The Entangling Data Prefetcher

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4th Data Prefetching Championship
February 1, 2026

Where does Berti fails?

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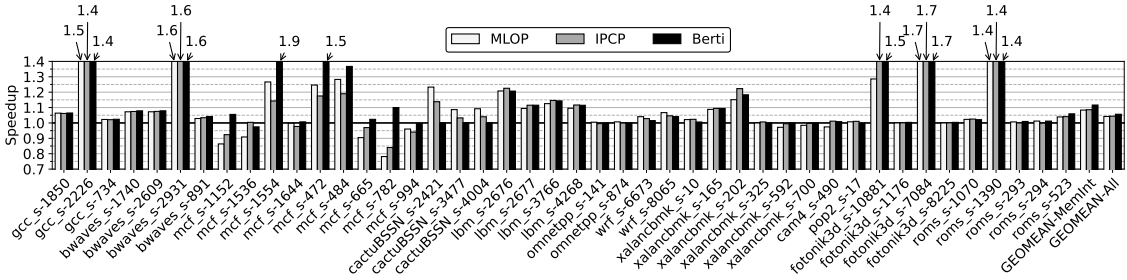

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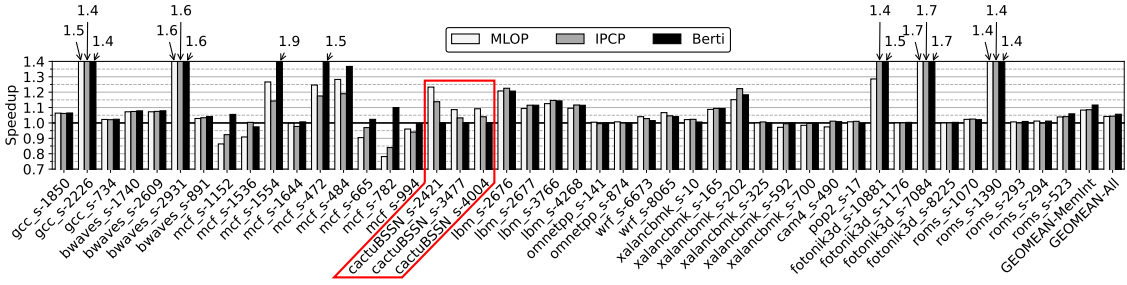

In `cactuBSSN` Berti achieves 0% performance improvement

Why can Berti not cover `cactuBSSN`?

- Too many IPs
- *Very-long-time distance strides*

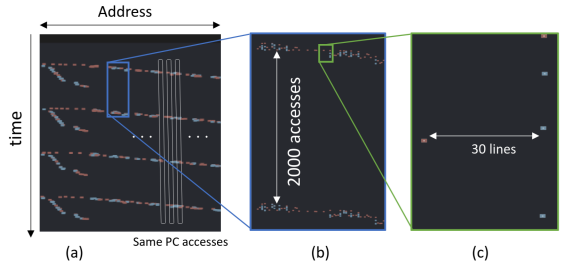

Fig. 1: A part of memory access pattern of `607.cactuBSSN_s-2421B`. The horizontal axis is the physical address and the vertical axis is time. [1]

[1] T-SKID: Timing Skid Prefetcher, *Tomoki Nakamura et. al*, DPC-3 and DATE

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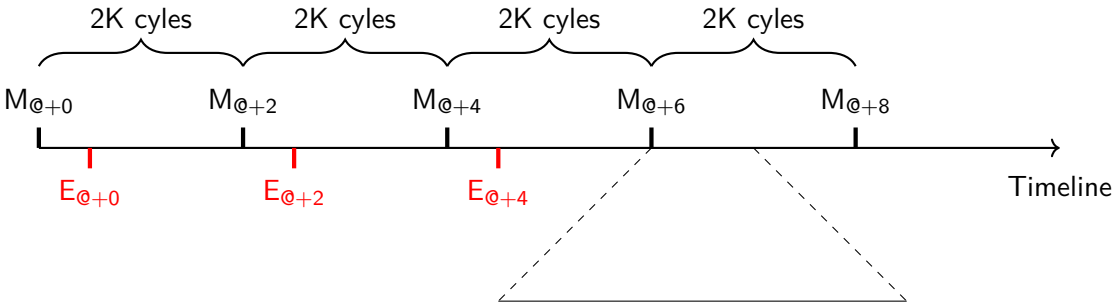

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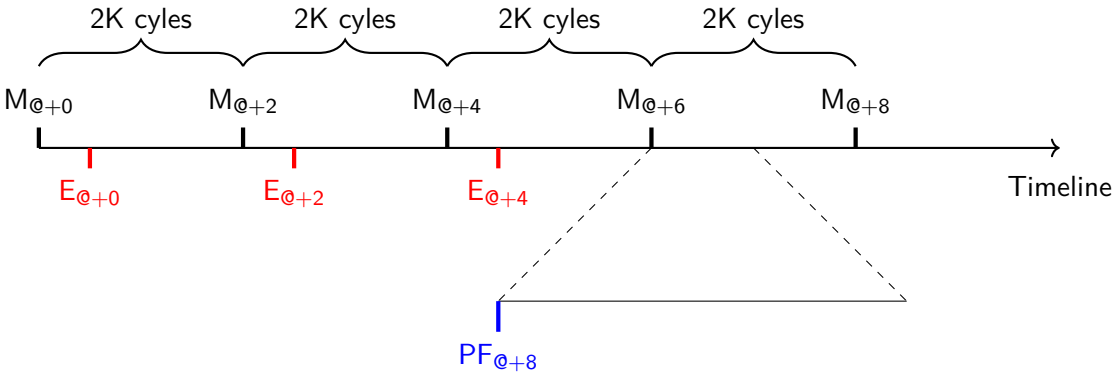

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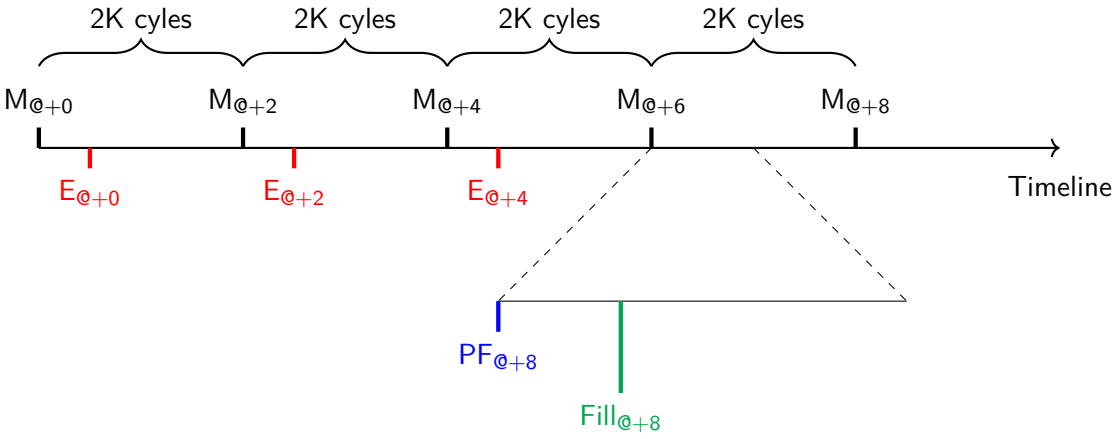

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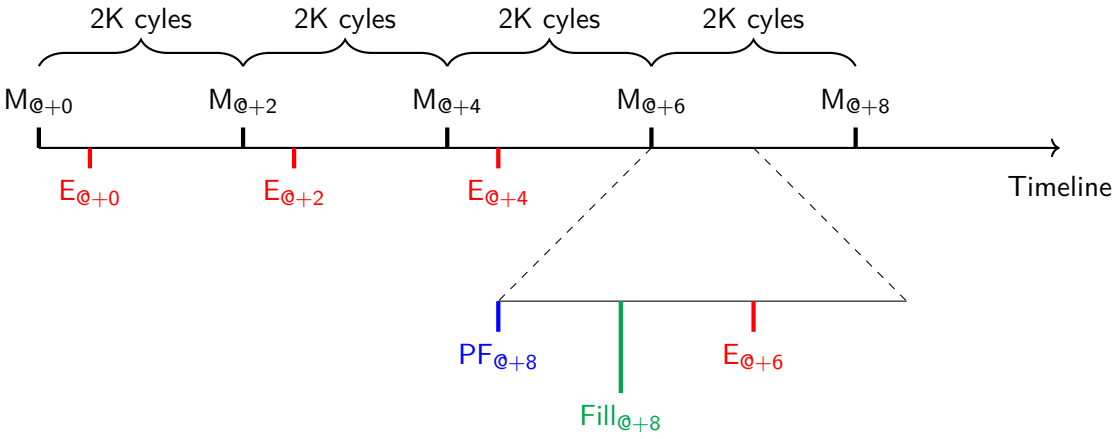

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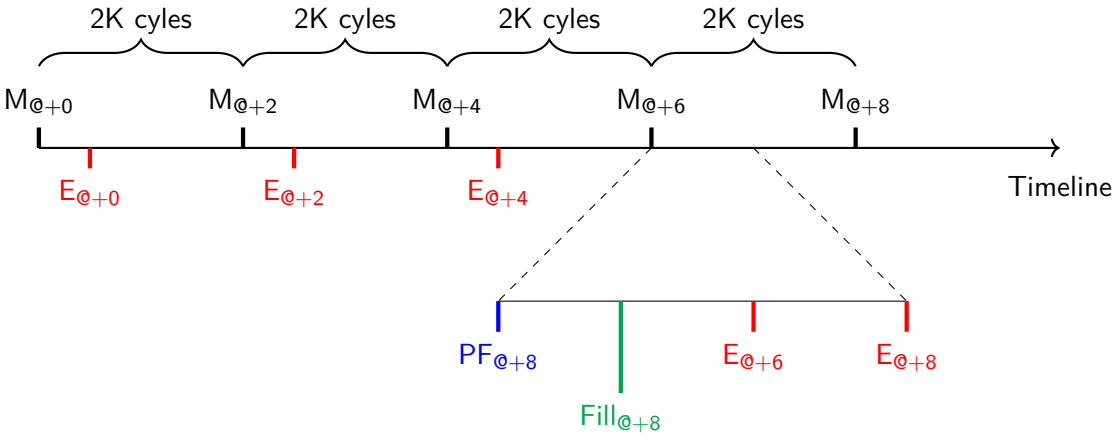

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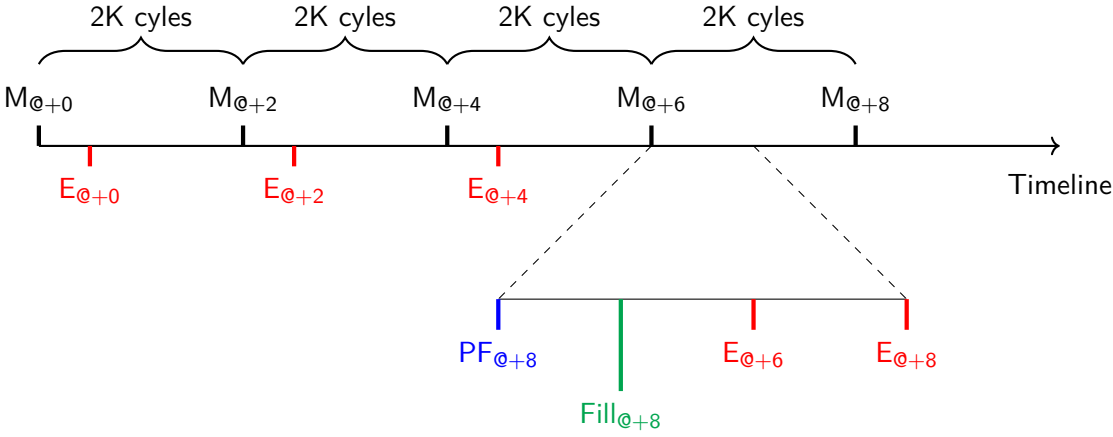

Berti fails to capture regular strides with large inter-access intervals (hundreds of cycles).

T-SKID

T-SKID[2] captures long-reuse and zero-strides patterns:

- The IP that uses and learns stride patterns **CAN** be different from the one that trigger
- It covers very-long-time distance & zero- stride
- Builds on top of an IP-Stride

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It inherents all the issues of an IP-Stride prefetcher

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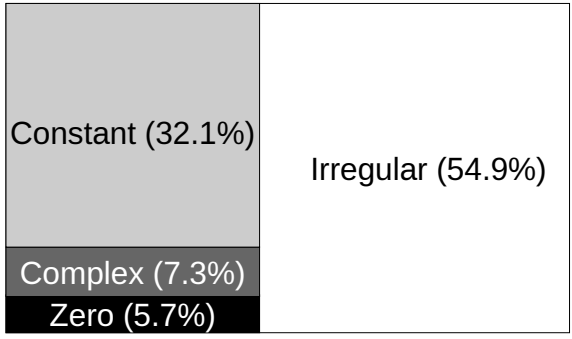
Which portions of patterns are not covered by Berti or T-SKID



SPEC CPU2017 patterns

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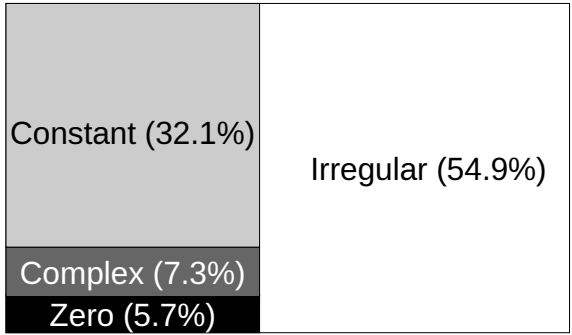

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Berti can not cover zero- and very-long-time distance strides (~5.7%)

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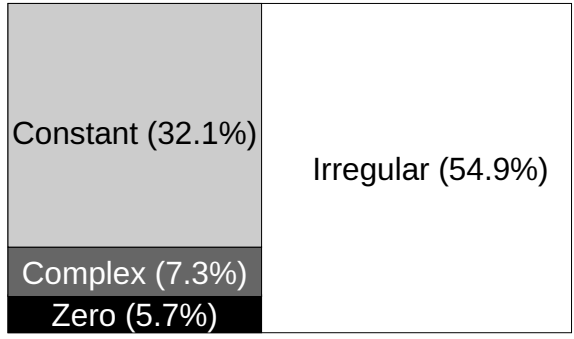

SPEC CPU2017 patterns

Berti can not cover zero- and very-long-time distance strides (~5.7%)

T-SKID can not cover complex stride patterns (~7.3%)

Can a prefetcher cover complex and long time distance patterns?

Can we have a prefetcher that covers both patterns at the same time?

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The Entangling Data Prefetcher (EDP)

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The Entangling Data Prefetcher (EDP)

- Cover complex patterns
- Cover very-long-time distance strides & zero-strides
- Improve timeliness

The Entangling Data Prefetcher

Complex patterns

The Entangling Data Prefetcher is built on top of Berti:

- Use **deltas** (distance between two or more accesses)
- It uses only **timely** deltas to prefetch

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Complex patterns

Already covered thanks to Berti ☺

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Long time distance patterns

Decoupling IP that learns patterns and IP that trigger patterns (similar to T-SKID)

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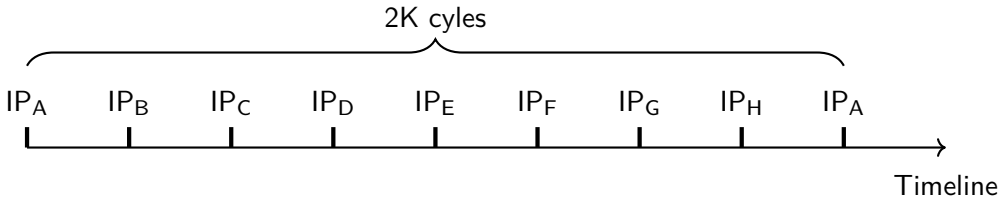

Why not use a previous IP to trigger prefetch requests

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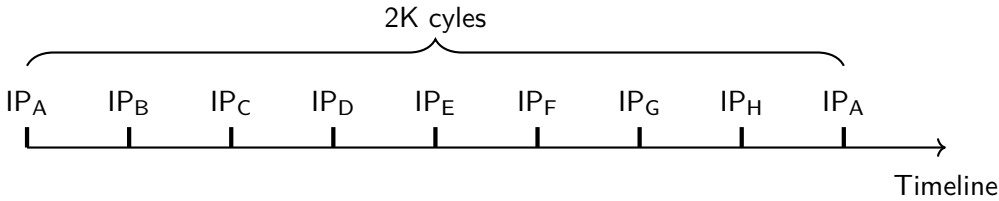

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But which one?

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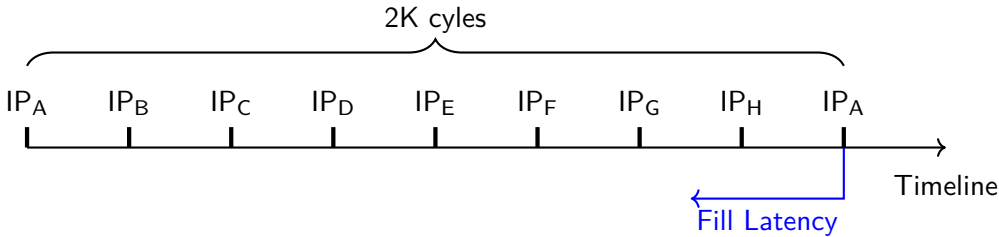

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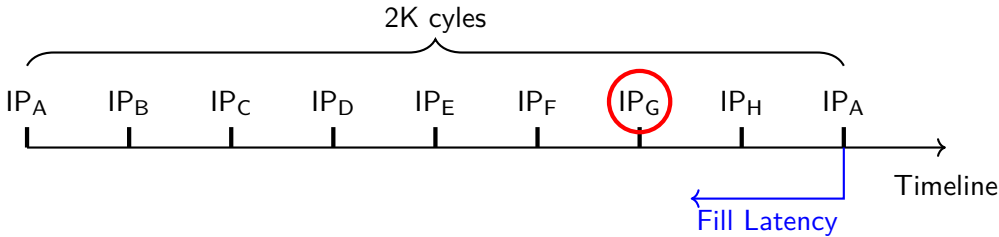
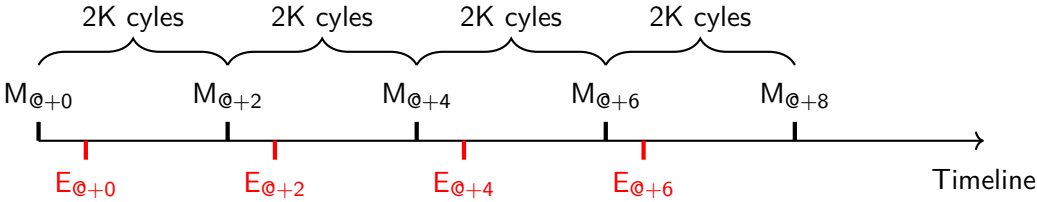


An IP sufficiently in advance

The Entangling Data Prefetcher

A load triggers the prefetcher for another load →entangled pairs



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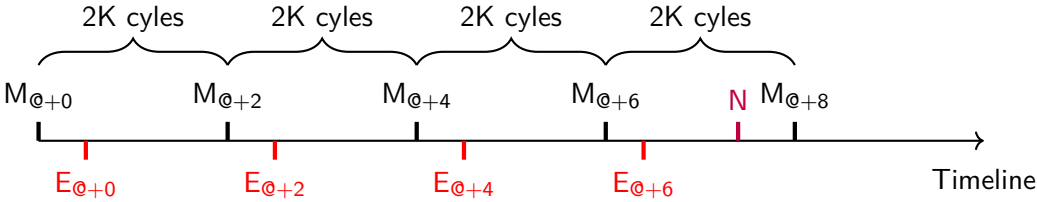

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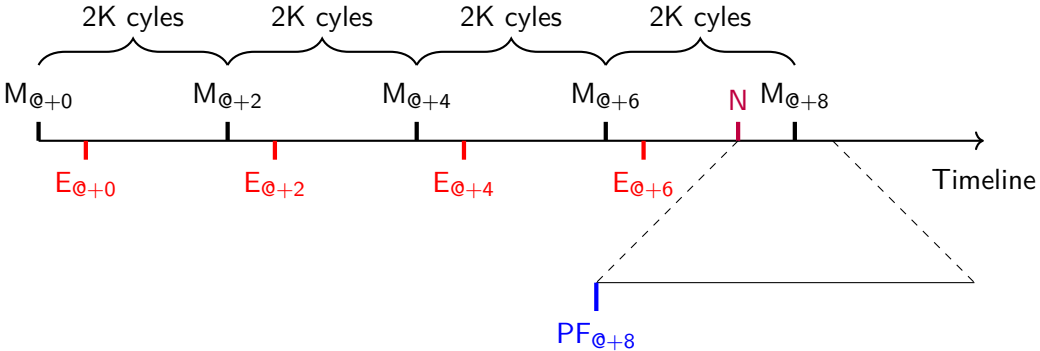

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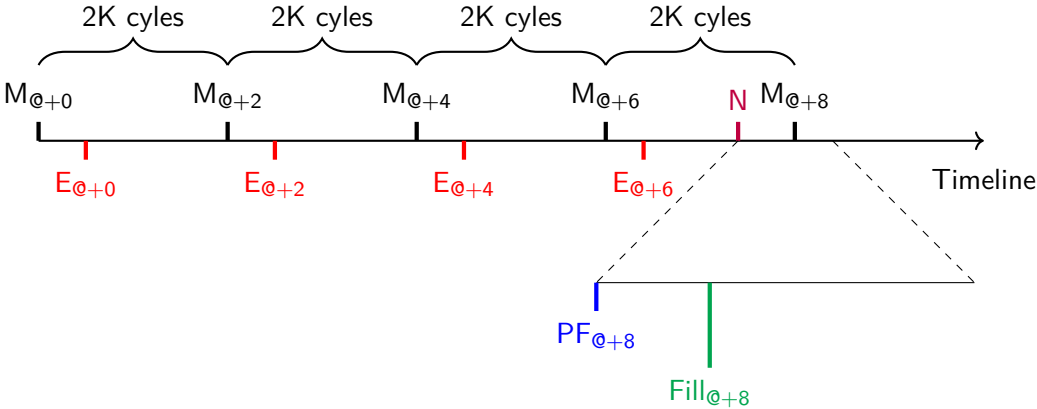

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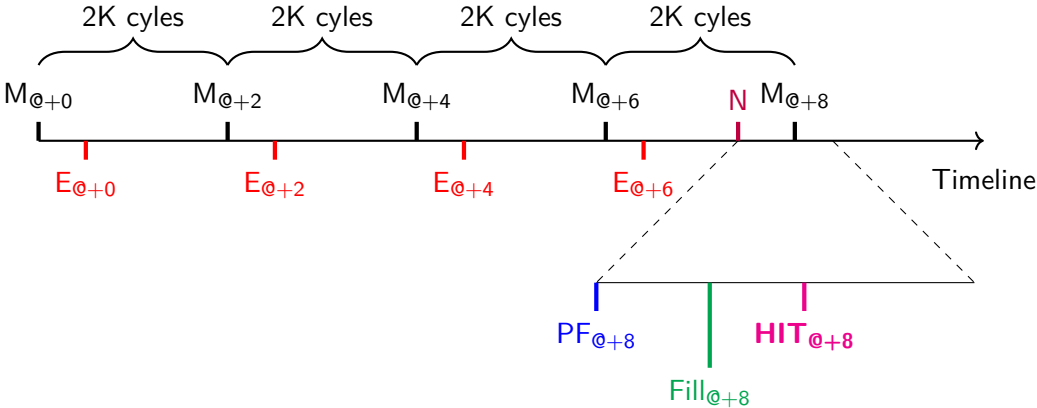

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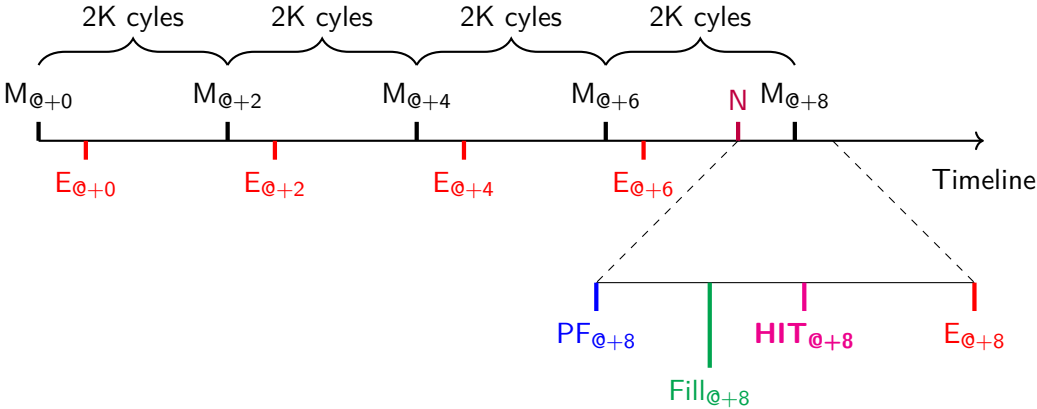

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Throttling the prefetcher

But... one IP can insert multiple requests for different IPs at the same time

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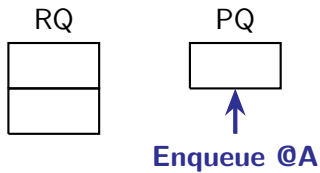
Two solutions:

1. Delay queue
2. A filter

The Entangling Data Prefetcher

A delay queue

Under **low-contention**, the prefetch request enqueue a request and issue in the next few cycles



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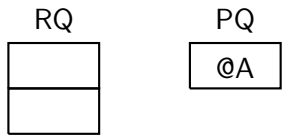

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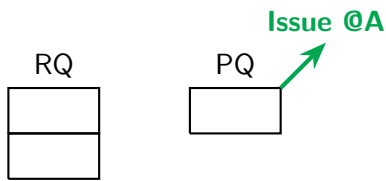

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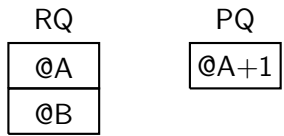

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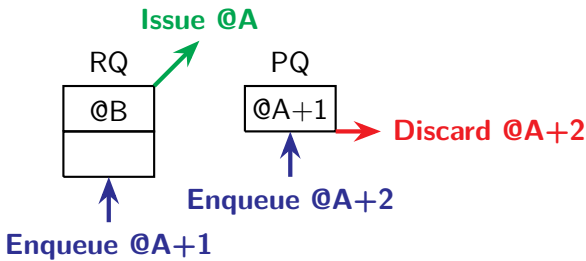

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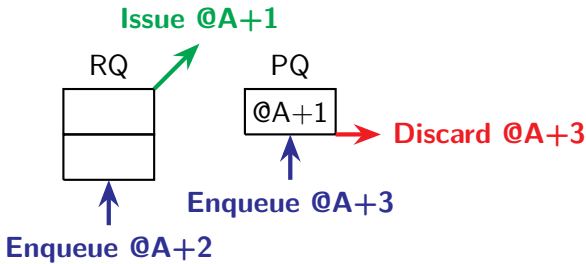

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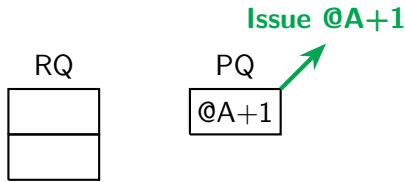
. . . and it becomes useless



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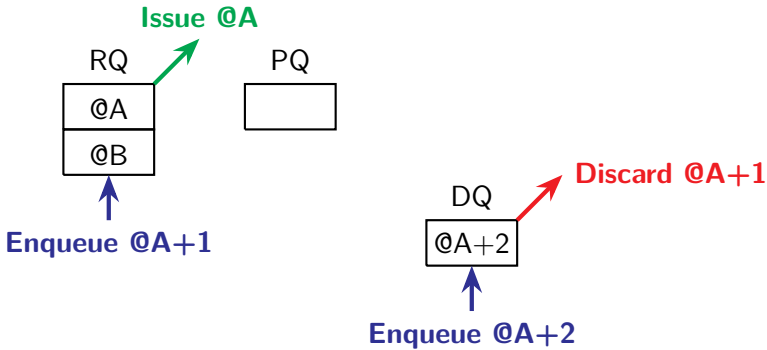
Our **delay queue** keep renewing the request to keep the useful one



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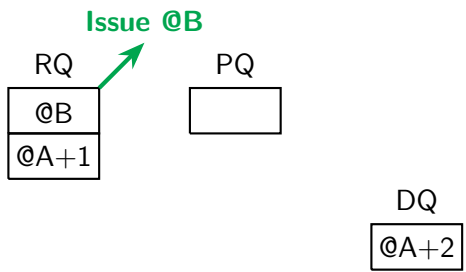

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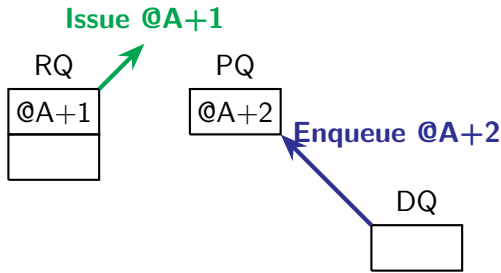

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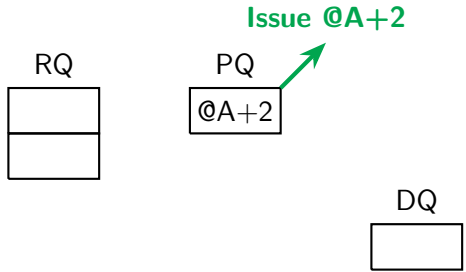

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A filter that reject potential not useful prefetch requests

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- Otherwise (entry equal to 0) →**ISSUE**
- On a cache eviction, the entry is set to 0.

L2 & LLC

We include Pythia at L2:

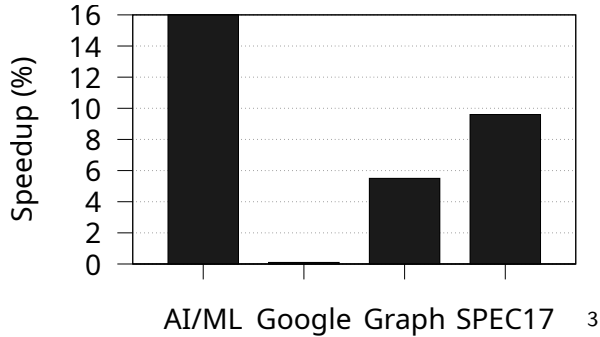
- Detects some patterns that are not detected by EDP
- It can issue prefetch request when L1D is under very high-contention

And a throttling mechanism in LLC:

- If too many cores access the LLC, it send a signal to reduce the aggressiveness of EDP
- If one core issues significant portion of non-demand/prefetch request to LLC
  $\rightarrow$disconnect EDP for that core

Evaluation

Singlecore



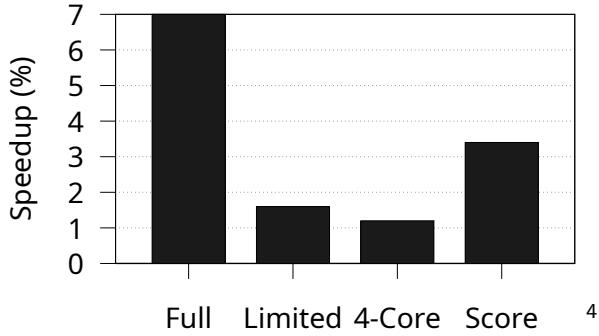
[3]

Speedup over 16% in AI/ML and over 9% in SPEC17

[3] Not including all release traces

Evaluation

All



[4]

7.1% over singlecore and 1.4% over multicore

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Thank you!

Any question?