Practical Scrubbing

Getting to the bad sector at the right time

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Hard disk errors & Scrubbing

What could go wrong?

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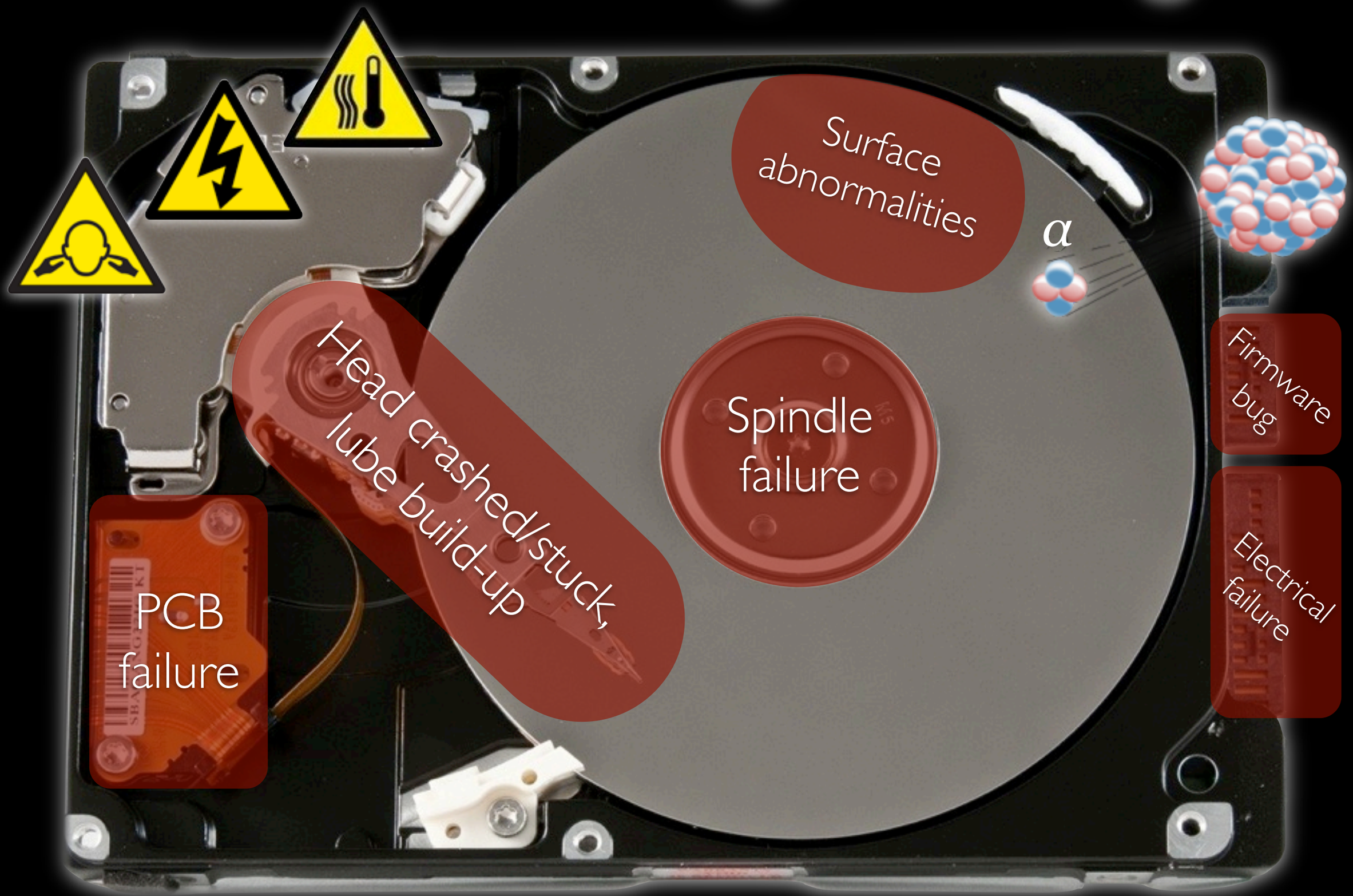

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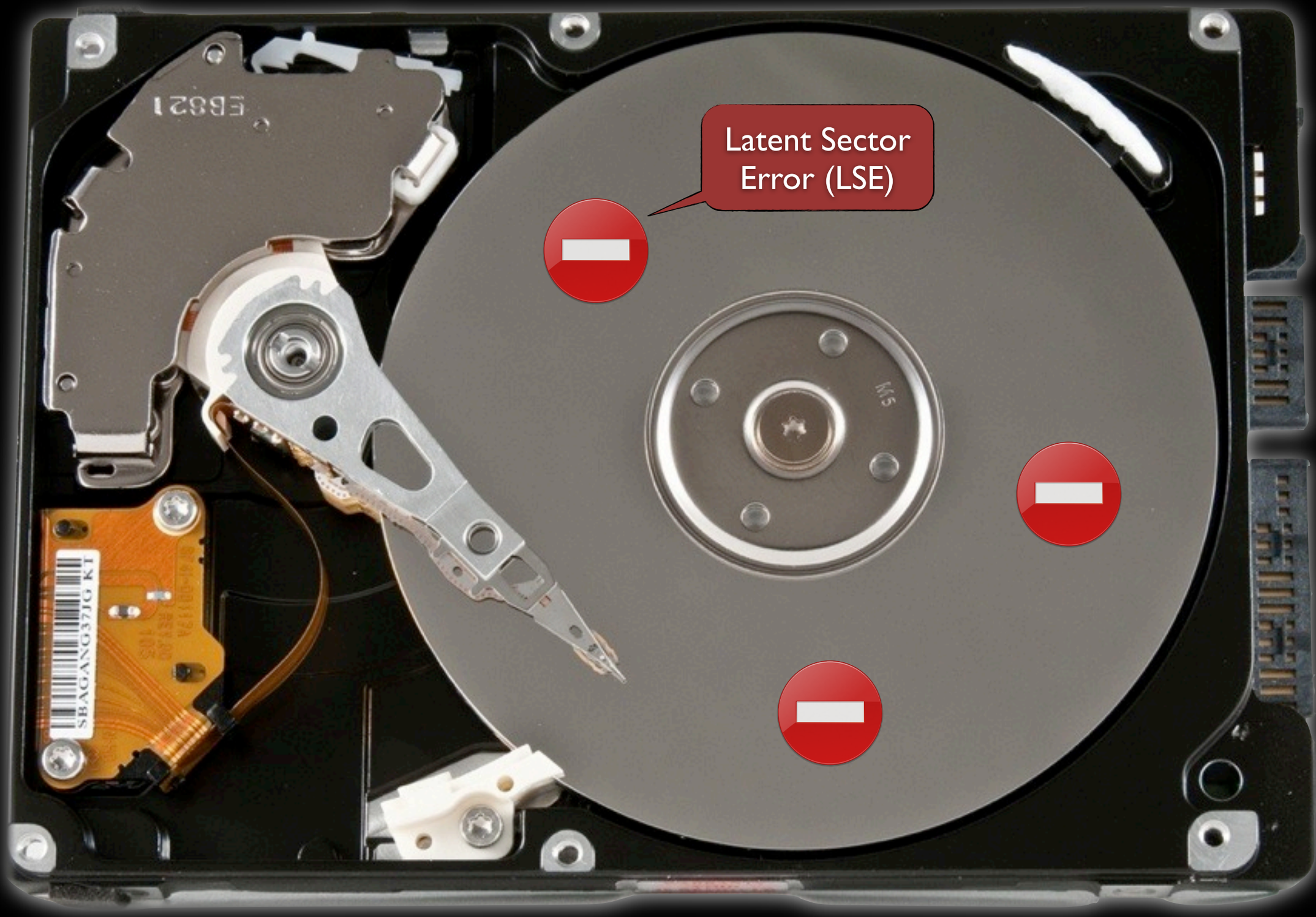
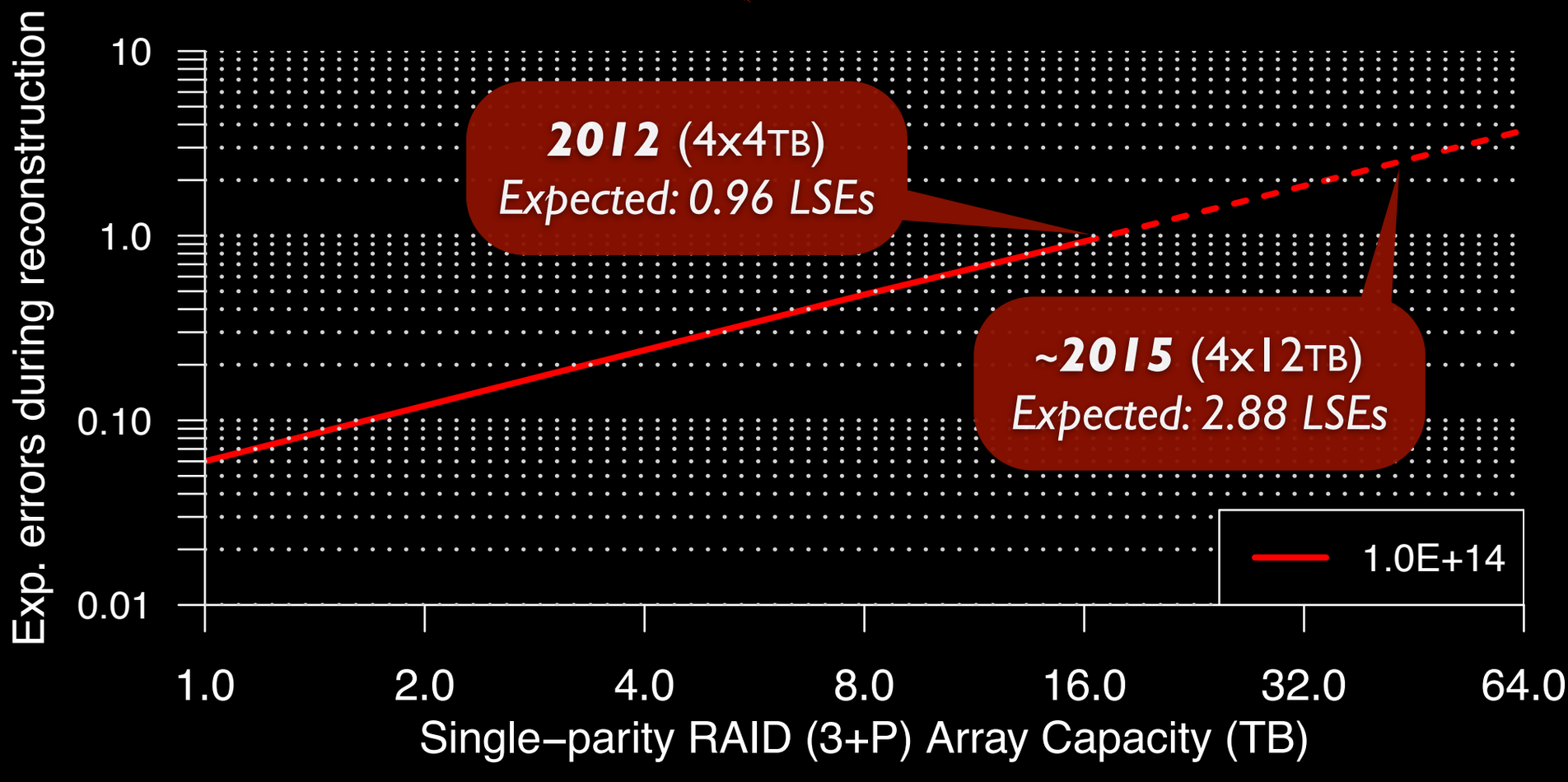


L. Bairavasundaram et al., “An analysis of latent sector errors in disk drives”, ACM SIGMETRICS 2007.

What could go wrong?

No Redundancy + LSE = Data Loss



Steven R. Hetzler, "*System Impacts of Storage Trends: Hard Errors and Testability*". In USENIX ;login:, v.36/3

Scrubbing

- *Goal:* Detect LSEs timely to enable recovery
- *How:* Background process verifying sector contents
  - *Detection speed:* verify sectors at high frequency
  - *Verification cost:* avoid delaying workload requests

- *Previous Work:* Focus on detecting LSEs fast
- ***Cost of scrubbing?*** Practical questions raised:

How do I *implement* a scrubber? How do I *configure* it to find LSEs fast?

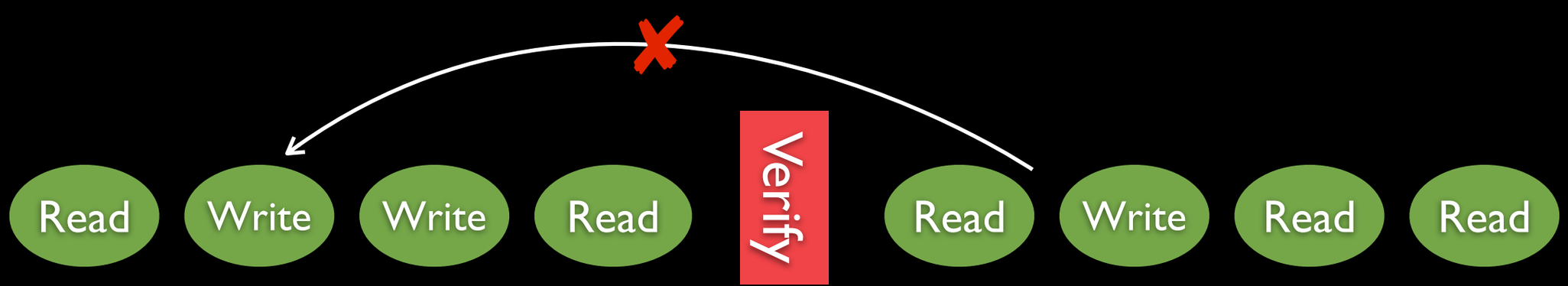
When should I scrub, to *minimize impact* on the system?

Implementation & Configuration

Data scrubbing

- ~~Option 1~~: Use READs to verify data integrity
  - Overhead: *Data transfer cost, Cache pollution*
  - Correctness: *Might not check medium surface*

- Option 2: Use VERIFY firmware command
  - Caveat: *Treated as scheduling barriers*
  - Solution: *Disguise scrubber's VERIFYs as READs*



Data scrubbing

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System Overview

Filesystem Layer

Generic Block Layer

Scrubbing Framework

?

Verify

Verify

Verify

Verify

Verify

Verify

I/O Scheduler

On-disk cache

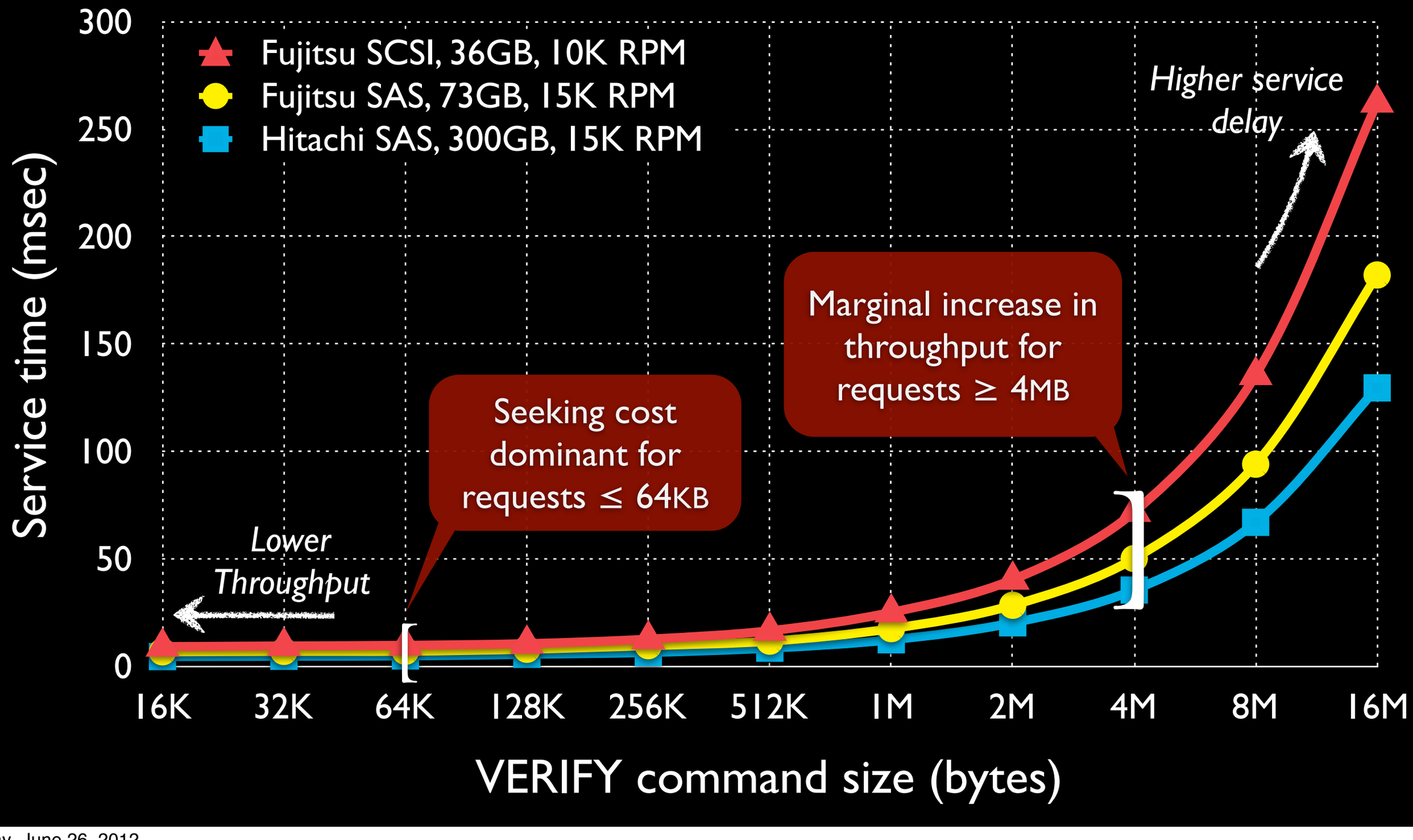
Hard disk

Parameter 1:

VERIFY request size

larger requests! *smaller requests?!*

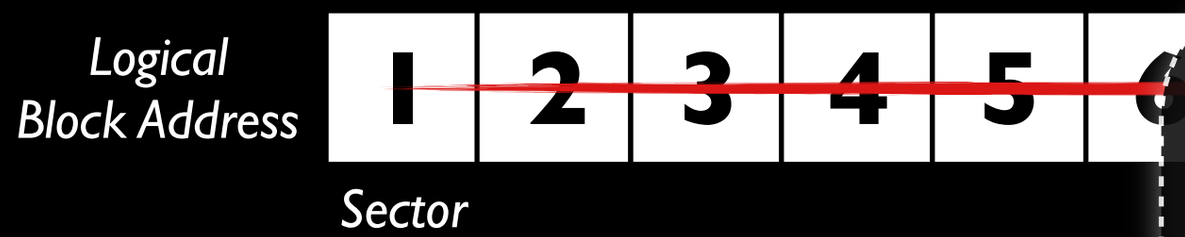
Finding the sweet spot between scrub throughput and service delay



Parameter 2:

Scrubbing Order

- ~~Sequential~~ scrubbing (used in the field today)

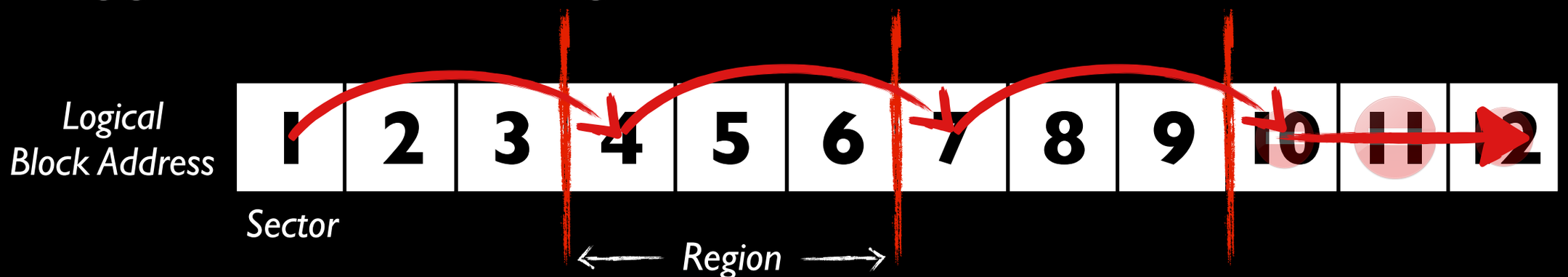


Can we afford this?

HDD capacities: CAGR +100%

Data transfer speed: CAGR +40%

- Staggered scrubbing (fast LSE detection) *[Oprea, Juels FAST'10]*



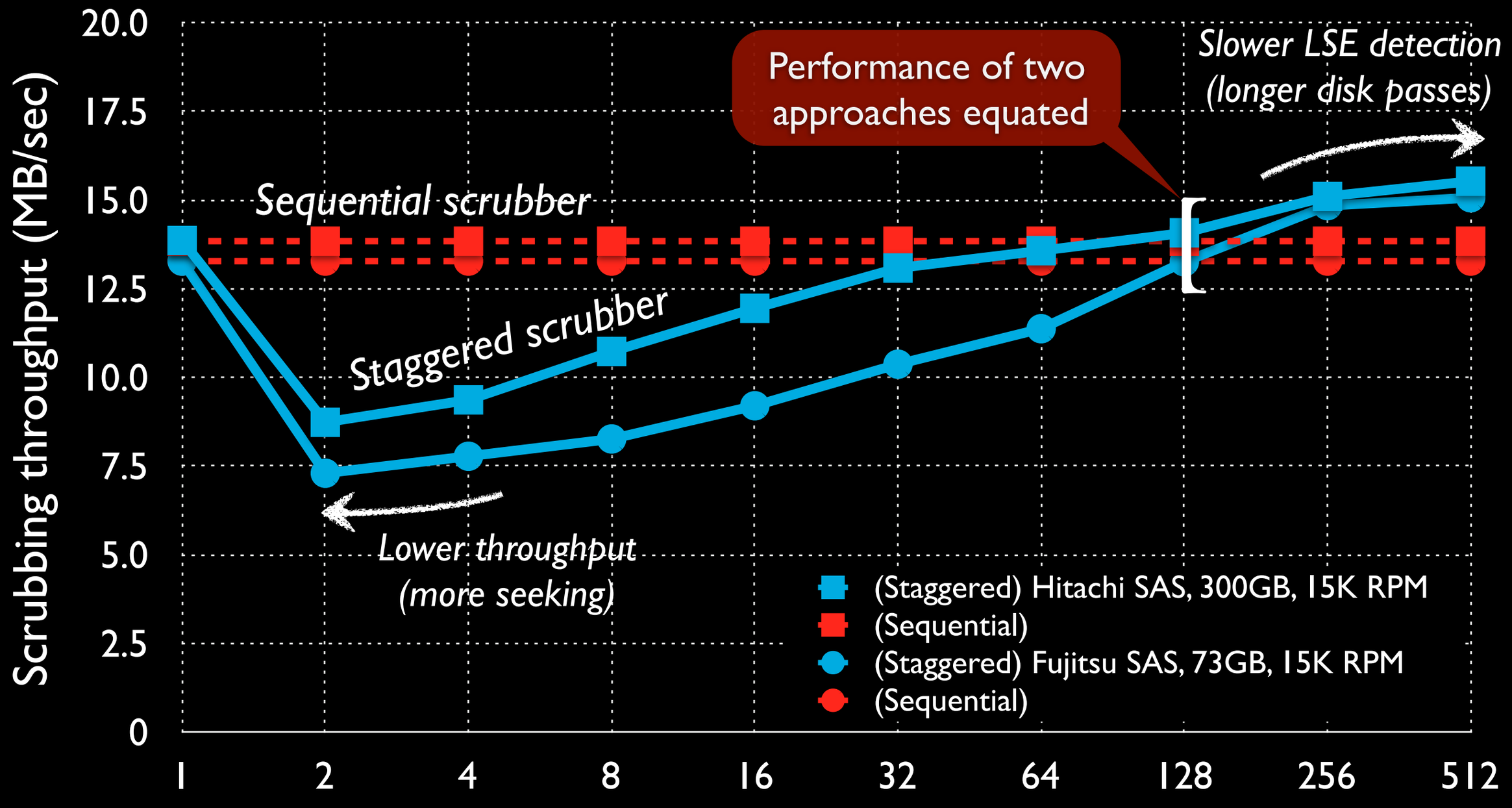
Staggered scrubbing guarantees fast LSE detection, but:
seeking overhead never evaluated in implementation

Parameter 3:

Number of Regions

more, smaller regions! *fewer, larger regions?!*

Limit seeking between regions, but retain frequent disk passes



System Overview

Filesystem Layer

Generic Block Layer

VERIFY size:
[64KB, 4MB]

Scrubbing Framework

Regions:
≥128

I/O Scheduler

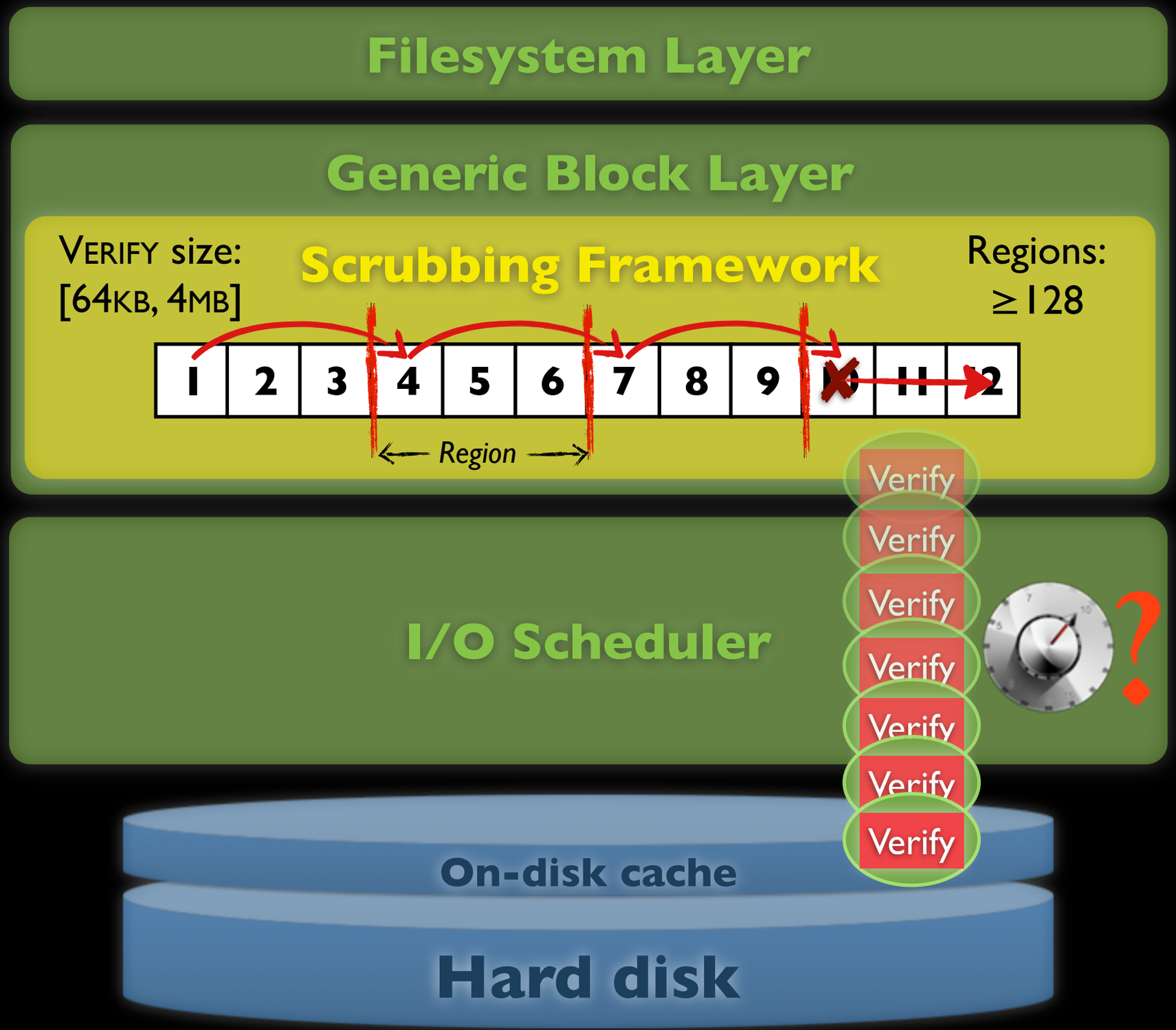
Verify
Verify
Verify
Verify
Verify
Verify
Verify

On-disk cache

Hard disk

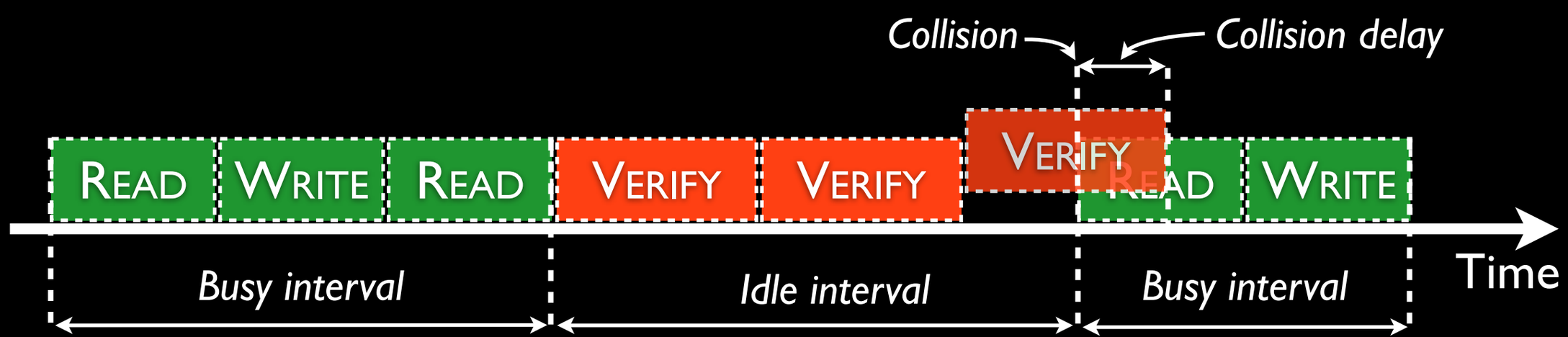
Minimizing Impact

System Overview



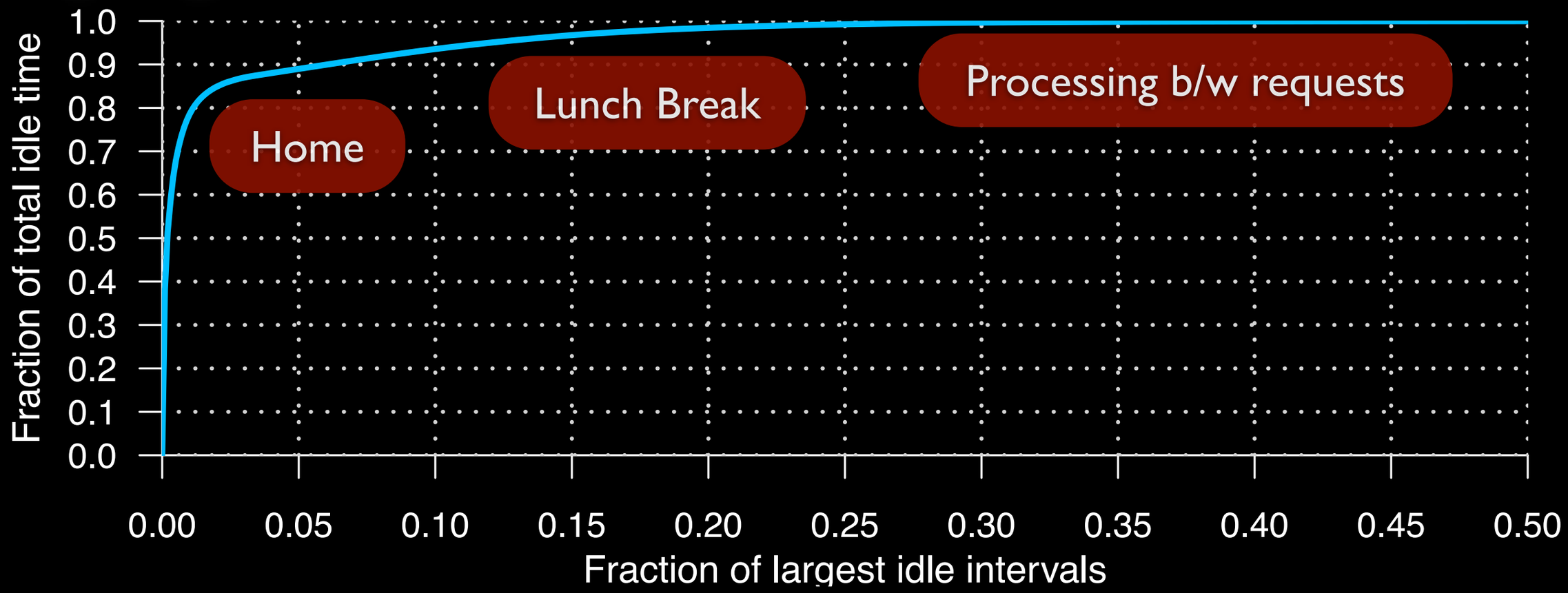
Background Scheduling

- Fire VERIFY requests only when disk otherwise idle
  - Previous work: *Focus on unobtrusive READS/WRITES [Lumb'02, Bachmat'02]*
- Avoid collisions with workload requests
  - Start time: *When should we start firing VERIFYS?*
  - Stop time: *When do we stop to avoid collision?*
- Statistical analysis of idleness
  - I/O traces: *2 systems, 77 disks, diverse workloads [SNIA, IOTTA repository]*



Idleness & Long Tails

Property: Long Tail - *Majority of idle time in few idle intervals* *[Riska '09]*



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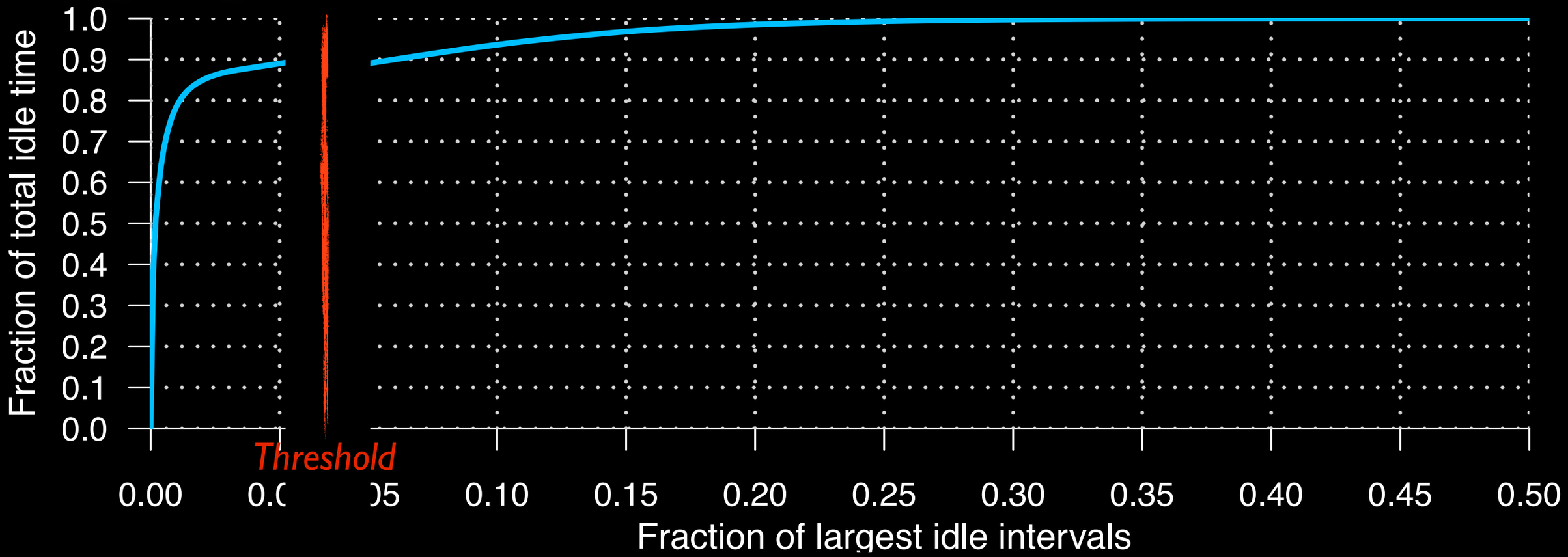
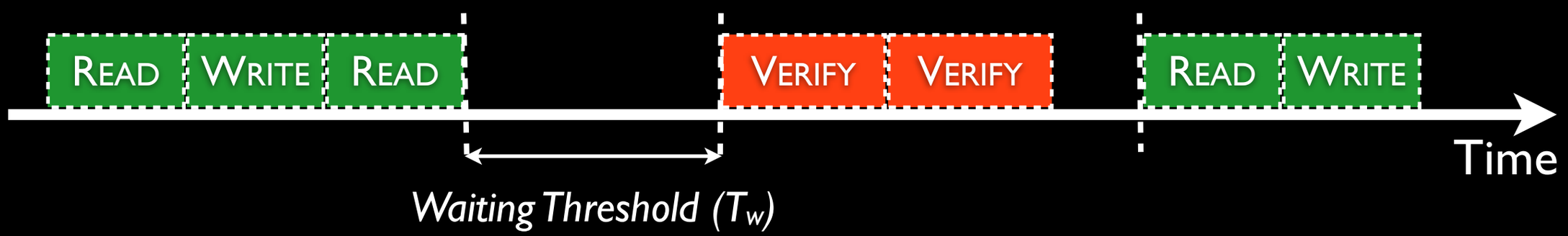


Predictor: Waiting - *Fire past threshold*



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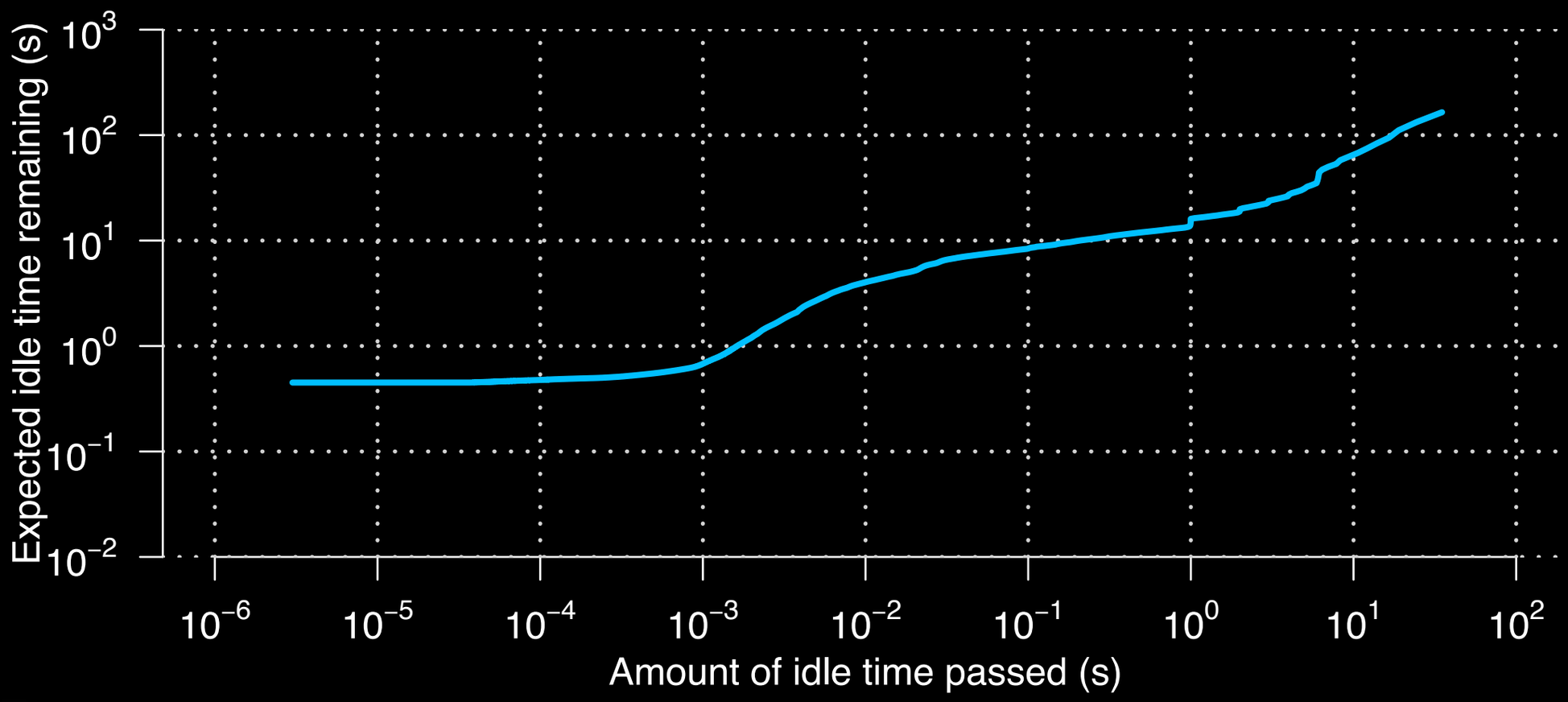
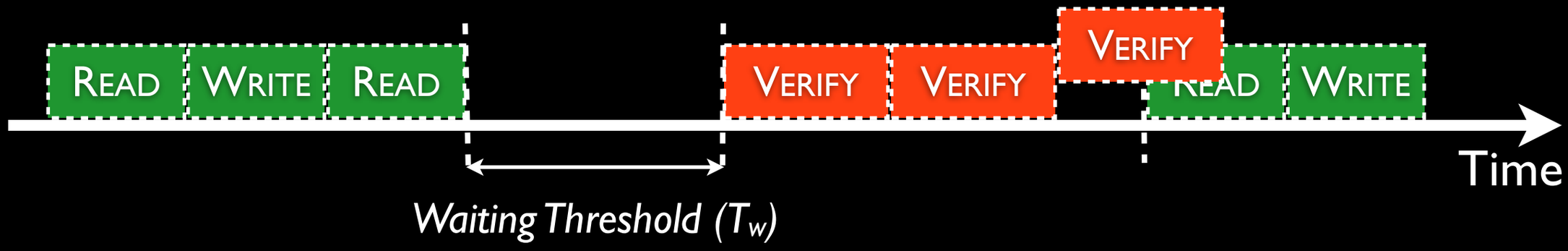
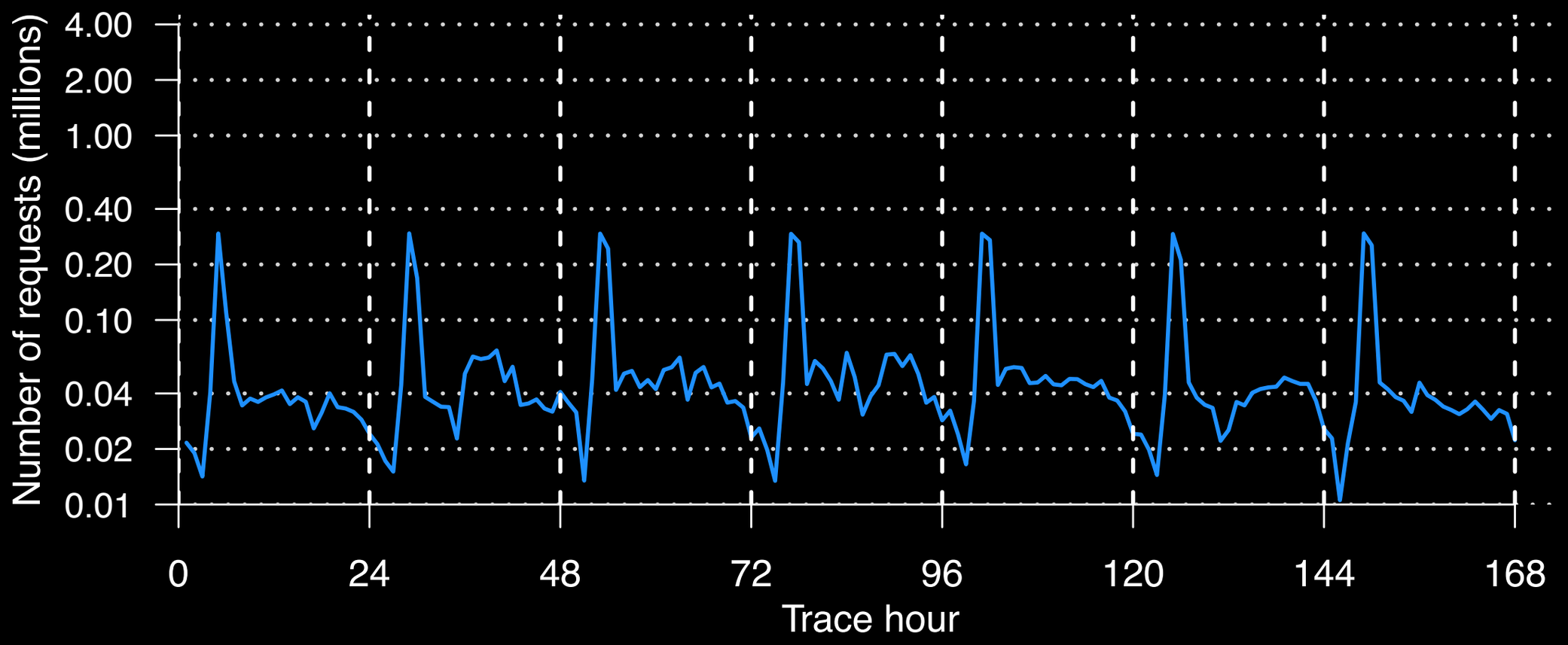


Predictor: Waiting - *Fire past threshold, stop only on collision*

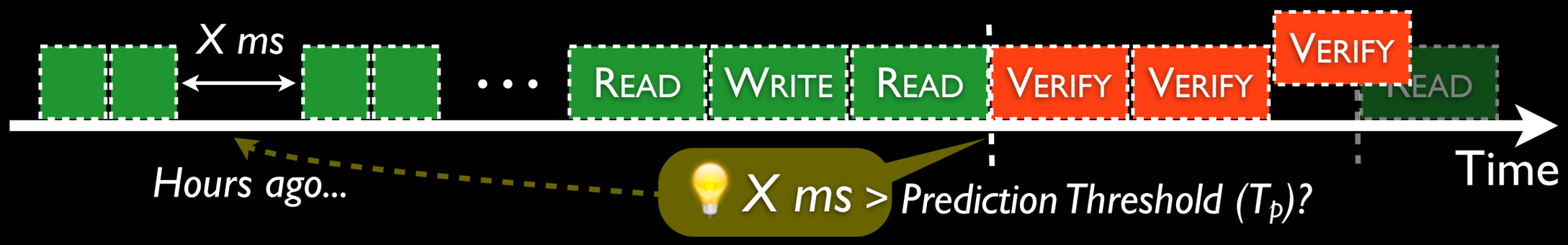


Idleness & Periodicity

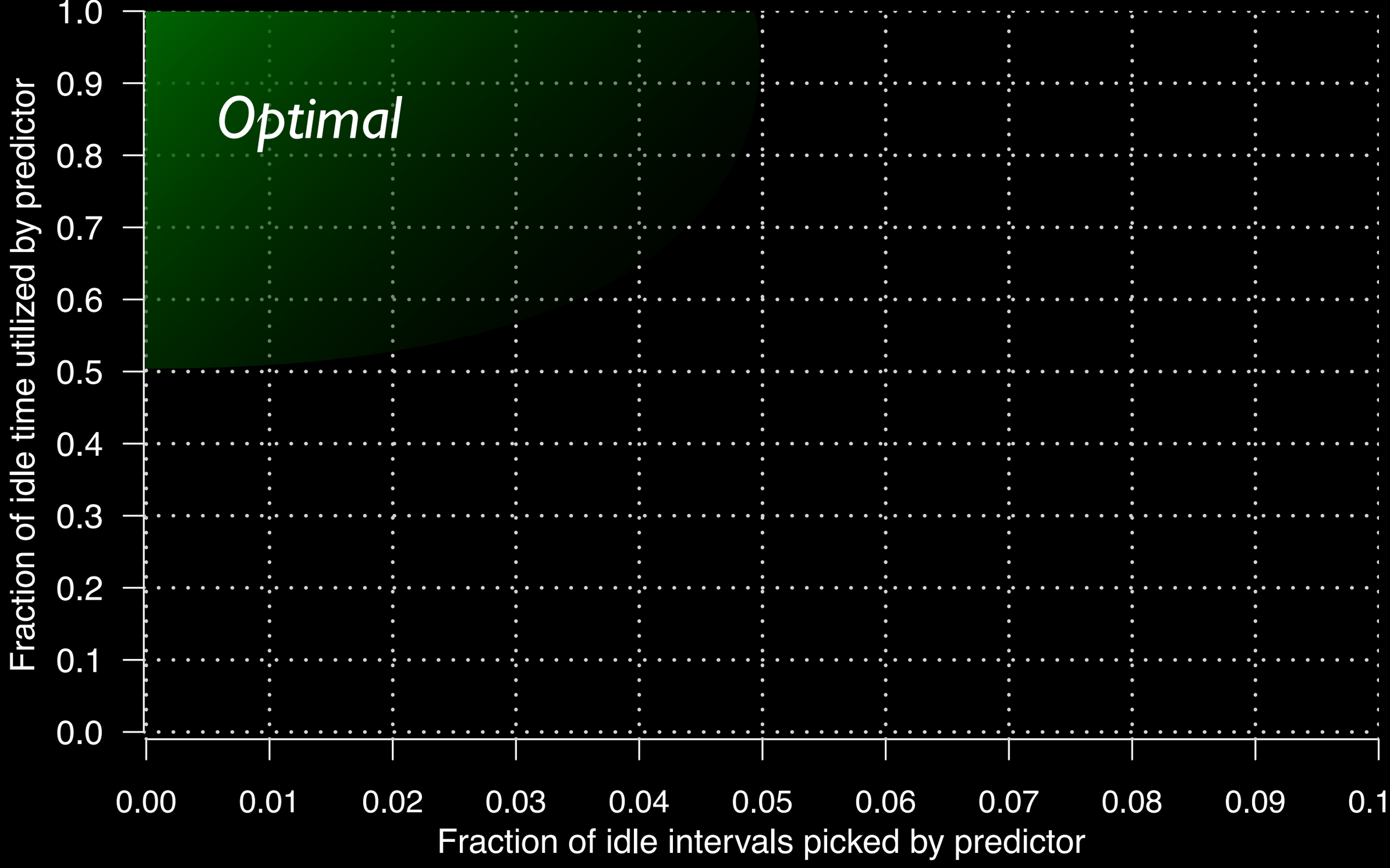
Property: Periodicity - *Repeating patterns in disk traffic*



Predictor: Autoregression - *Fire if prediction > threshold, don't stop*



Predictor evaluation



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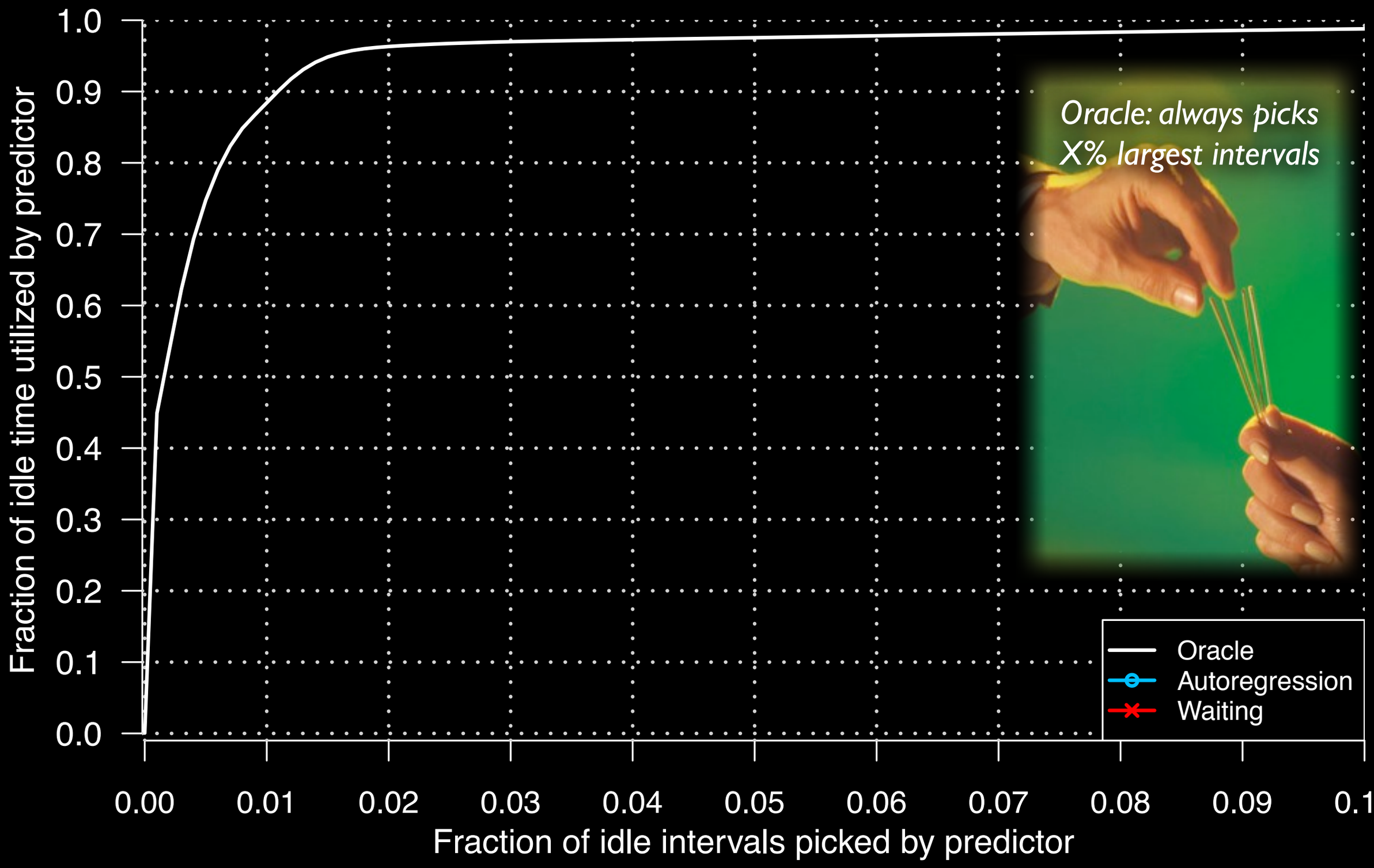

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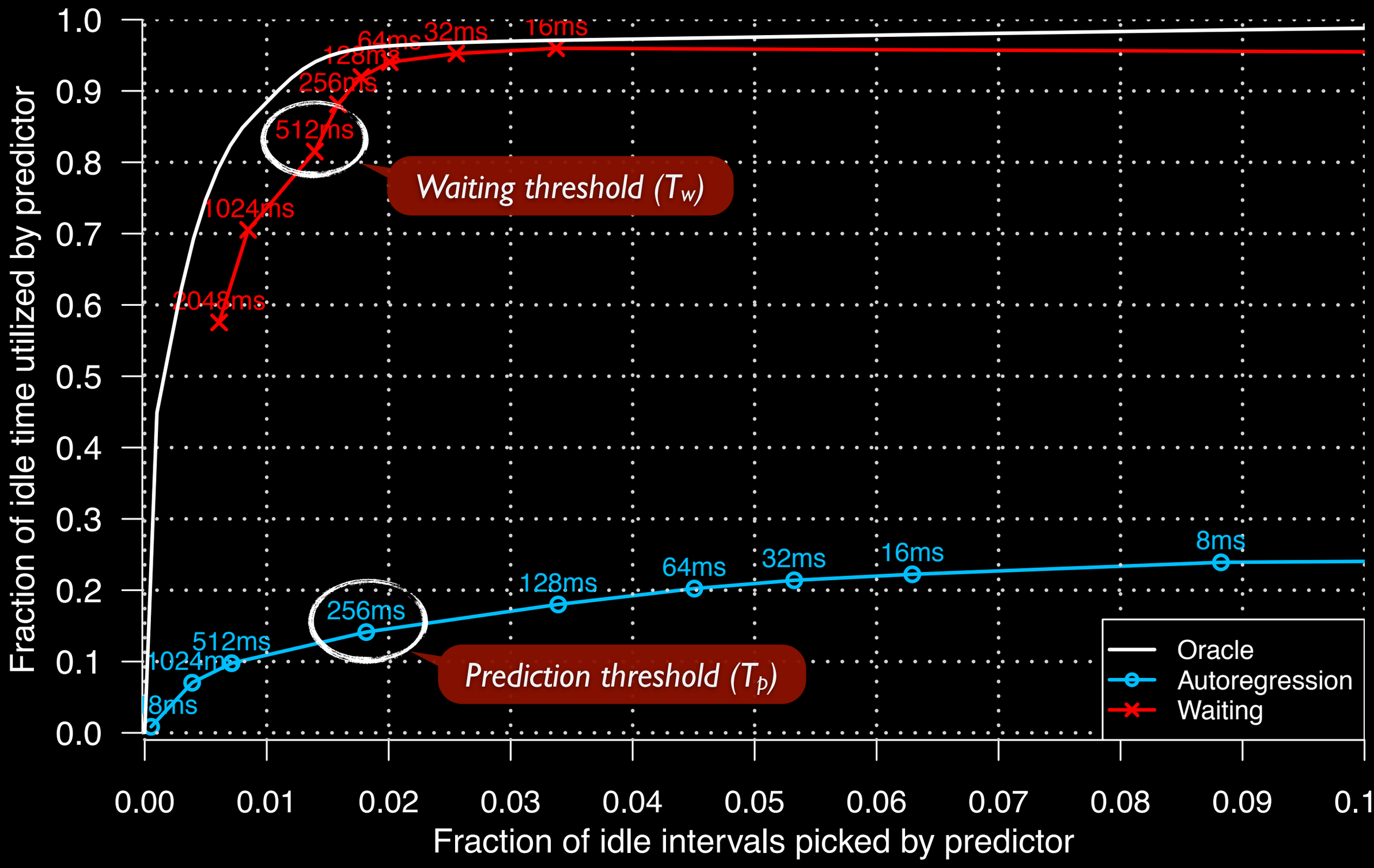


Fine-tuning the wait

VERIFY
request size

Waiting
threshold

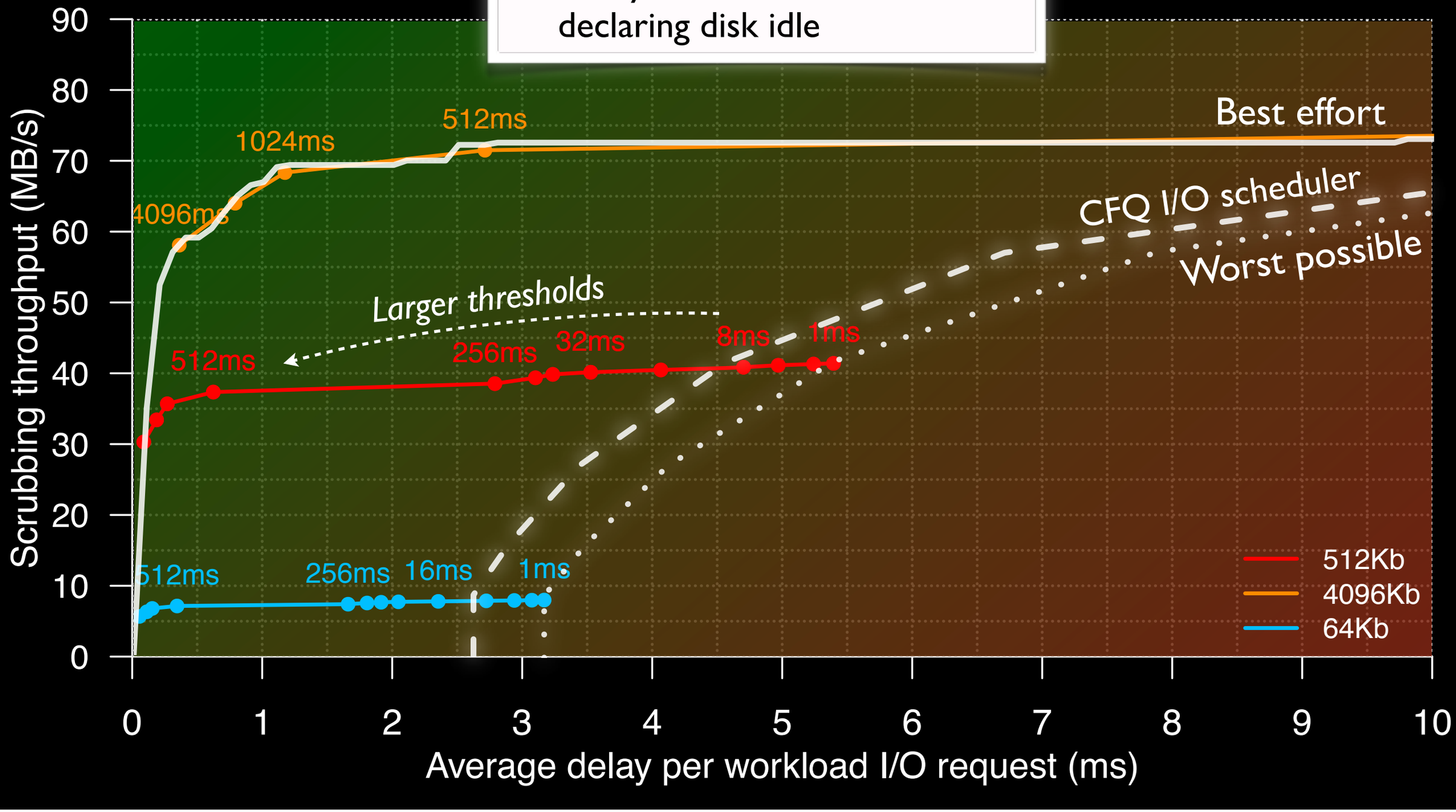
Fine-tuning the wait

VERIFY request size

Complete Fair Queueing (CFQ):

- Default Linux I/O scheduler
- Always waits *10ms* before declaring disk idle

Waiting threshold



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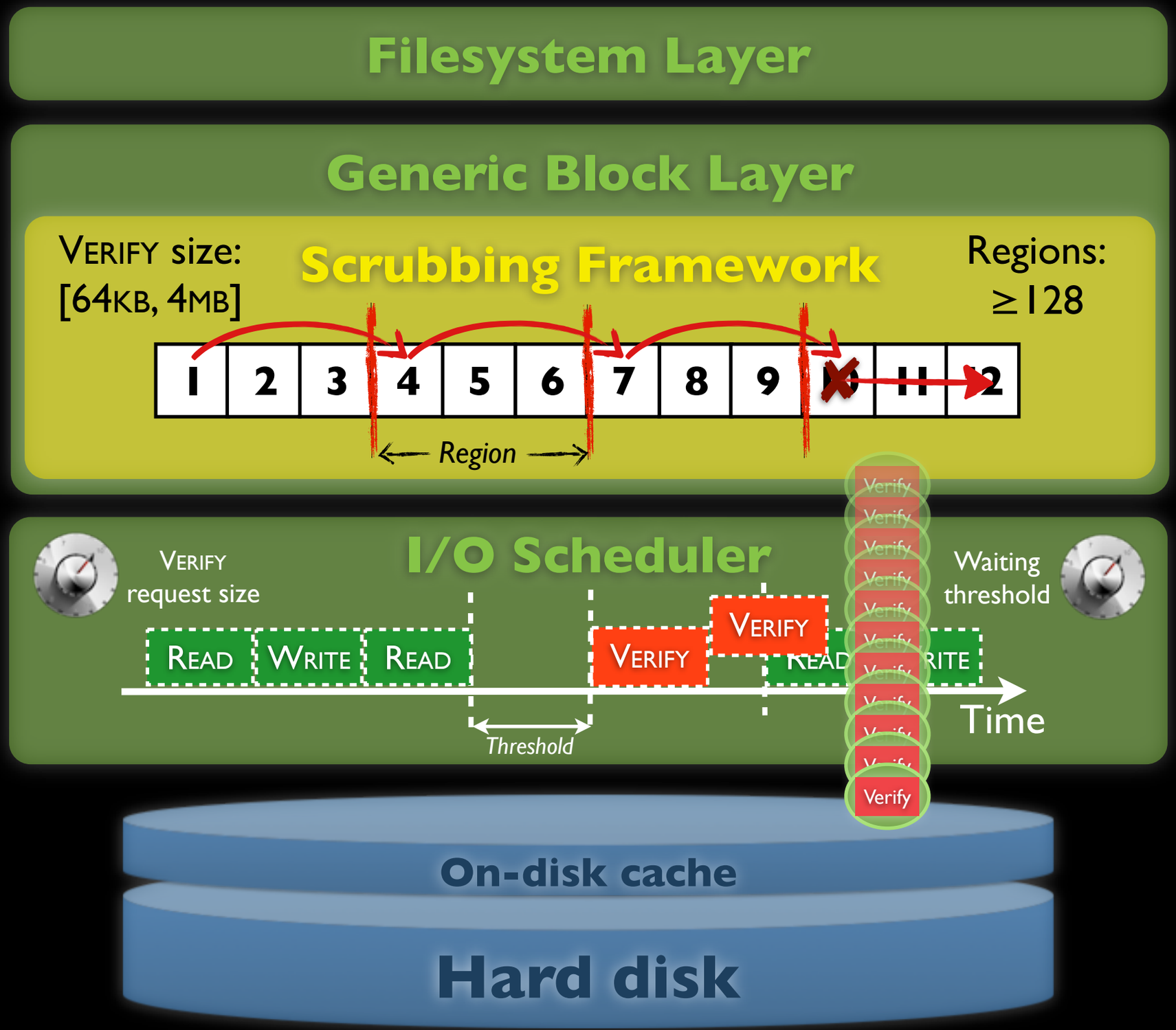
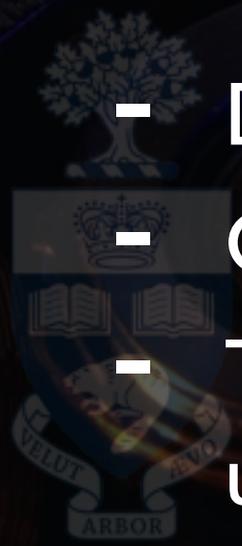
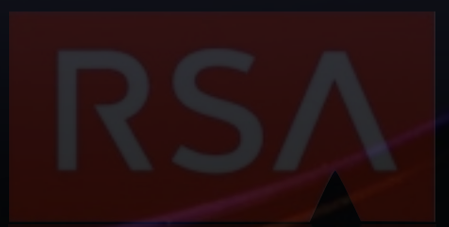


Also in the paper

- Scrubbing framework implementation
  - Open-sourced* framework simplifying development of scrubbing algorithms
  - Why VERIFY is implemented incorrectly in ATA drives
  - Scrubbing impact evaluation in implementation using synthetic/realistic workloads
- Detailed statistical analysis
  - Detection of longer tails than reported in previous work
  - Characterization of periods in traces
  - TPC-C benchmark: idle time distribution unrepresentative of OLTP workloads





The Security Division of EMC

* Kernel/User-level sources available at http://www.cs.toronto.edu/~gamvrosi