The Impact of Solid State Drive on Search Engine Cache Management

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with
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and
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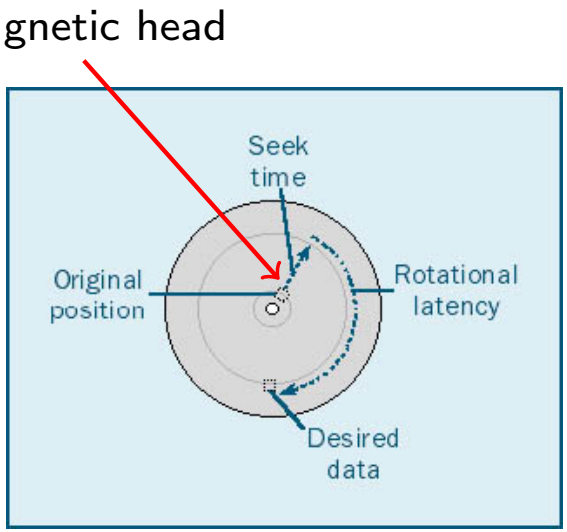
Monash University
May 12, 2014

Outline

Hard Disk Drive

Hard Disk Drive (HDD)



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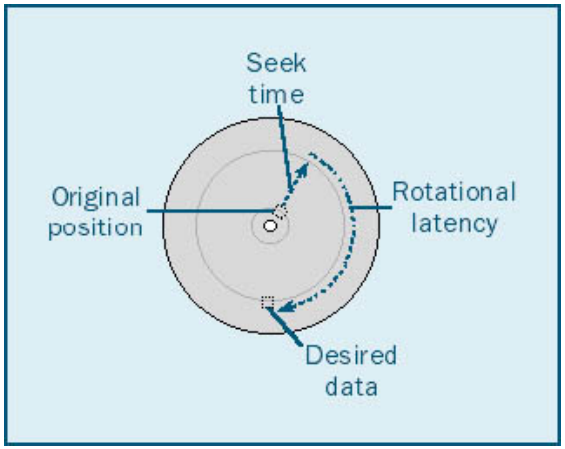

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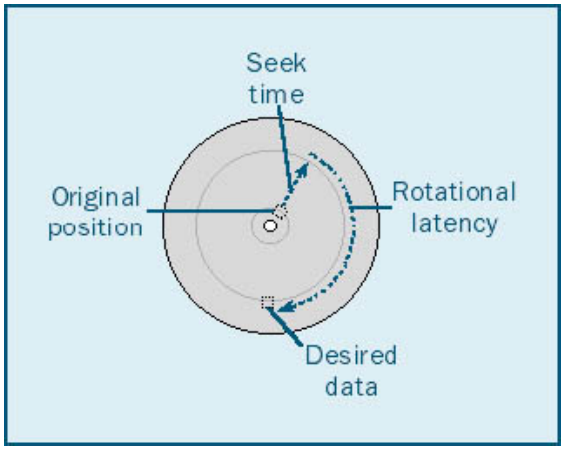

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Caching technology is used to reduce the latency.

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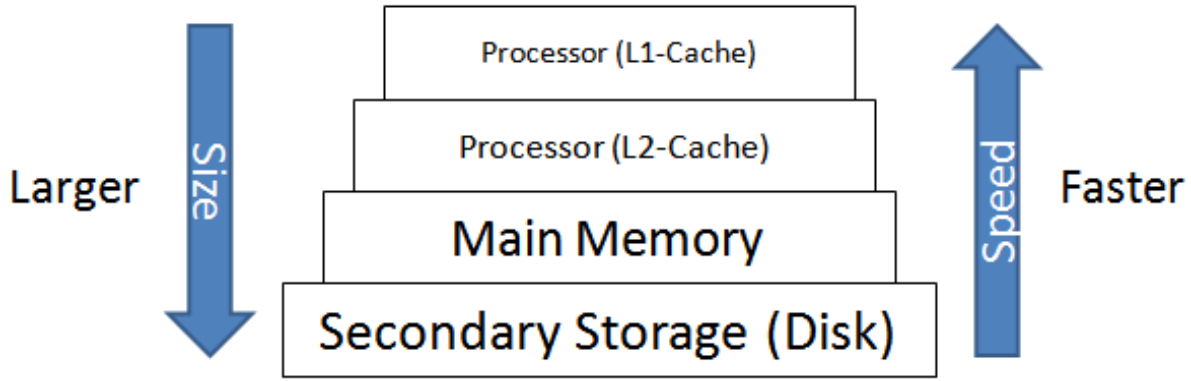
Almost everything is a cache in computer architecture...



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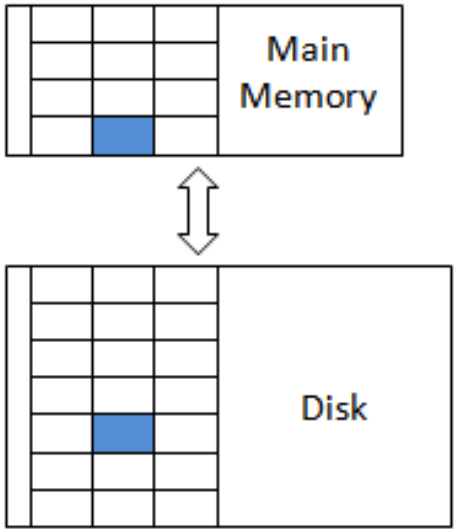

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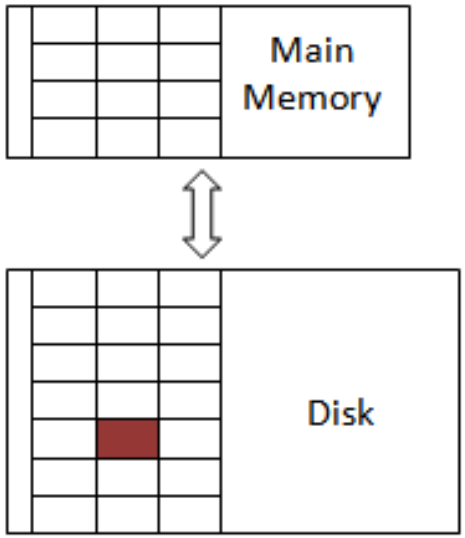

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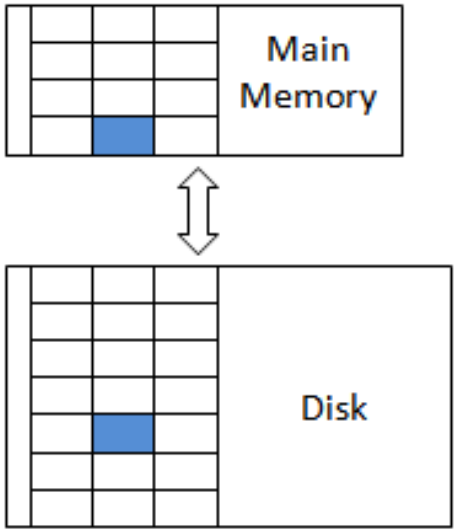

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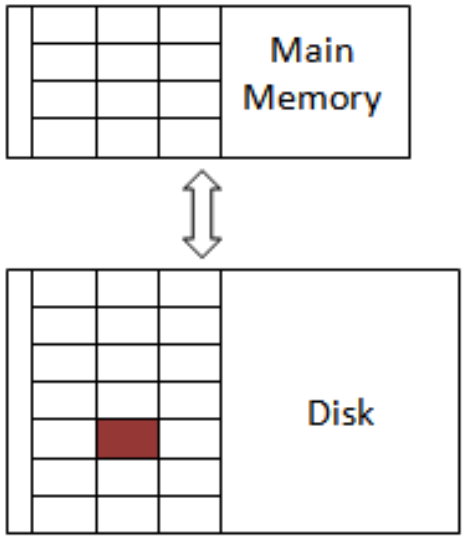

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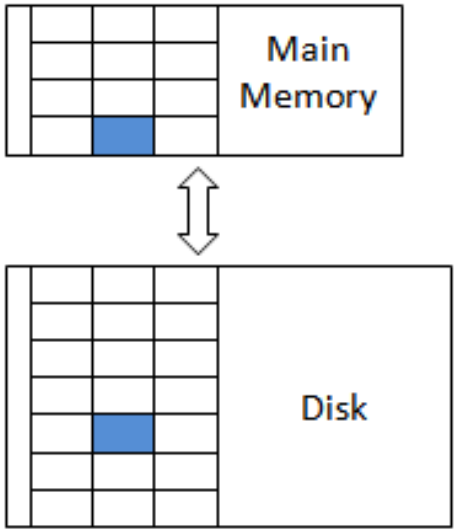

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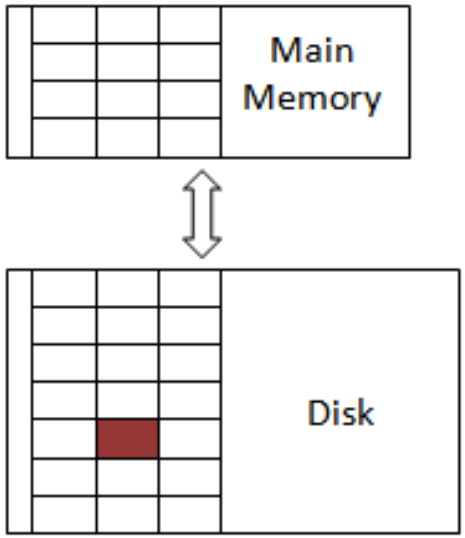

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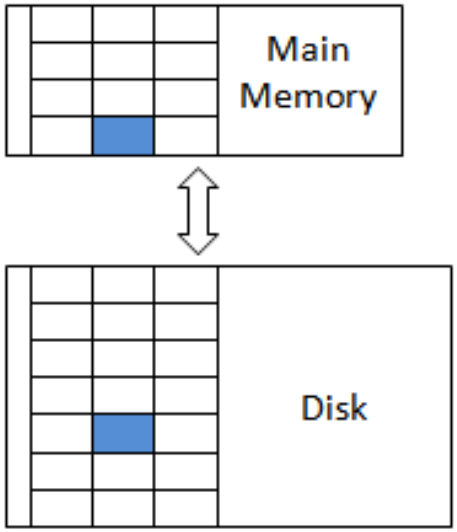

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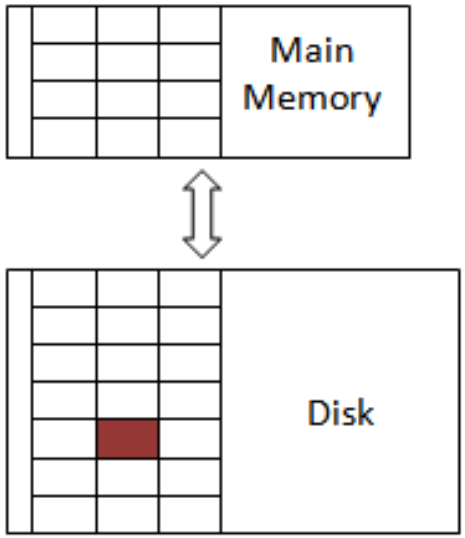

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$$\text{Hit ratio} + \text{Miss ratio} = 1$$

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Solid State Drive (SSD)
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- SSD: **New Faster ($10 \sim 100$x)** HDD with compatible interface
- Strong technical merits: [Chen et al., 2009]
  1. Lower power consumption
  2. More compact size
  3. Better shock resistance
  4. Extraordinarily faster random data access

The Rise of SSD

Words of Pioneer (by Jim Gray, 2006)

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SSD in Large-Scale System Architectures

- **Google** 2008 (or later)
- **Baidu** 2008
- Facebook 2010
- Myspace 2010
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Trends

Flash memory based SSD is replacing and is going to completely replace HDD as the major storage medium!

Challenges

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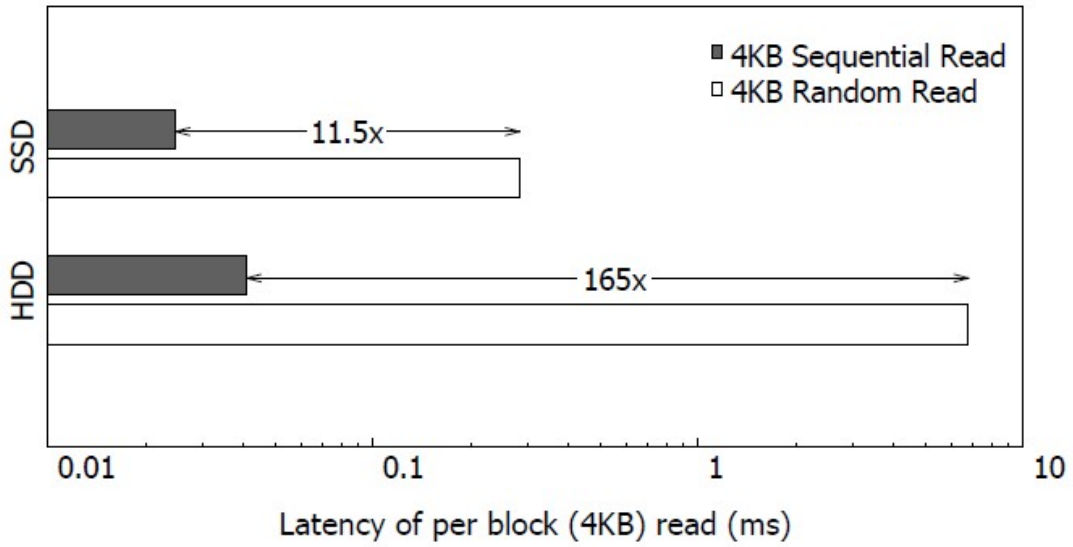

[Tong et al., 2013]

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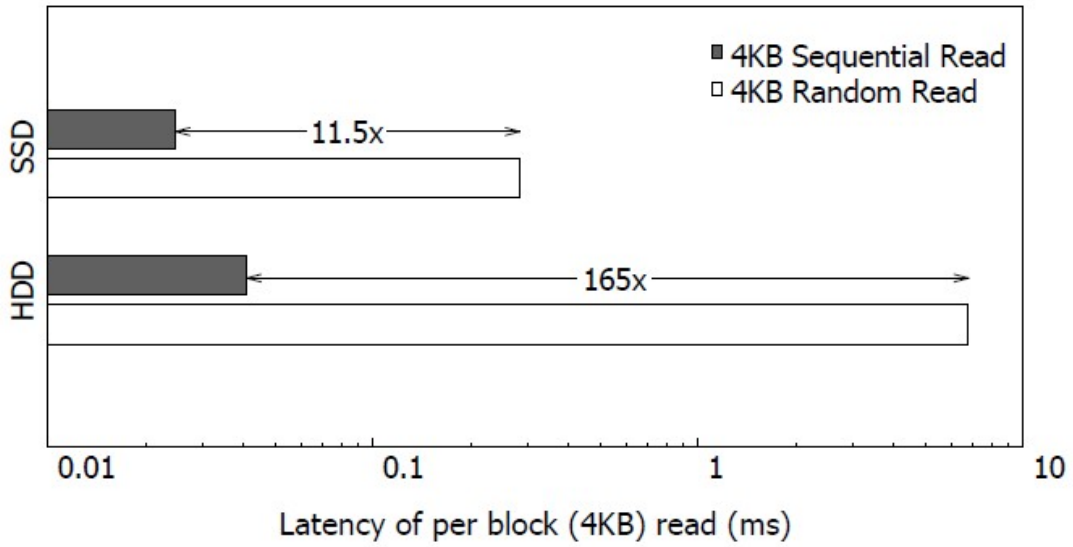

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What now?

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RQ2: How could we deal with that?

- What to do if the efficiency of the entire system is affected by such impact?
- Can we propose better cache policies for SSD-based systems?

1 Background and Motivation

2 Research Questions and Answers

- RQ1: What is the impact of SSD on buffer management?
- RQ2: How could we deal with that?

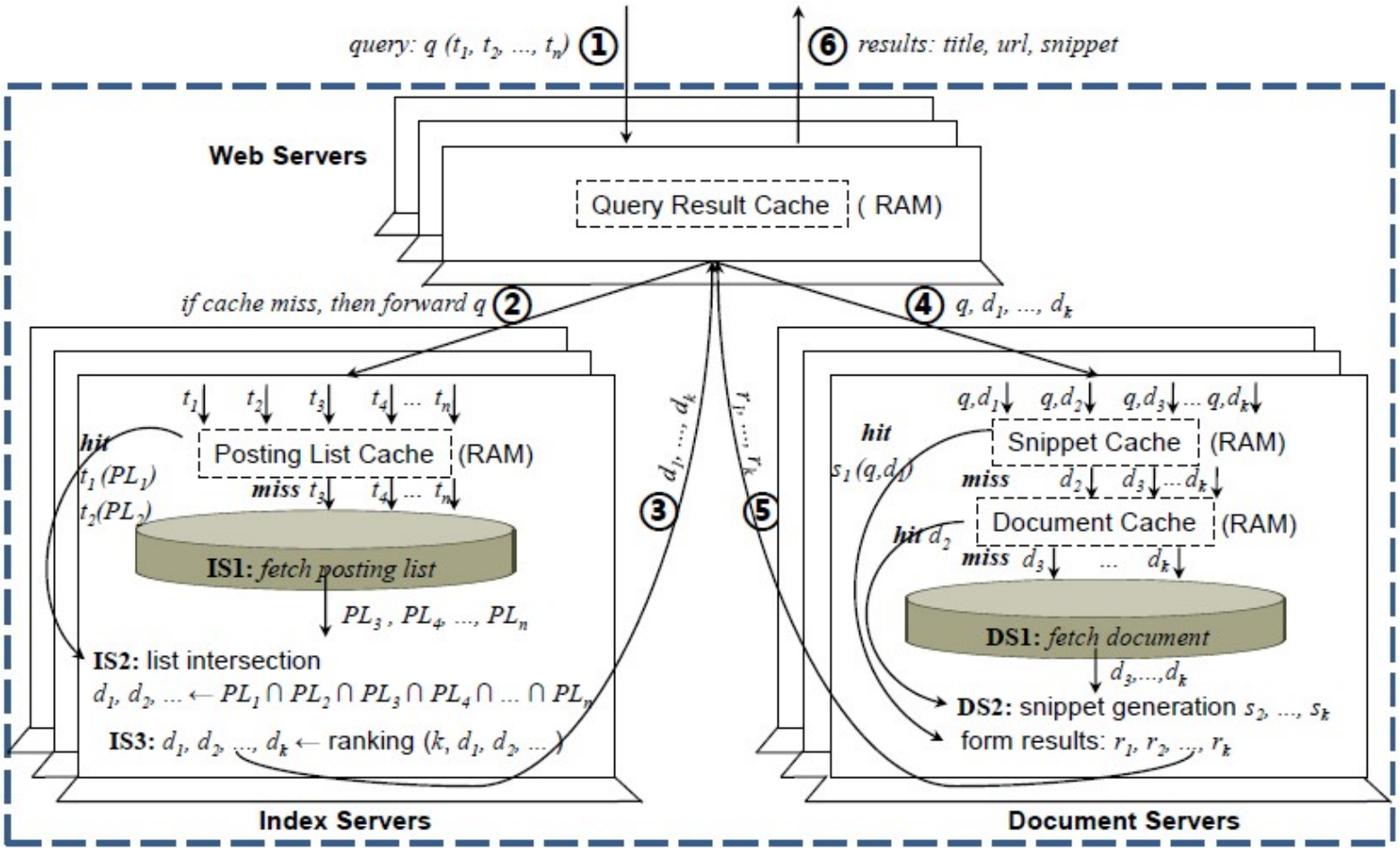
Large-scale experimental study

RQ1 can be answered by evaluating the effectiveness of existing caching policies on an SSD-based search engine.

Settings

- Datasets
  - Web documents: 12,000,000 (∼100GB)
  - Queries: 1,000,000
- Device
  - SSD: ADATA 256GB SSD
  - HDD: Seagate 3TB 7200rpm
- System: Apache Lucene
- Measure: Query time (NOT hit ratio)

Overview of search engine architecture



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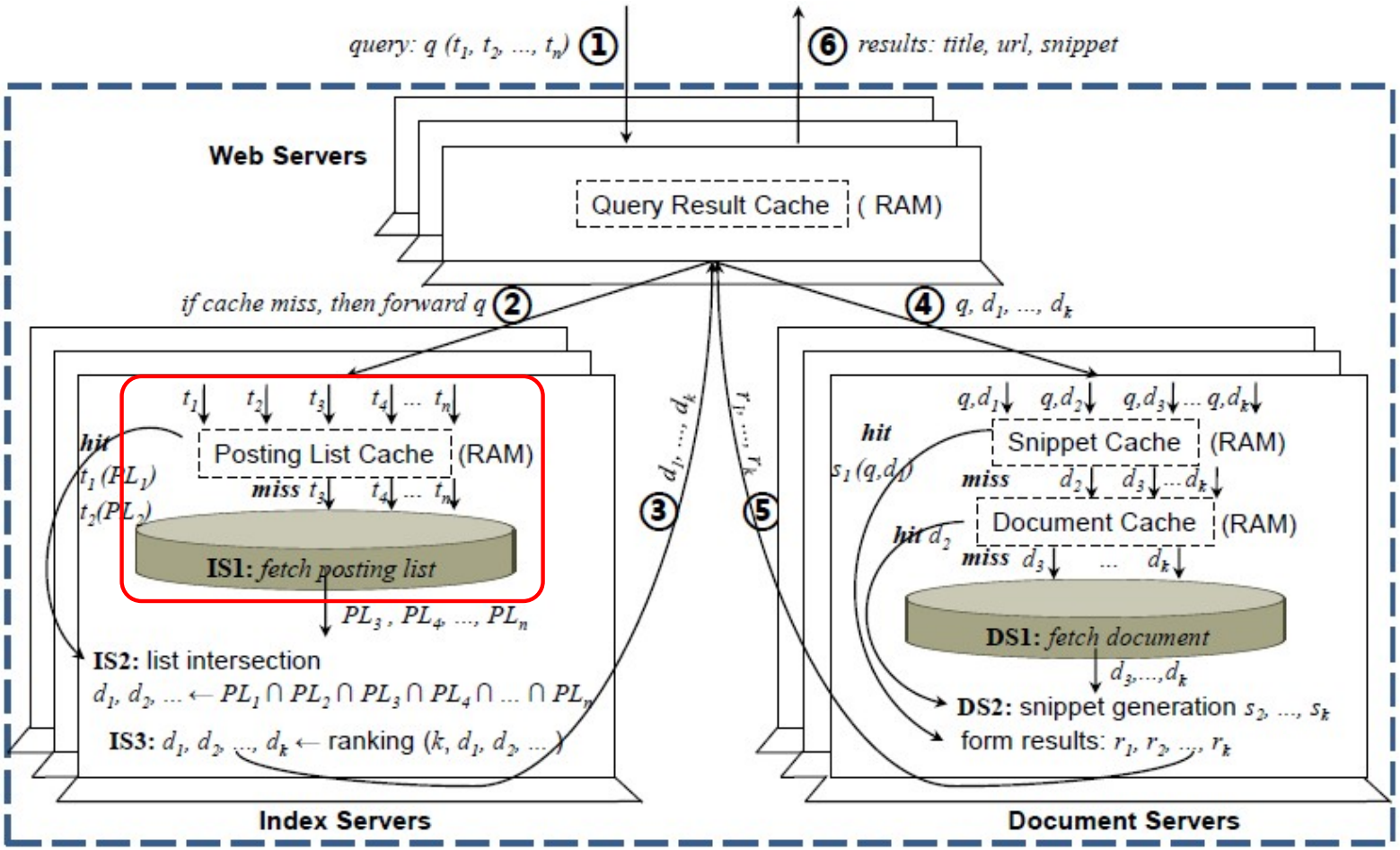

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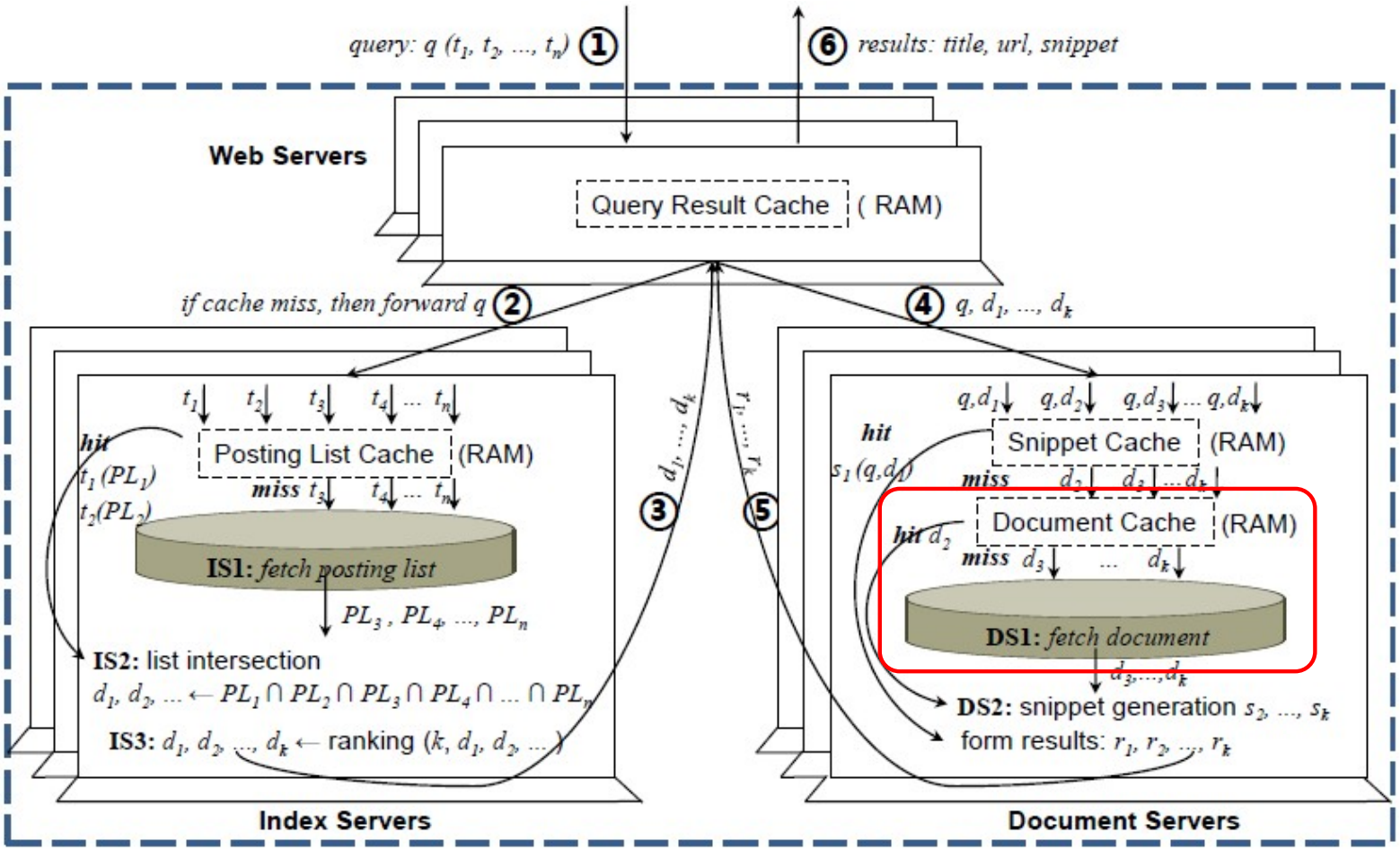

[Wang et al., 2013]

Index Server and List (Index) Cache

Posting Lists (Inverted Lists)

- `Clayton` (2, 4, 5, 10, 100, 107, ..., 1,000,000)
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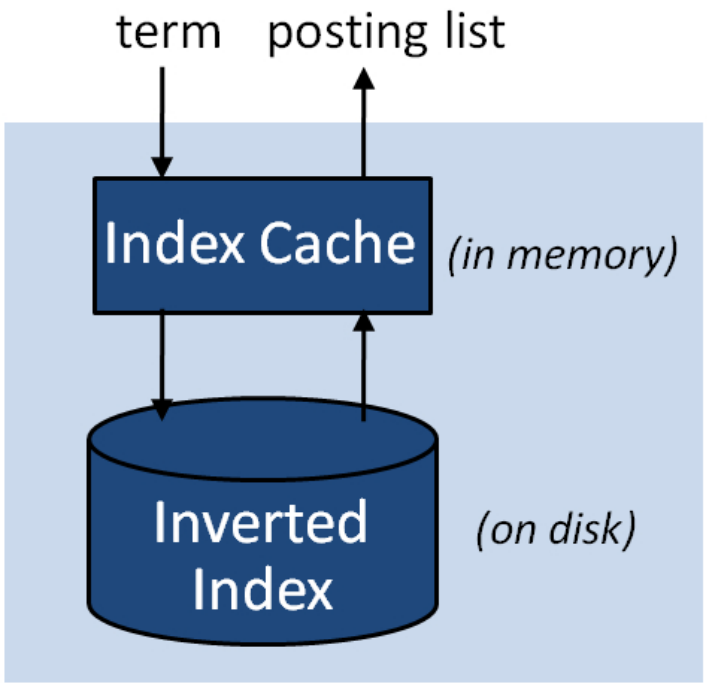

Index Server

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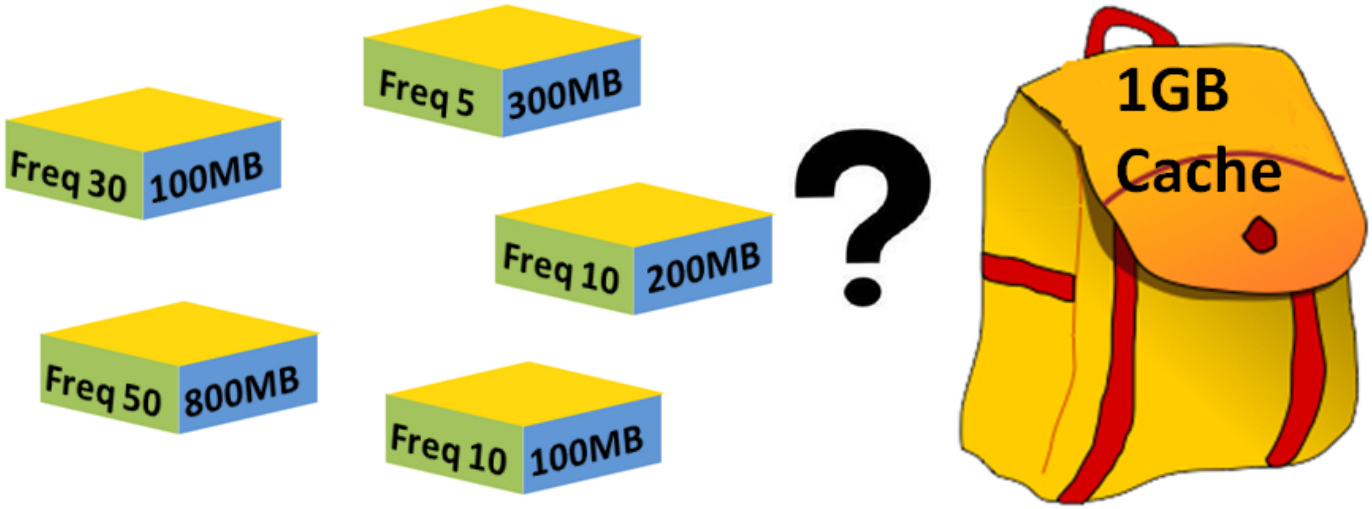

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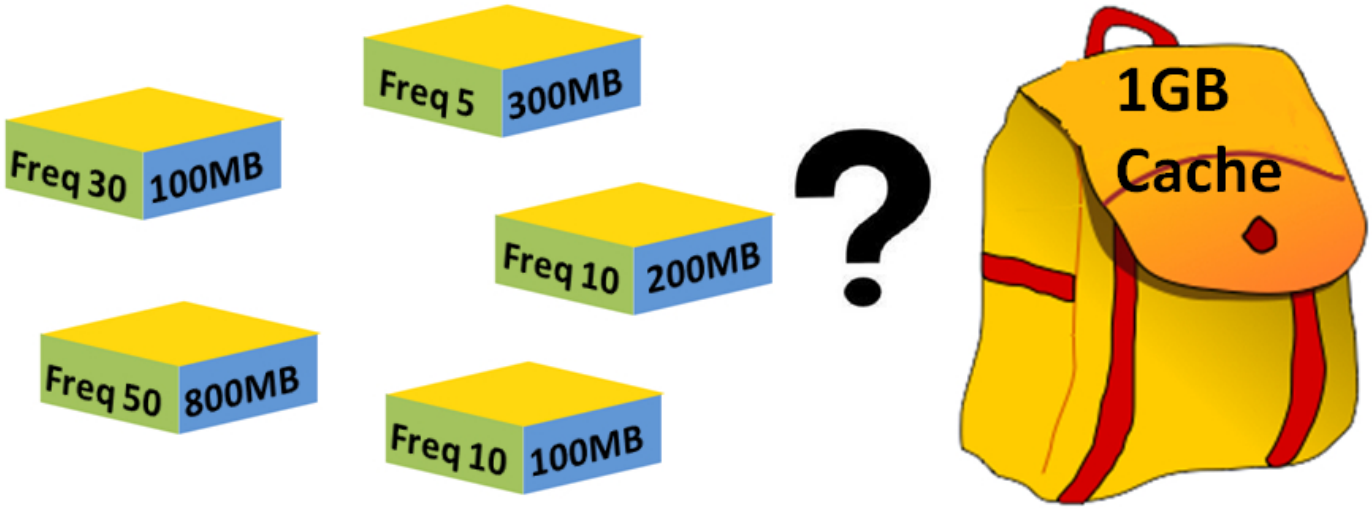

Metrics to consider

- High Frequency First?
- High Frequency/Size First?

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Frequency/Size is a better metric (for HDD).

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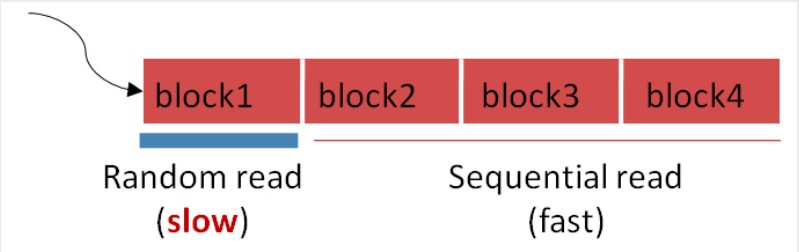

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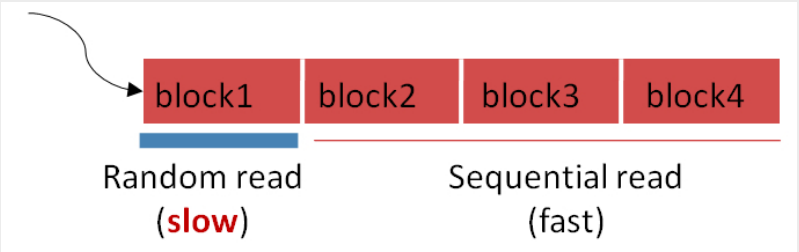

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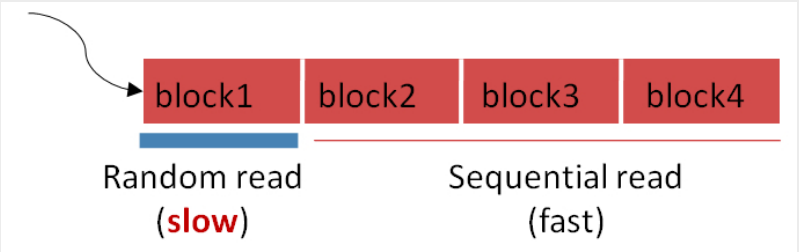

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- High benefit gained when size is taken into account

How does SSD change the story? [Wang et al., 2013]

Differences

On SSD

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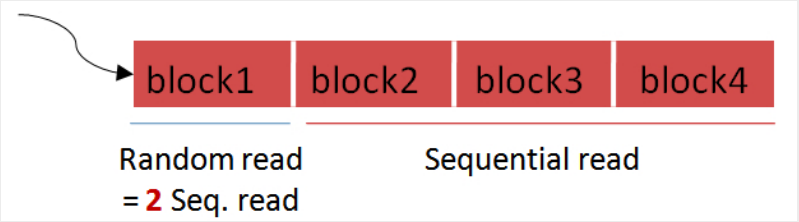

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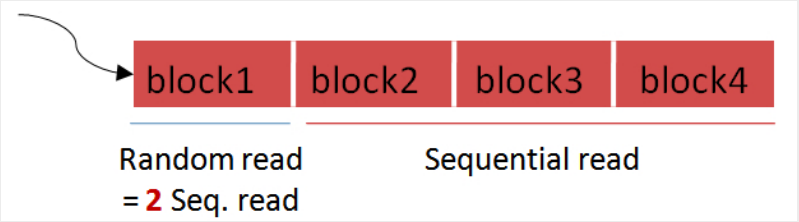
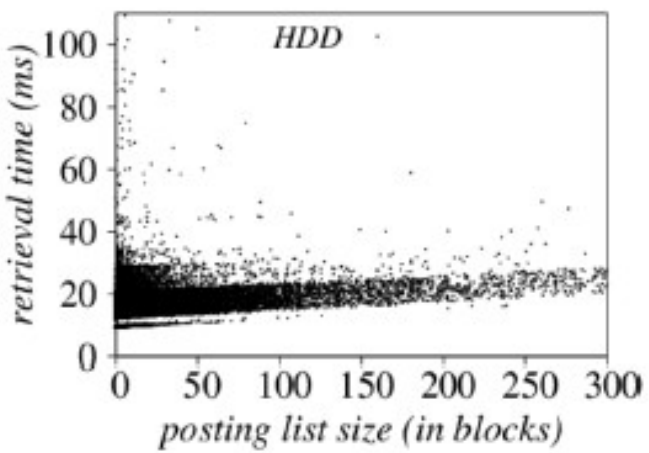


- Long lists have slower access time
  $\Longrightarrow$ Admitting too many short lists offers less benefit

How does SSD change the story? (Cont.)

Read access latency of posting lists of varying lengths



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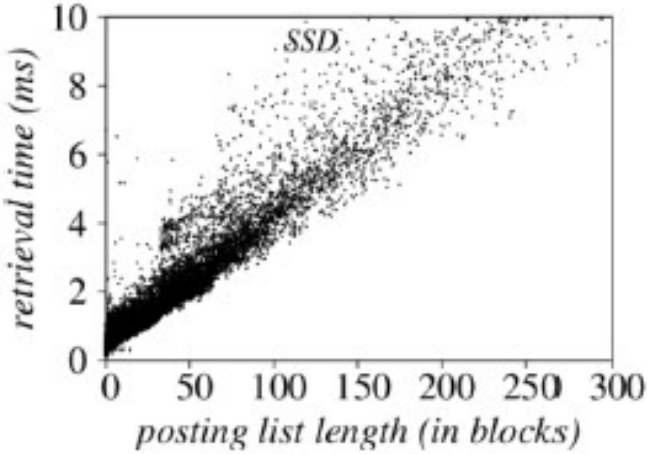

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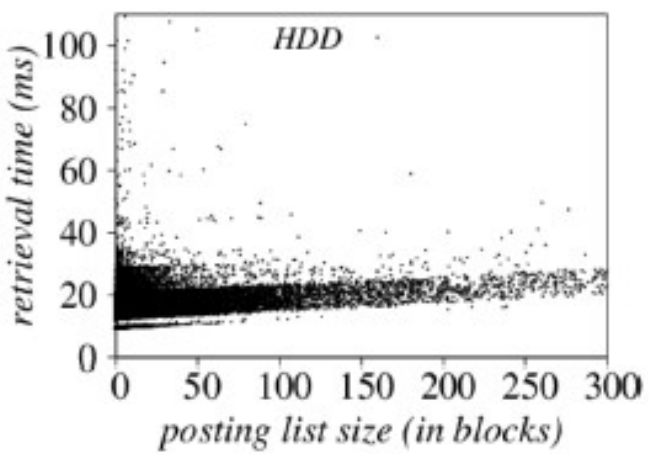

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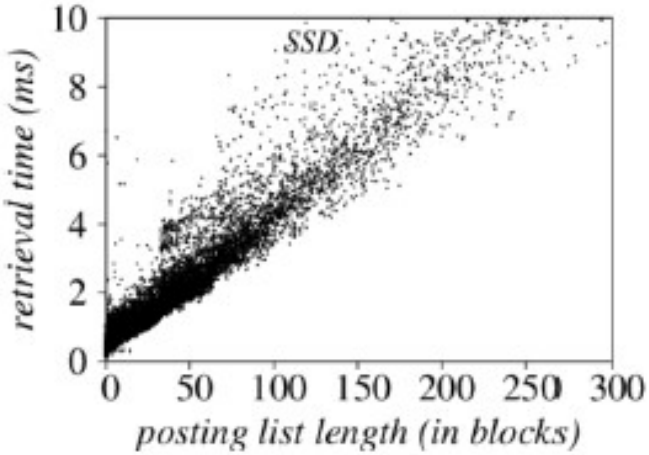

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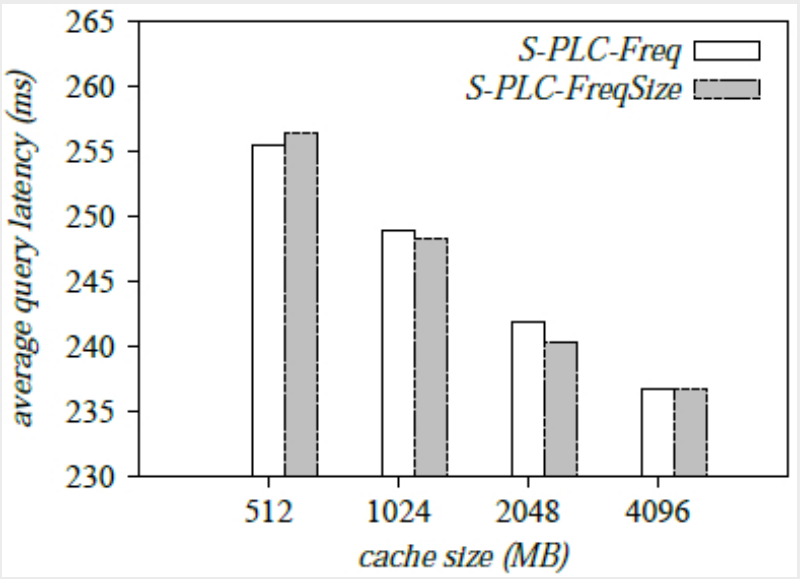
Conjecture 1

The best cache policy may have changed

Evaluation on Index Server

Static List Cache Policy



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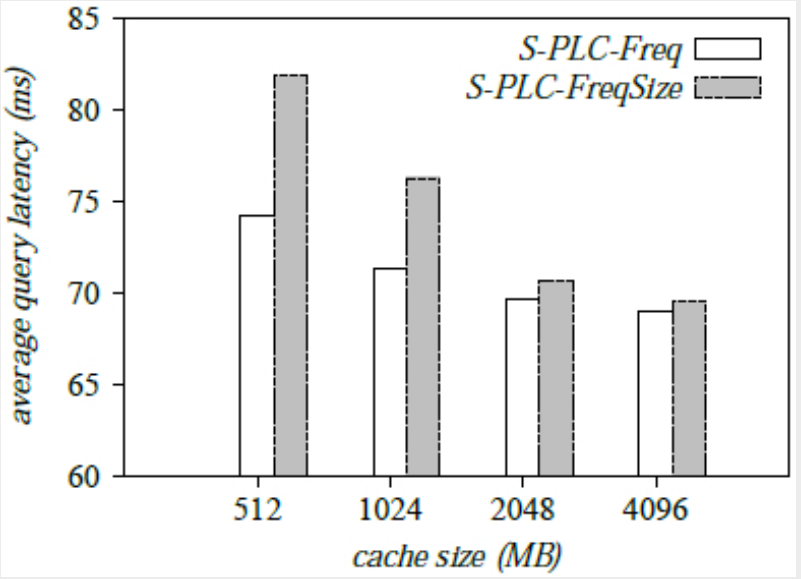

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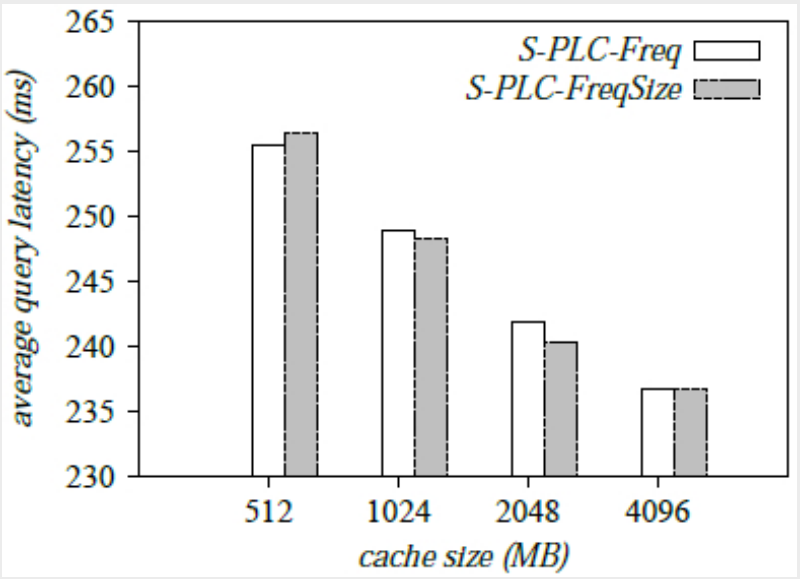

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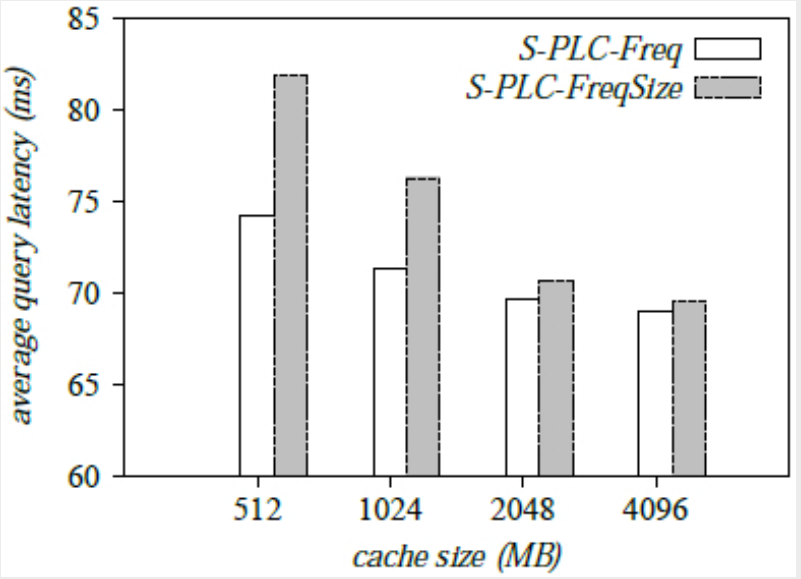

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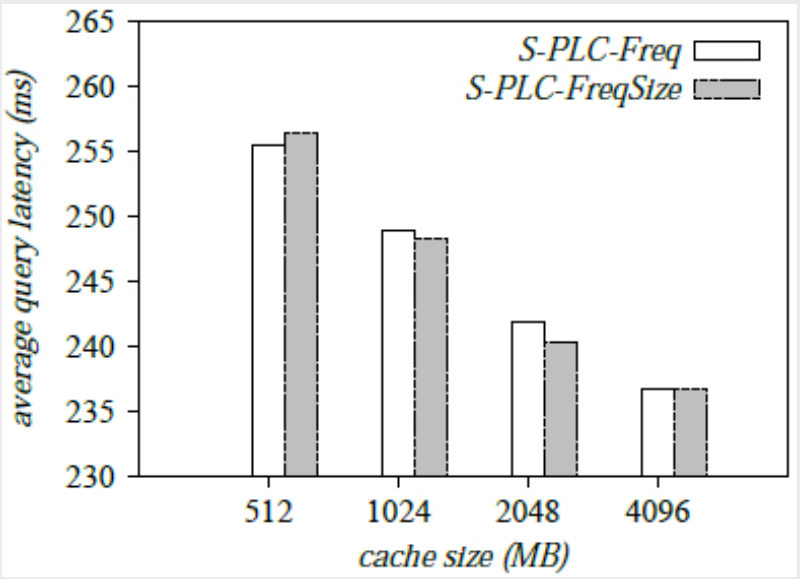

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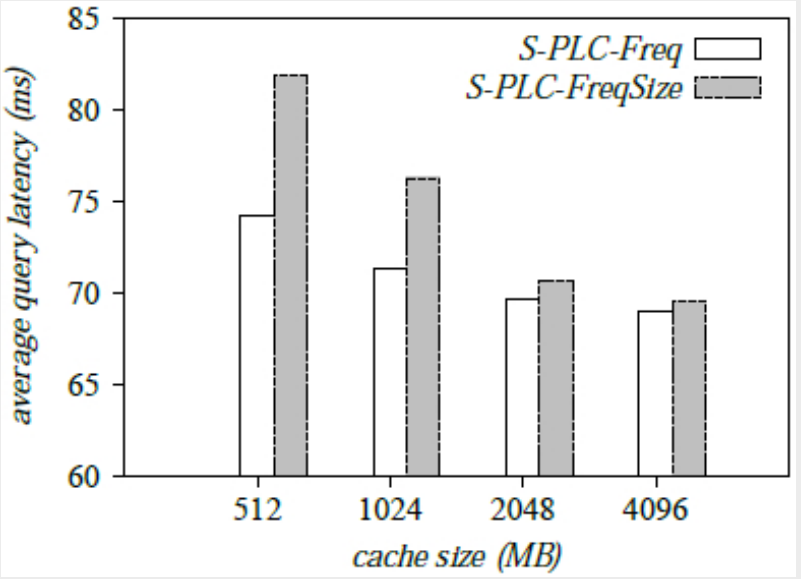

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★Do not rely on your knowledge acquired in HDD era.

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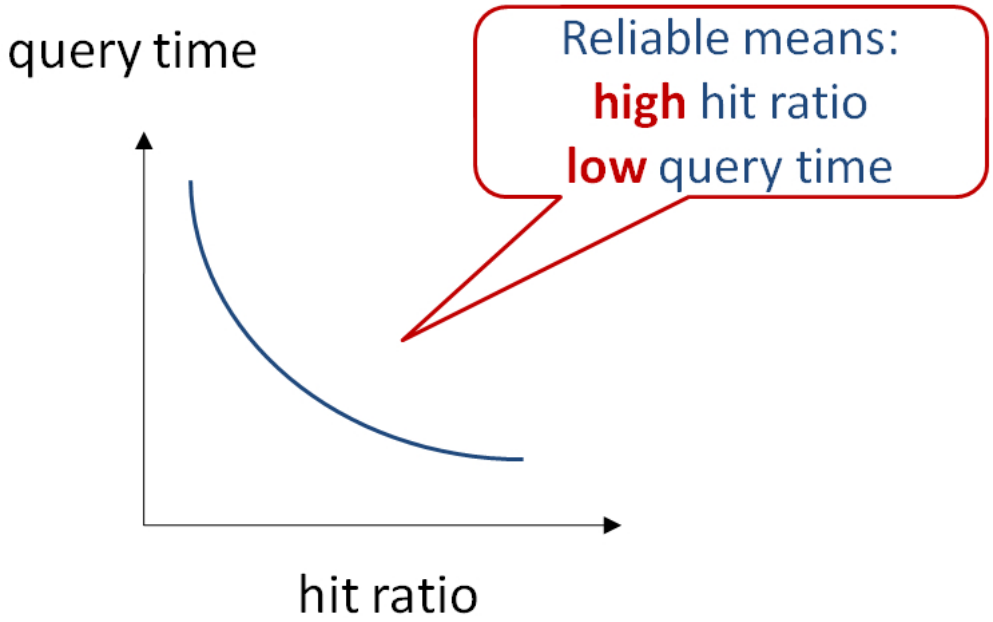

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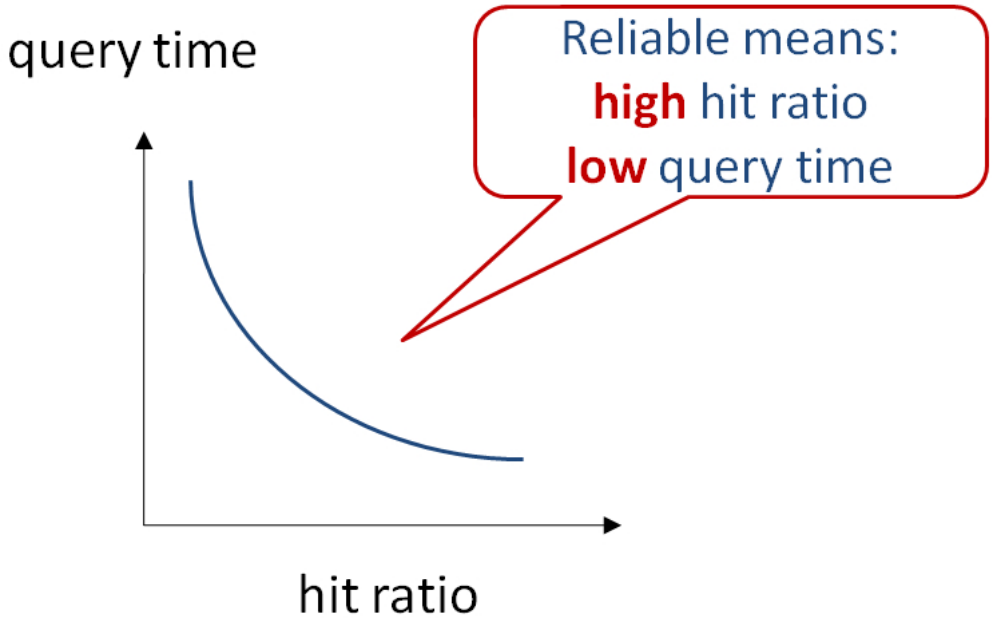
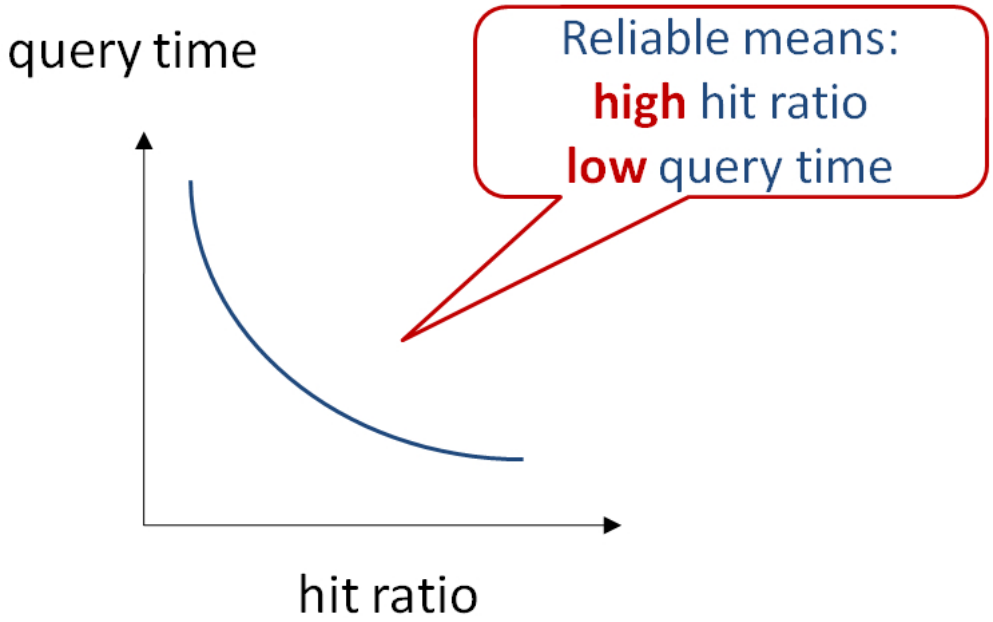


Previously on HDD	Now on SSD
Reliable	?
As list access is a constant	NO
So, can measure the effectiveness of the cache	?

Is Hit Ratio Reliable?



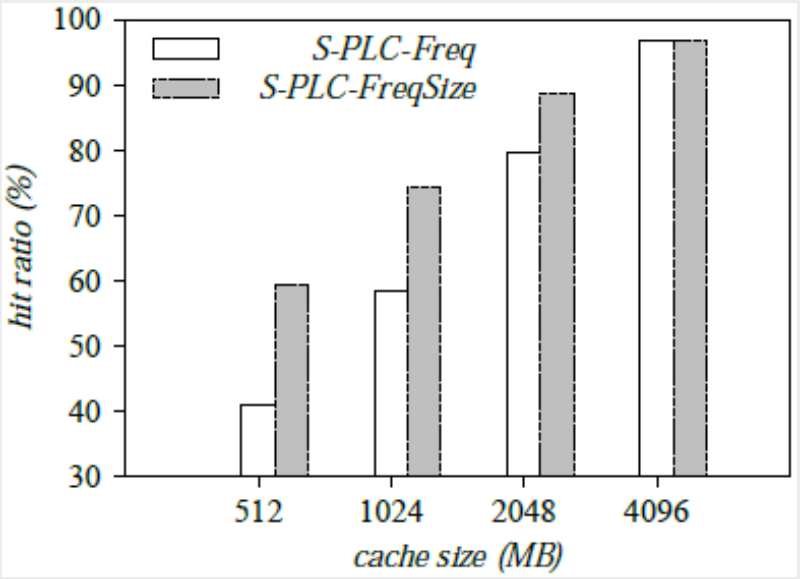
Previously on HDD	Now on SSD
Reliable	?
As list access is a constant	NO
So, can measure the effectiveness of the cache	?

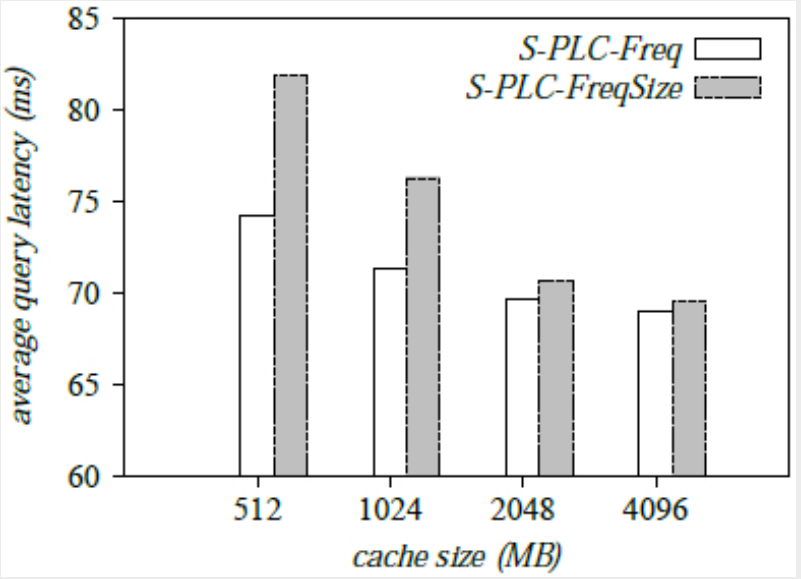
Conjecture 2

Cache hit ratio might not be reliable.

Is Hit Ratio Reliable? (Cont.)

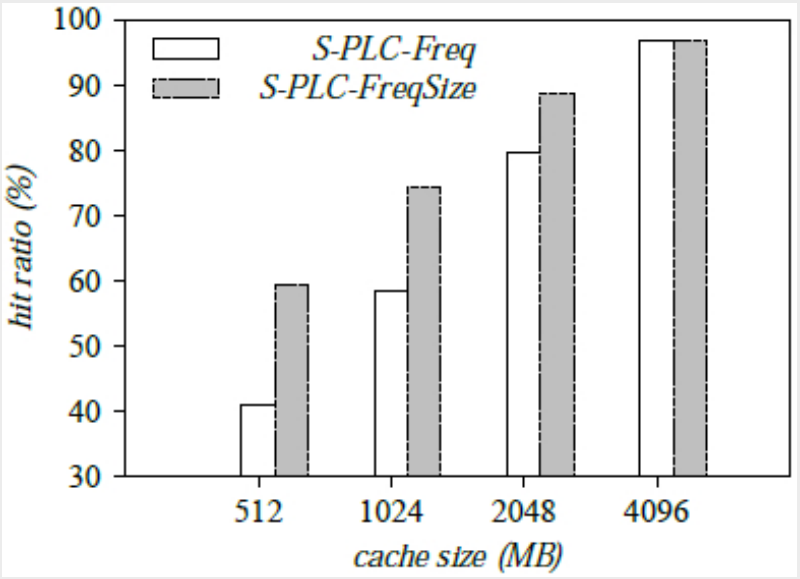
Static List Cache Policy (on SSD)

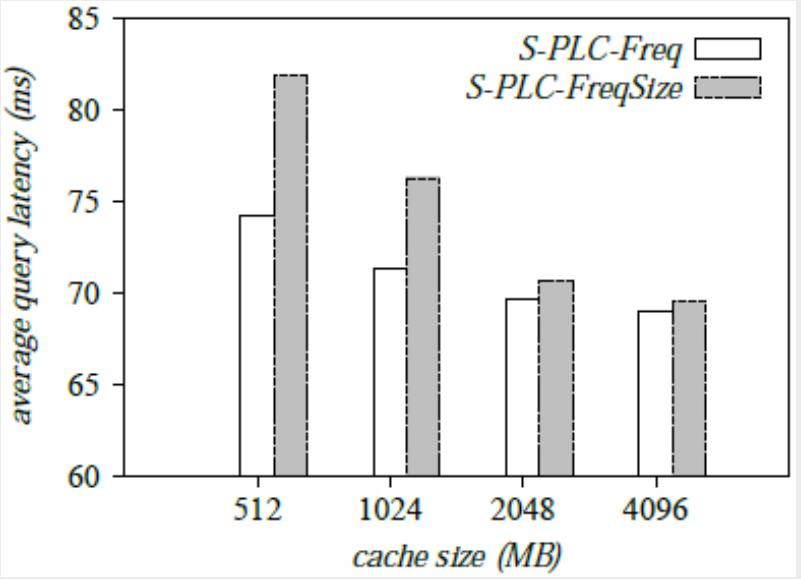




Is Hit Ratio Reliable? (Cont.)

Static List Cache Policy (on SSD)



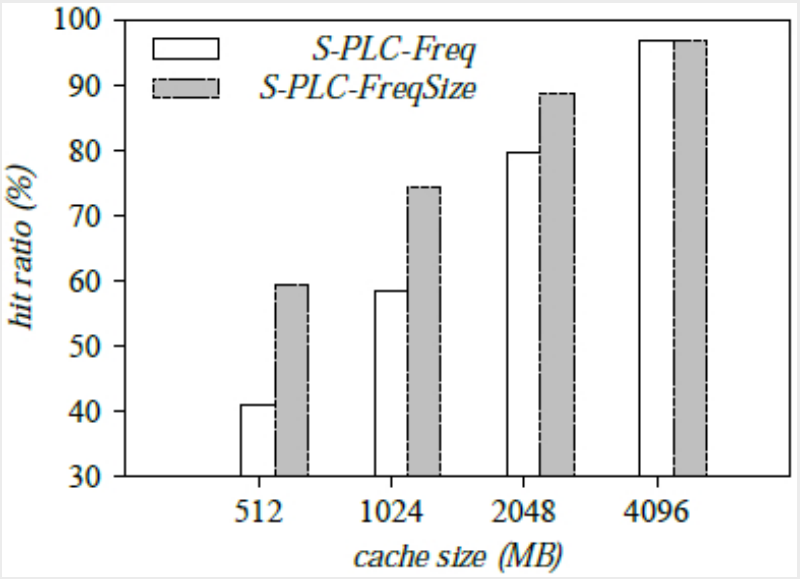


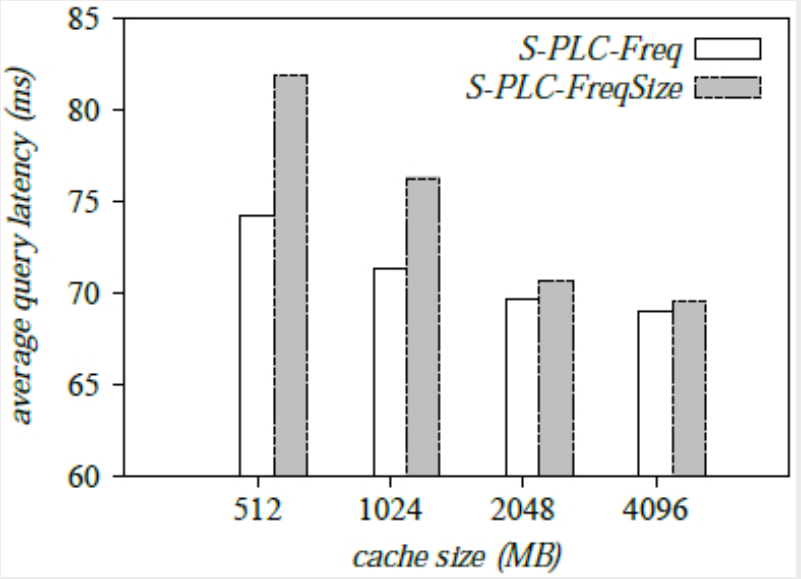
Conjecture 2

Cache hit ratio might not be reliable – Confirmed

Is Hit Ratio Reliable? (Cont.)

Static List Cache Policy (on SSD)



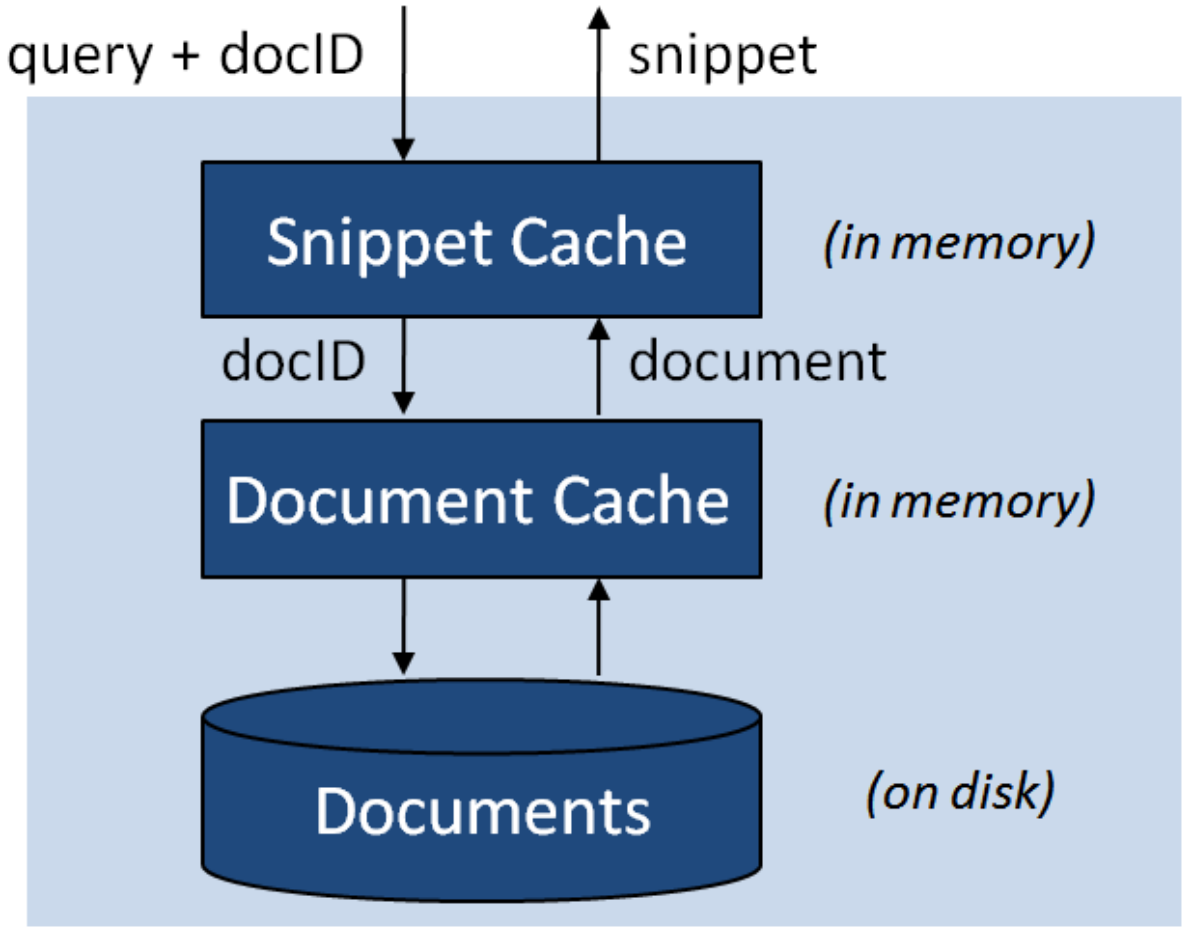


Conjecture 2

Cache hit ratio might not be reliable – Confirmed

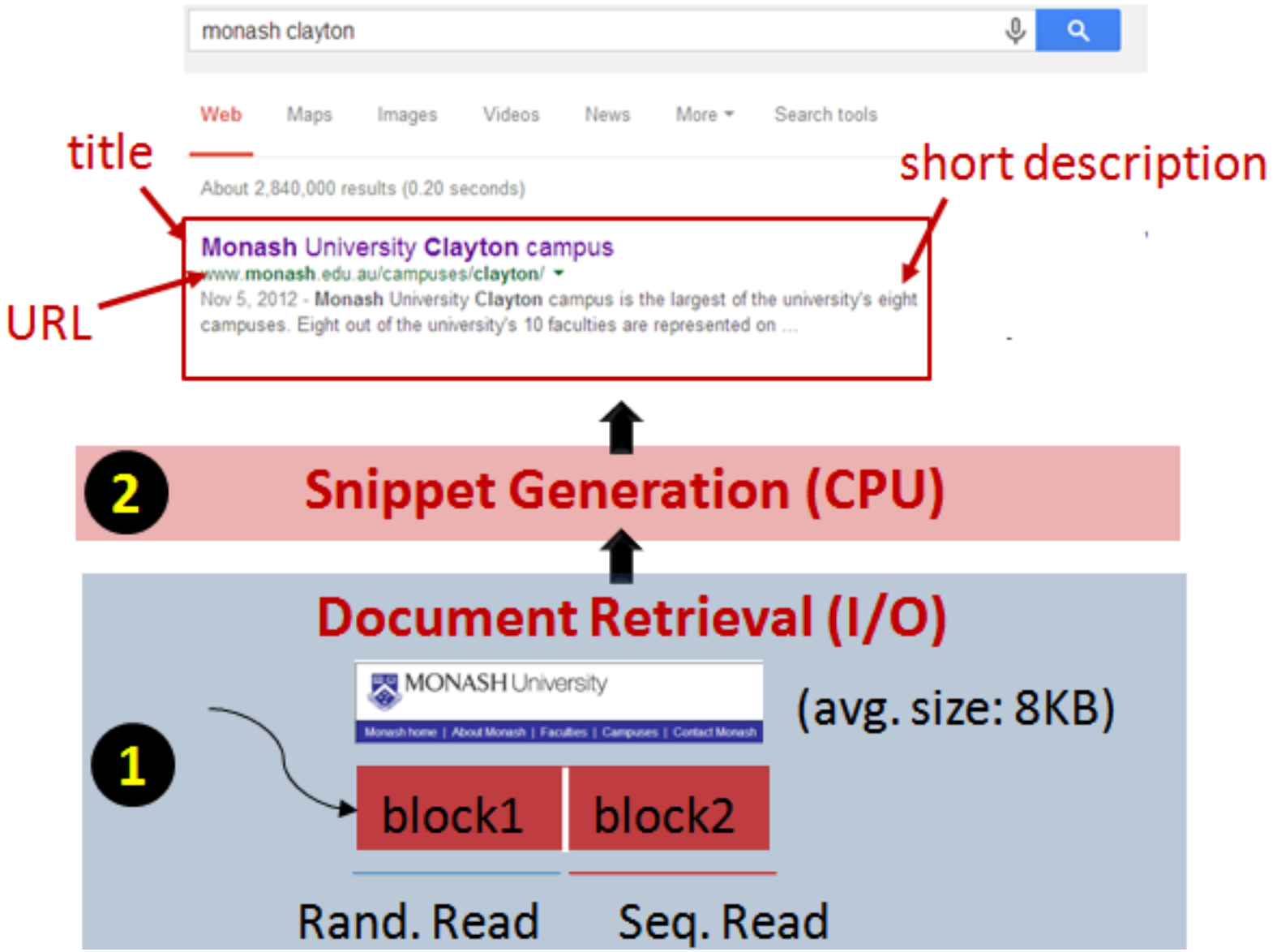
★Use query time, not hit ratio

Document Server and Its Cache

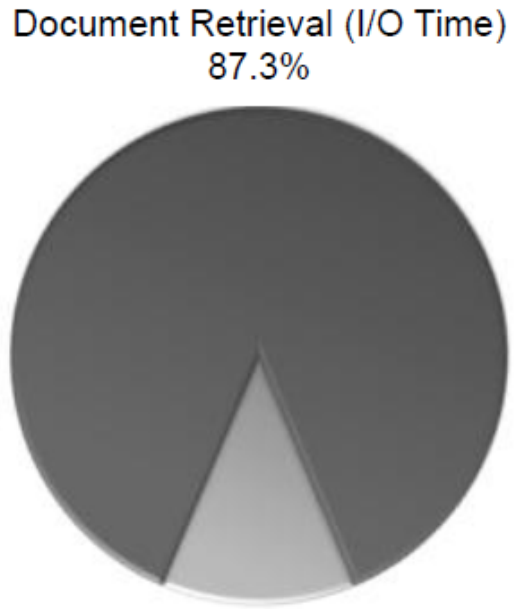


Document Server

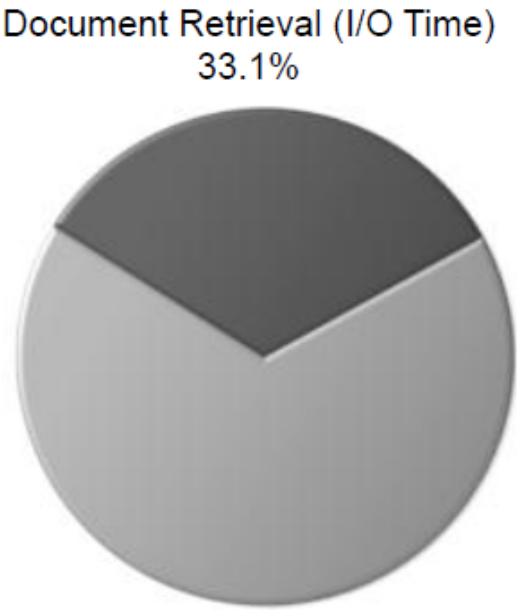
Document Server and Its Cache (Cont.)



Evaluation on Document Server

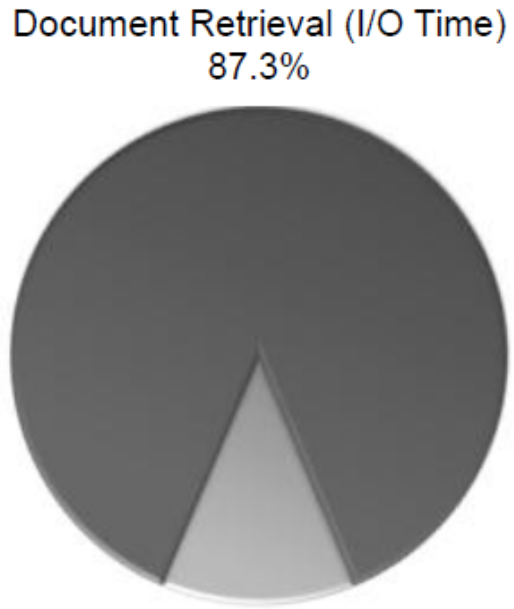


(a) on HDD

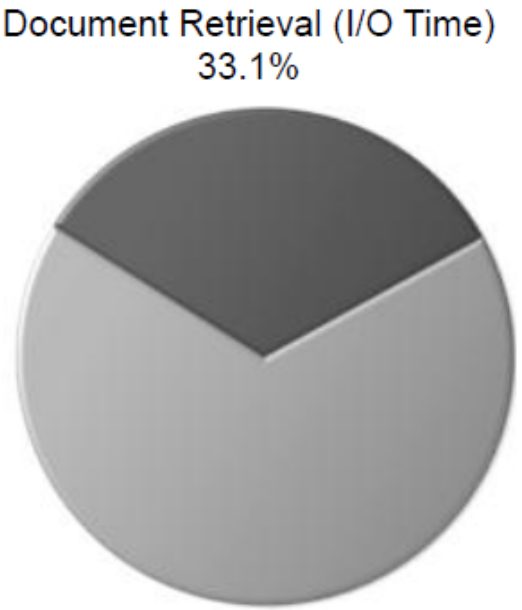


(b) on SSD

Evaluation on Document Server



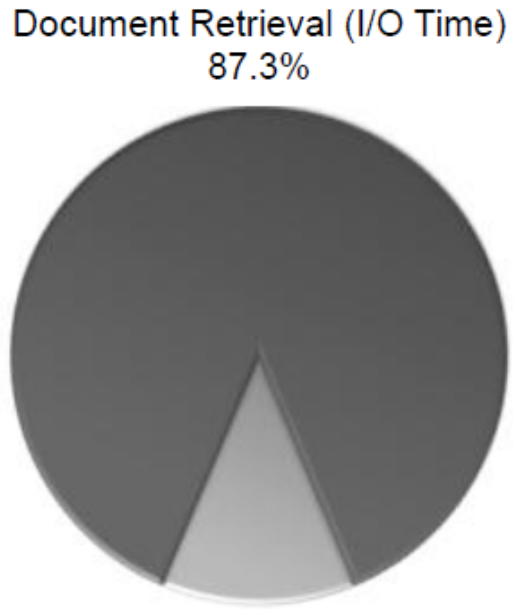
(a) on HDD



(b) on SSD

Document retrieval is no longer the bottleneck on document server

Evaluation on Document Server



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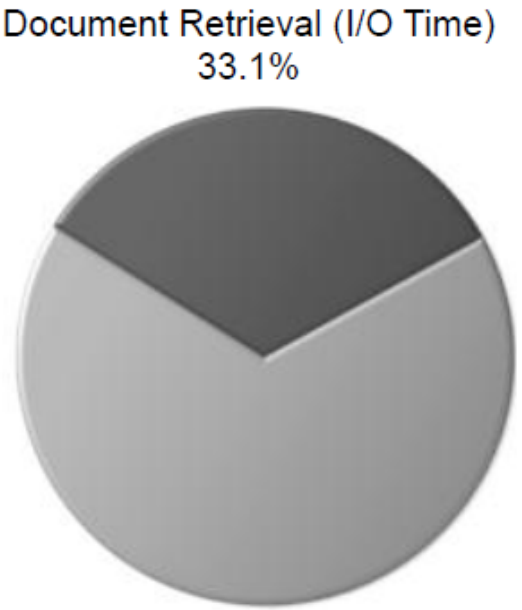


(b) on SSD

Document retrieval is no longer the bottleneck on document server

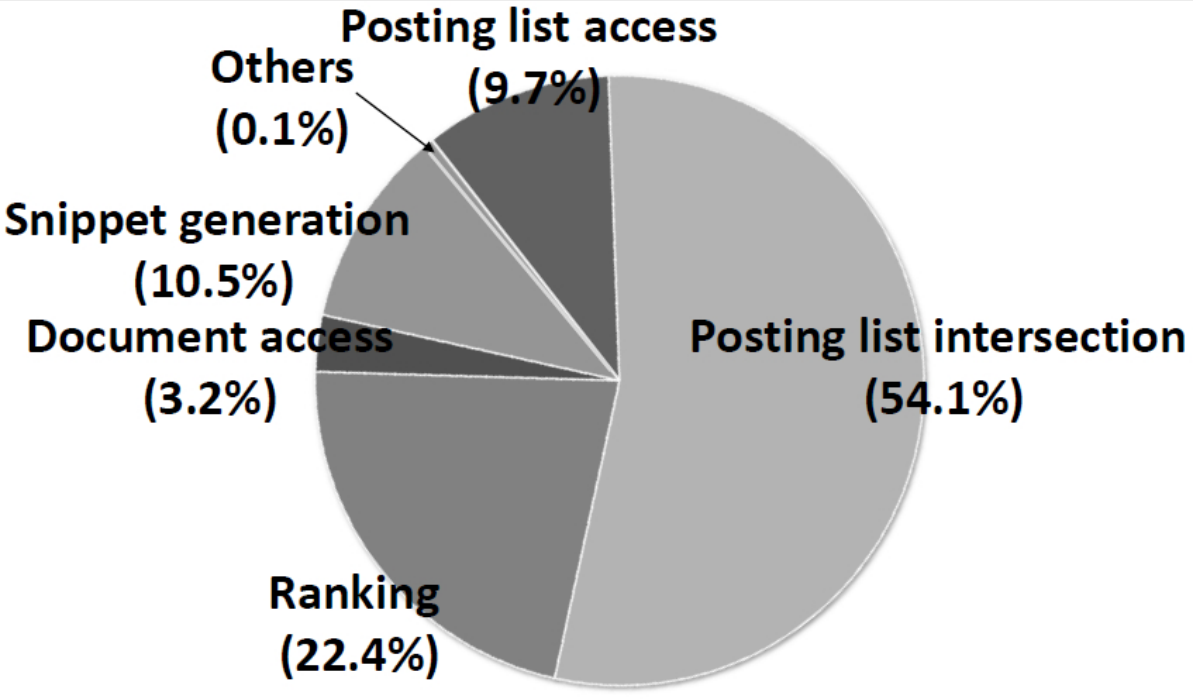
Conjecture 3

Is it the same case for the whole system?

The Impact on the Entire System Efficiency

Time break down for query processing (on SSD)

All caches are enabled



The Impact on the Entire System Efficiency

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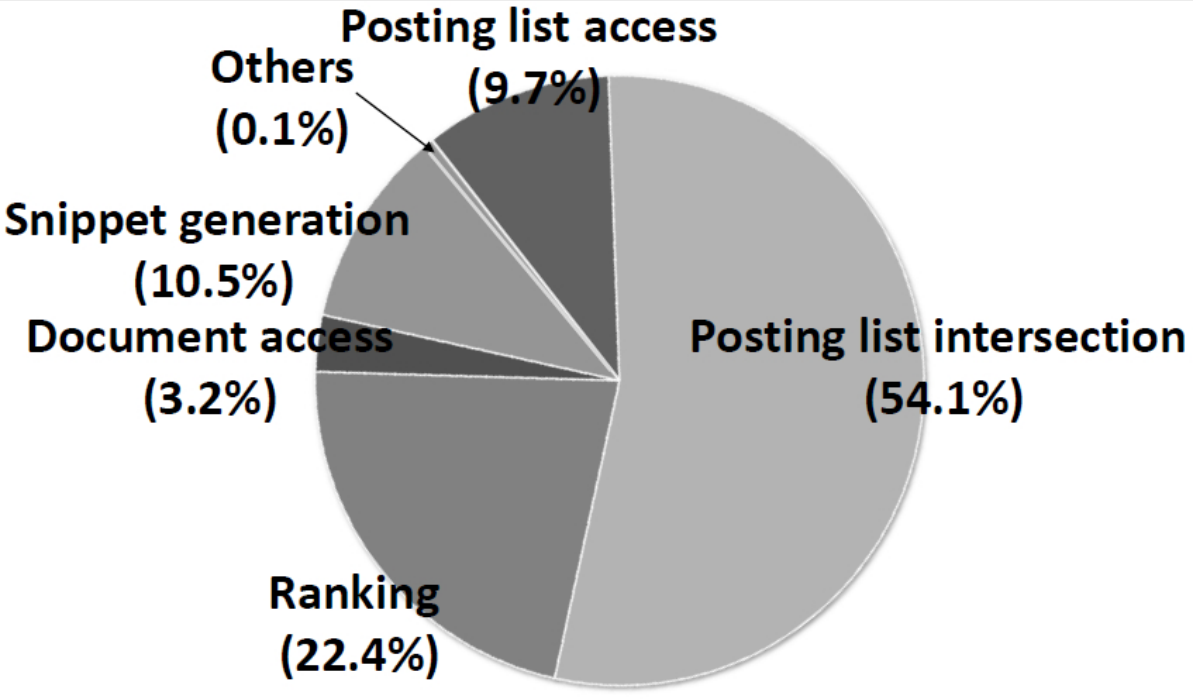


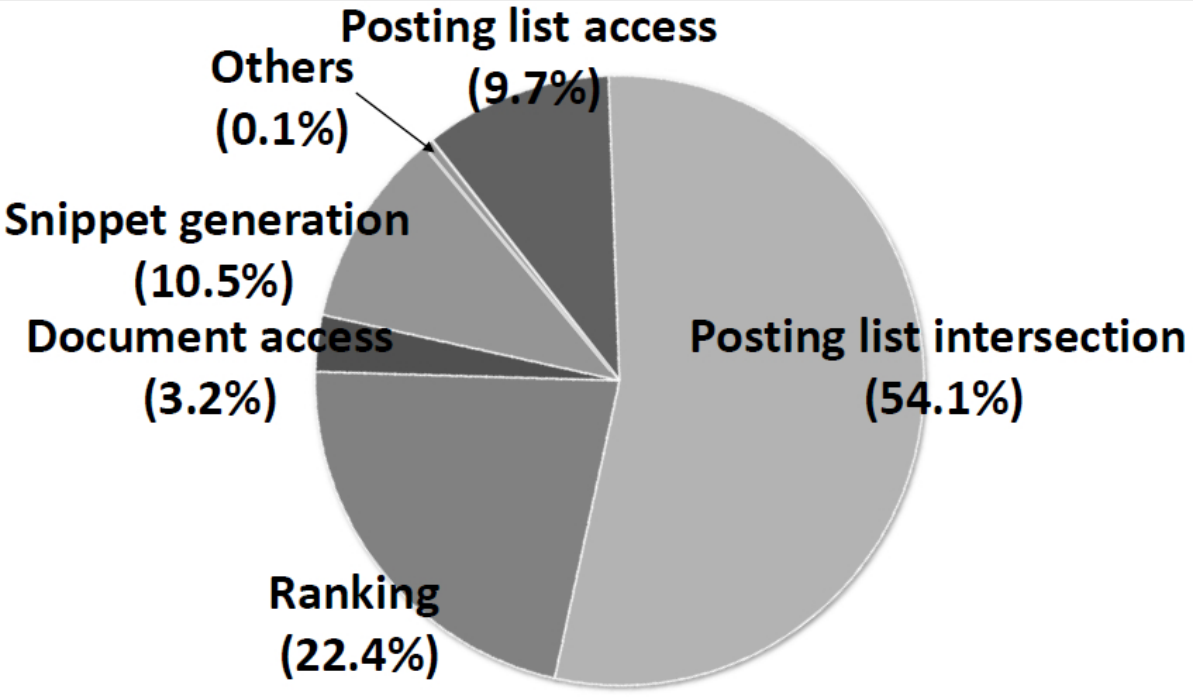
Conjecture 3

Is it the same case for the whole system? – Confirmed

The Impact on the Entire System Efficiency

Time break down for query processing (on SSD)

All caches are enabled



Conjecture 3

Is it the same case for the whole system? – Confirmed

★Disk accessing is no longer the bottleneck!

1 Background and Motivation

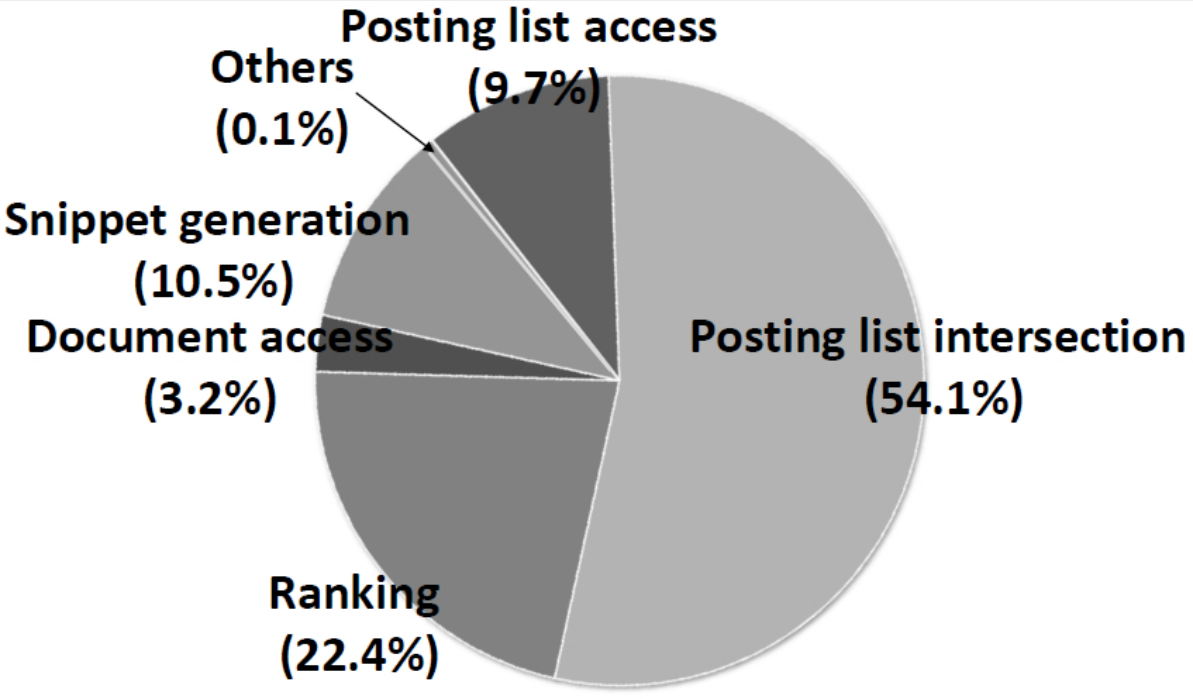
2 Research Questions and Answers

- RQ1: What is the impact of SSD on buffer management?
- RQ2: How could we deal with that?

The Impact on the Entire System Efficiency (Cont.)

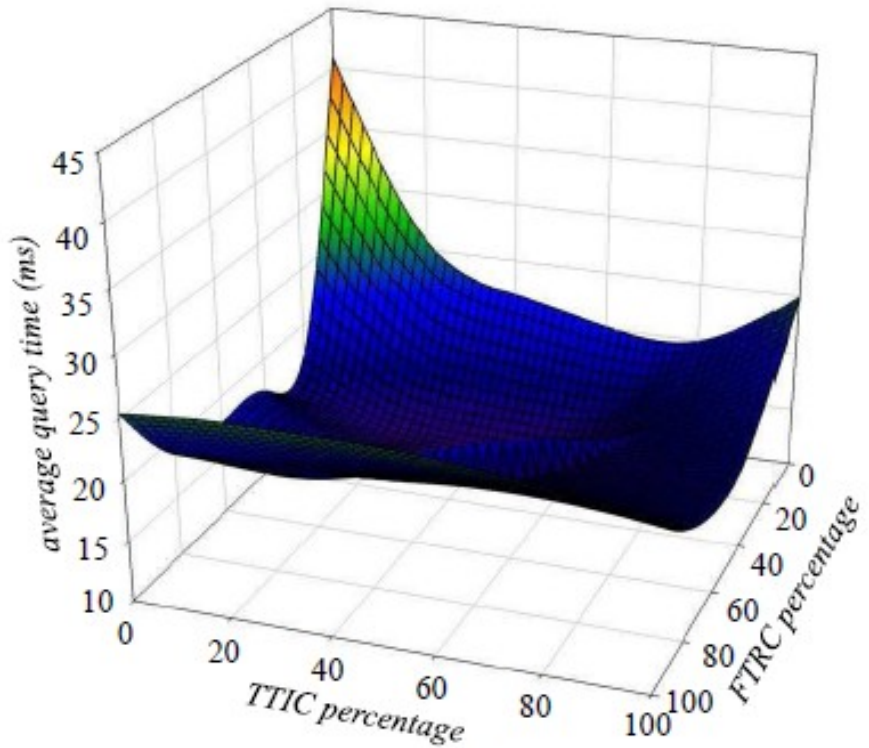
Time break down for query processing (on SSD)

All caches are enabled

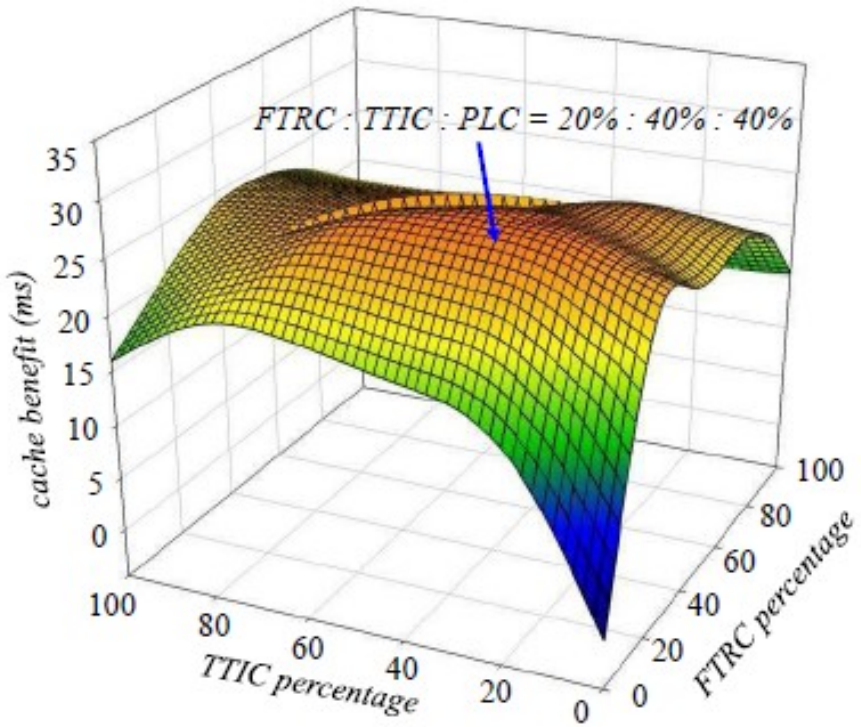


Problems	The time spent on intersection and ranking should be reduced
Solution	Adopting full-term-ranking-cache (FTRC) [Altingövde et al., 2011] and two-term-intersection-cache (TTIC) [Long and Suel, 2005]

Incorporating PLC+FTRC+TTIC

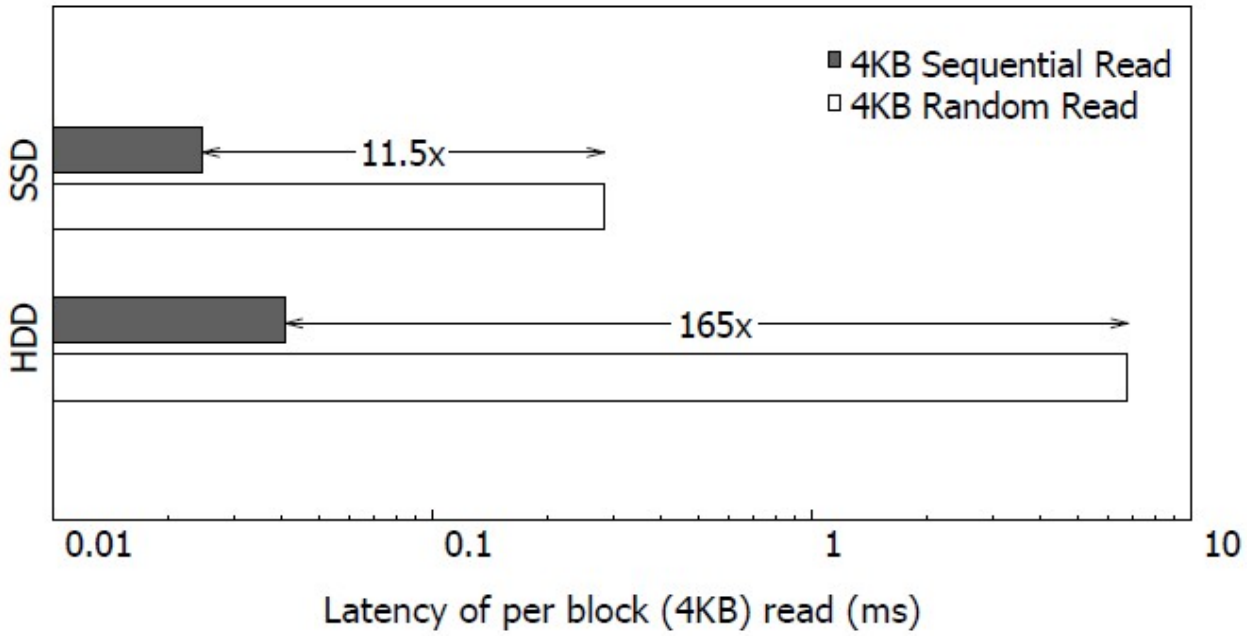


(a) query latency

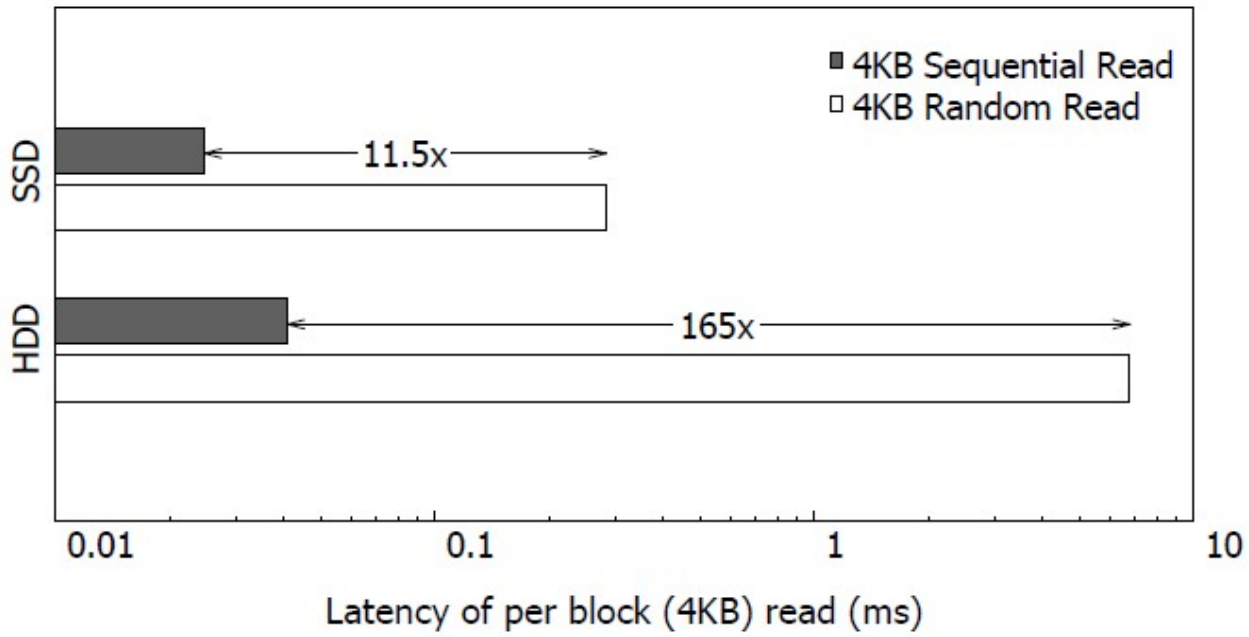


(b) cache benefit

New Static List Caching Policy



New Static List Caching Policy



Can we convert the latencies of random seek and sequential read into a uniform measure?

New Static List Caching Policy (Cont.)

Latency-Aware Caching (Static): BLOCK [Tong et al., 2013]

- For term t, $\mathcal{B}(t)$ represents the I/O cost that can be saved during the whole query evaluating process if $\ell(t)$ is kept in the cache
- Estimating model and existing static caching policies:

$$\mathcal{B}(t) = \mathcal{C}(t) \times \frac{f_q(t)}{|\ell(t)|} \tag{1}$$

$$\mathcal{B}(t) = \begin{cases} \frac{f_q(t)}{|\ell(t)|} & , \mathcal{C}(t) = 1 \quad \Leftrightarrow \quad \text{QTFDF} \\ f_q(t) & , \mathcal{C}(t) = |\ell(t)| \quad \Leftrightarrow \quad \text{QTF} \\ \frac{f_q(t)}{|\ell(t)|} \times \mathcal{T}(t) & , \mathcal{C}(t) = \mathcal{T}(t) \quad \Leftrightarrow \quad \text{MECH} \end{cases} \tag{2}$$

New Static List Caching Policy (Cont.)

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$$\mathcal{T}_{hdd}(t) = D_{seek} + D_{rotate} + D_{read} \times \frac{|\ell(t)|}{D_{block}} \tag{3}$$

$$\mathcal{T}_{ssd}(t) = S_{read} \times \frac{|\ell(t)|}{S_{page}} \tag{4}$$

New Static List Caching Policy (Cont.)

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- New method: BLOCK

$$\mathcal{C}_{block}(t) = \overbrace{1}^{\text{1 random read}} + \underbrace{\left(\overbrace{\left\lceil \frac{|\ell(t)|}{B_s} \right\rceil}^{\text{\# of Sequential read}} - 1 \right) \div \gamma}_{\text{\# of equivalent random read}} \tag{5}$$

New Static List Caching Policy (Cont.)

Latency-Aware Caching (Static): BLOCK [Tong et al., 2013]

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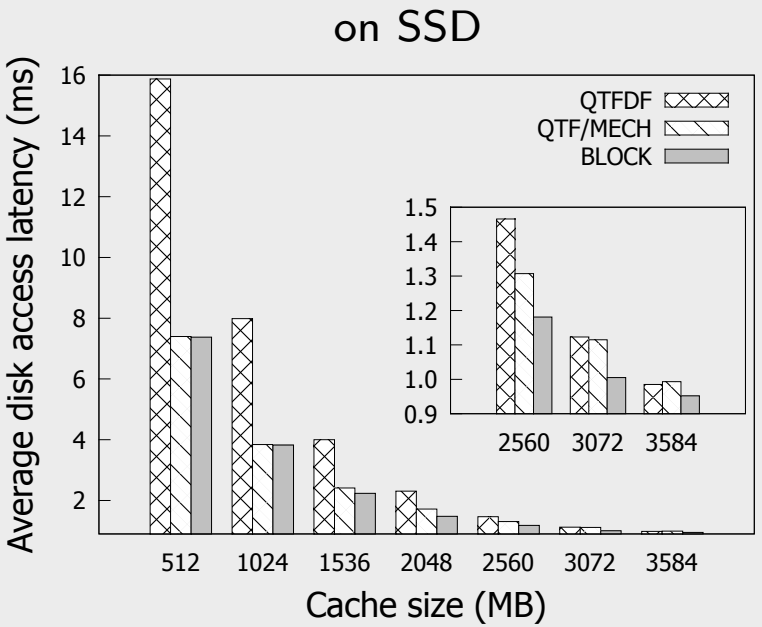
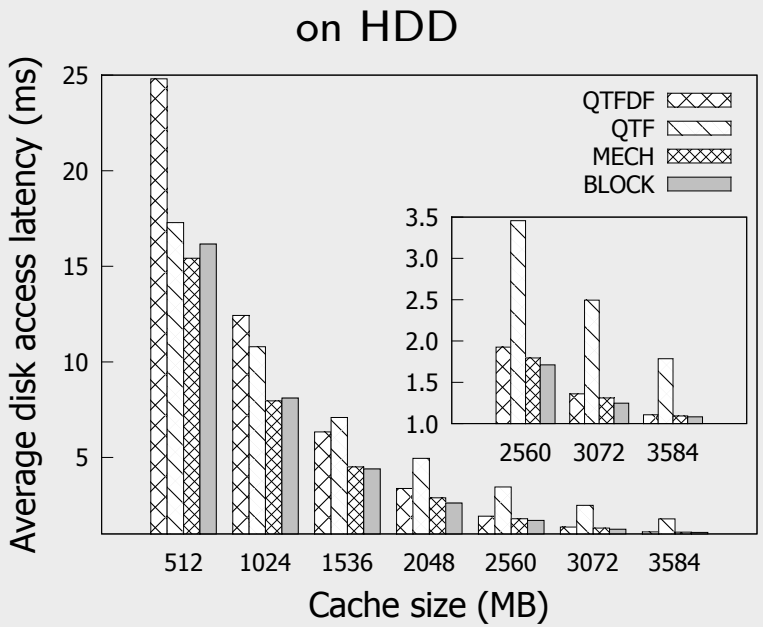
  - 1 access = 1 random seek + several sequential reads
    = 1 random seek + a few equivalent random seeks

New Static List Caching Policy (Cont.)

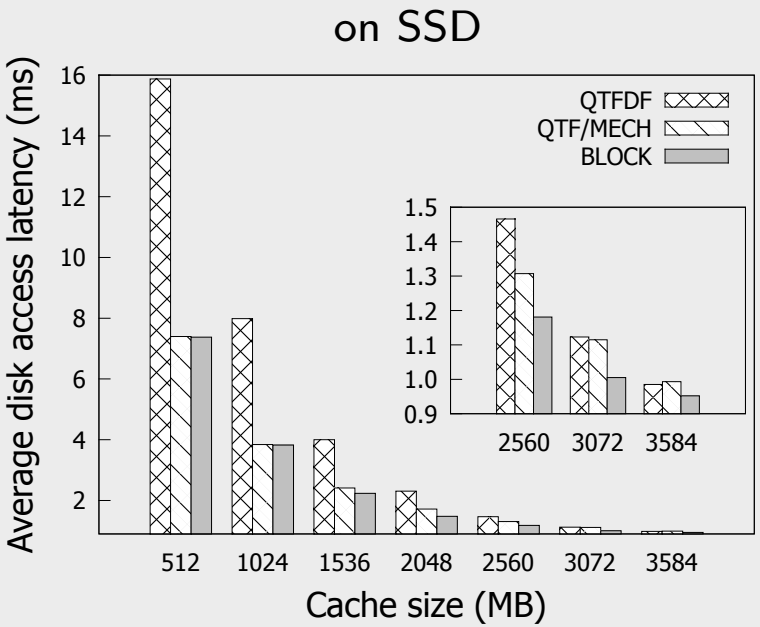
Experimental Results

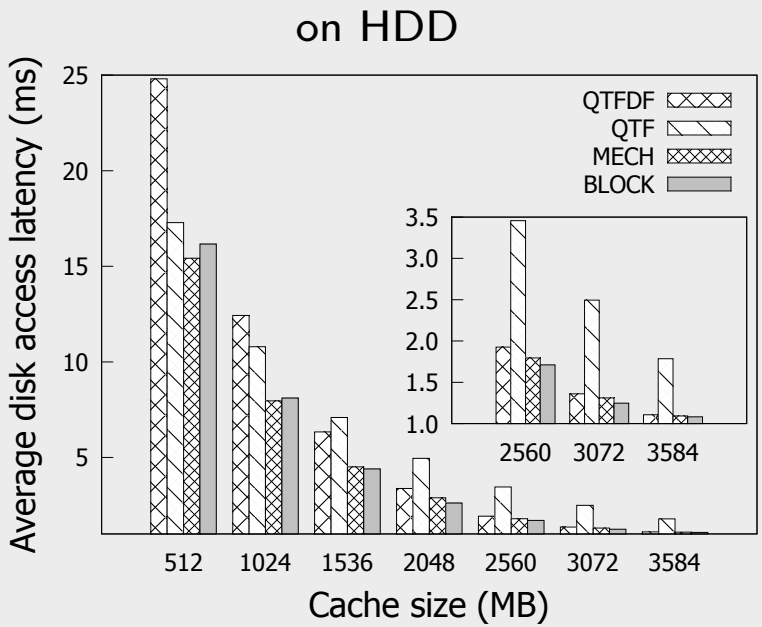




New Static List Caching Policy (Cont.)

Experimental Results

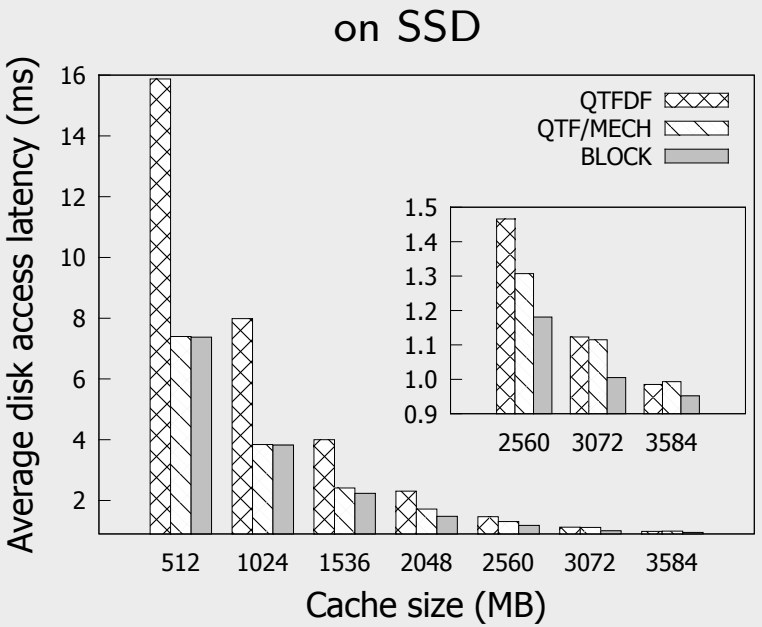


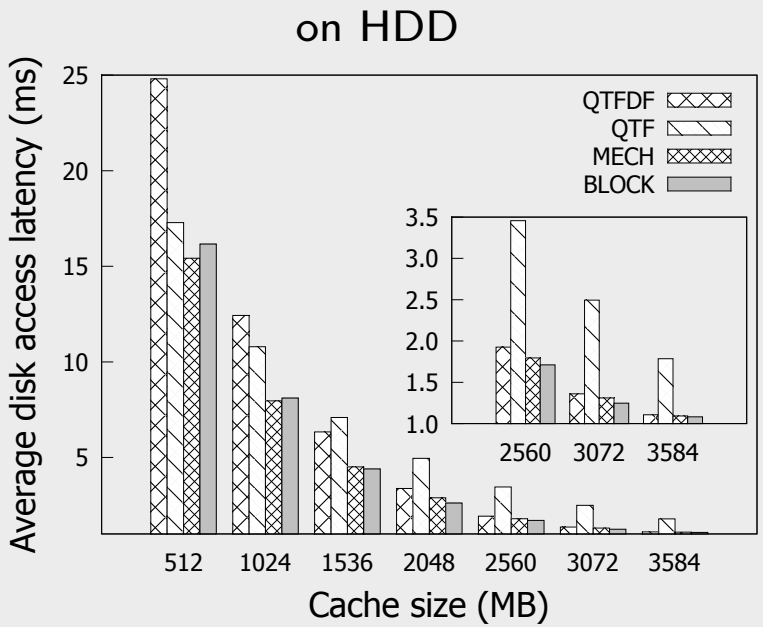


- BLOCK outperforms other methods on SSD

New Static List Caching Policy (Cont.)

Experimental Results

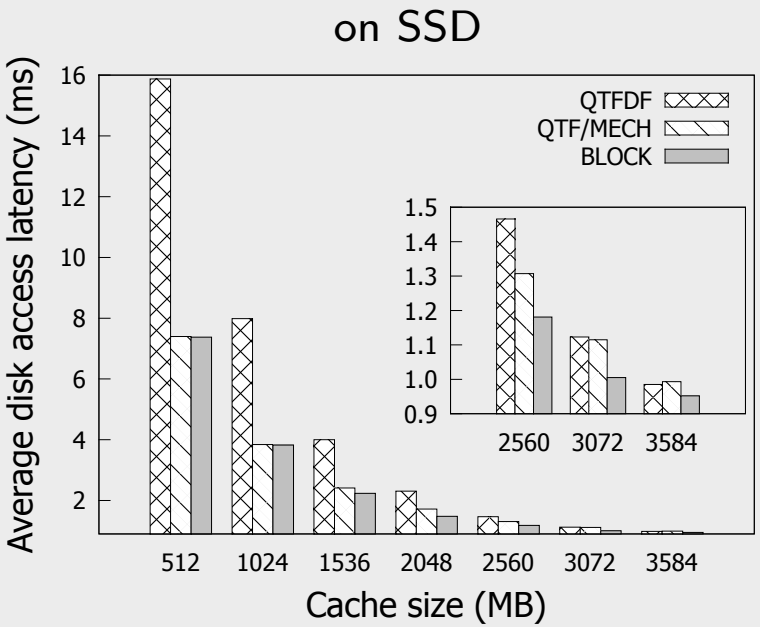


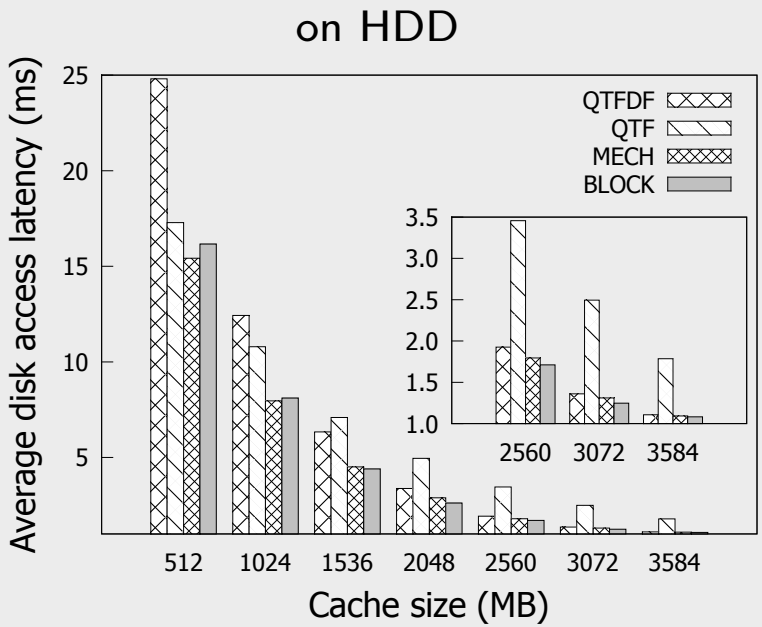


- BLOCK outperforms other methods on SSD
  1. BLOCK beats QTFDF (by far the best policy on HDD) by 20%-60%

New Static List Caching Policy (Cont.)

Experimental Results





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  2. BLOCK outperforms QTF/MECH (identical on SSD) too

New Static List Caching Policy (Cont.)

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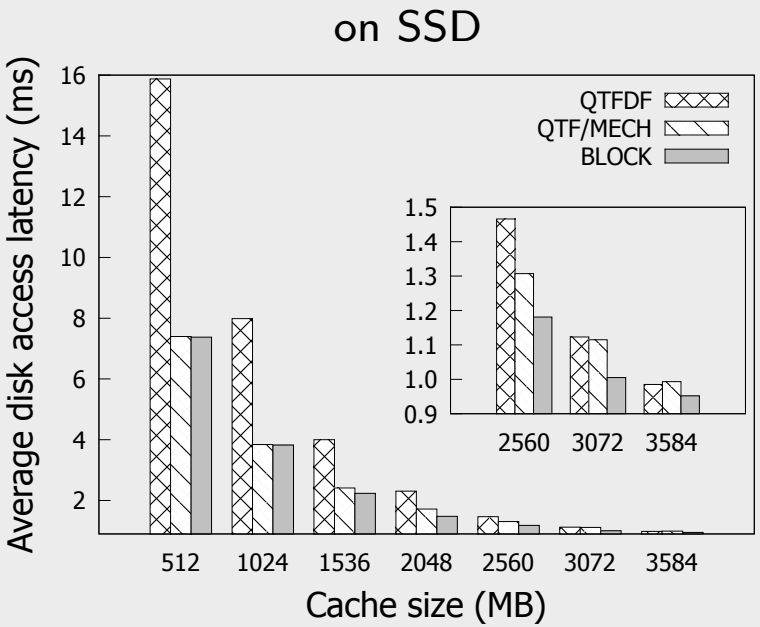

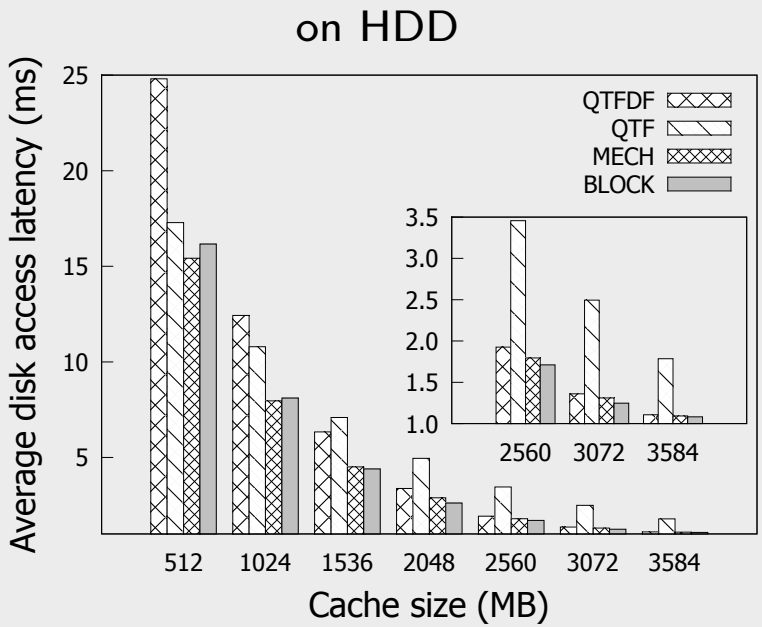

- BLOCK outperforms other methods on SSD
  1. BLOCK beats QTFDF (by far the best policy on HDD) by 20%-60%
  2. BLOCK outperforms QTF/MECH (identical on SSD) too
- BLOCK is better even on HDD (though not that significantly)

References


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Tong, J., Wang, G., and Liu, X. (2013).
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In *CIKM*, pages 1209–1212.


Wang, J., Lo, E., Yiu, M. L., Tong, J., Wang, G., and Liu, X. (2013).
The impact of solid state drive on search engine cache management.
In *SIGIR*, pages 693–702.

Thanks for your time!

Questions & Comments?

For more details of RQ1, please refer to:

- J. Wang, E. Lo, M, Yiu, J. Tong, G. Wang, X. Liu,
  The impact of Solid State Disk on Search Engine Cache Management,
  In *SIGIR*, 2013, pp. 693-702.

For more details of RQ2, please refer to:

- J. Tong, G. Wang, X. Liu,
  Latency-Aware Strategy for Static List Caching in Flash-based Web Search Engines,
  In *CIKM*, 2013, pp. 1209-1212.