Prefetching and Caching for Minimizing Service Costs: Optimal and Approximation Strategies

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The Ohio State University

IFIP Performance 2020

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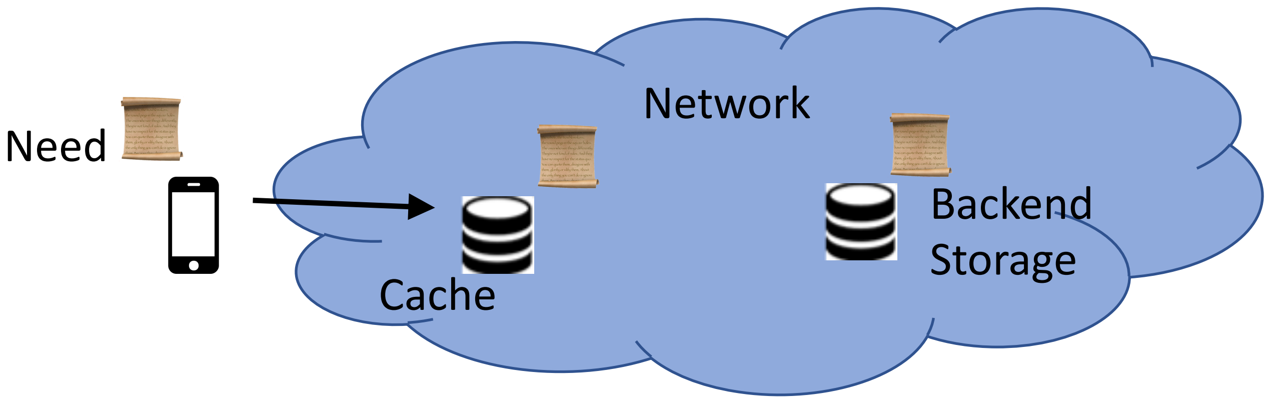

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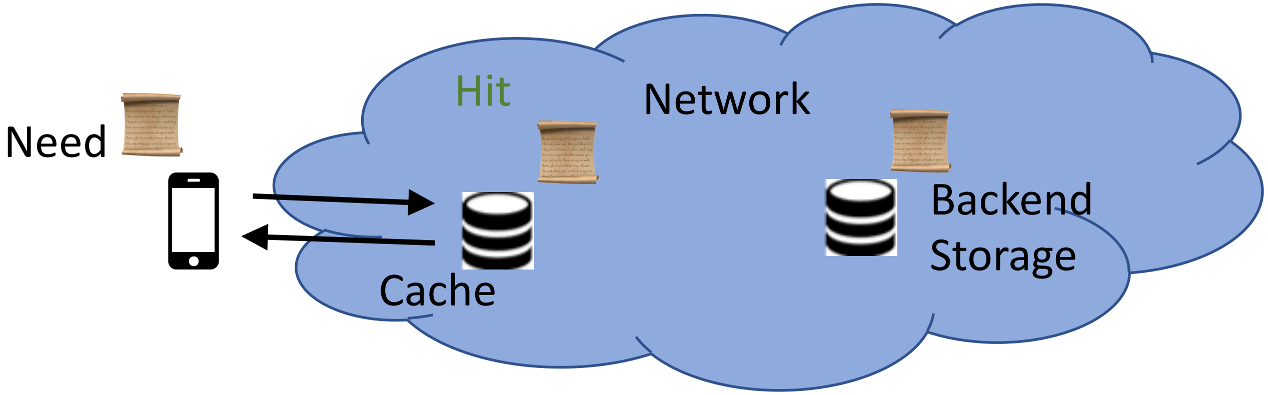

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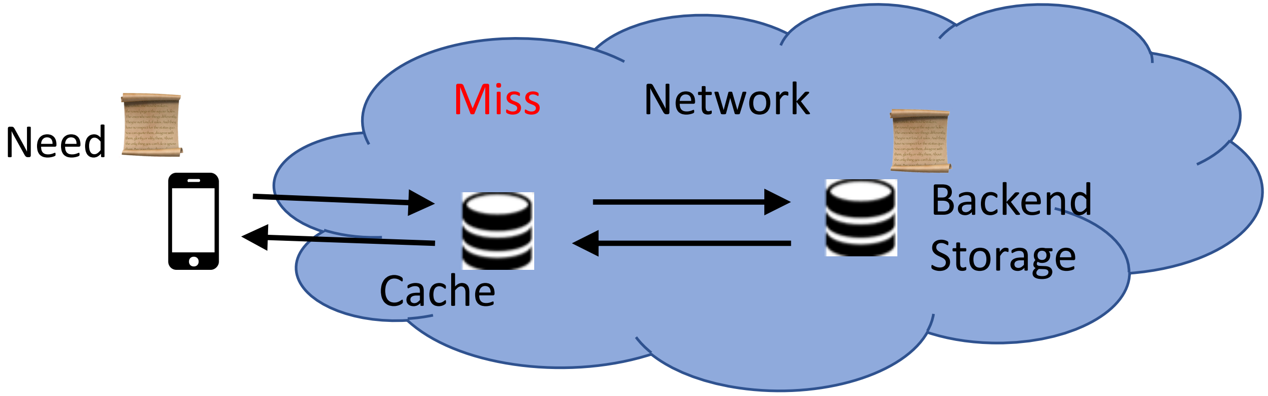

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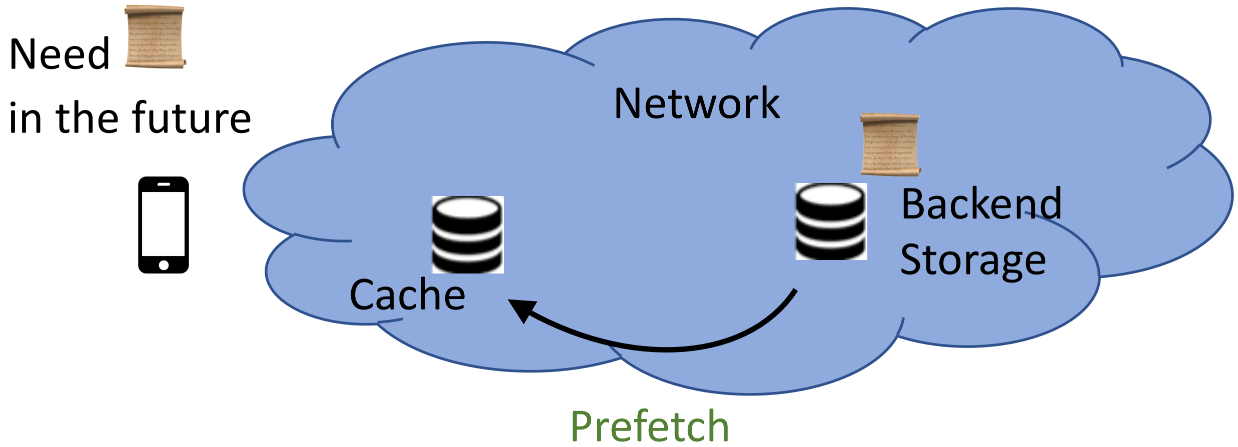

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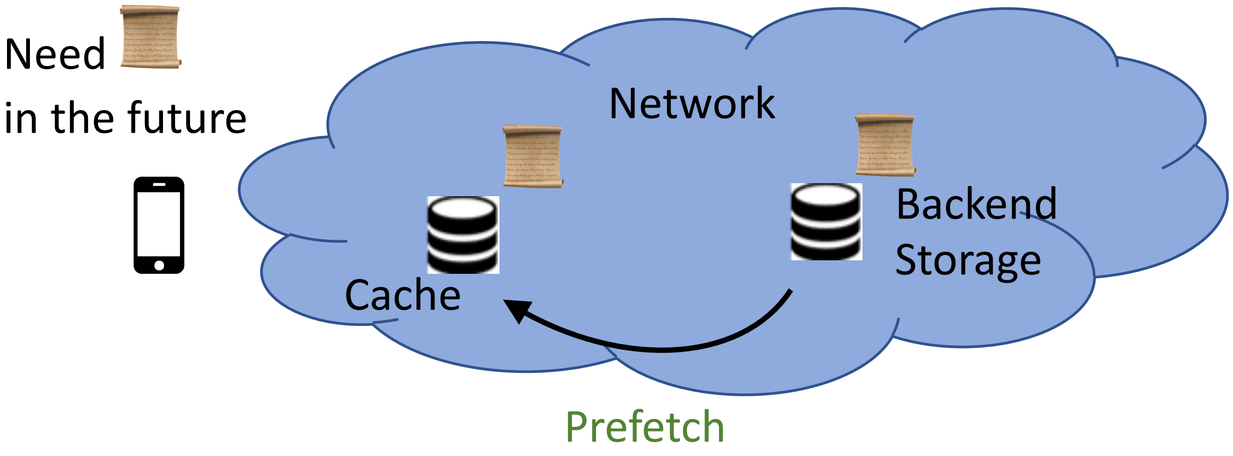

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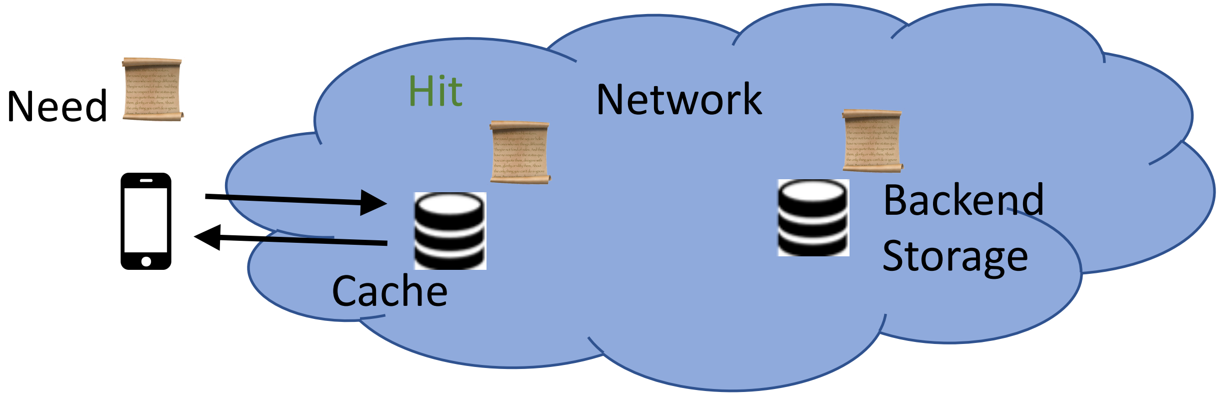

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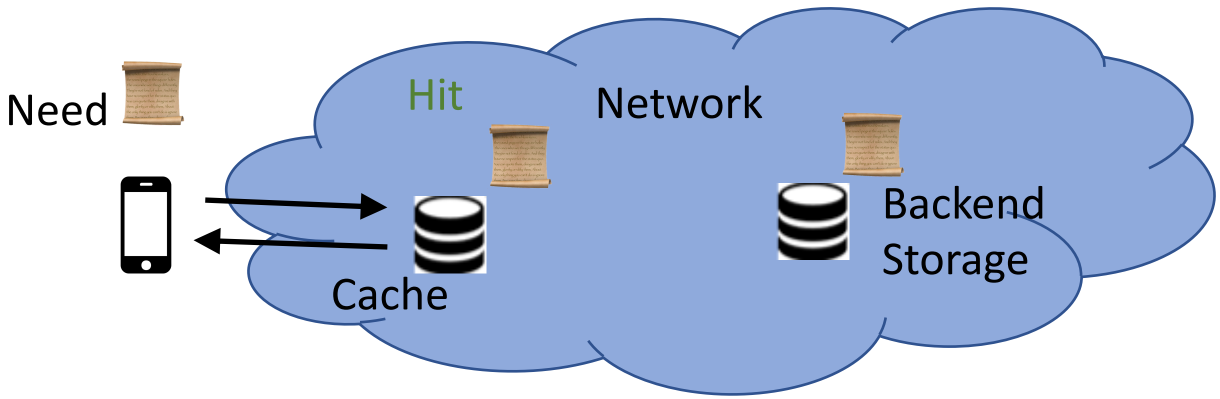
- Benefits of prefetching and caching:
  - Service delay is lower
  - Prefetching is less time-sensitive, compared to fetching



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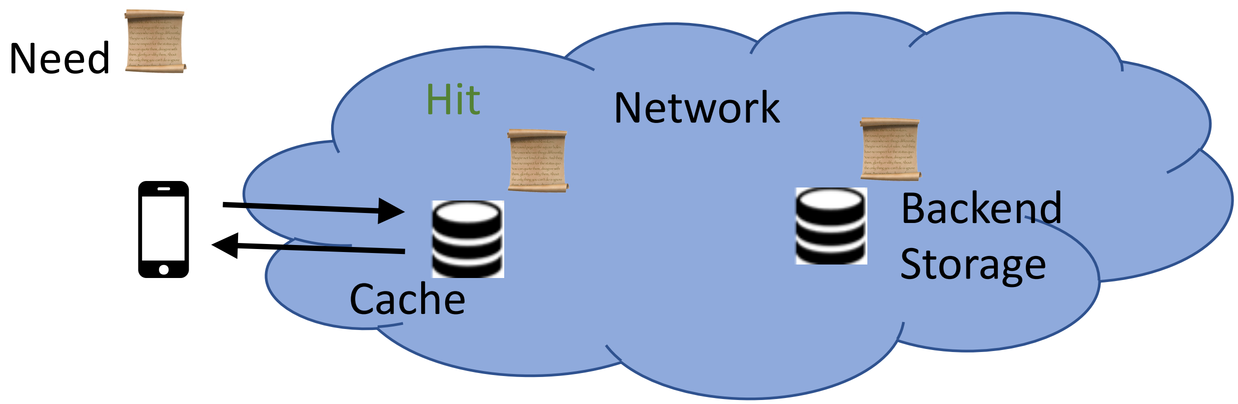

Is prefetching always a good choice?

If not, for which requests should we choose to prefetch?

Problem Formulation

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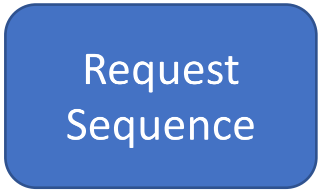

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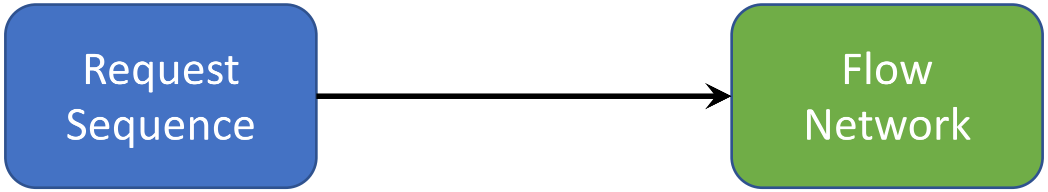

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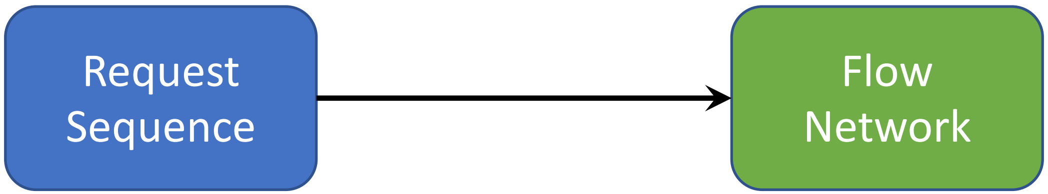
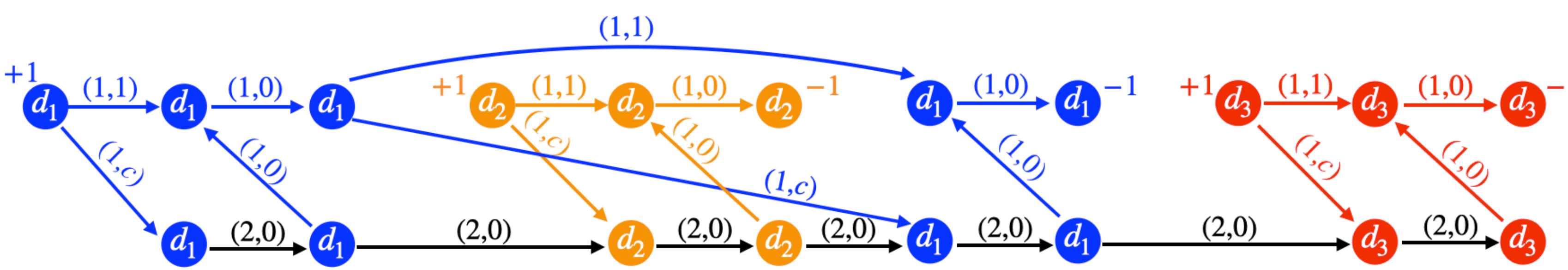


Cache of size 2

Request sequence: d_1, d_2, d_1, d_3



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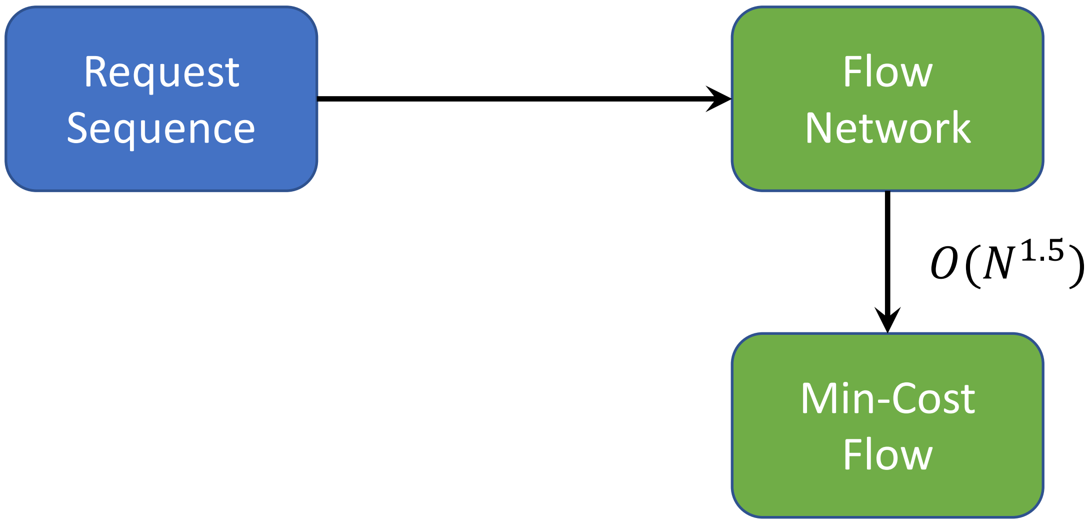

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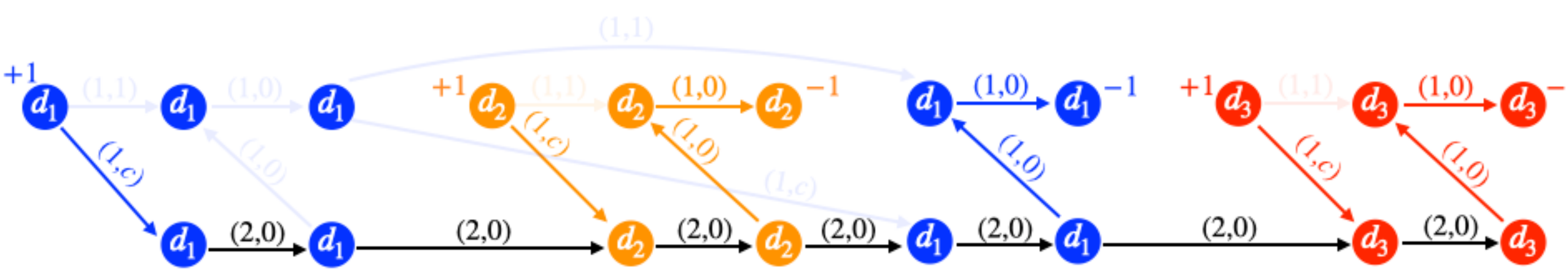

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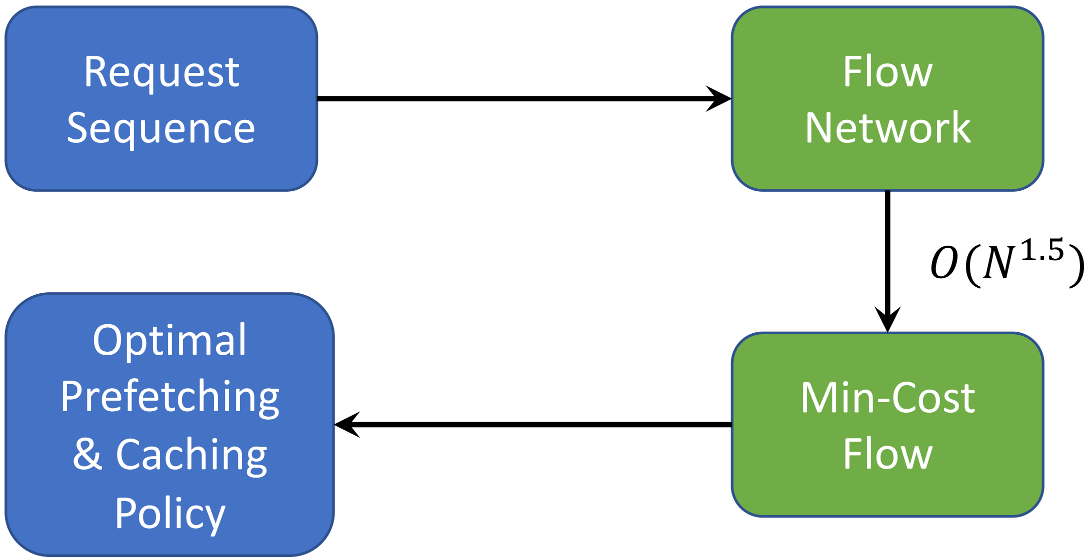

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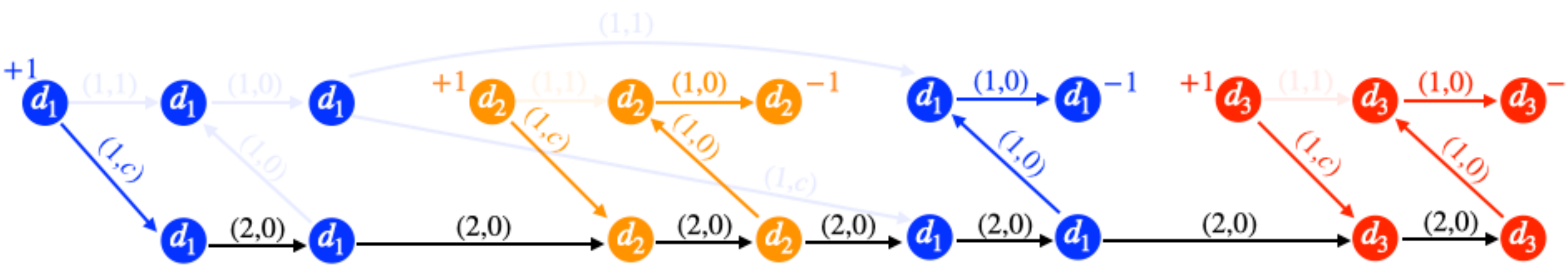
Prefetch $R_1 = d_1$, Prefetch $R_2 = d_2$,

Hit $R_3 = d_1$, Prefetch $R_4 = d_3$ & evict d_1



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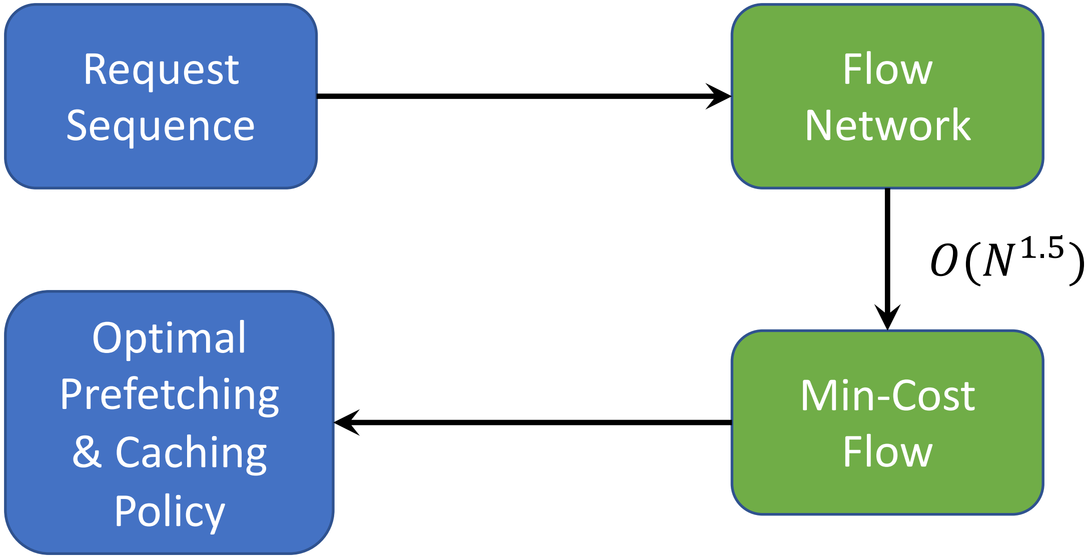

Drawbacks:

- Cannot analytically answer the two proposed questions
- Need to know all future requests to make optimal decisions
- The decision for a request is unavailable unless the entire sequence is processed

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- FF item: the item that is stored in the cache, and requested farthest in future.

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Approximation Strategy

Approximation policy π_A:

When the requested data is not cached, prefetch the data item and evict the FF item, if

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Otherwise, fetch the data and do not load it into the cache.

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- π_A only requires near future information.
- The time complexity is $O(N)$.
- π_A achieves near optimal performance.

Competitive Ratio

Always prefetching policy π_P:

Always prefetch the requested data item if it is not cached, and evict the FF item.

Always fetching policy π_F (Belady's algorithm):

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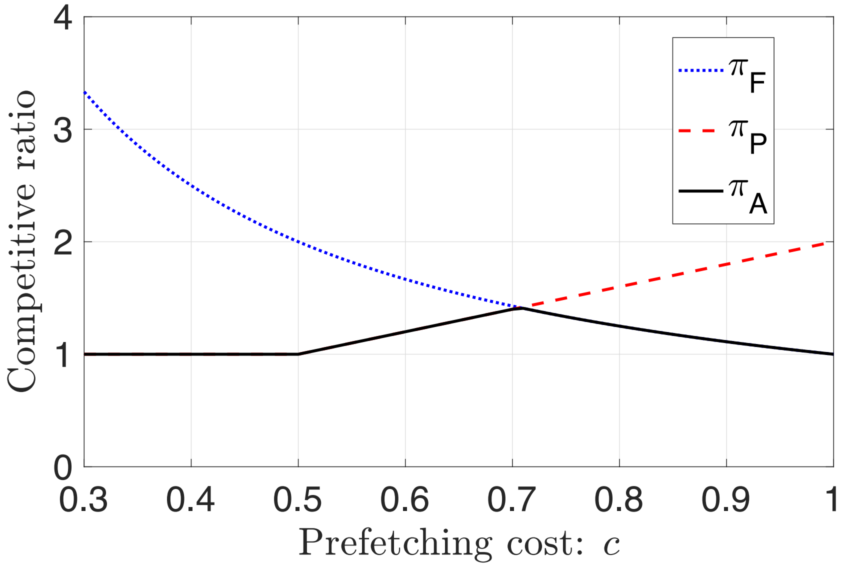

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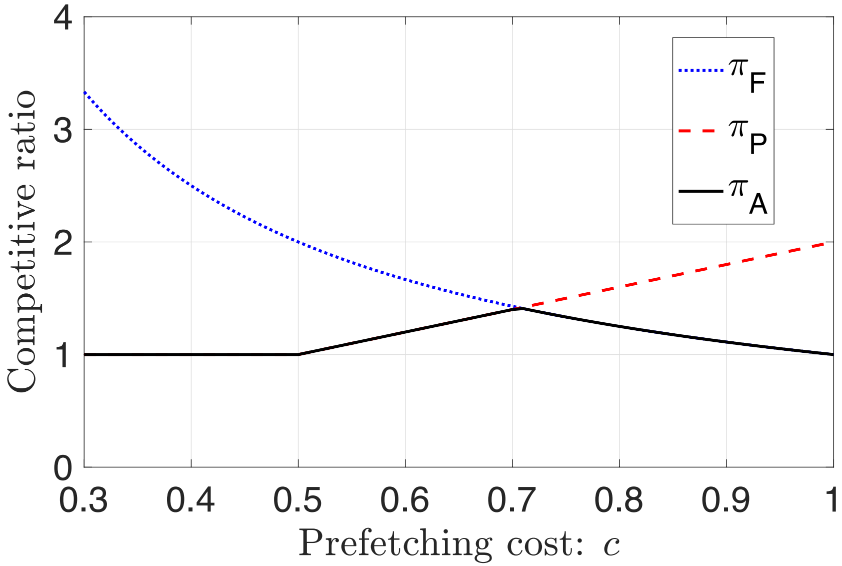

The competitive ratio of π_A is

- equal to 1 for $c \leq 0.5$ or $c = 1$
- at most $\sqrt{2}$
- always less than the ones of π_P and π_F

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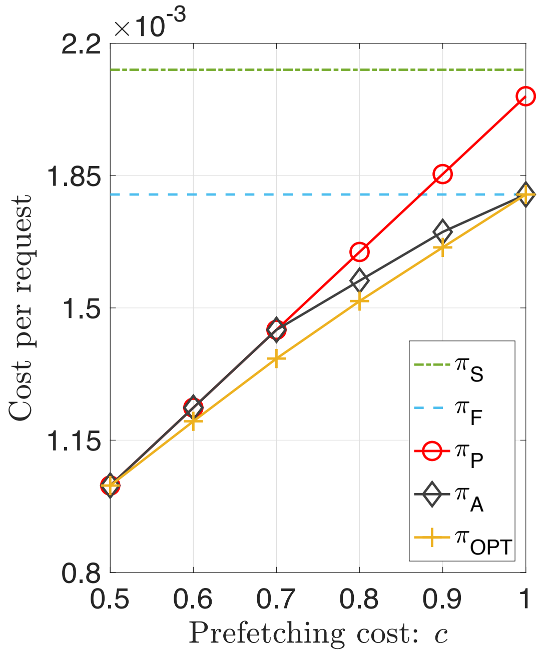

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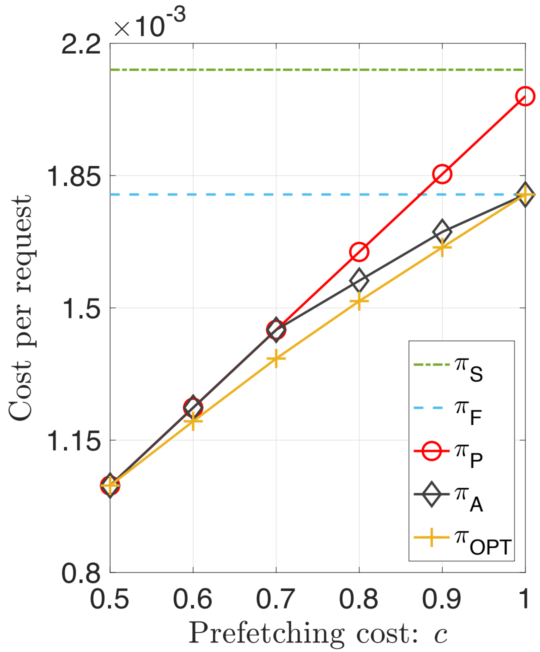
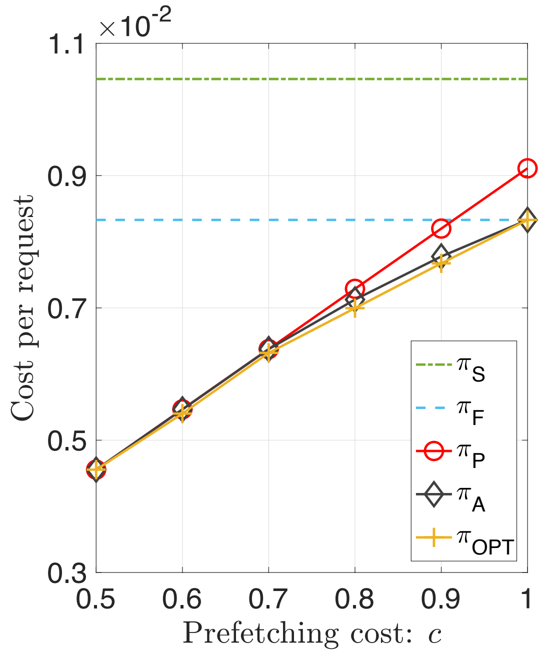
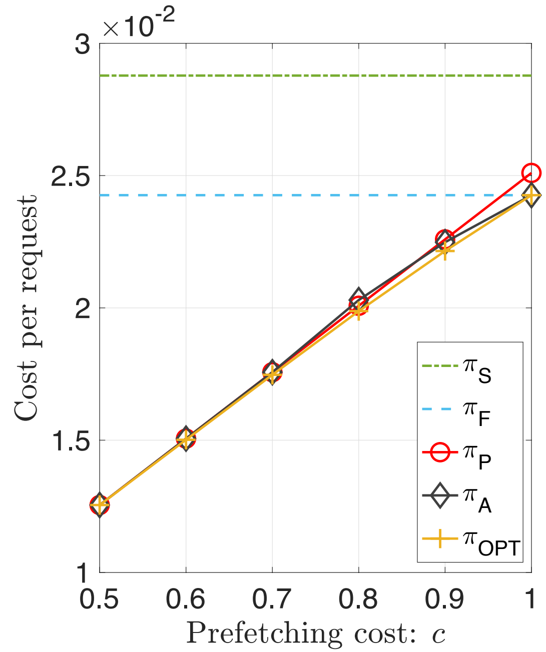


$p_i = c_2 \cdot \exp(-i^{0.6})$



$p_i = c_3 \cdot i^{-2}$



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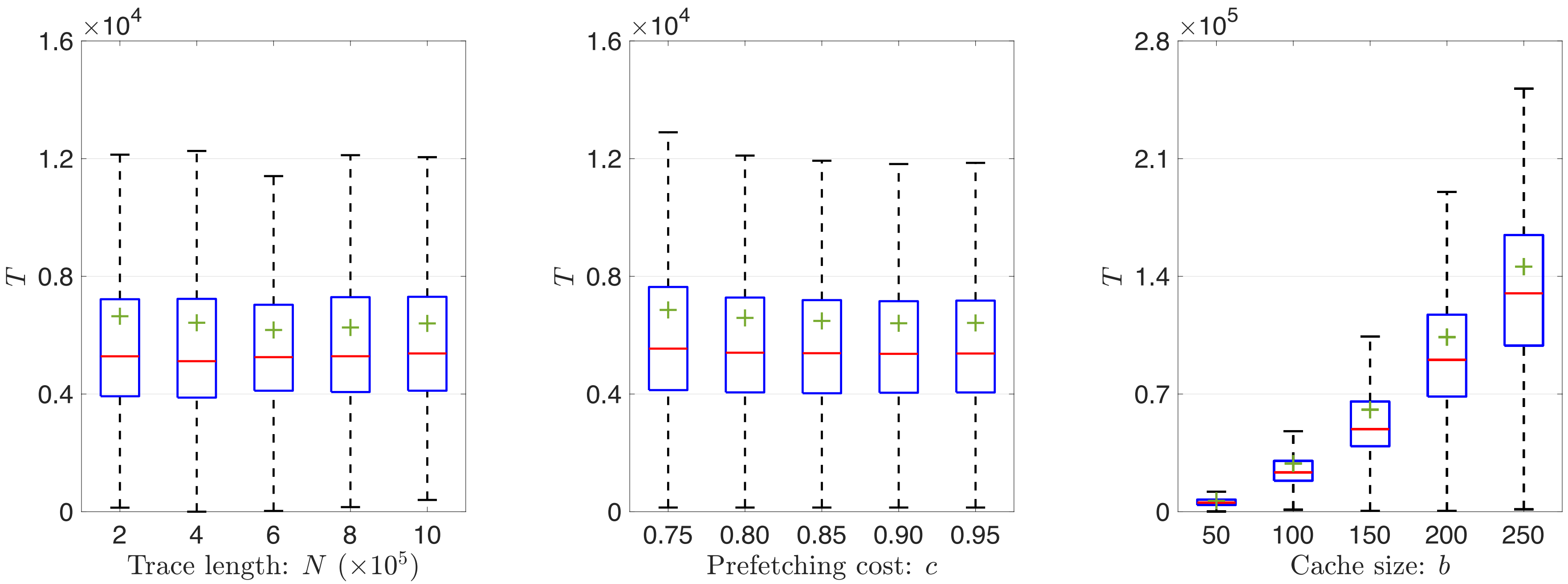
$c = 0.85, b = 50$ | $N = 5\times10^5, b = 50$ | $N = 5\times10^5, c = 0.85$



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- Proposed a flow-based optimal offline policy
- Analytically characterized the optimal offline policy
  - Optimal eviction policy
  - Sufficient conditions for optimal prefetching
- Designed a lightweight approximation policy
  - Require near-future information
  - Achieve near-optimal performance

Q & A

Thank you!