CLIC
CLient-Informed Caching for Storage Servers

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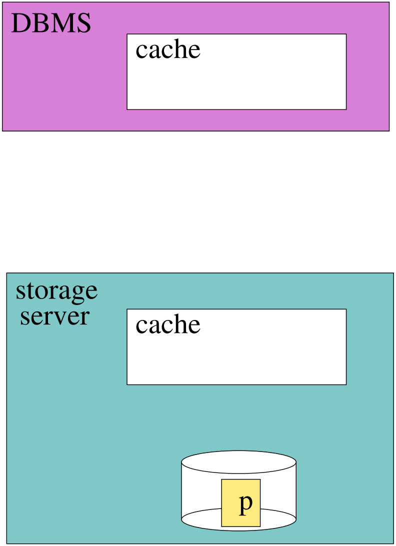
Two-Tier Caching



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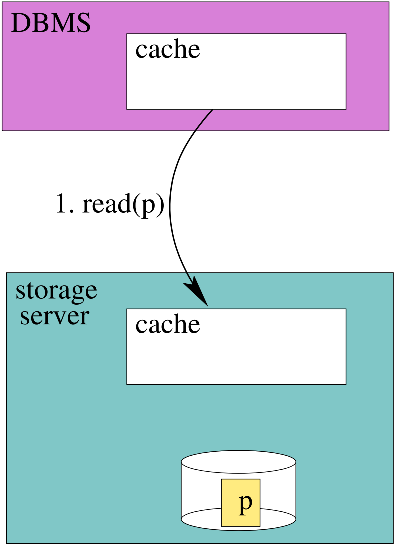

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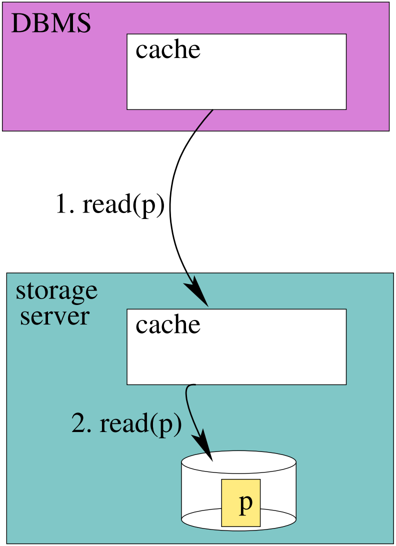

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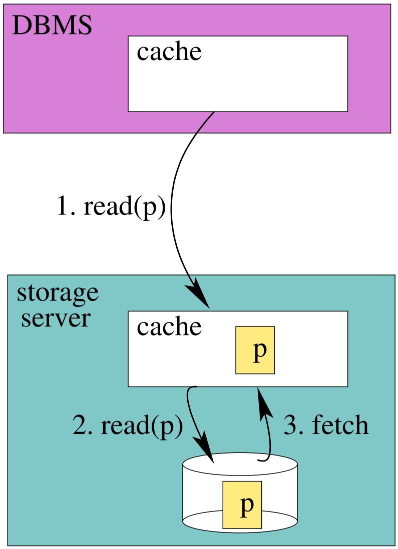

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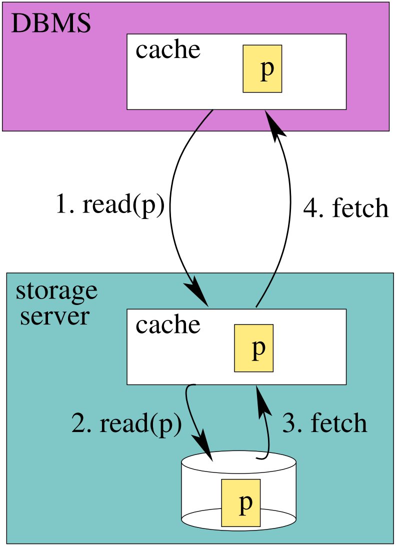

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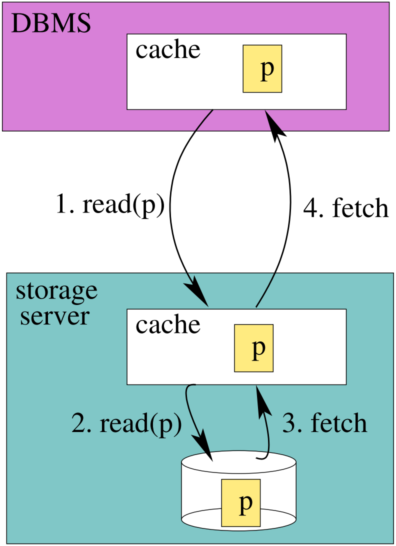

Problems:

- cache inclusion

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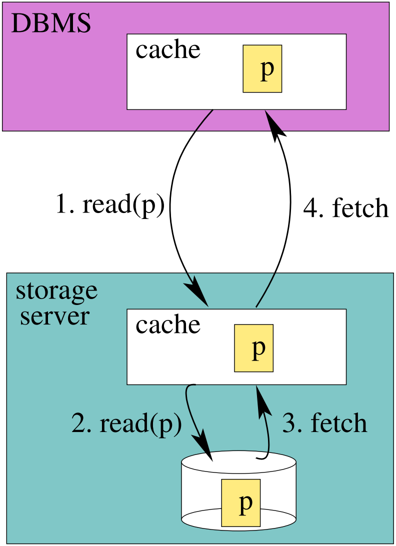

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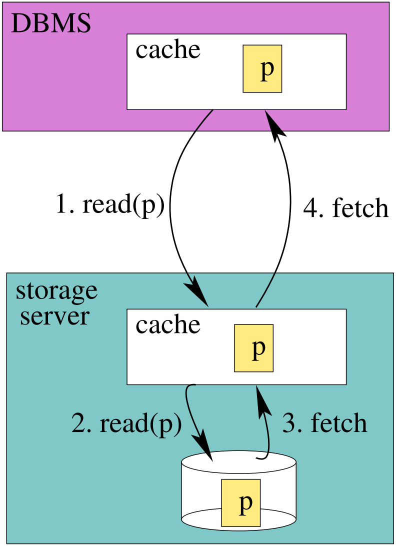

Problems:

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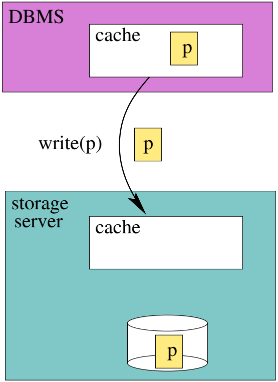
- poor temporal locality

One Solution:

- hinting

Example: Write Hints



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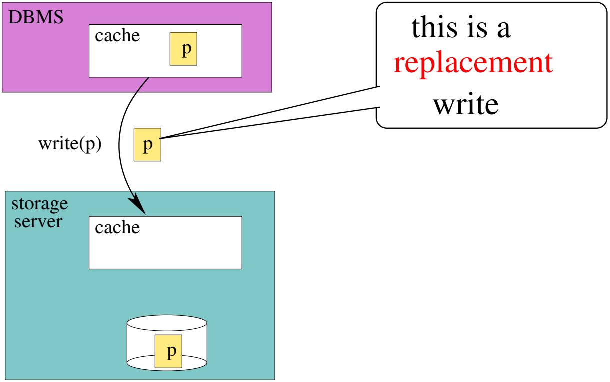

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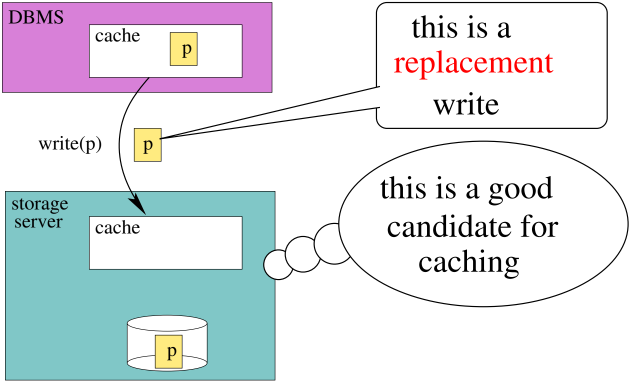

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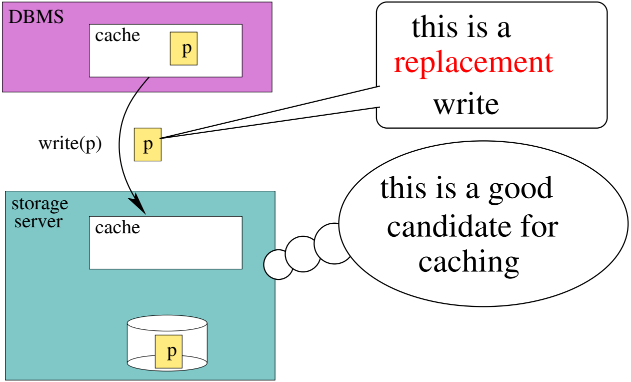

The storage server can use TQ, an ad hoc hint-aware replacement policy, to exploit write hints.

Problems with Ad Hoc Hint-Aware Policies

narrowness: new hints? multiple hints?

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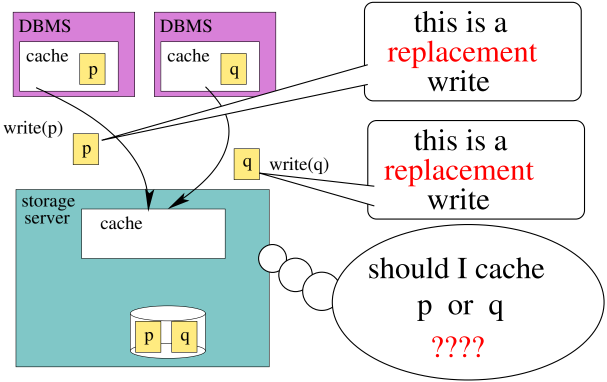
single source: multiple hint generators?



The CLIC Approach

- a hint-aware caching policy for 2nd-tier caches

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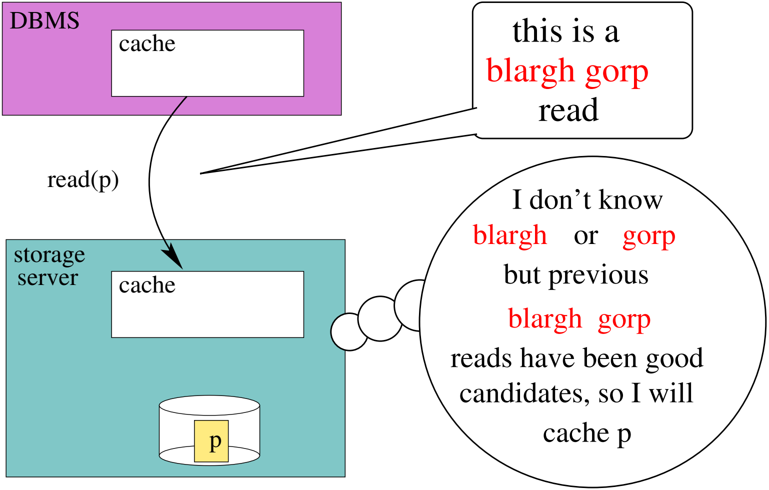
CLIC Hints

CLIC separates the generation of hints (done by the storage clients) from the interpretation of those hints for caching purposes (done by the storage server).

CLIC Illustrated



Generating Hints

- Storage client must be modified to generate one or more types of hints.
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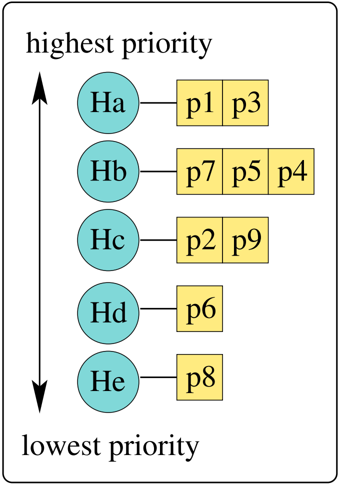
Example: Hints from DB2

- buffer pool ID
- object ID: identifies a group of related DB objects
- object type ID: distinguishes table from index
- request type: read, replacement/recovery write
- DB2 buffer priority

A CLIC-Managed Cache



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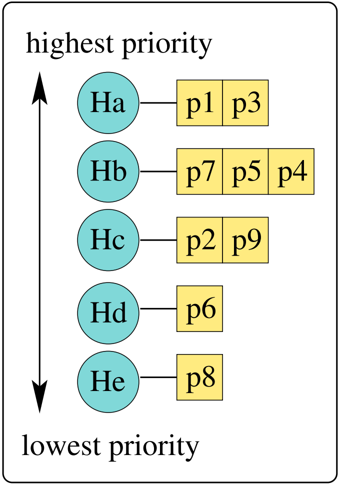

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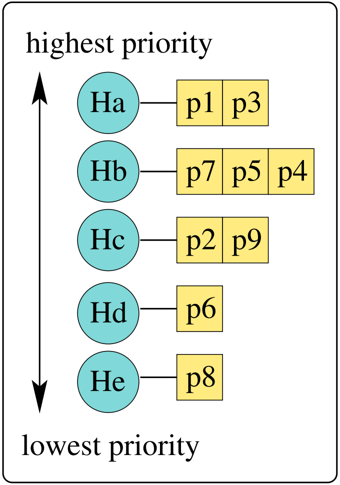

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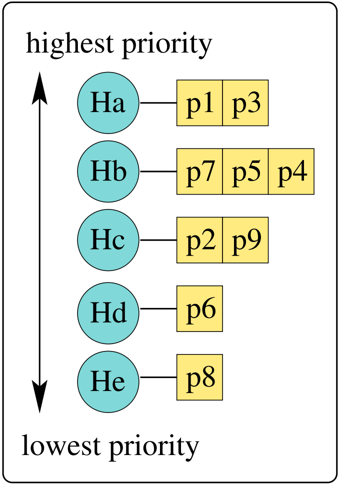

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- CLIC chooses hint set priorities using a simple cost/benefit analysis

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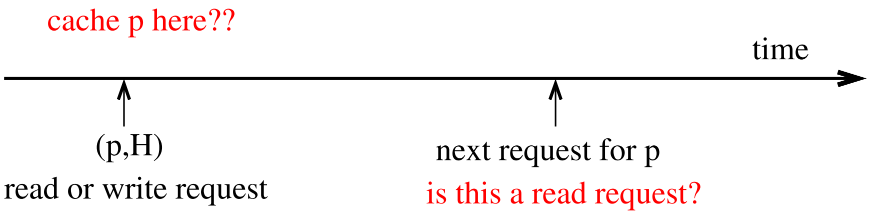

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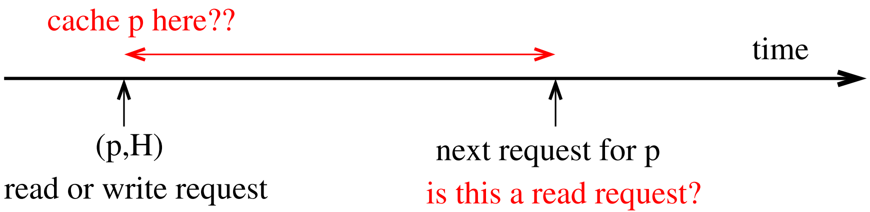
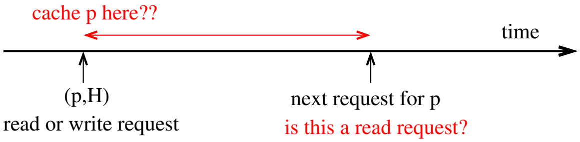


- there is a benefit to caching if the next request for *p* is a read request
- the cost of obtaining this benefit is that *p* must remain cached until the read request

Assigning Priorities to Hint Sets



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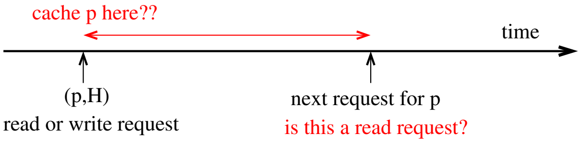

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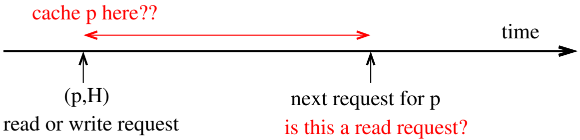
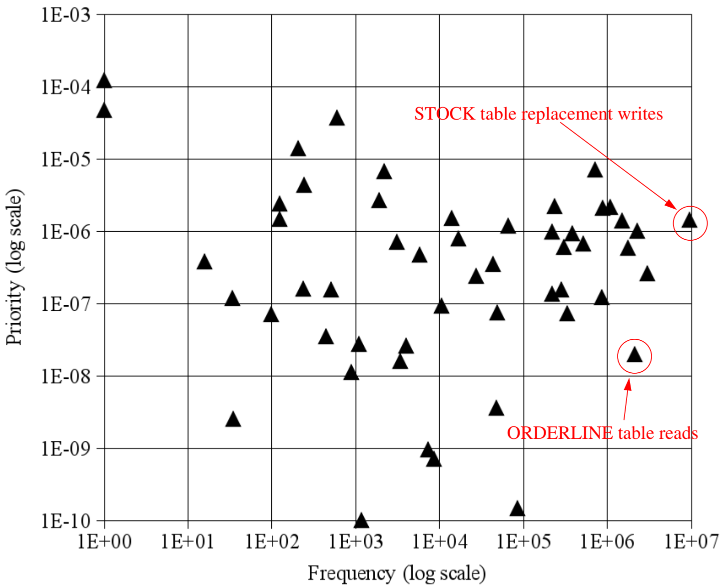


- when request (p, H) occurs, CLIC cannot know the the cost and benefit of caching p
- instead CLIC estimates the cost and benefit of caching p at (p, H) based on previous requests with hint set H
- CLIC assigns a priority to each hint set based on the cost and benefit of previous requests with hint set H

$$\text{Priority}(H) = \frac{\text{Read\_Hit\_Rate}(H)}{\text{Mean\_Time\_Until\_Read\_Hit}(H)}$$

DB2 Hint Analysis Example



Efficient Hint Analysis

- To analyze the cost and benefit of hint sets, CLIC must
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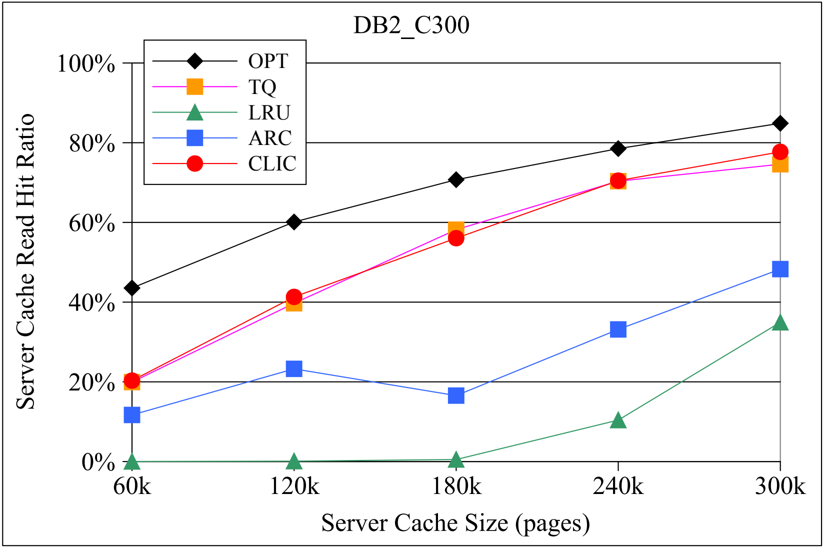
  - tracks read hit statistics only for frequently occurring hint sets
- We have also investigated the use of generalization to reduce the number of distinct hint sets.

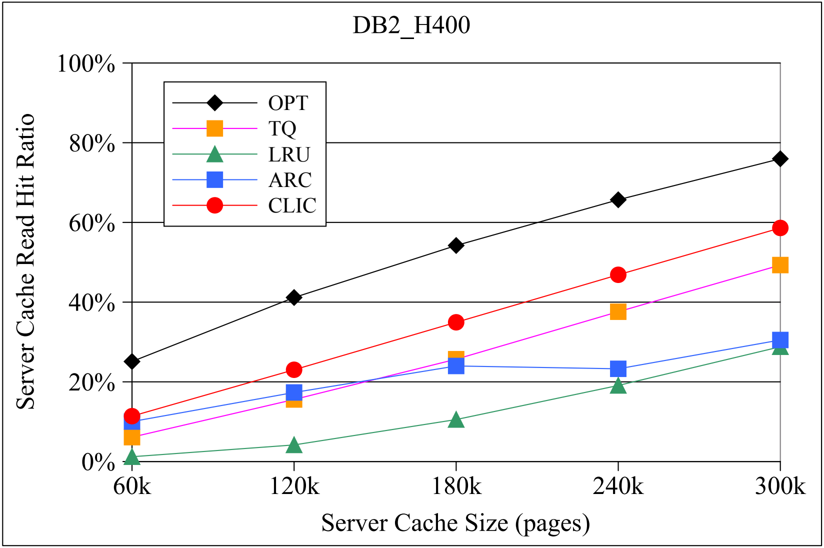
Performance

- we have used trace-driven simulation of the storage server buffer cache to compare CLIC to other replacement policies
- methodology
  1. modify DB2 and MySQL to generate hints and produce I/O traces
  2. run TPC-C (on-line transaction processing) and TPC-H (decision support) workloads on the database systems and collect I/O traces
  3. feed the traces to a simulation of second-tier cache, which implements CLIC, LRU, ARC, TQ and OPT
  4. measure the hit ratio achieved by different policies.

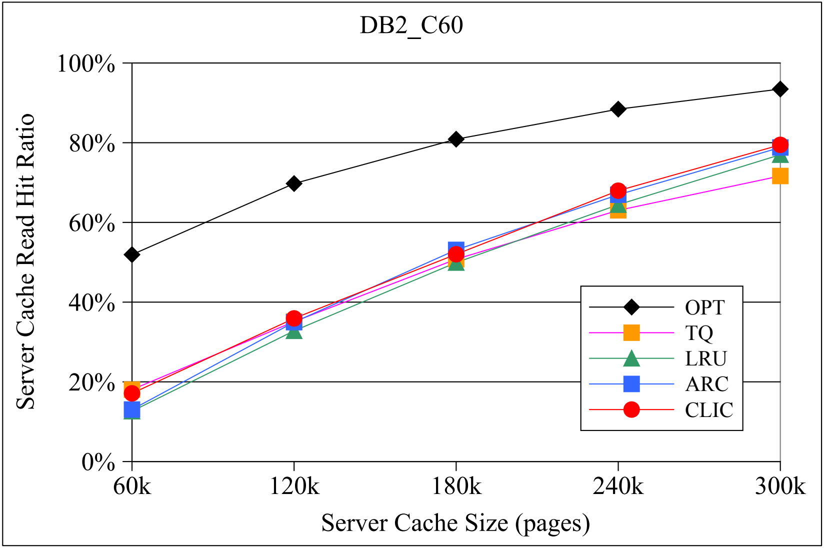
DB2 TPC-C - Medium DB2 Buffer Cache



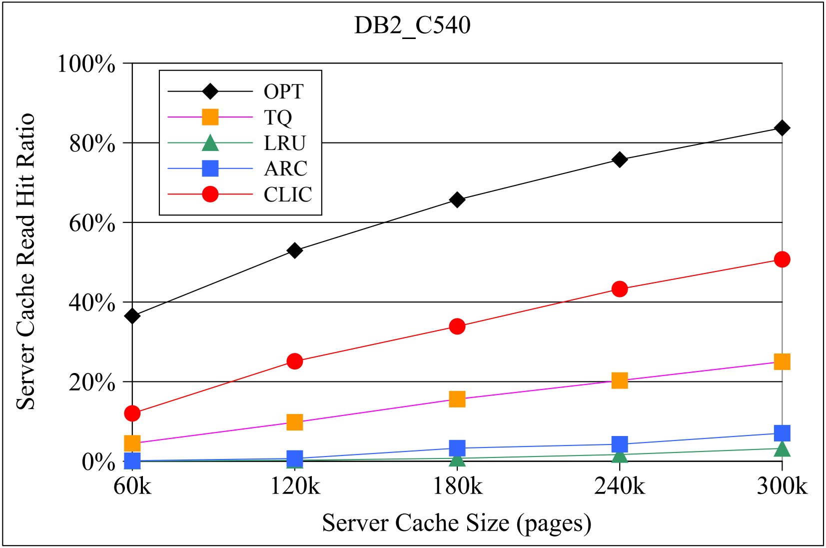
DB2 TPC-H - Medium DB2 Buffer Cache



DB2 TPC-C - Small DB2 Buffer Cache



DB2 TPC-C - Large DB2 Buffer Cache



Summary and Conclusions

- CLIC learns to identify I/O hints that signal good caching opportunities by tracking the request stream observed by the second-tier cache
- Because CLIC's responses to specific hints are not predefined, it naturally accommodates new hint types and hints from multiple storage clients.
- for our traces:
  - CLIC's performance usually dominates ARC's and LRU's, sometimes by a factor of 2 or more.
  - CLIC dominates the ad hoc, hint-aware TQ algorithm
  - CLIC's space overhead can be kept low (1% of storage server cache size in our experiments)