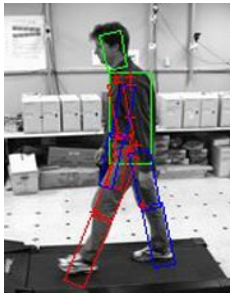
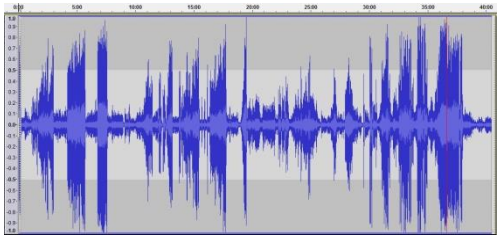
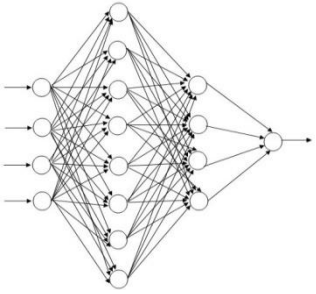
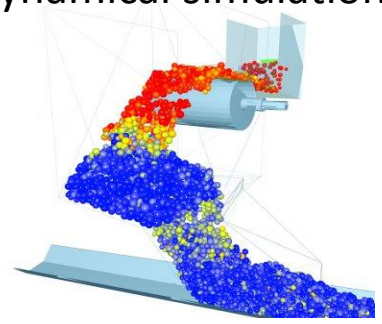
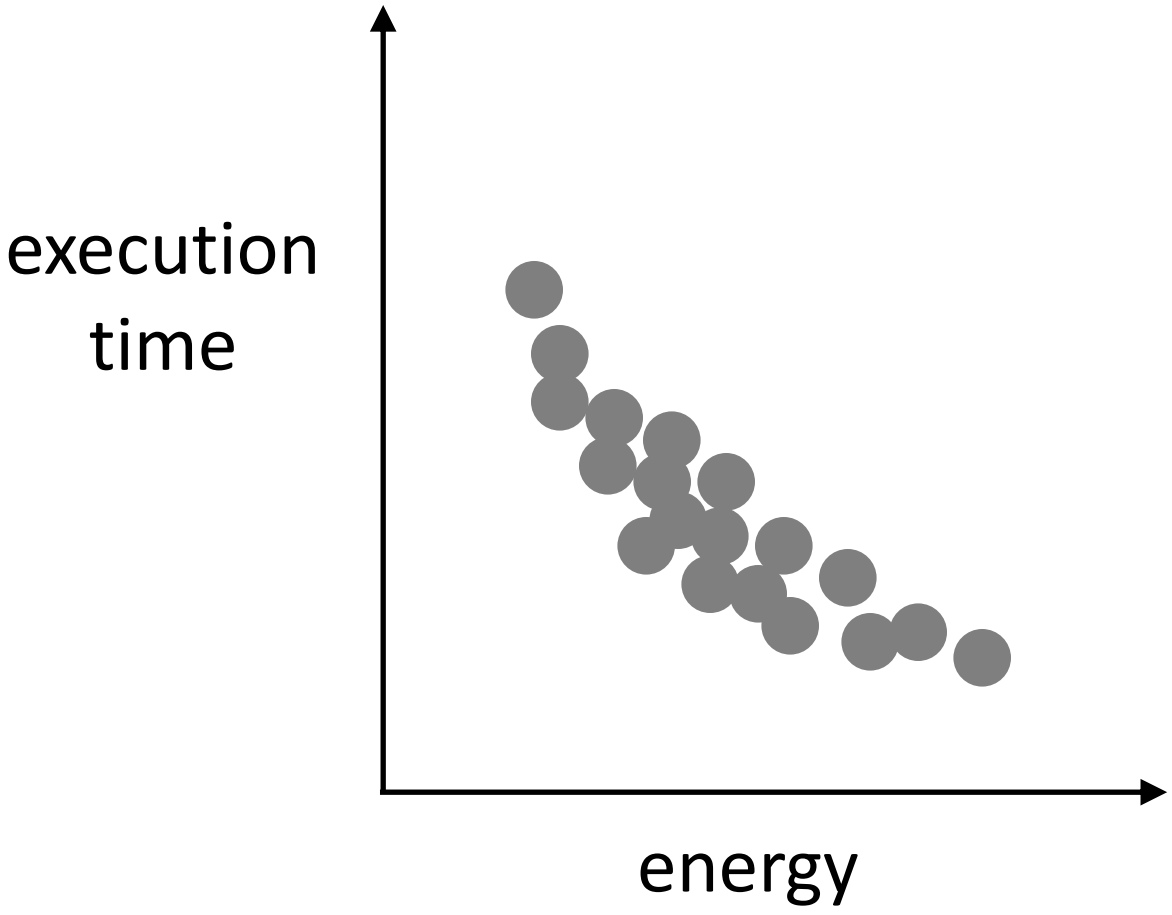


Approximate Computing

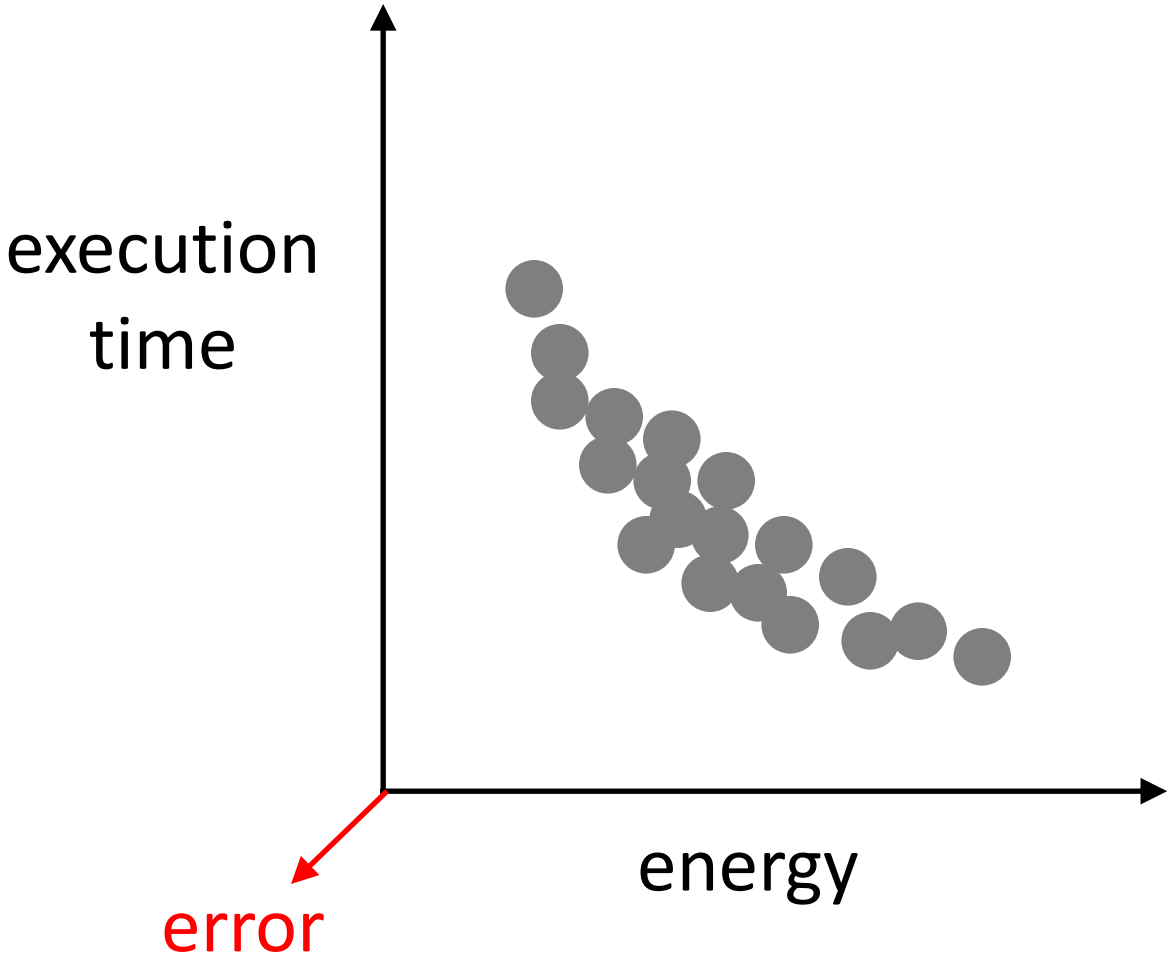
Not all computations need to be precise.

Data mining  http://www.zentut.com/	Computer vision  http://www.cc.gatech.edu/~cnieto6/	Audio and video processing  http://themusicparlour.blogspot.ca/
Gaming  http://www.businessweek.com/	Machine learning  http://www.analyticbridge.com/	Dynamical simulation  http://www.scientific-computing.com/

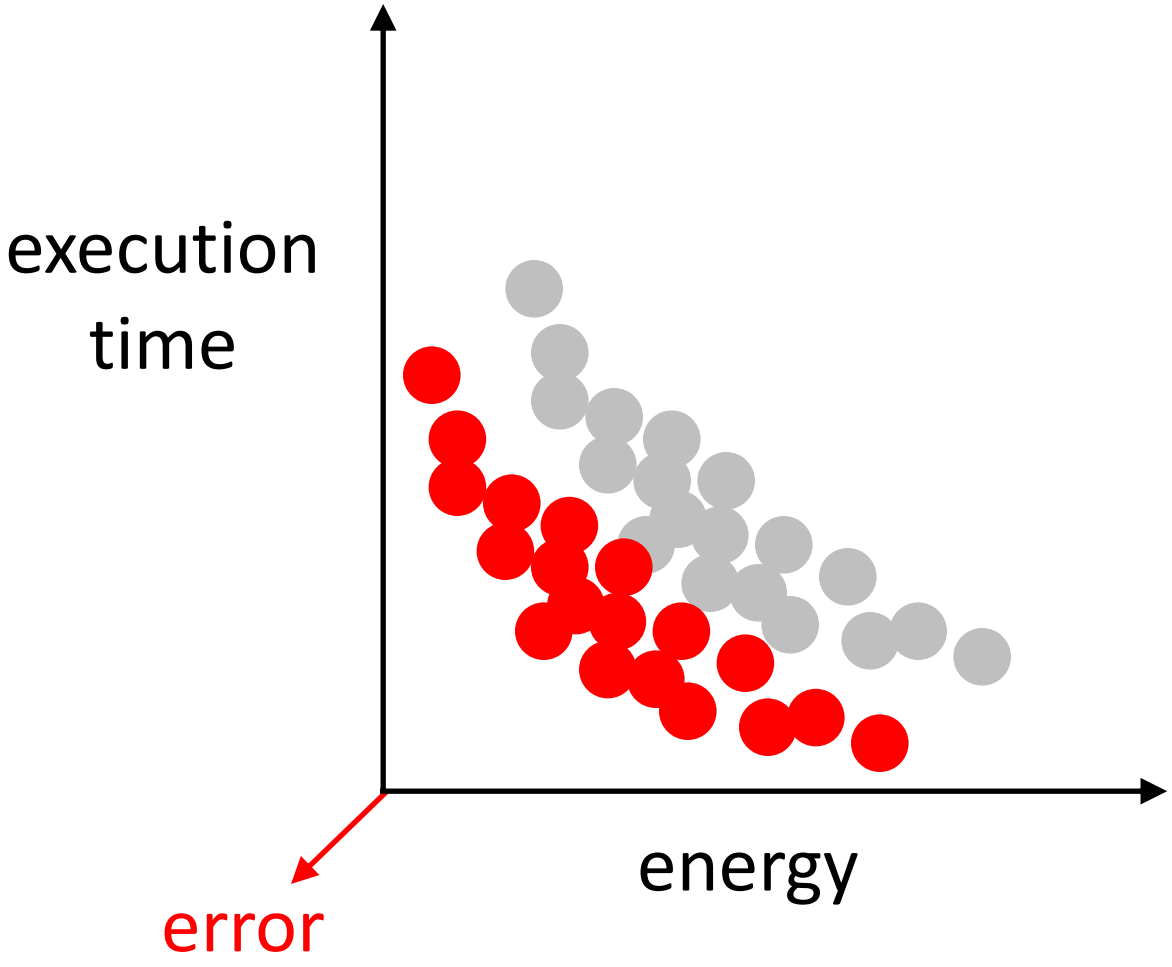
Approximate Computing



Approximate Computing



Approximate Computing



Approximate Computing

Many applications can tolerate approximate data.

- 40% to nearly 100% of data footprint is approximate [Sampson, MICRO 2013].

Approximate Computing

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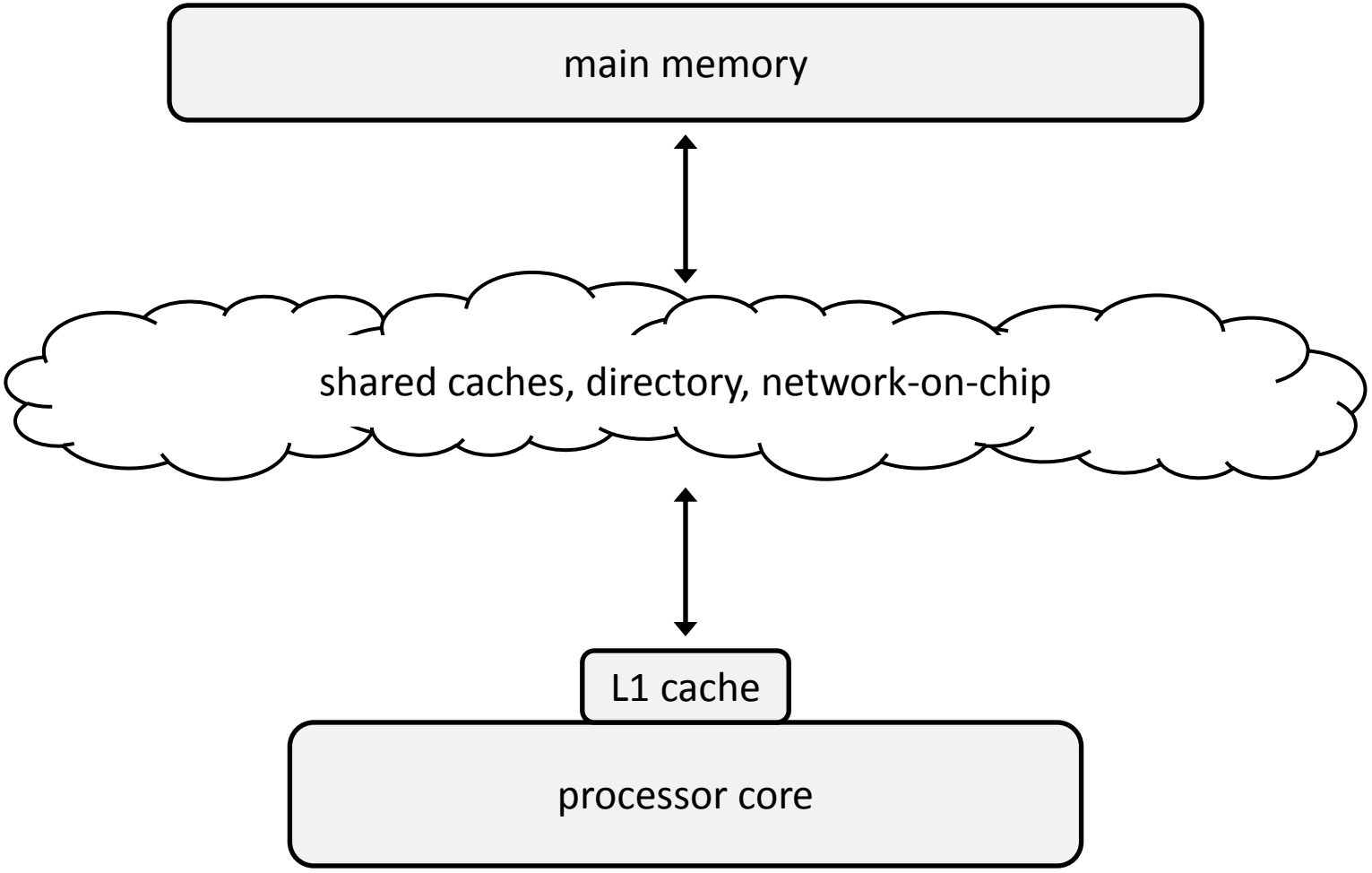
Approximate value locality:

- **Many data values are similar to or can be approximated from previously seen values.**

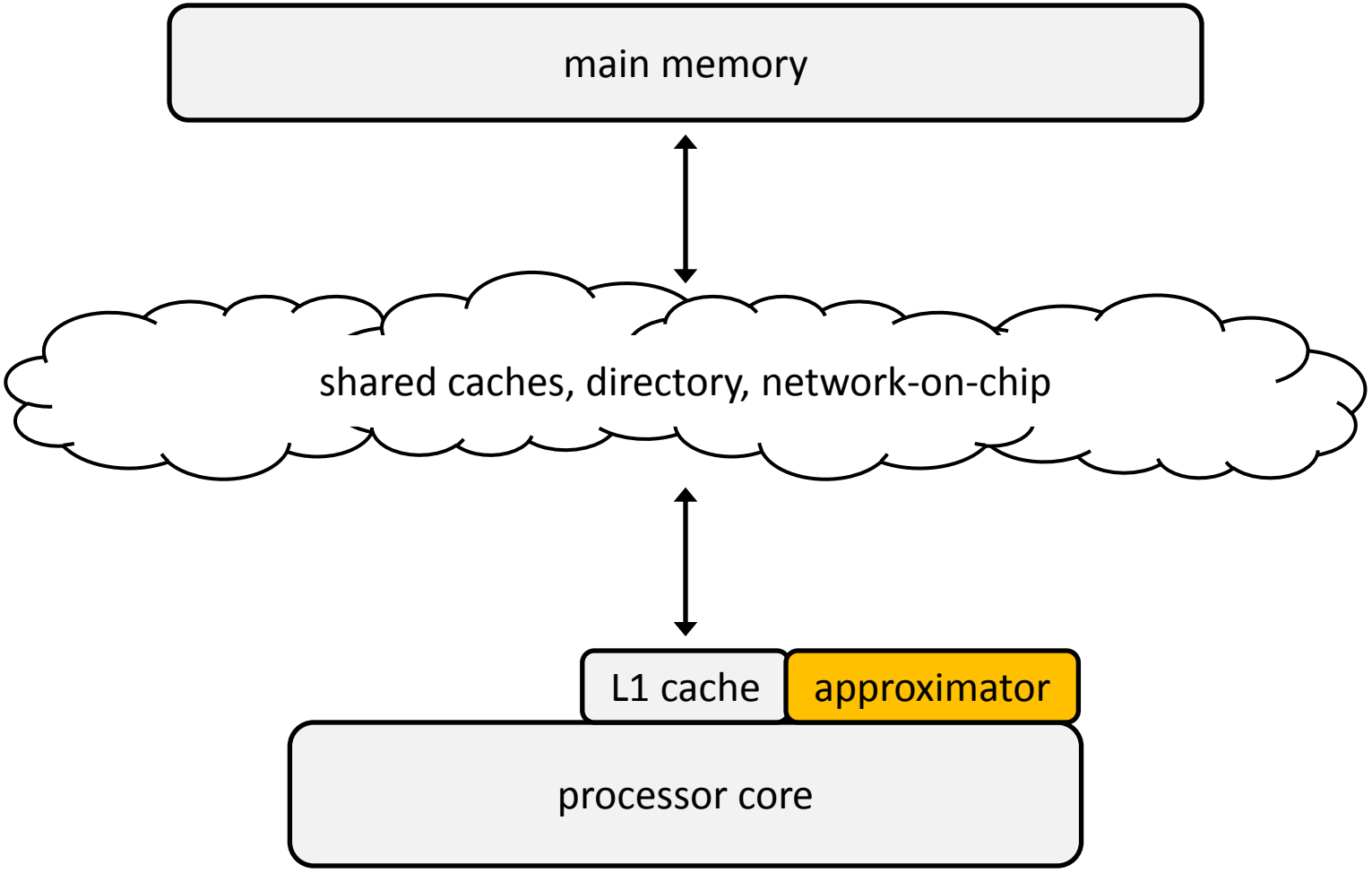
Outline

- Load Value Approximation
  - Non-Speculative Operation
- Approximator Design
  - Relaxed Confidence Windows
  - Approximation Degree
- Methodology
- Evaluation

Load Value Approximation



Load Value Approximation



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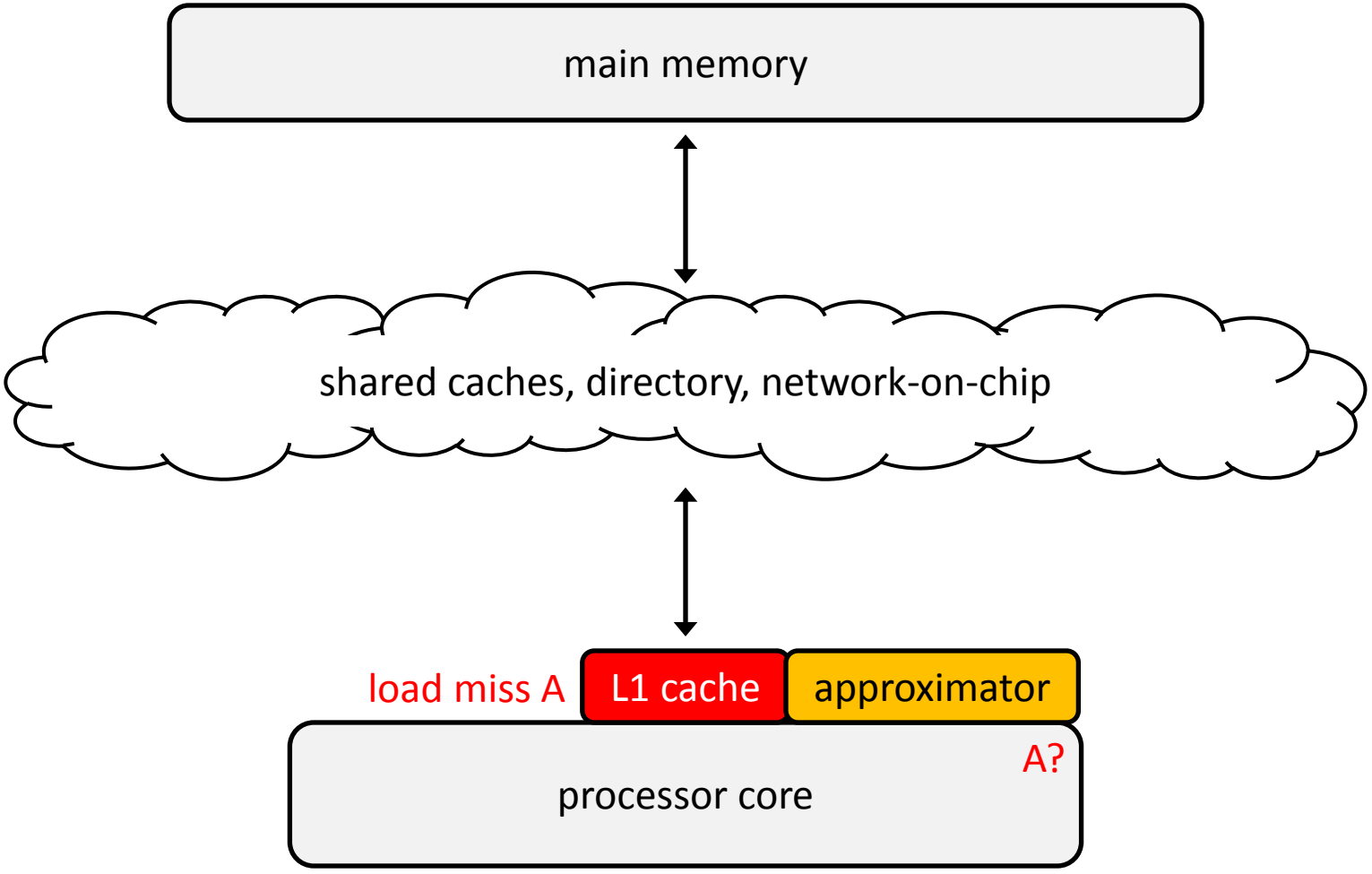

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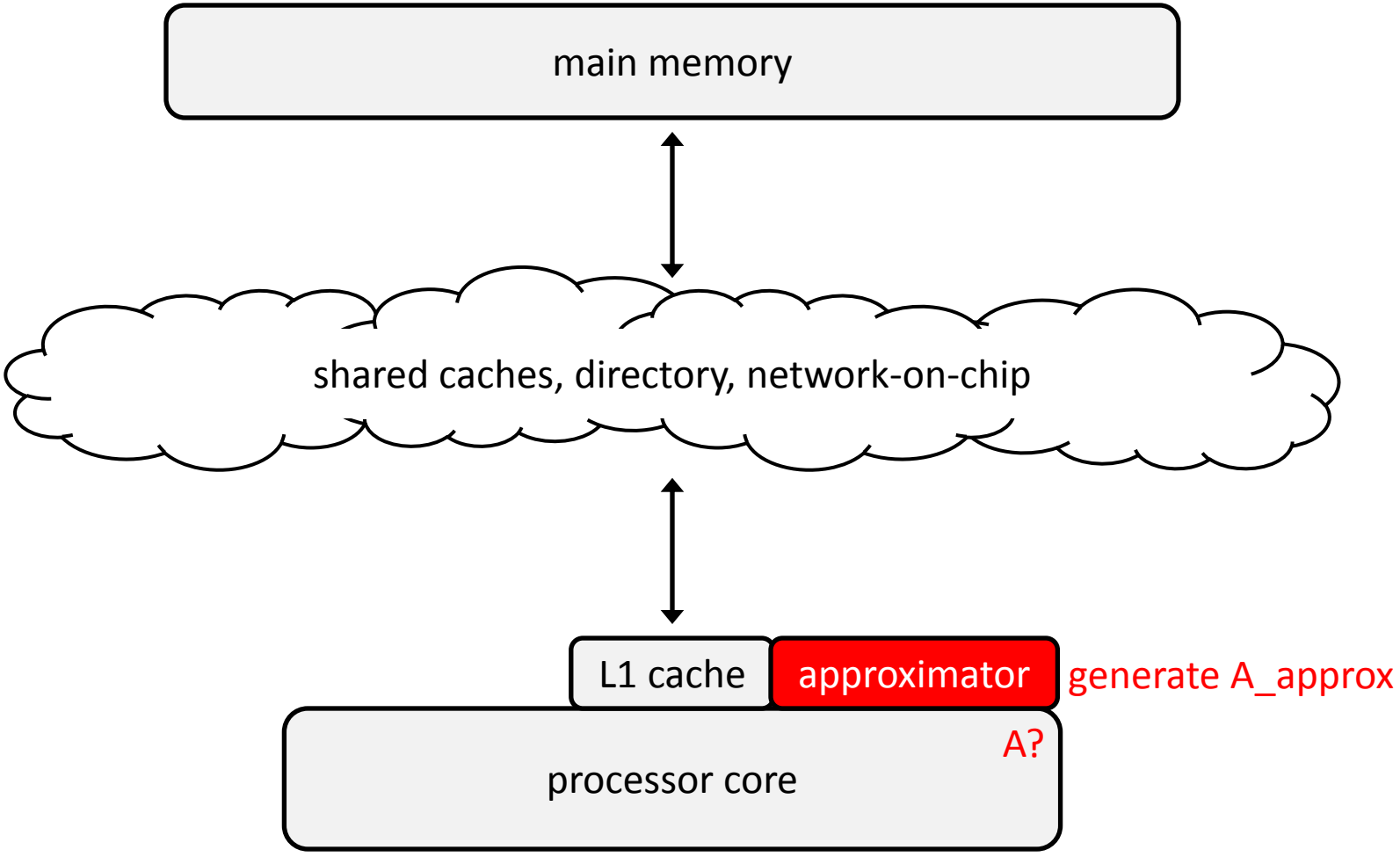
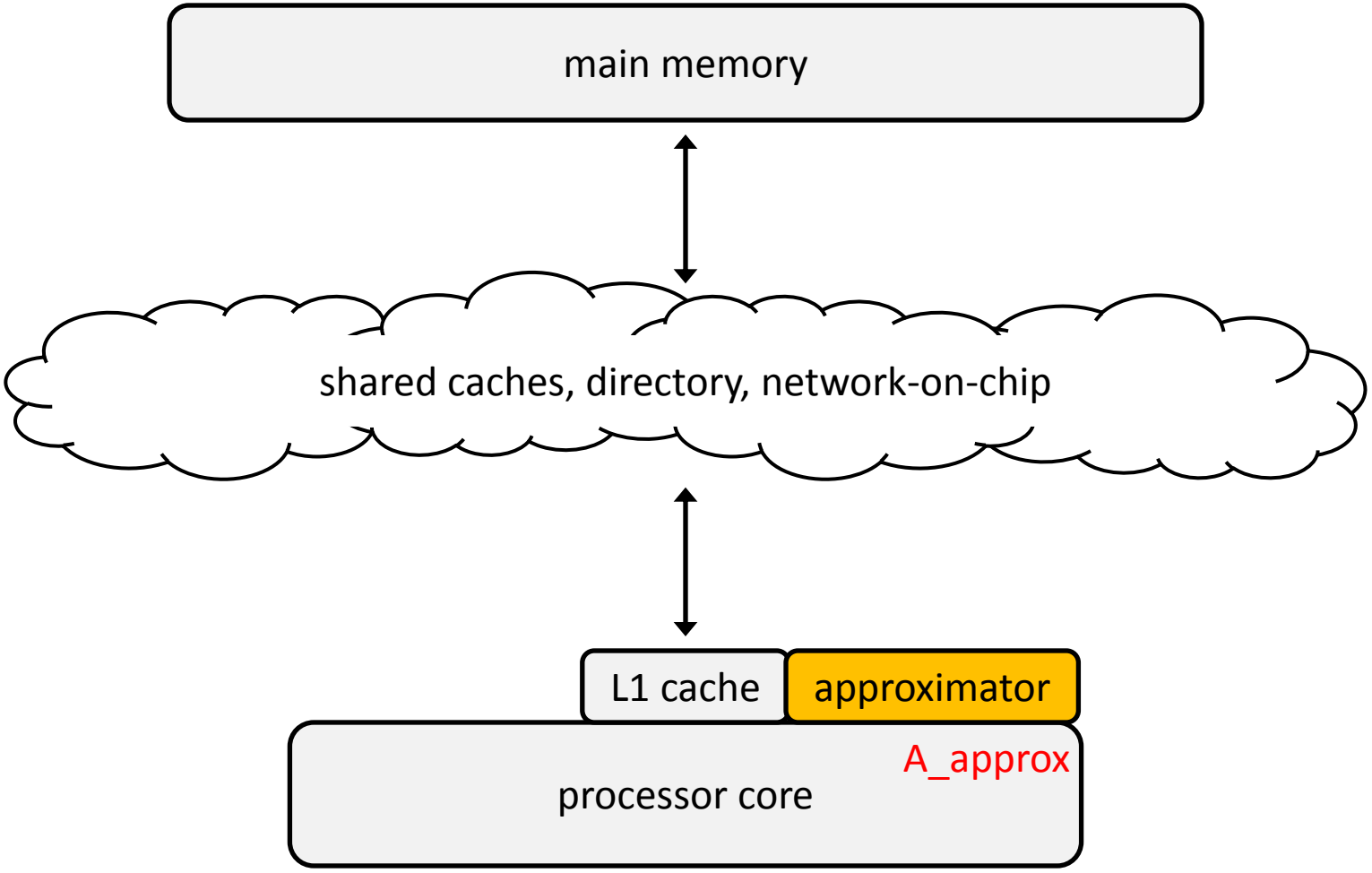


Load Value Approximation



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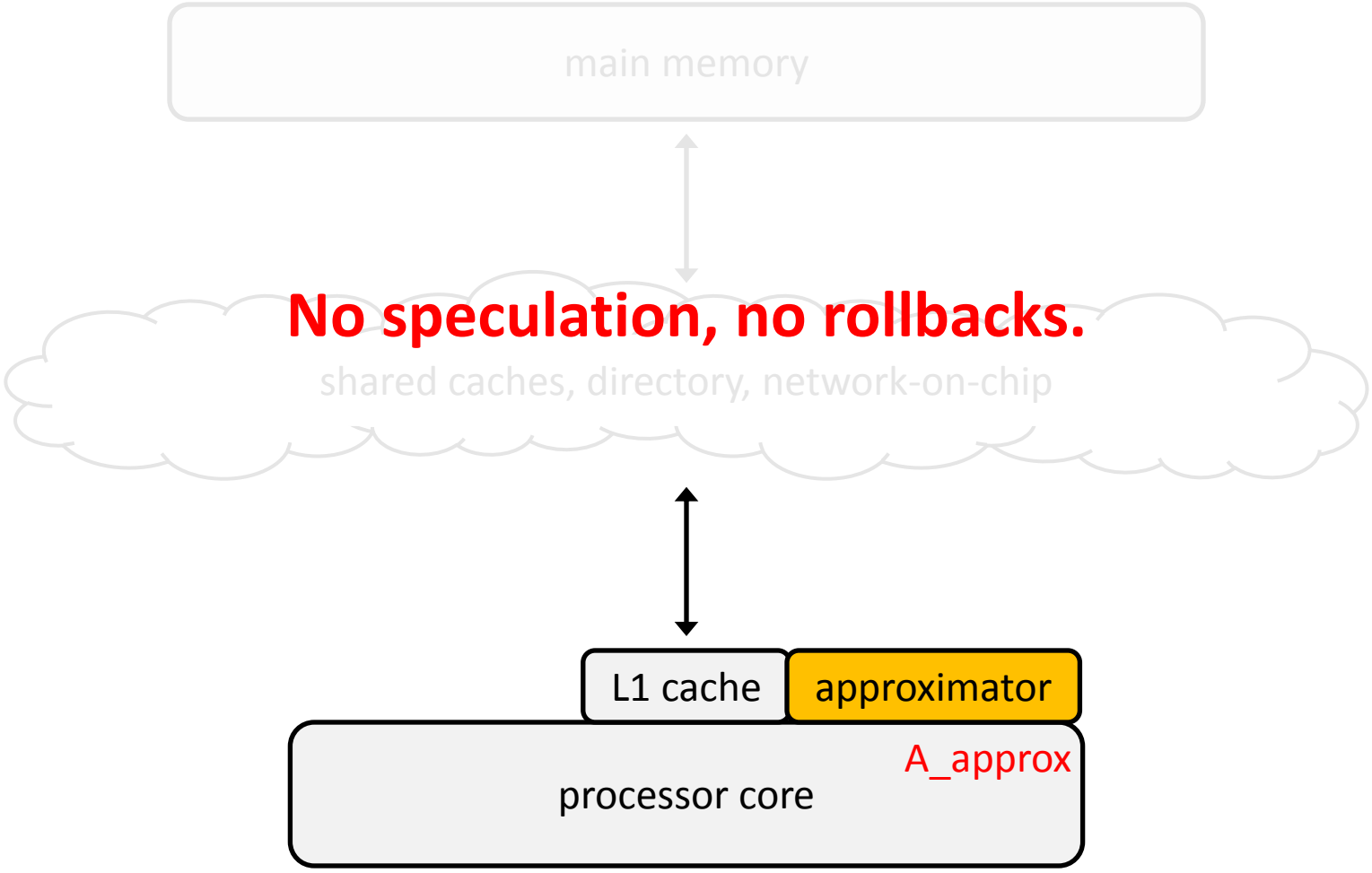

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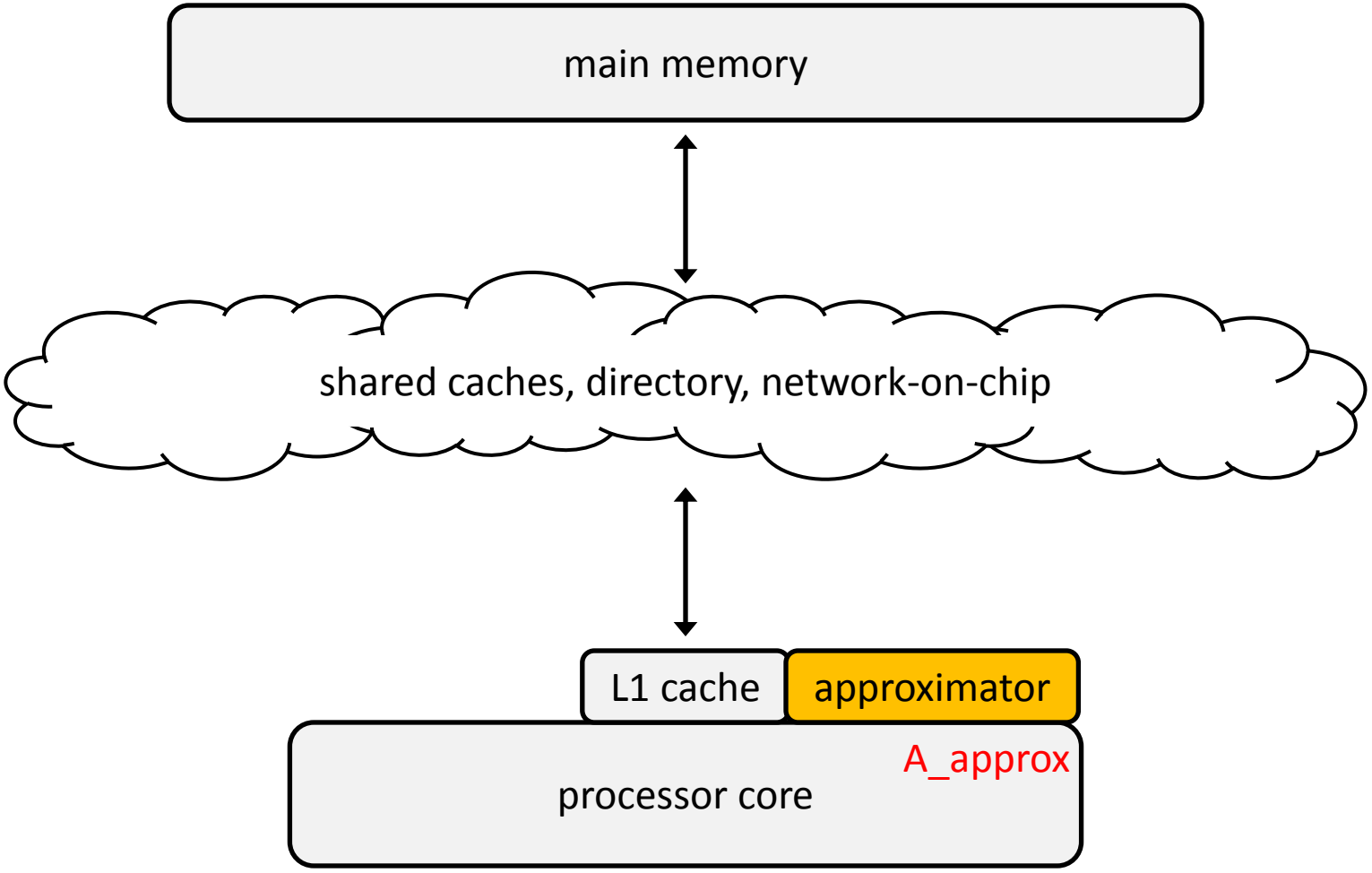

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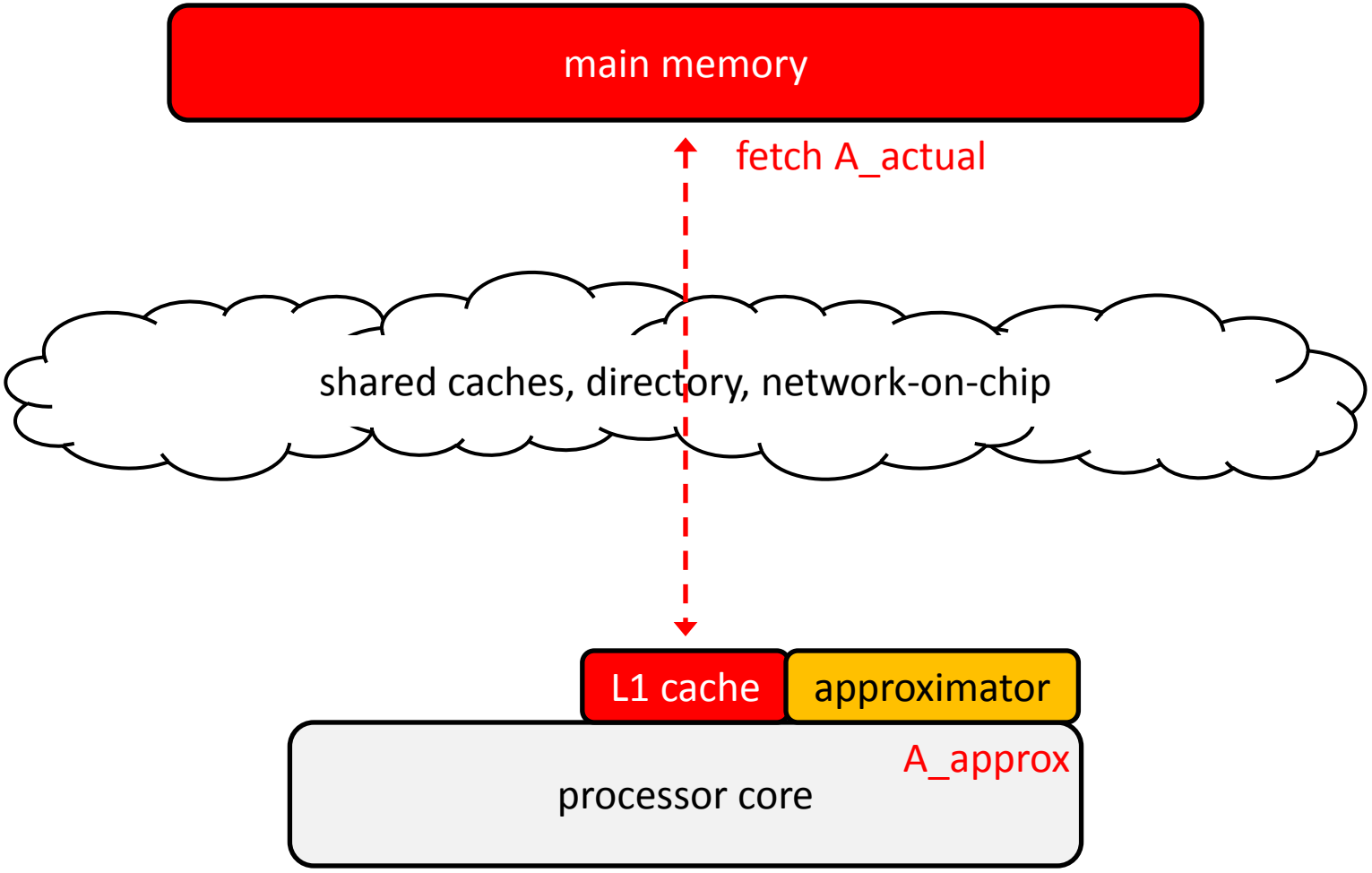

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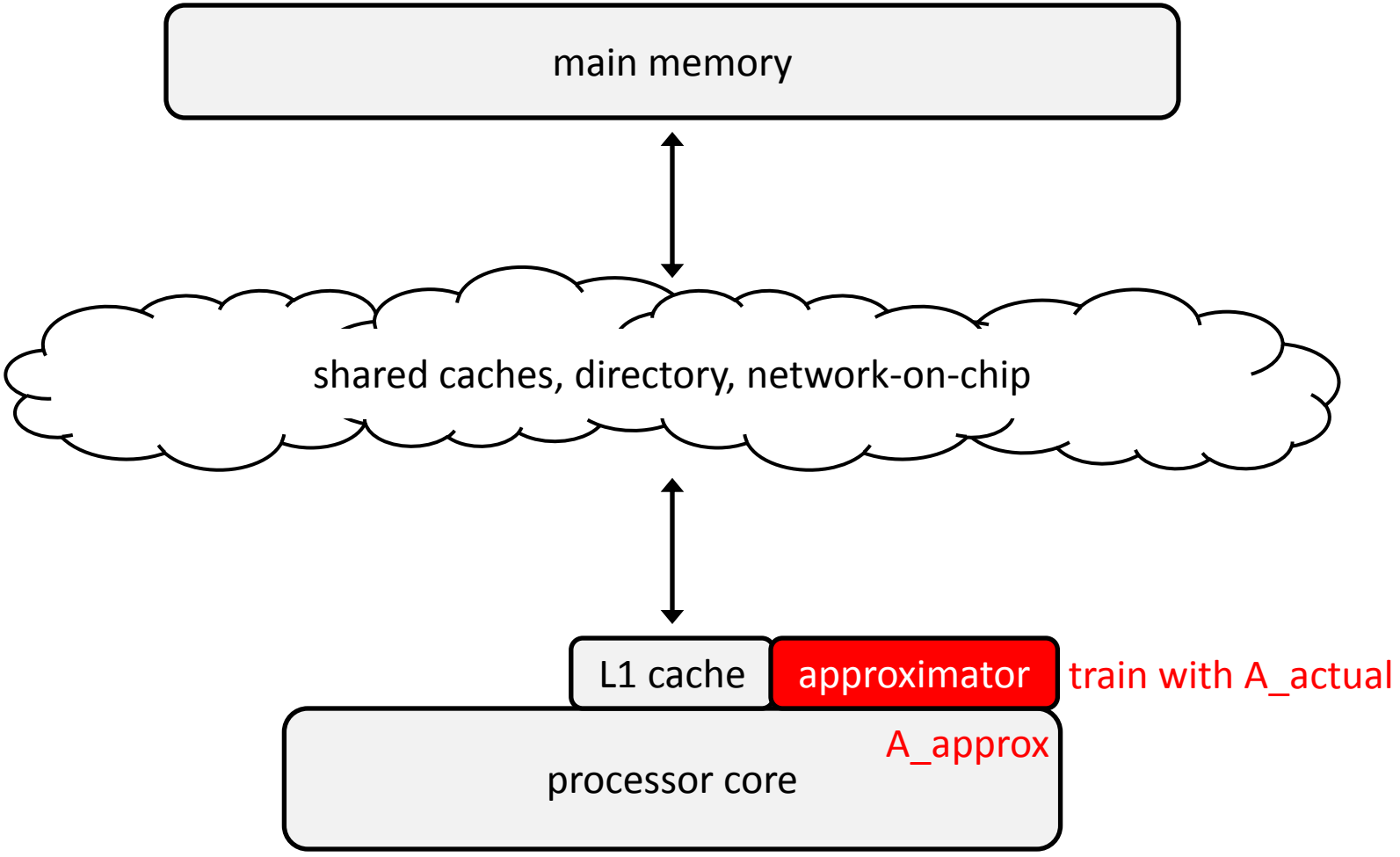

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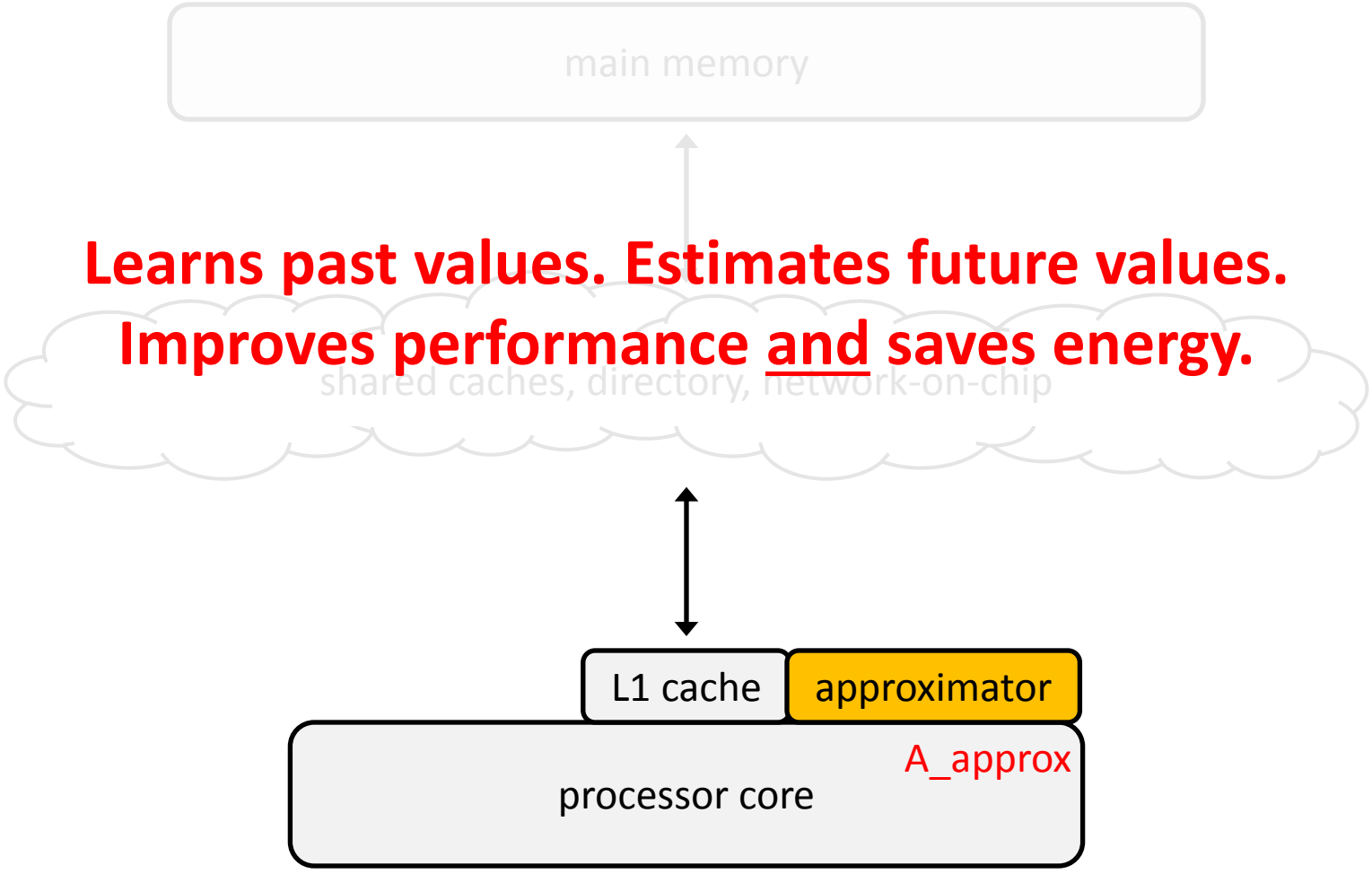
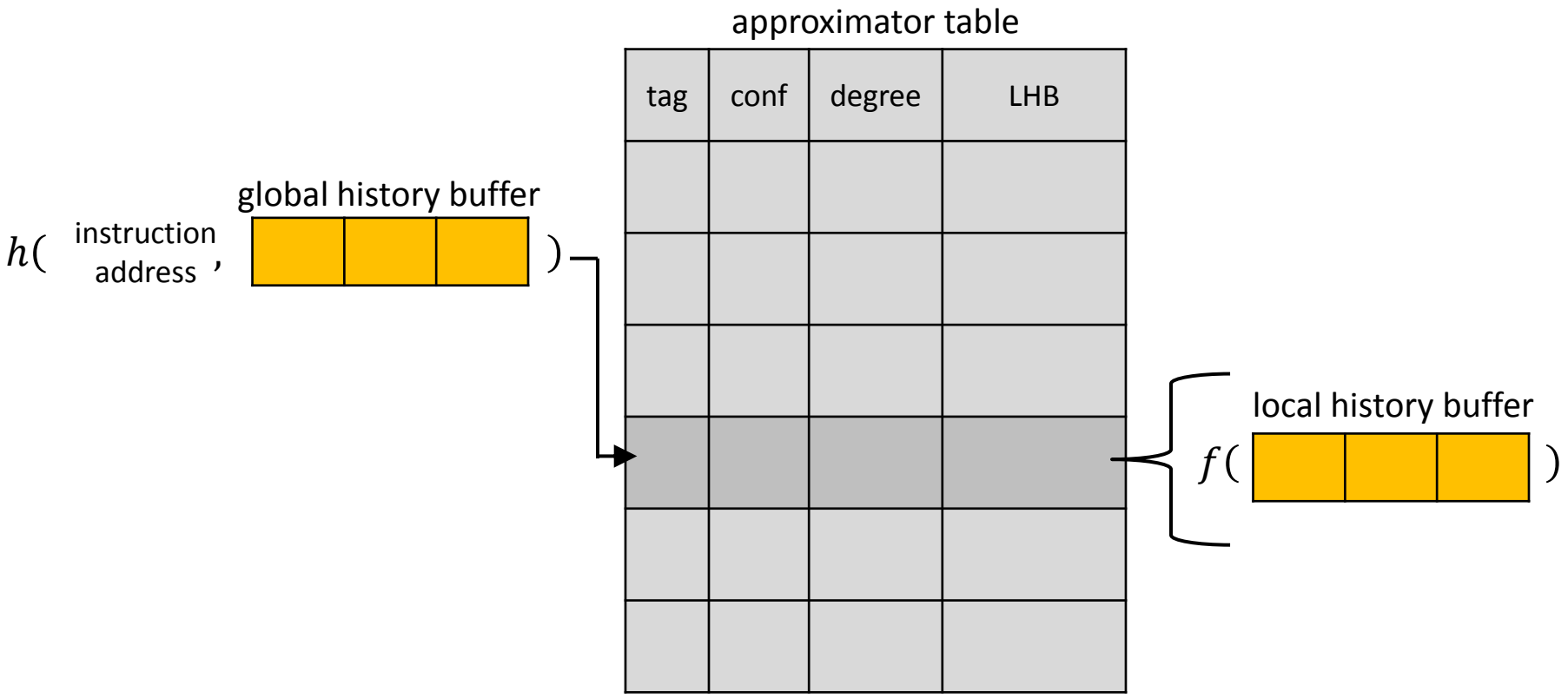


Learns past values. Estimates future values.
Improves performance and saves energy.

Approximator Design



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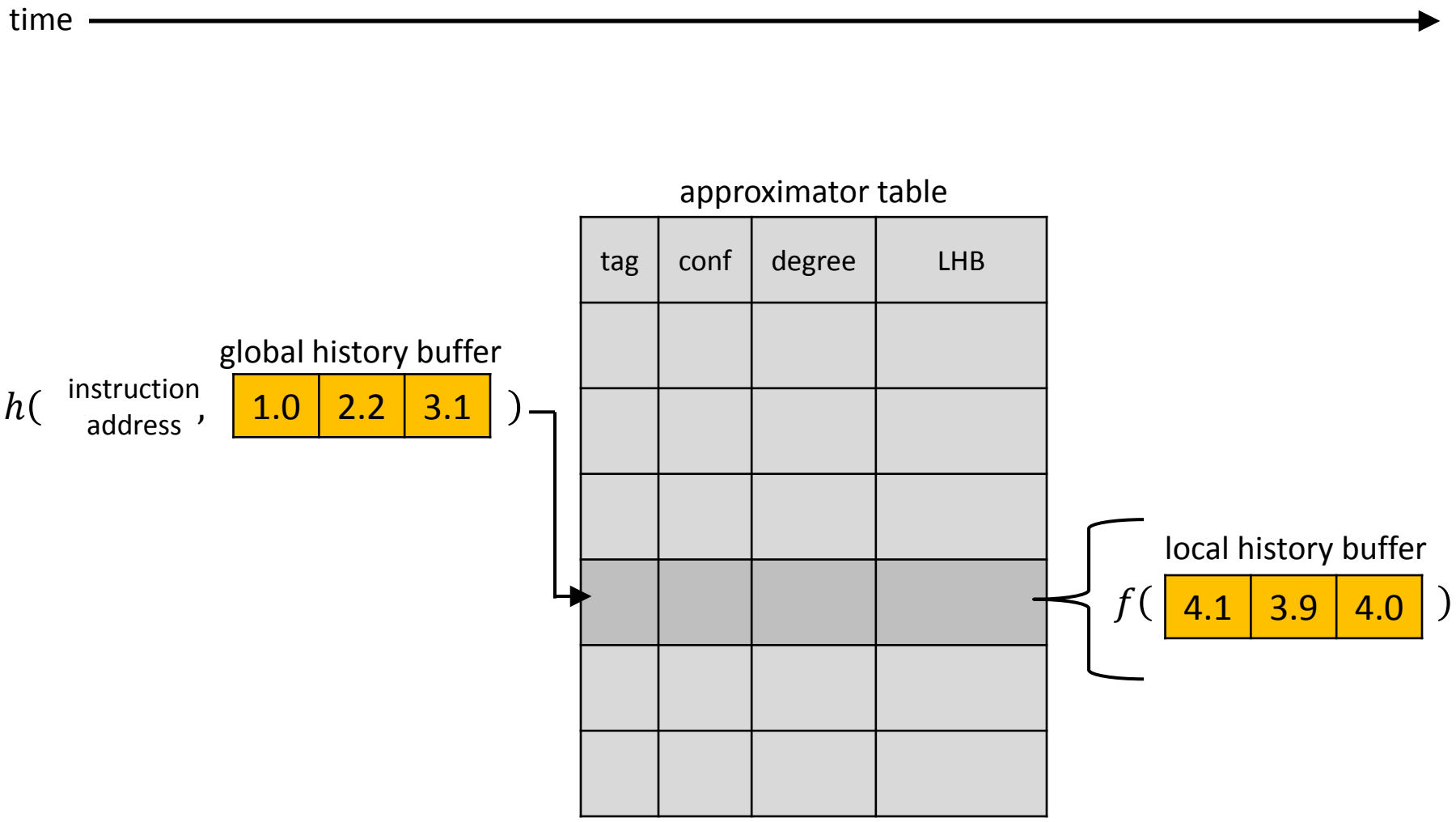

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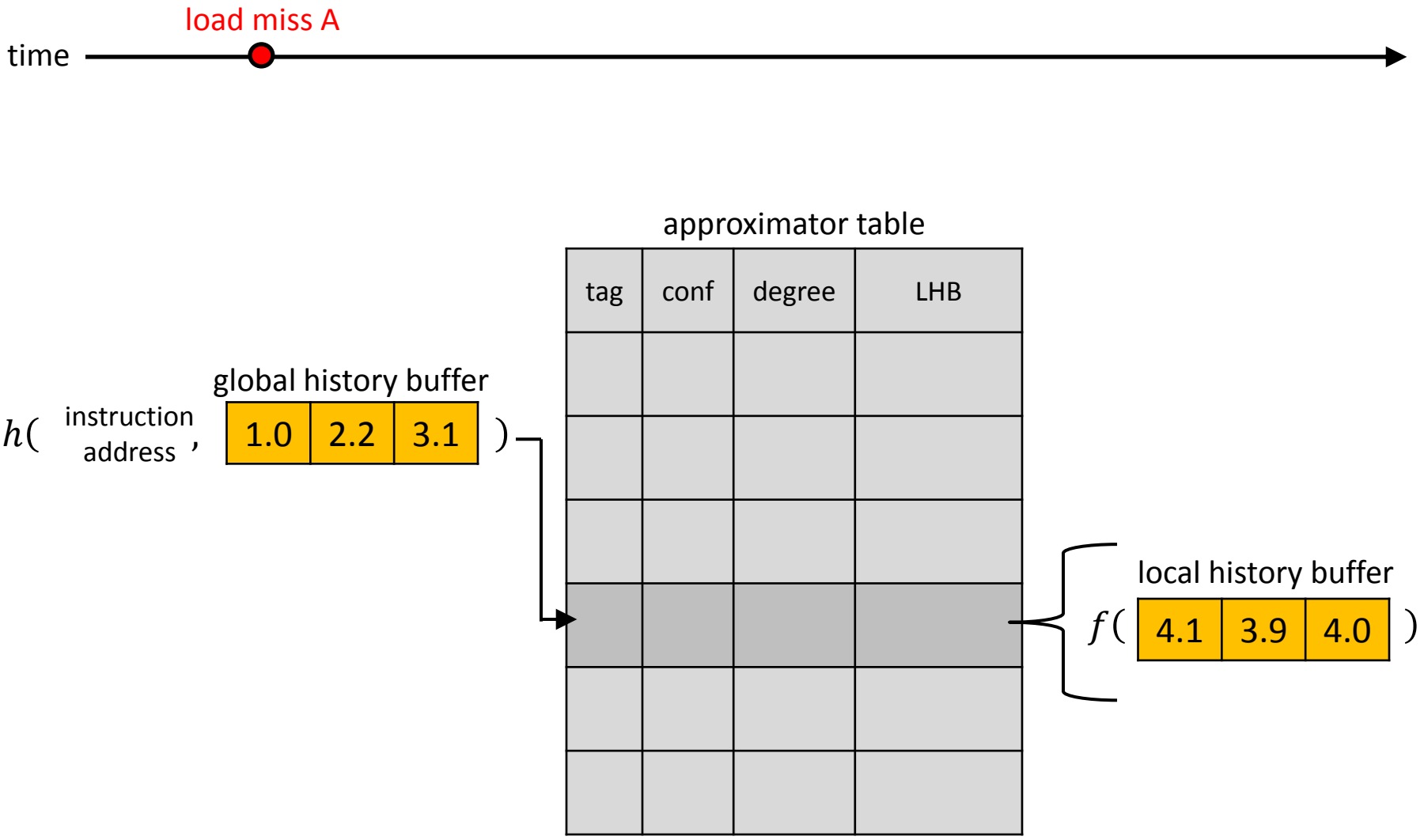

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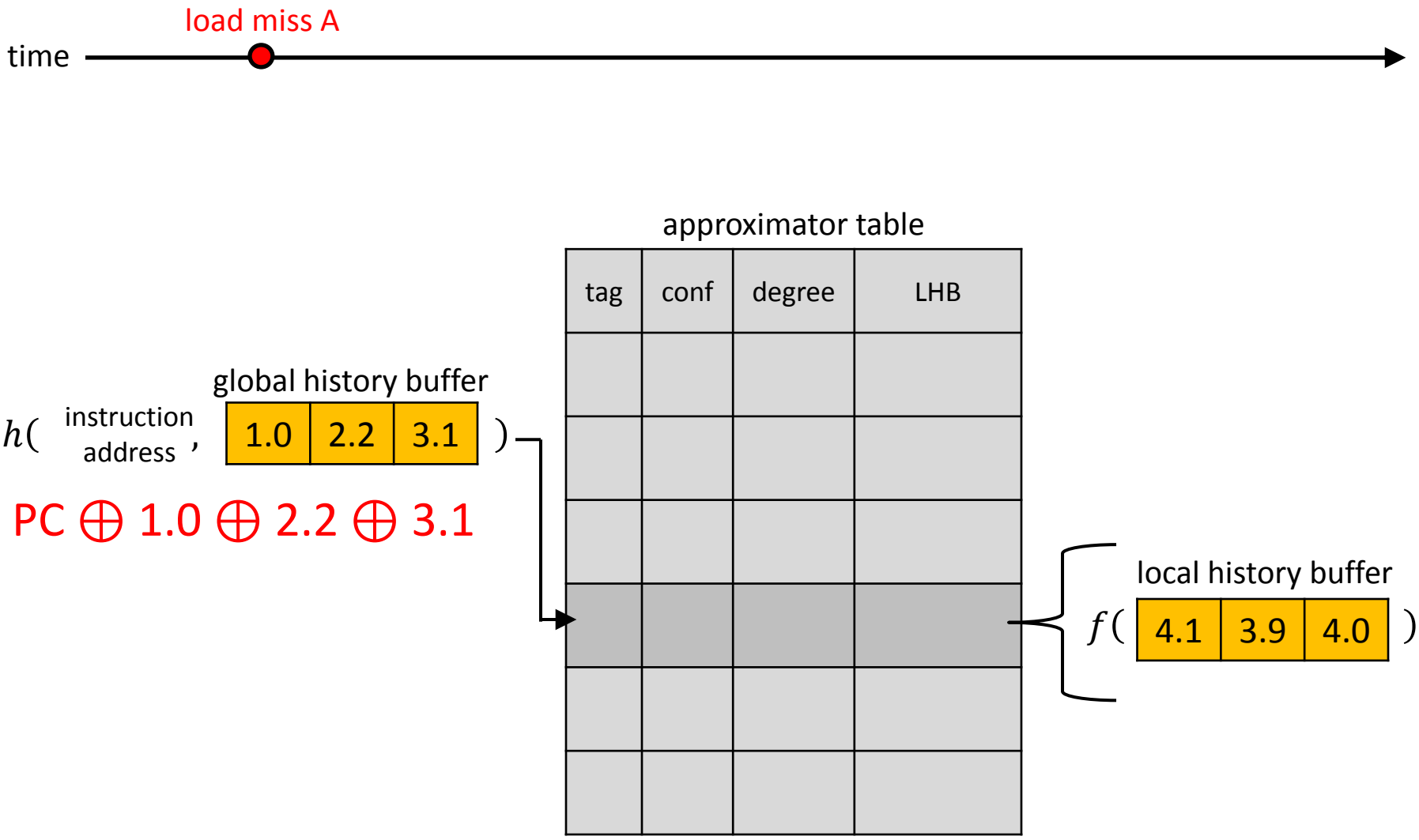

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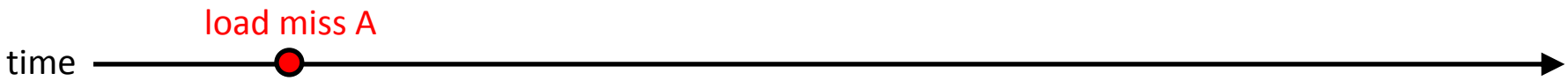


approximator table

tag	conf	degree	LHB

$h($ instruction address , global history buffer: 1.0 | 2.2 | 3.1 $)$

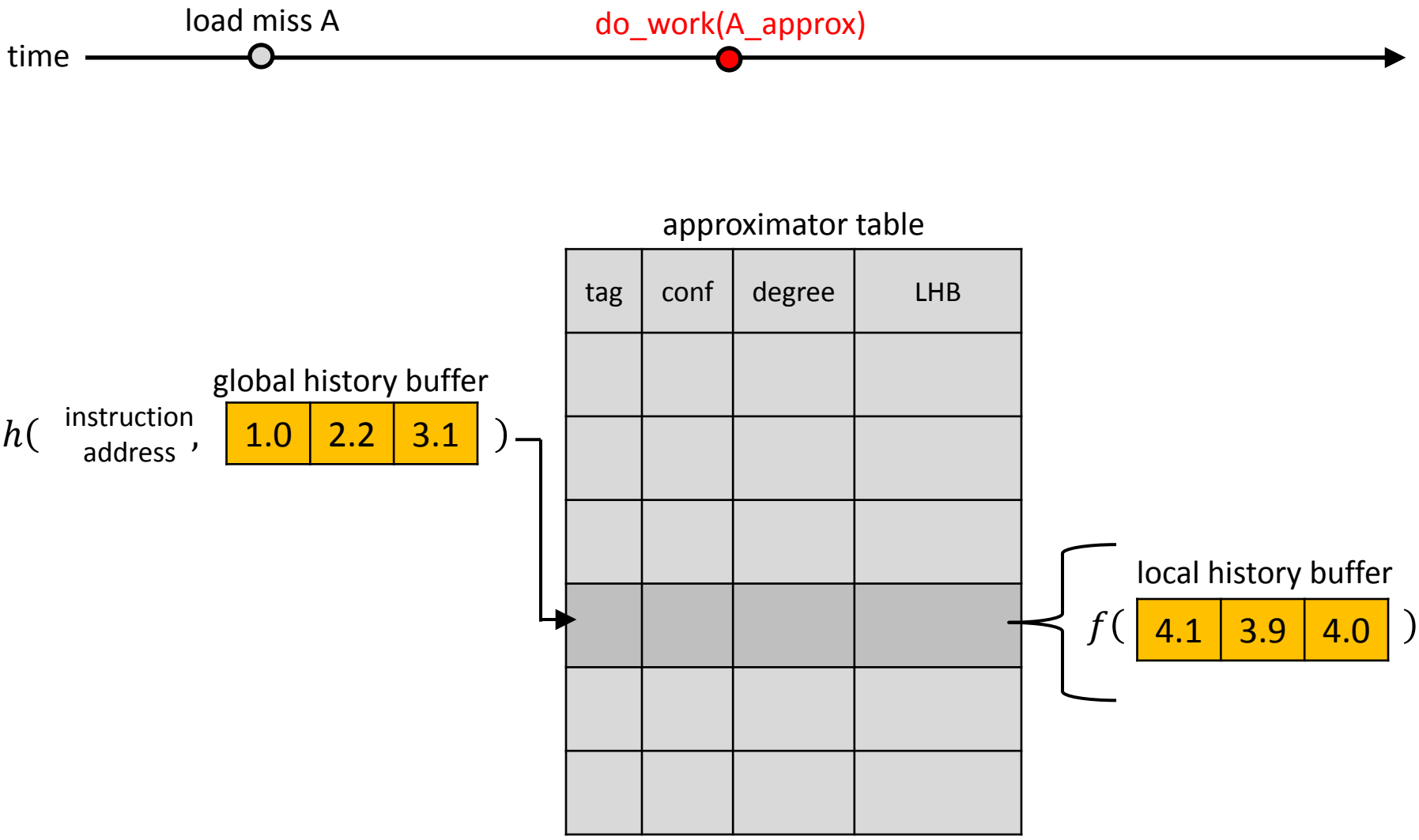
PC ⊕ 1.0 ⊕ 2.2 ⊕ 3.1

local history buffer: $f($ 4.1 | 3.9 | 4.0 $)$

(4.1 + 3.9 + 4.0) / 3

A_approx = 4.0

Approximator Design



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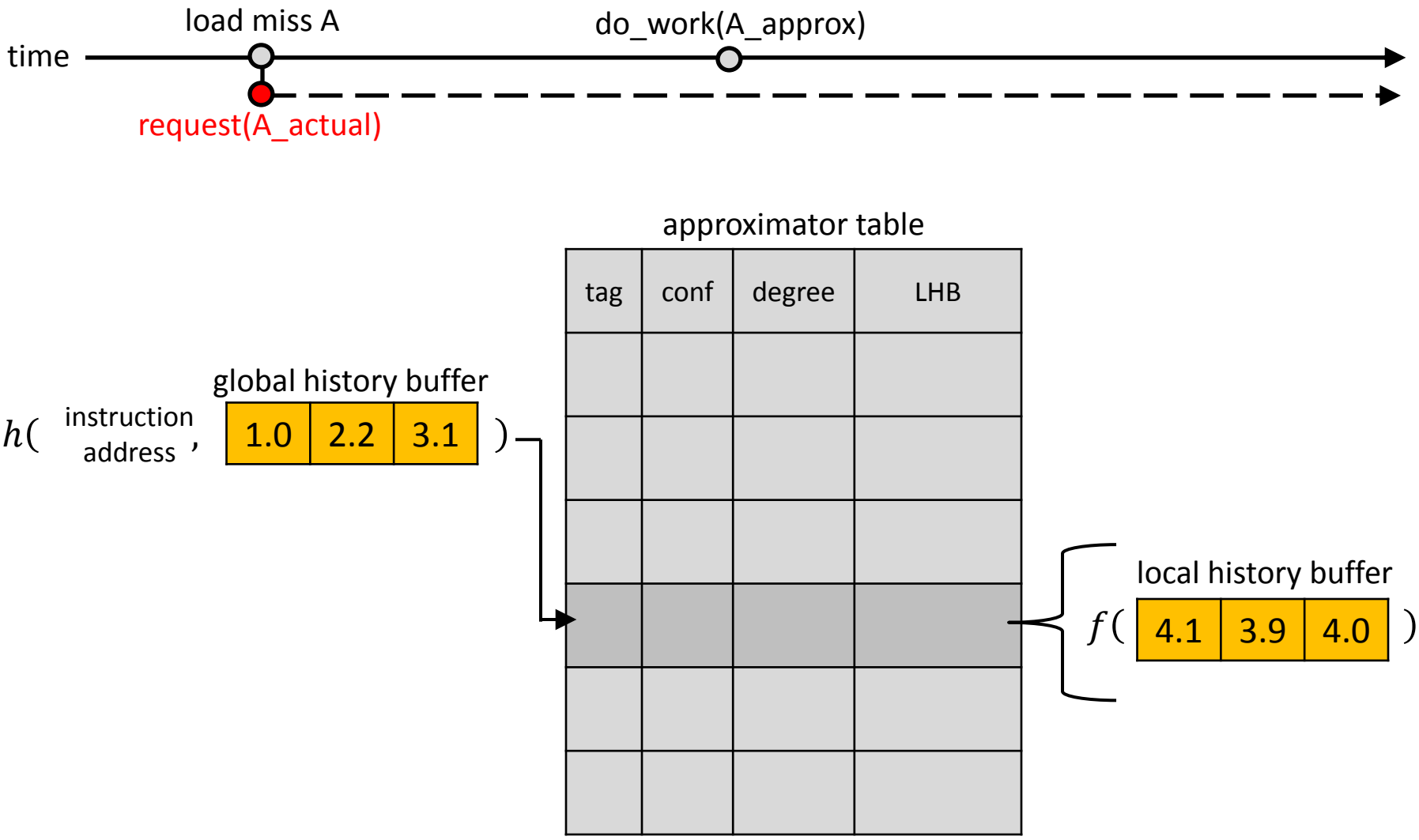

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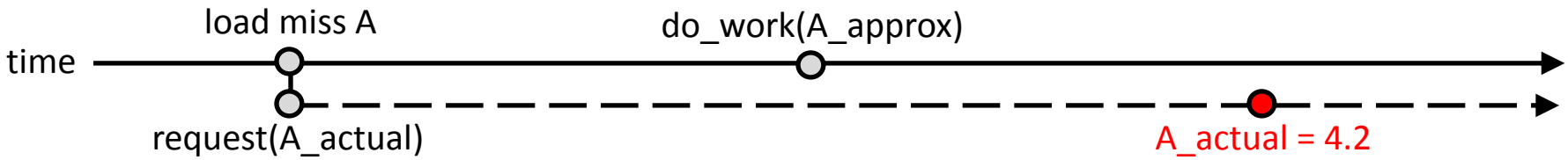

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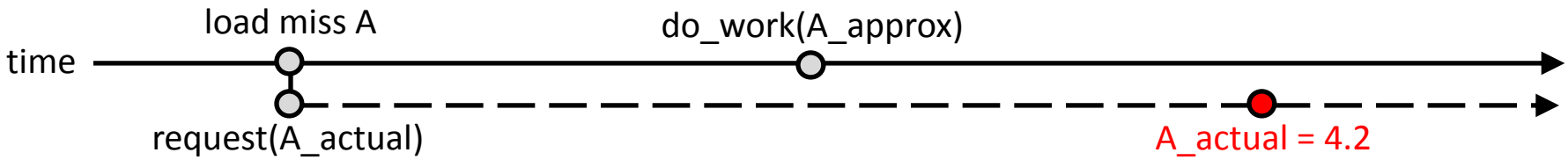
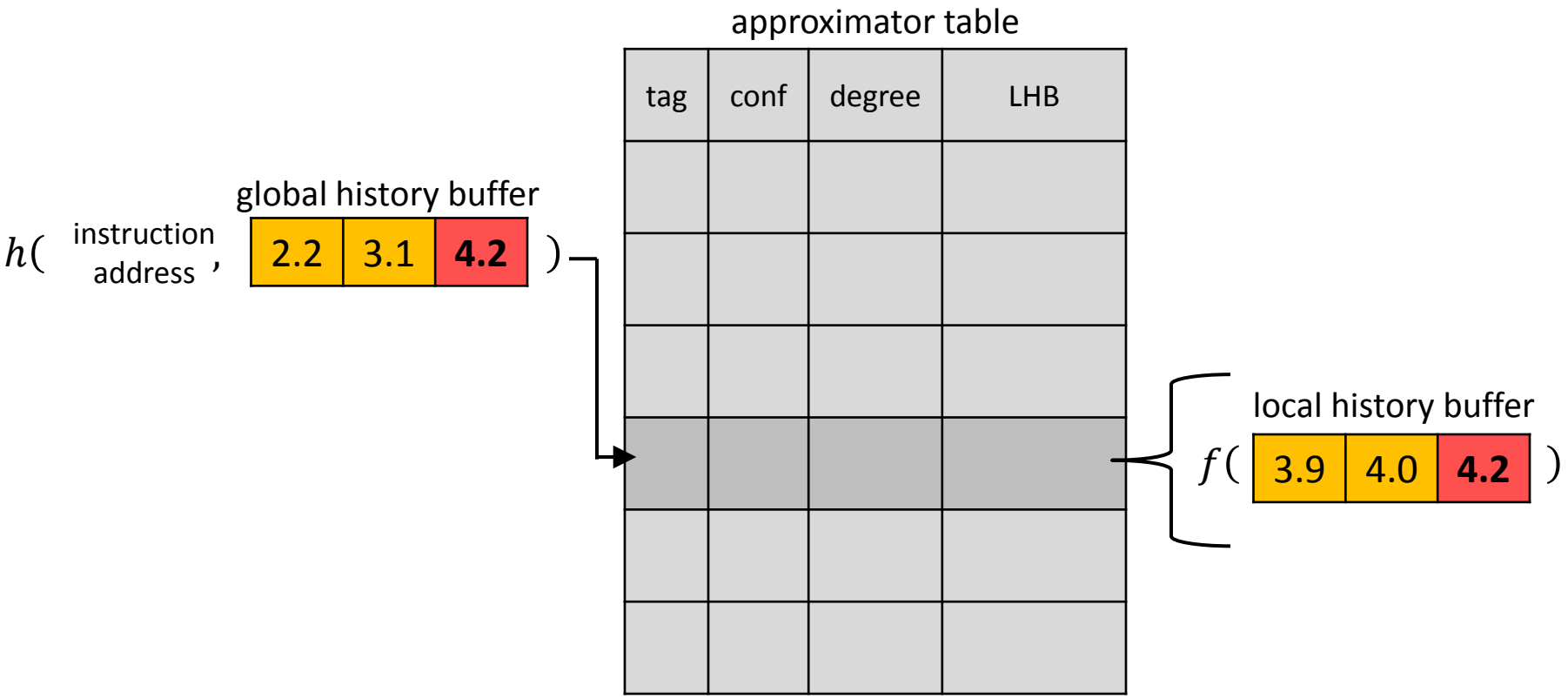




Approximator Design – Other Considerations

- Floating-point precision
- History buffer sizes
- Stale values

More details in paper.

Approximator Design

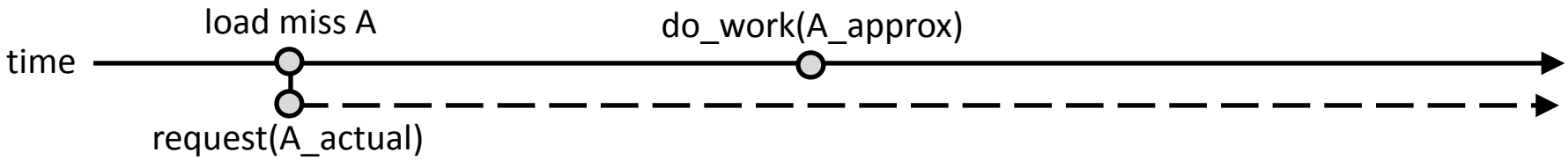
Relaxed Confidence Windows

- How do we avoid making bad approximations?
- Trade-off performance and error.

Approximation Degree

- Do we need to fetch the actual value from memory every time?
- Trade-off energy and error.

Relaxed Confidence Windows



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tag	conf	degree	LHB

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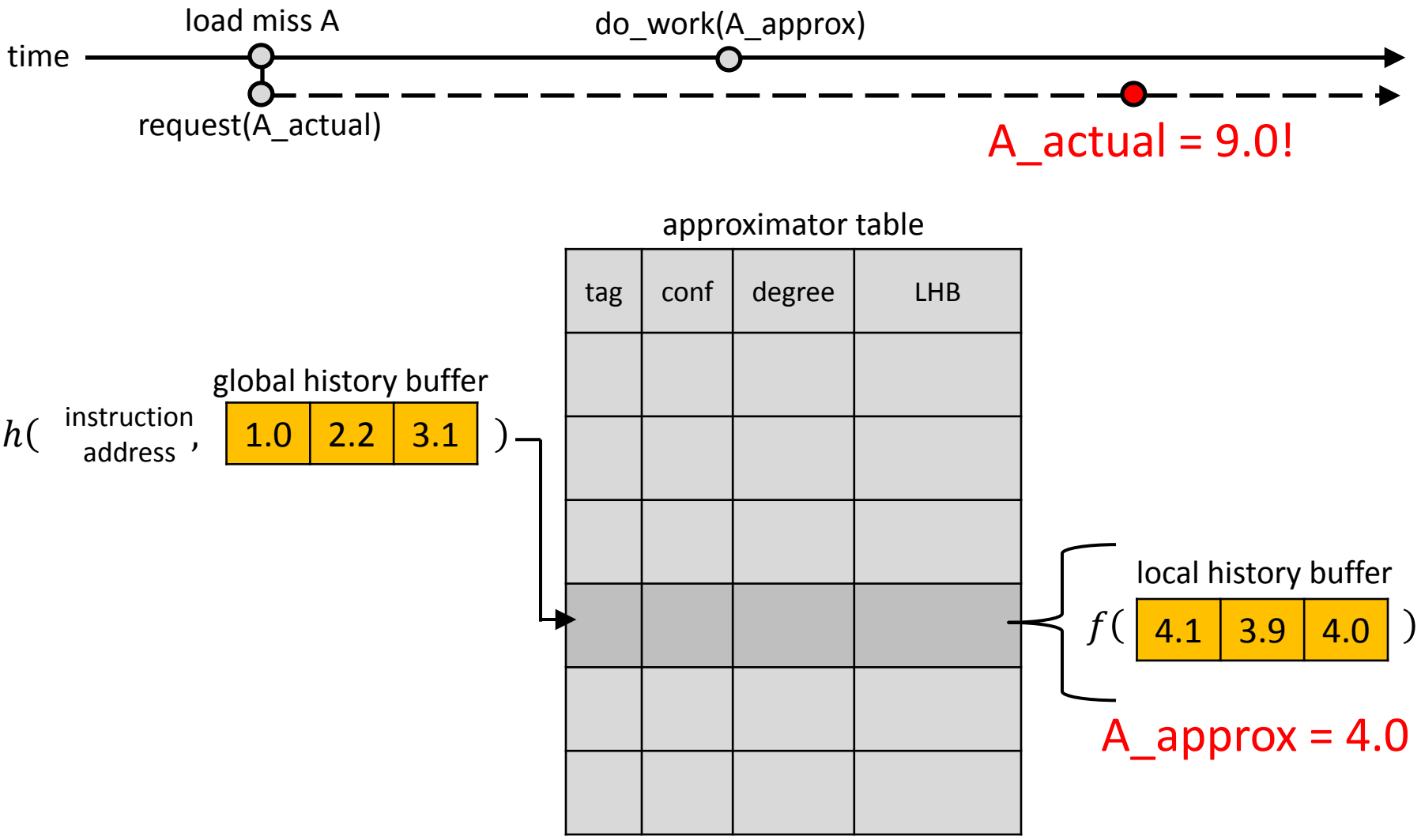
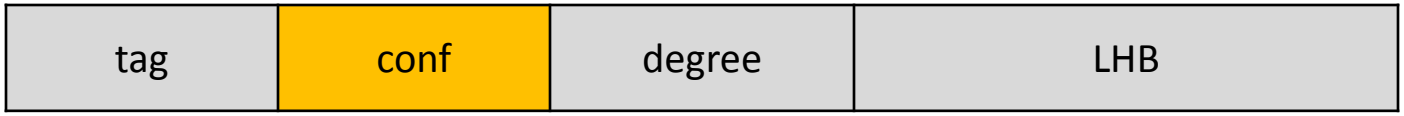
A_approx = 4.0

Relaxed Confidence Windows



Relaxed Confidence Windows



When approximating:

if *conf* >= 0: use *A_approx*

else: don't use *A_approx*

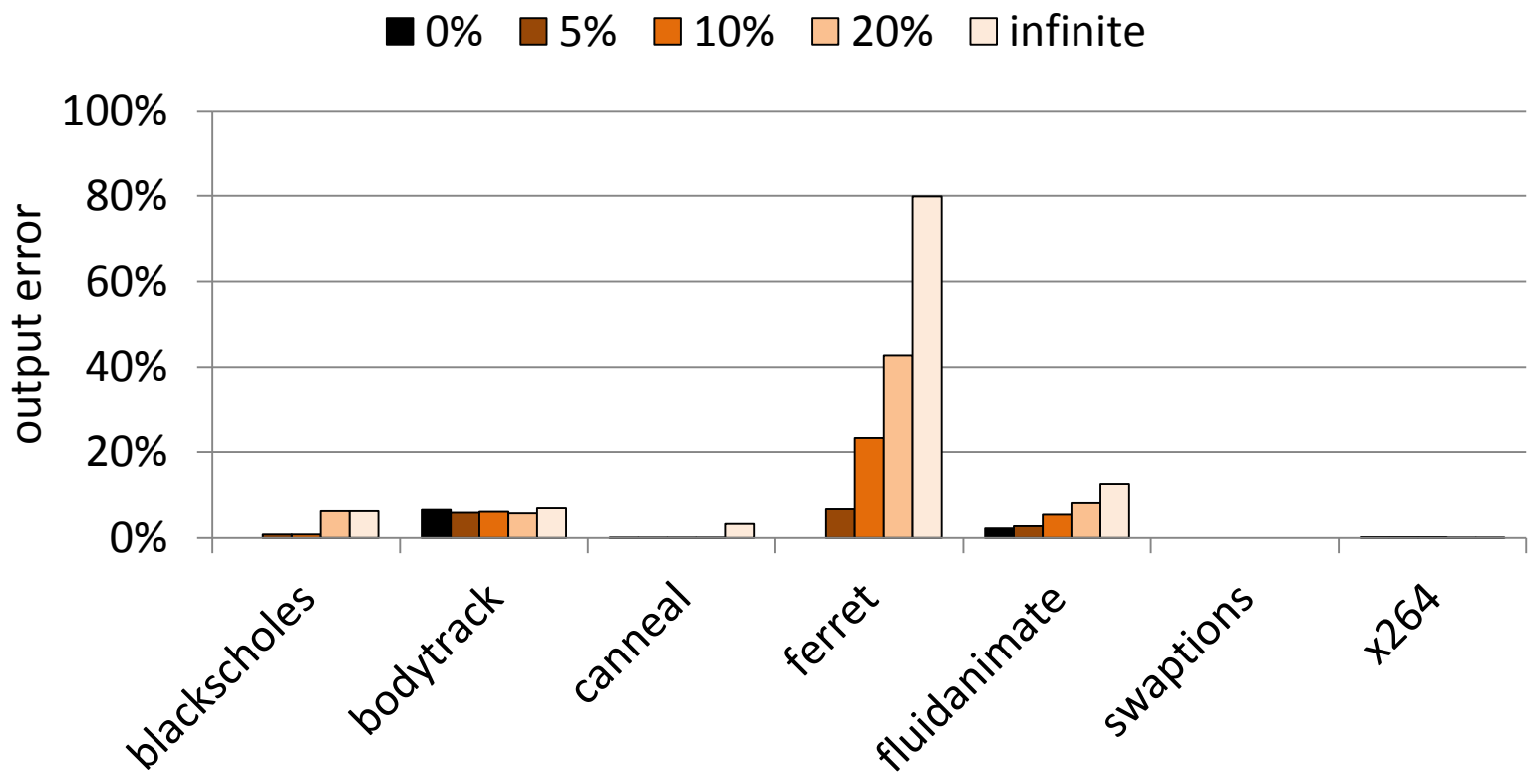
When updating:

if *A_approx*, *A_actual* differ by <= ***CONF_WINDOW%***: *conf*++

else: *conf*--

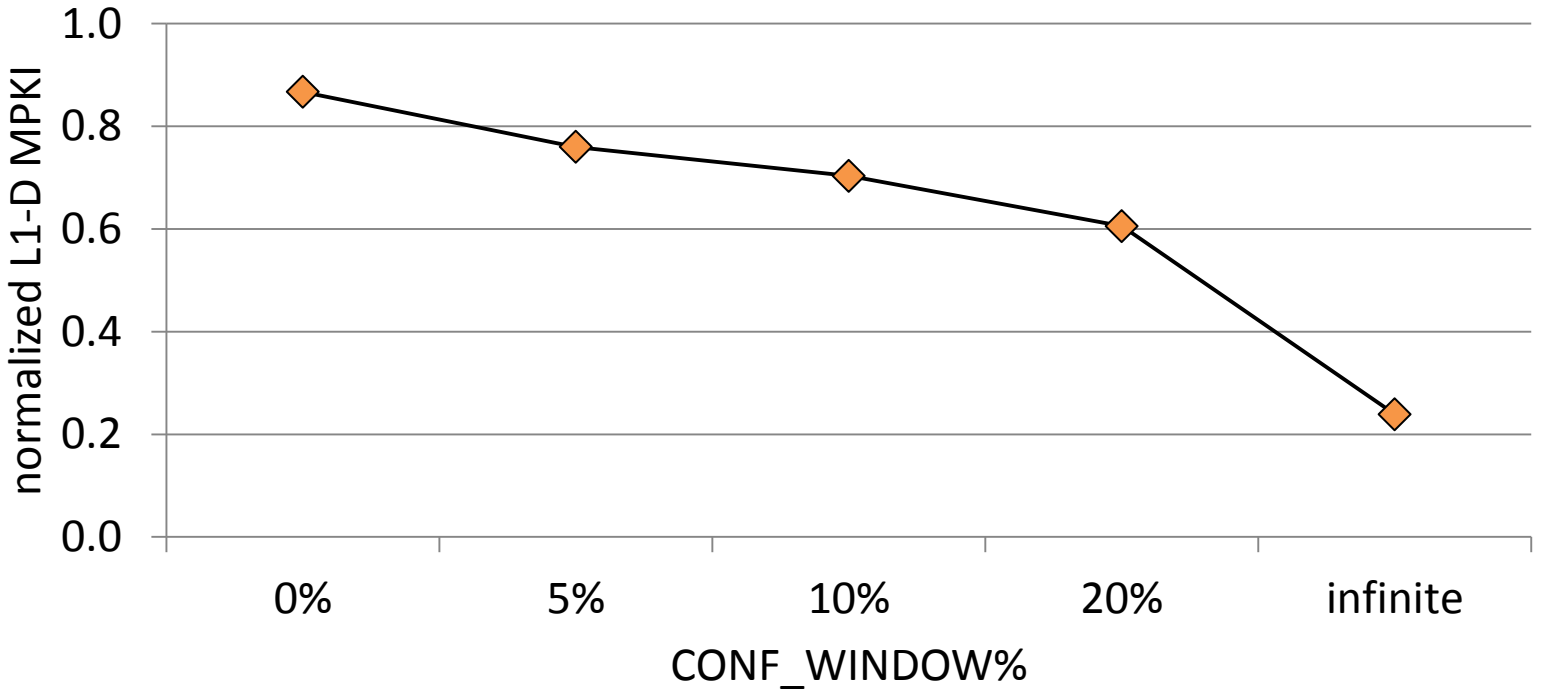
Relaxed Confidence Windows – Output Error

Varying *CONF_WINDOW%*:



Relaxed Confidence Windows – L1-D MPKI

Varying *CONF_WINDOW%*:



Approximator Design

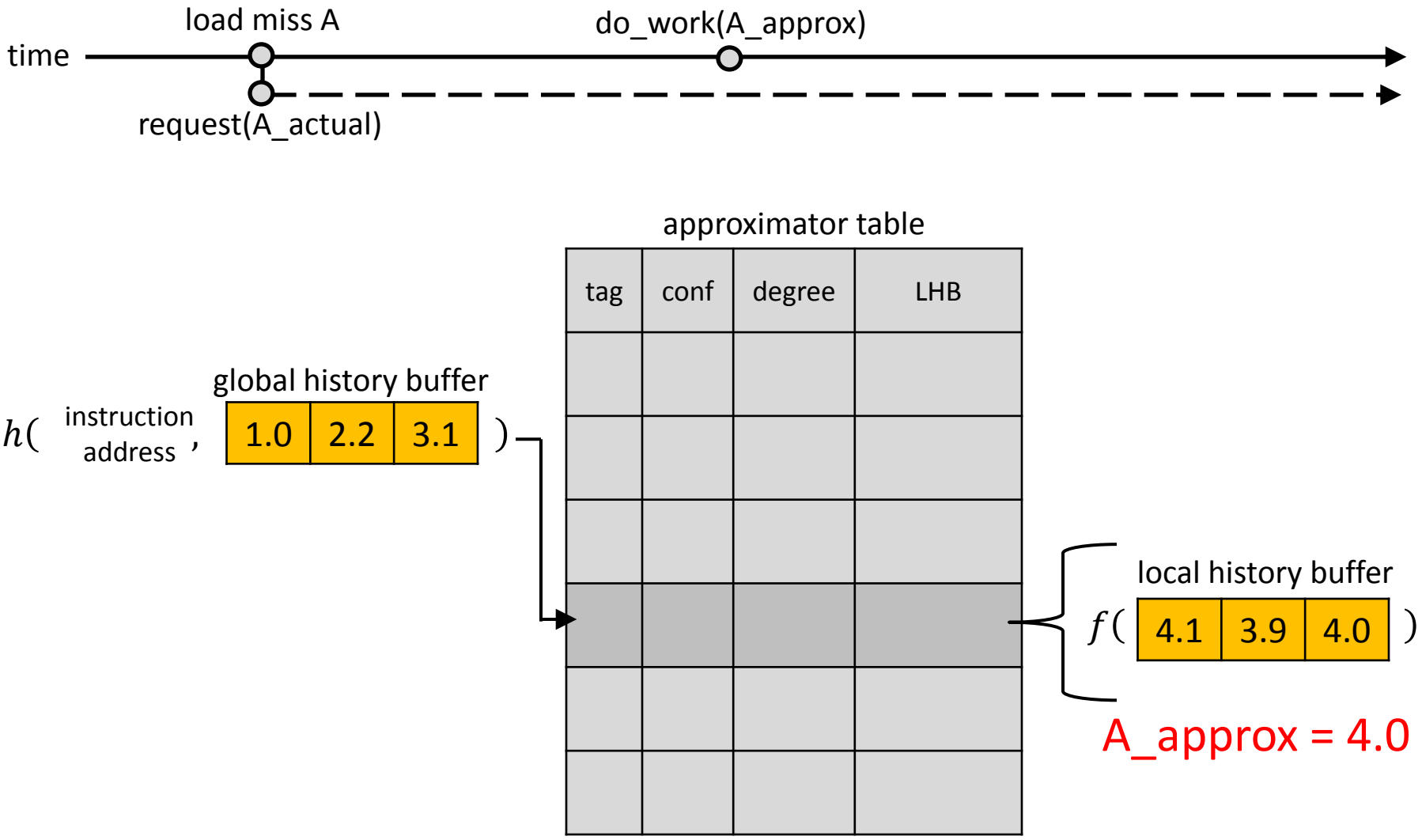
Relaxed Confidence Windows

- How do we avoid making bad approximations?
- Trade-off performance and error.

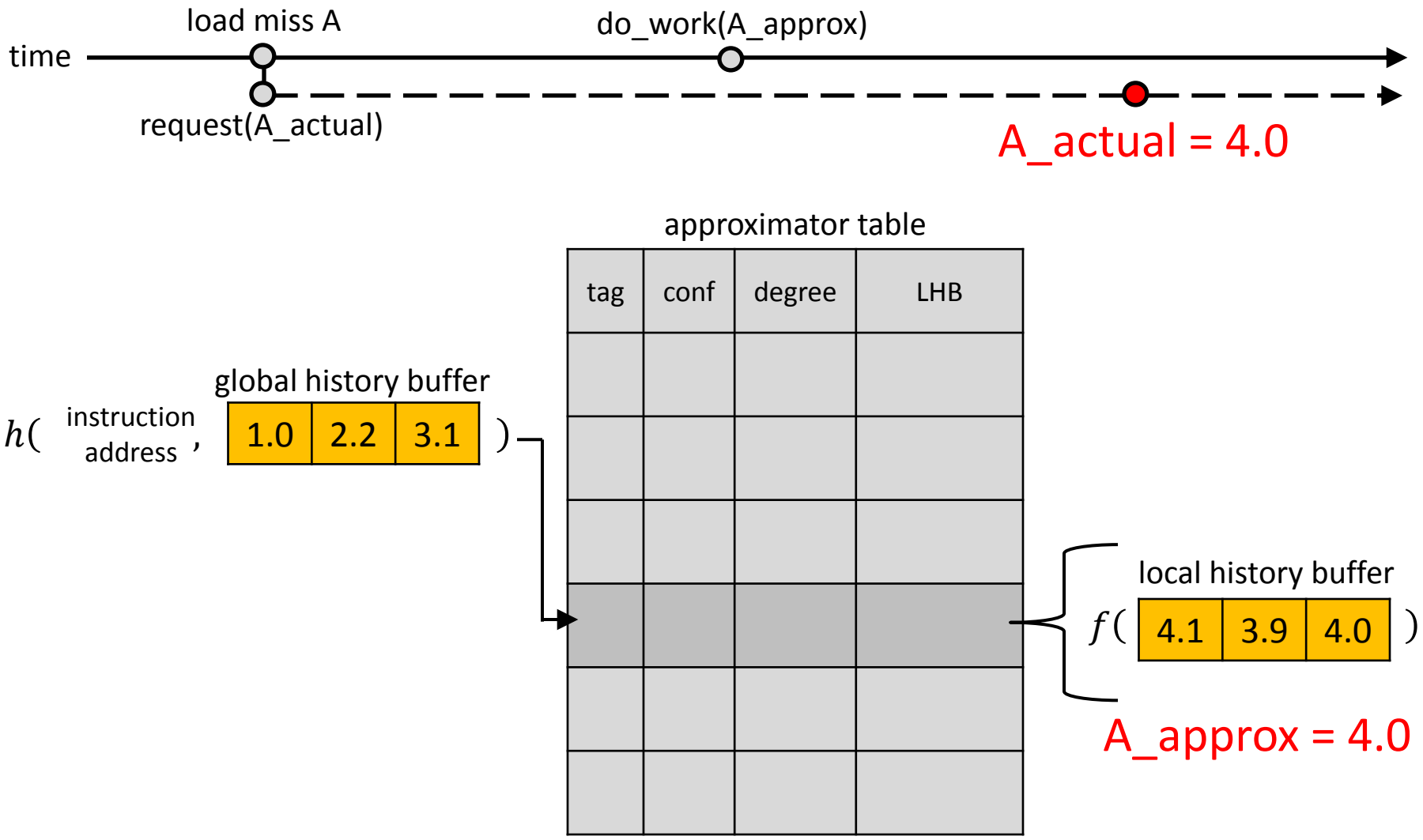
Approximation Degree

- **Do we need to fetch the actual value from memory every time?**
- **Trade-off energy and error.**

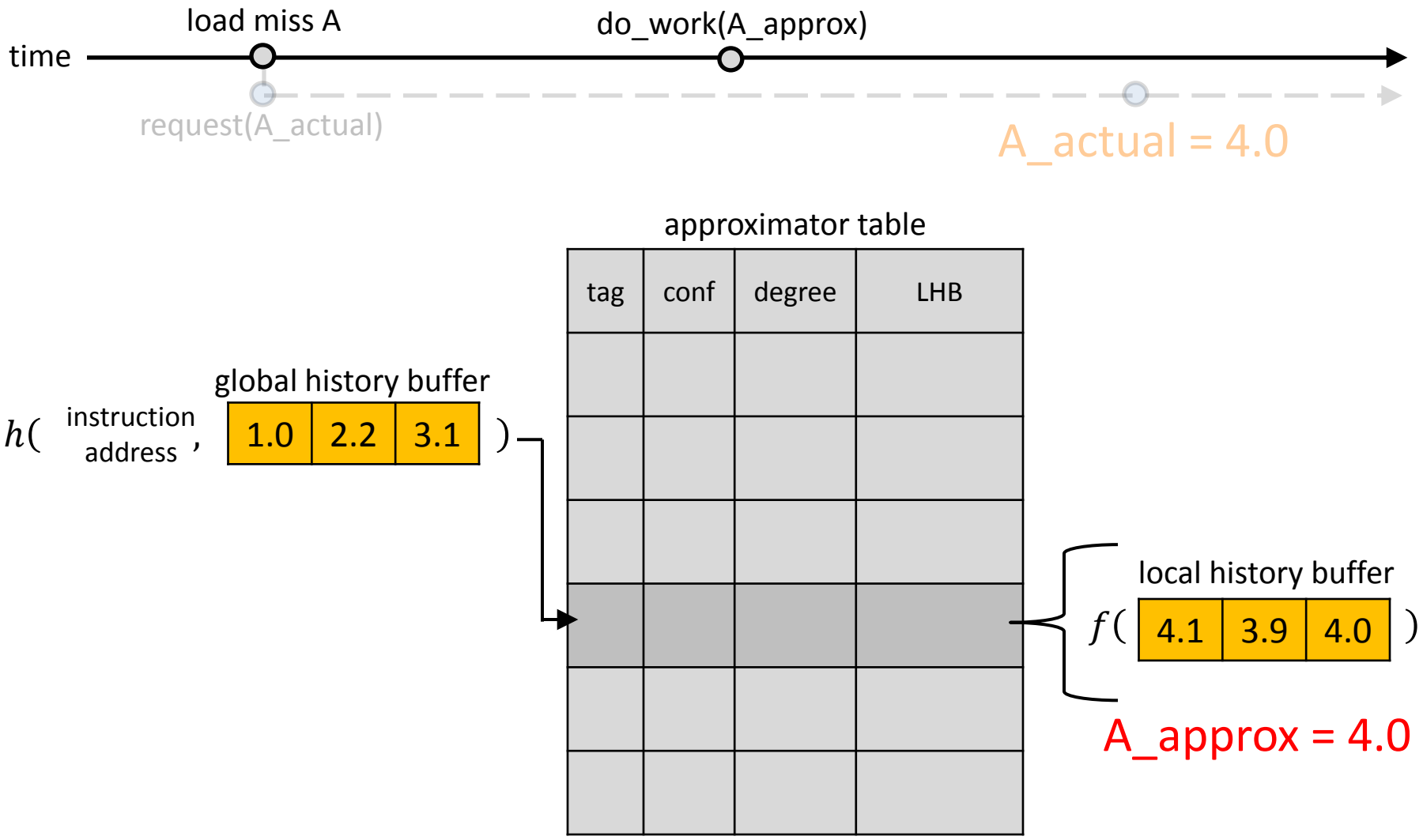
Approximation Degree



Approximation Degree



Approximation Degree



Approximation Degree

When approximating:

if *degree* == ***APPROX_DEGREE***: fetch *A_actual*

else: don't fetch *A_actual*

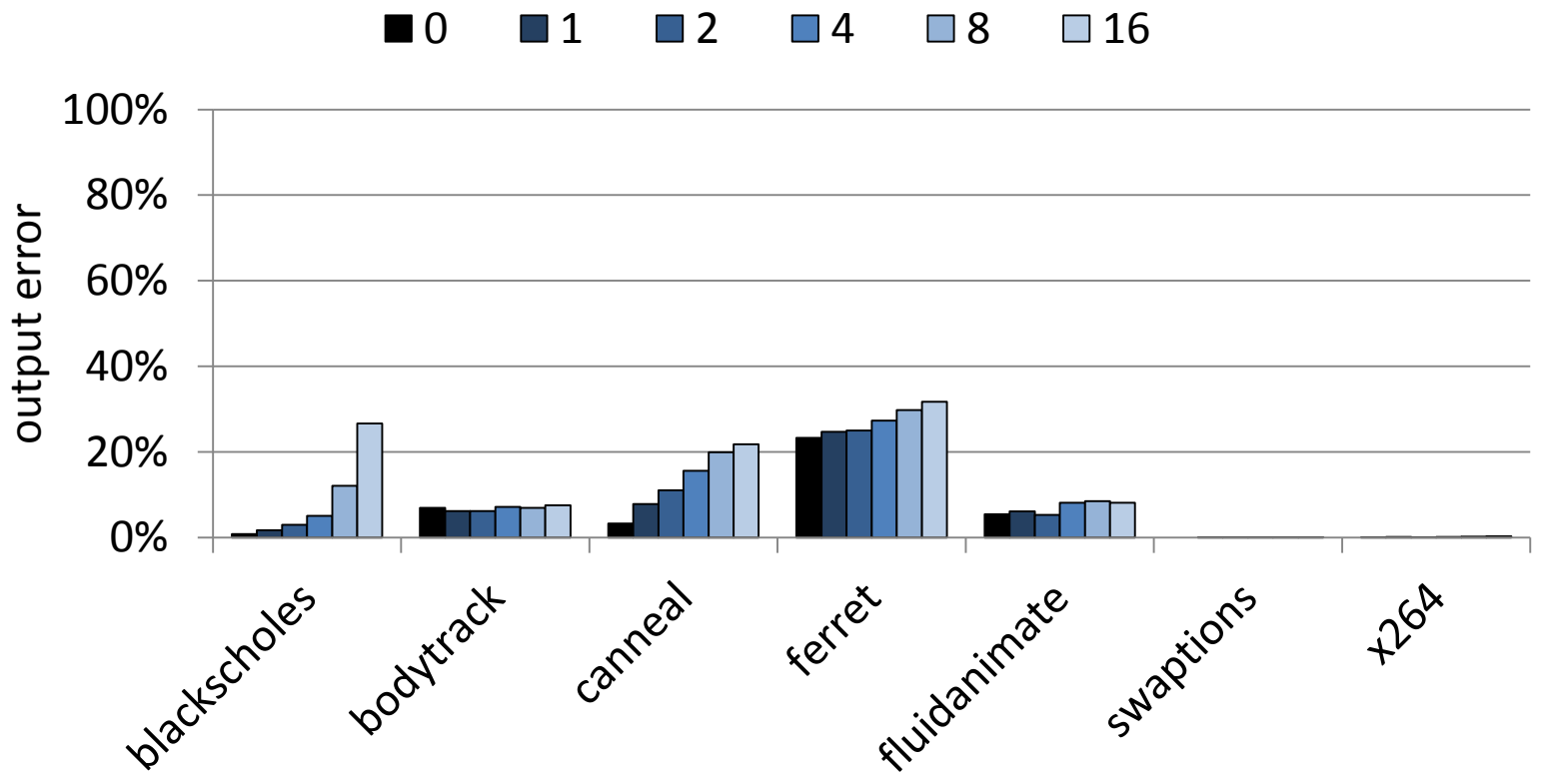
When updating:

if *degree* == ***APPROX_DEGREE***: *degree* = 0

else: *degree*++

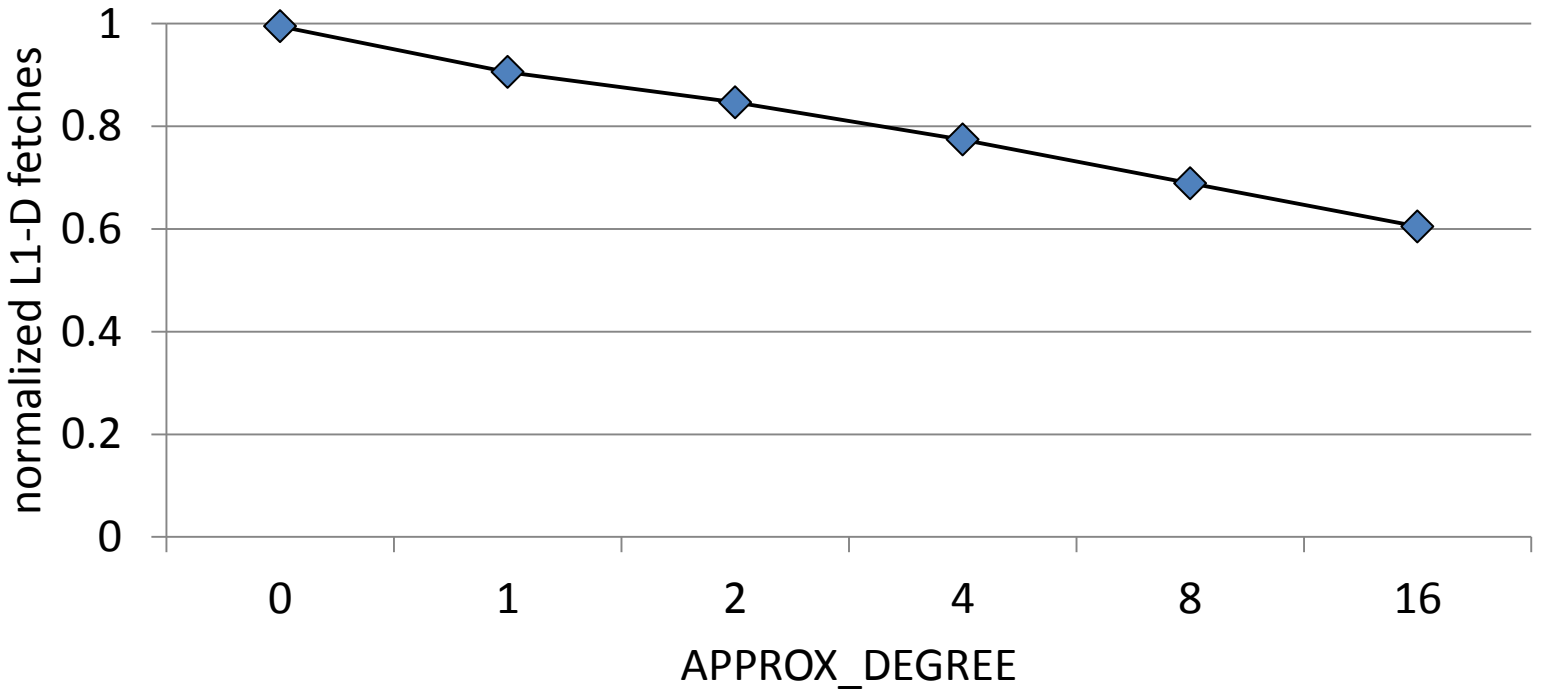
Approximation Degree – Output Error

Varying *APPROX_DEGREE*:



Approximation Degree – L1-D Fetches

Varying *APPROX_DEGREE*:



Methodology

Multi-threaded approximate applications

- PARSEC benchmark suite [Bienia, Princeton 2011]
- Programmer annotations and ISA extensions [Esmaeilzadeh, ASPLOS 2012]

Approximator design space exploration

- Pin dynamic binary instrumentation tool [Luk, PLDI 2005]

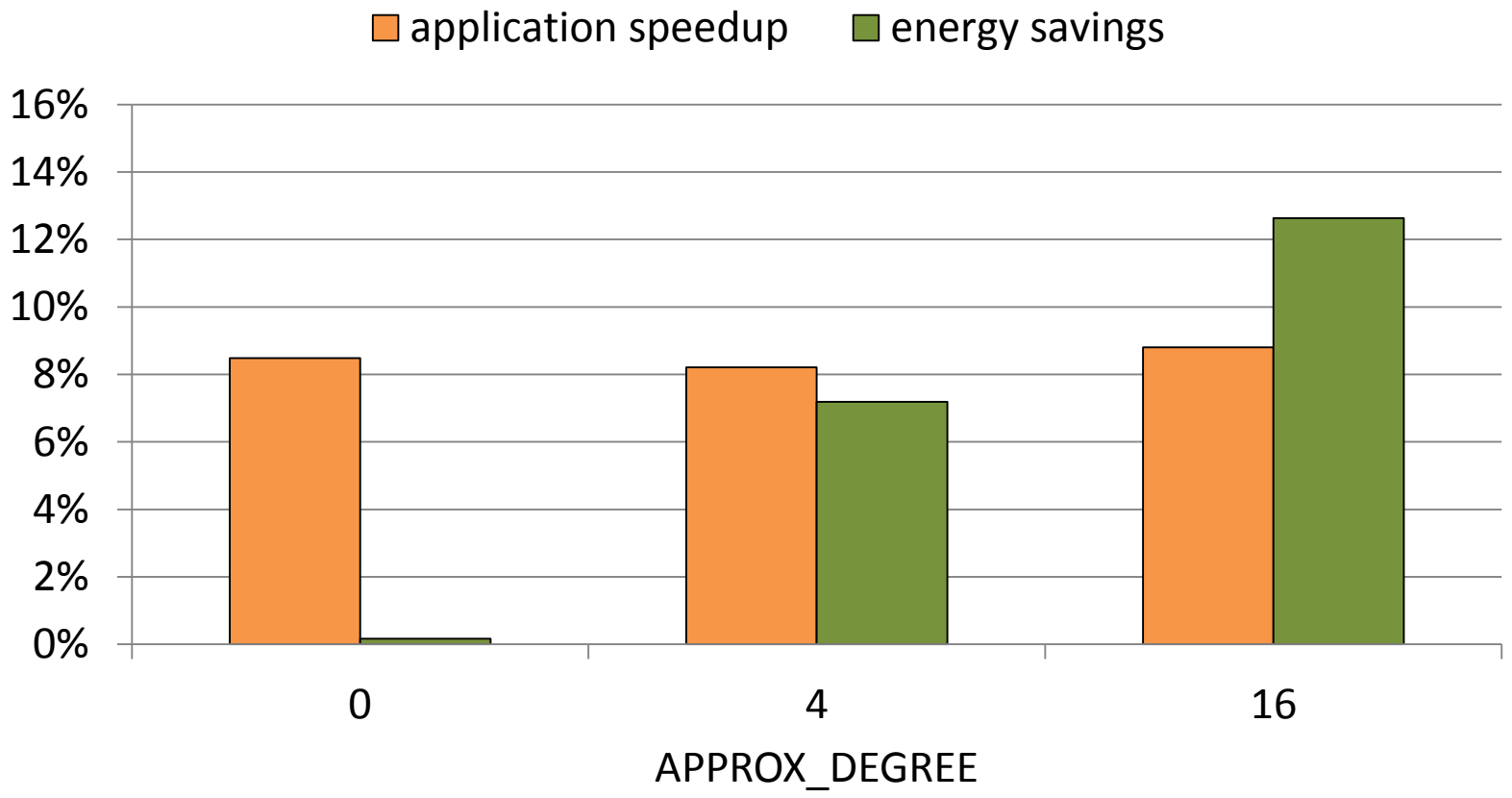
Full-system simulation

- FeS2 cycle-level x86 simulator [Neelakantam, ASPLOS 2008]

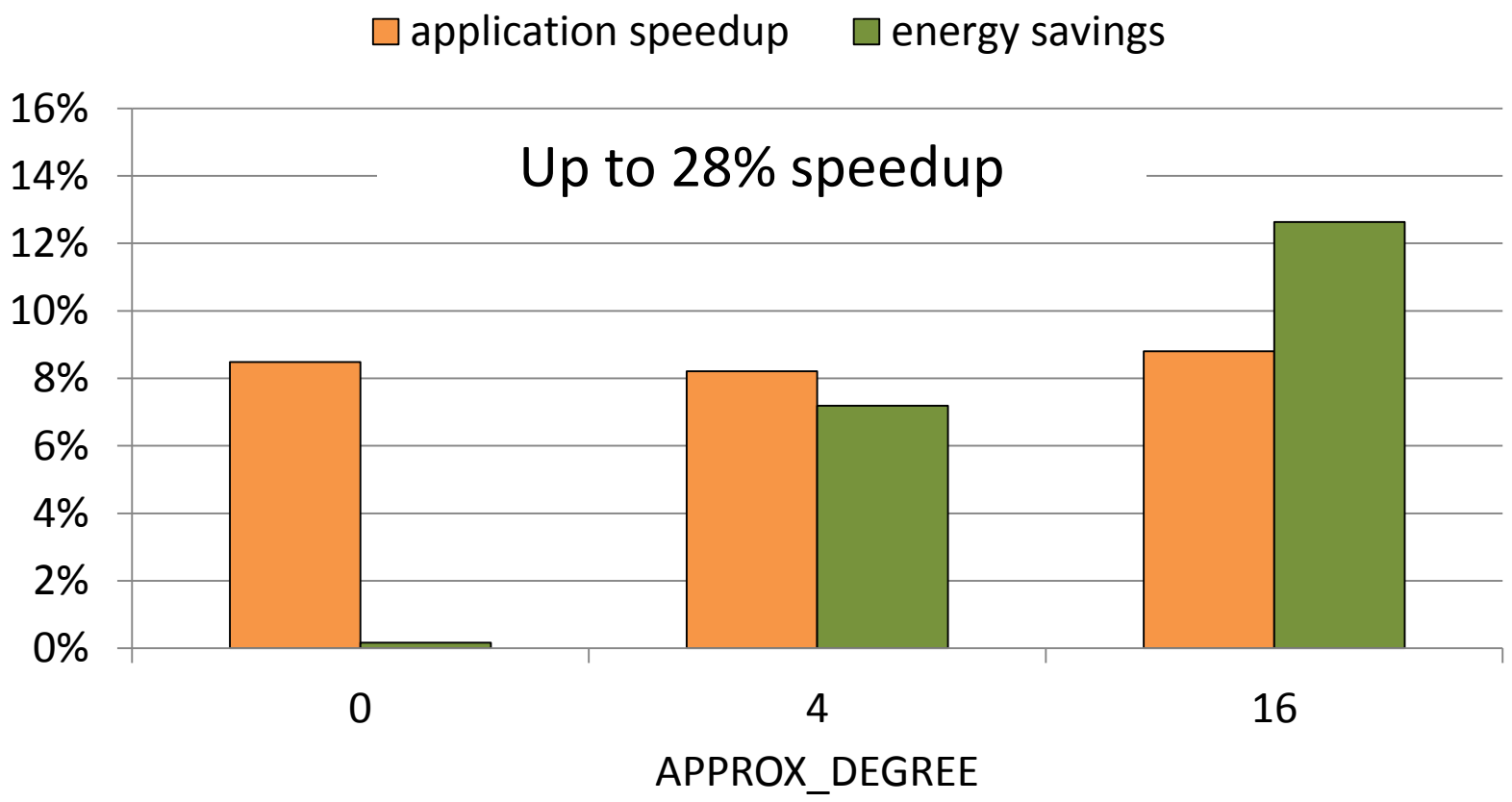
Approximator, cache and memory energy consumption

- CACTI modeling tool [Thoziyoor, HP 2008]

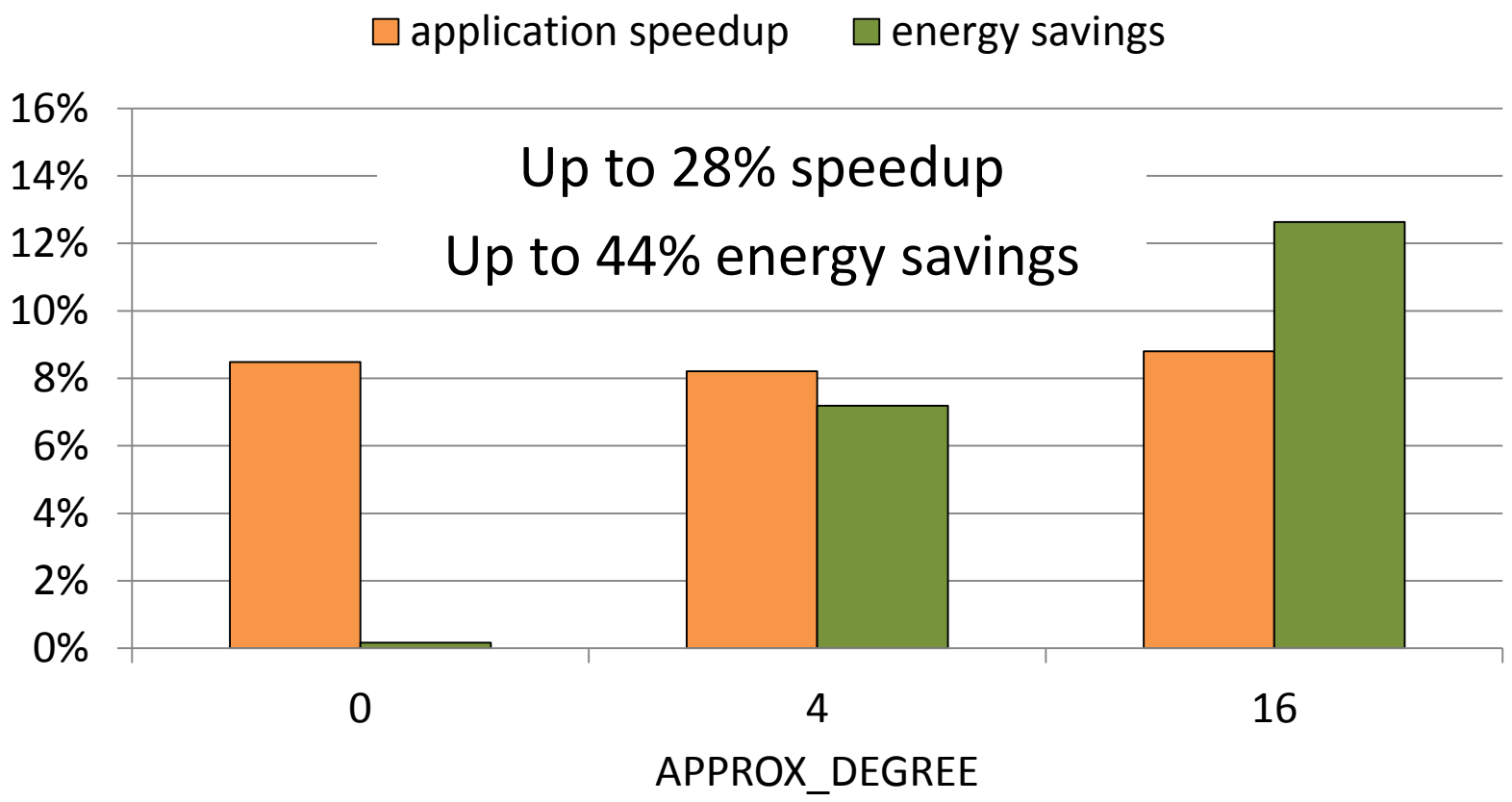
Evaluation


application speedup
energy savings
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
4
16
APPROX_DEGREE

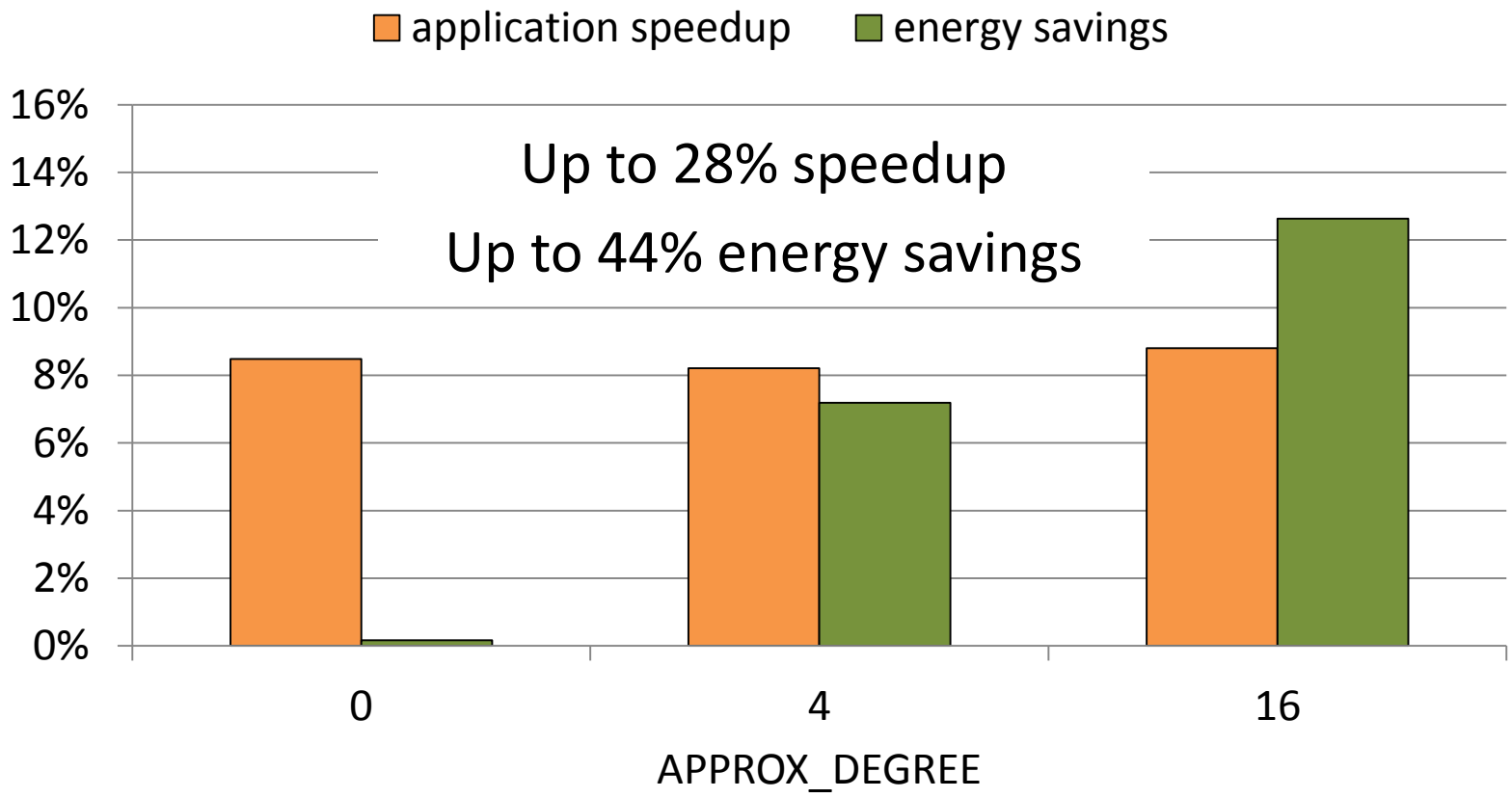
Evaluation


application speedup
energy savings
16%
14%
12%
10%
8%
6%
4%
2%
0%
Up to 28% speedup
0
4
16
APPROX_DEGREE

Evaluation


application speedup
energy savings
16%
14%
12%
10%
8%
6%
4%
2%
0%
Up to 28% speedup
Up to 44% energy savings
0
4
16
APPROX_DEGREE

Evaluation



Reduces L1-D MPKI by 30% over traditional value predictor and prefetcher.

Conclusion

Load Value Approximation

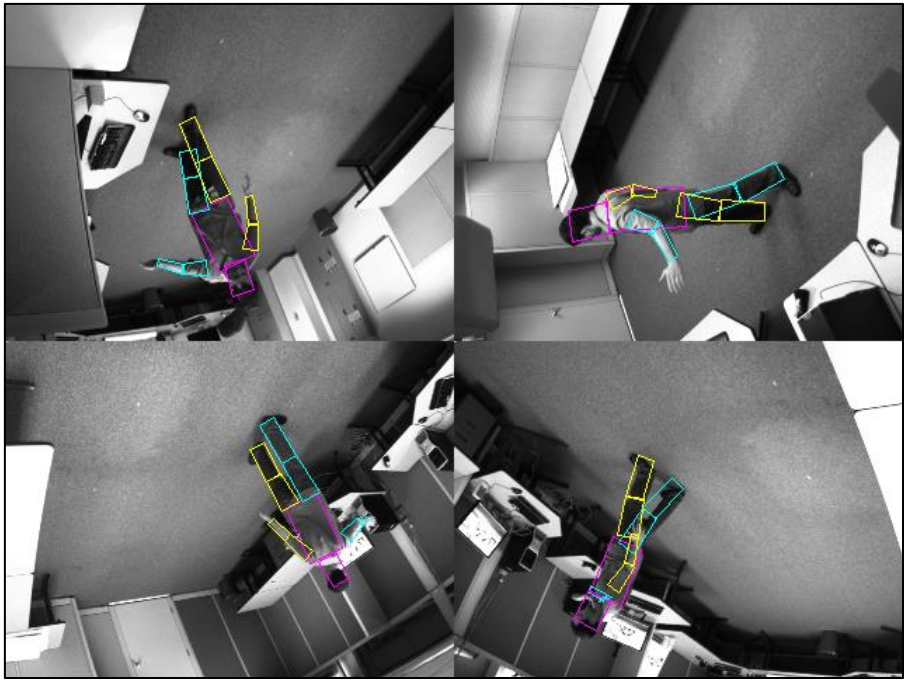
- Approximate Value Locality
- Non-Speculative
- Relaxed Confidence Windows
- Approximation Degree

↑ performance

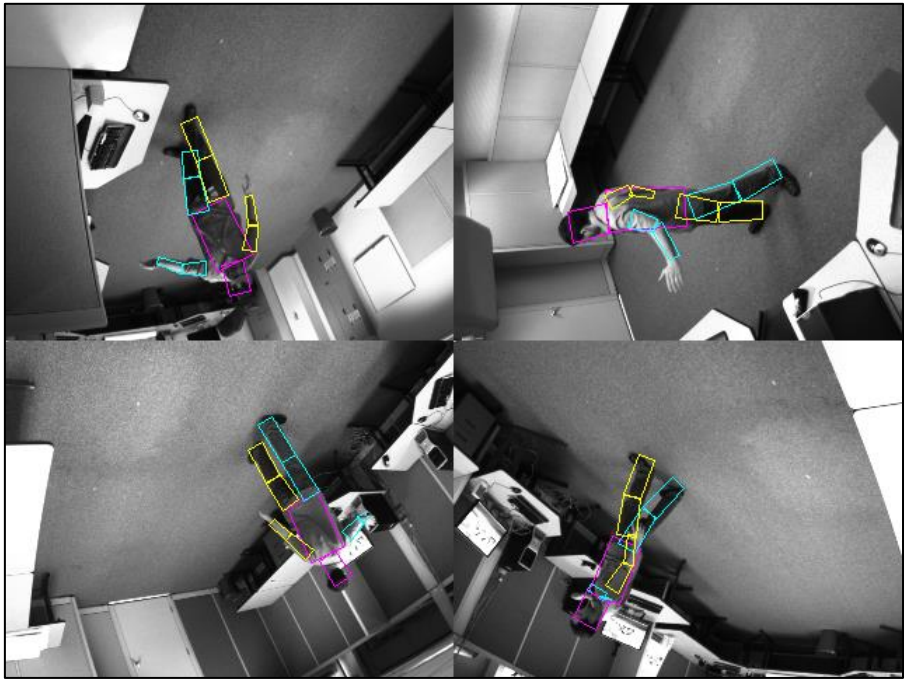
↓ energy consumption

low output error

Conclusion



baseline (precise)



load value approximation