SafeFetch:

Practical Double-Fetch Protection with Kernel-Fetch Caching

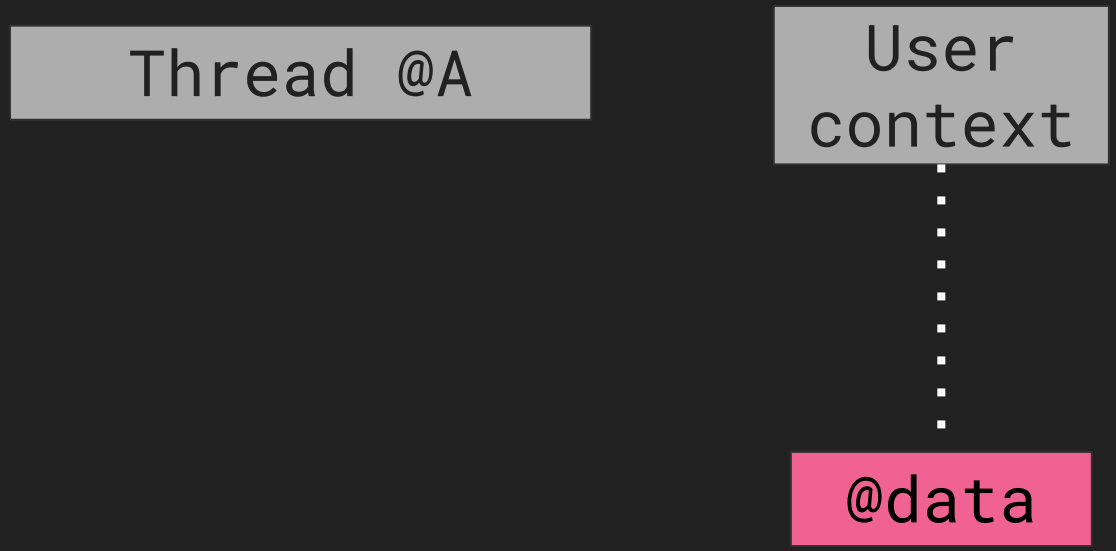
Victor Duta

Mitchel Alonserij Cristiano Giuffrida

Teaser

- Kernel double-fetch bugs
- State-of-the-art relies on COW semantics
- SafeFetch ideea => per-syscall caching of user data
- Low performance impact:
    - Less than 5% geomean overhead

Double-Fetch Anatomy



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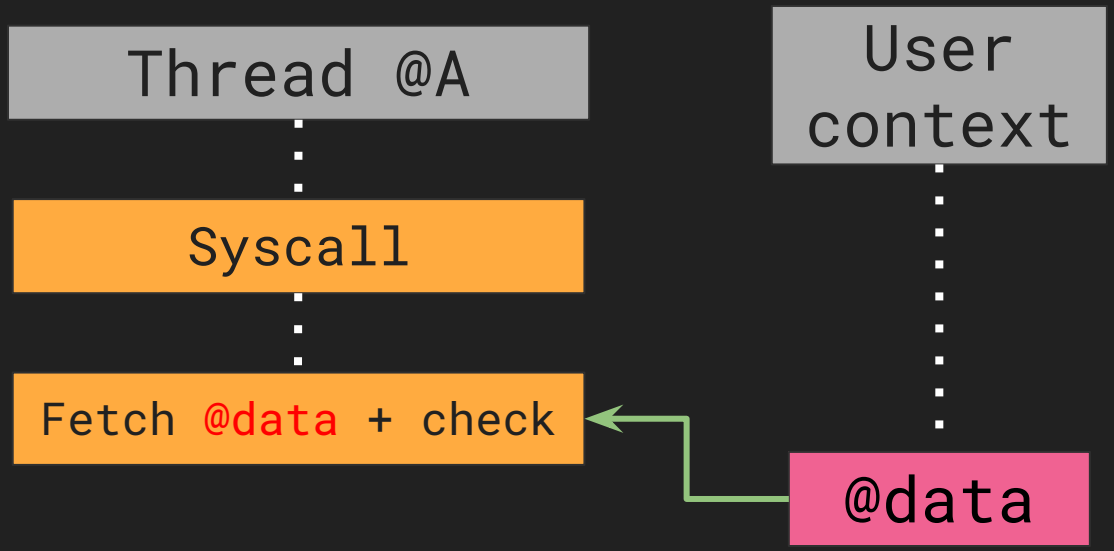

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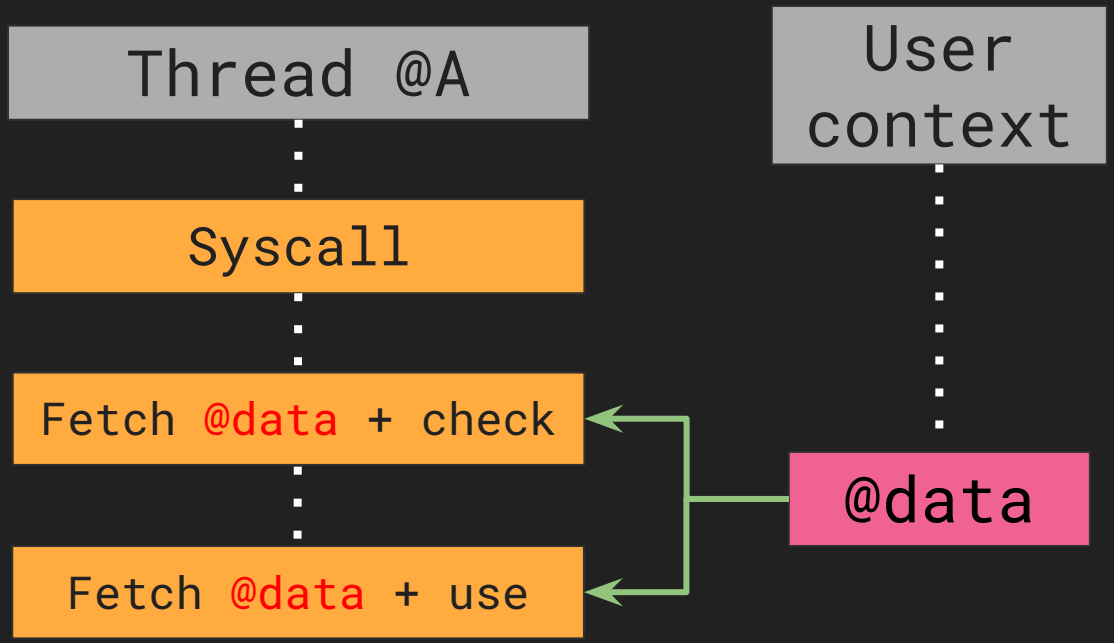

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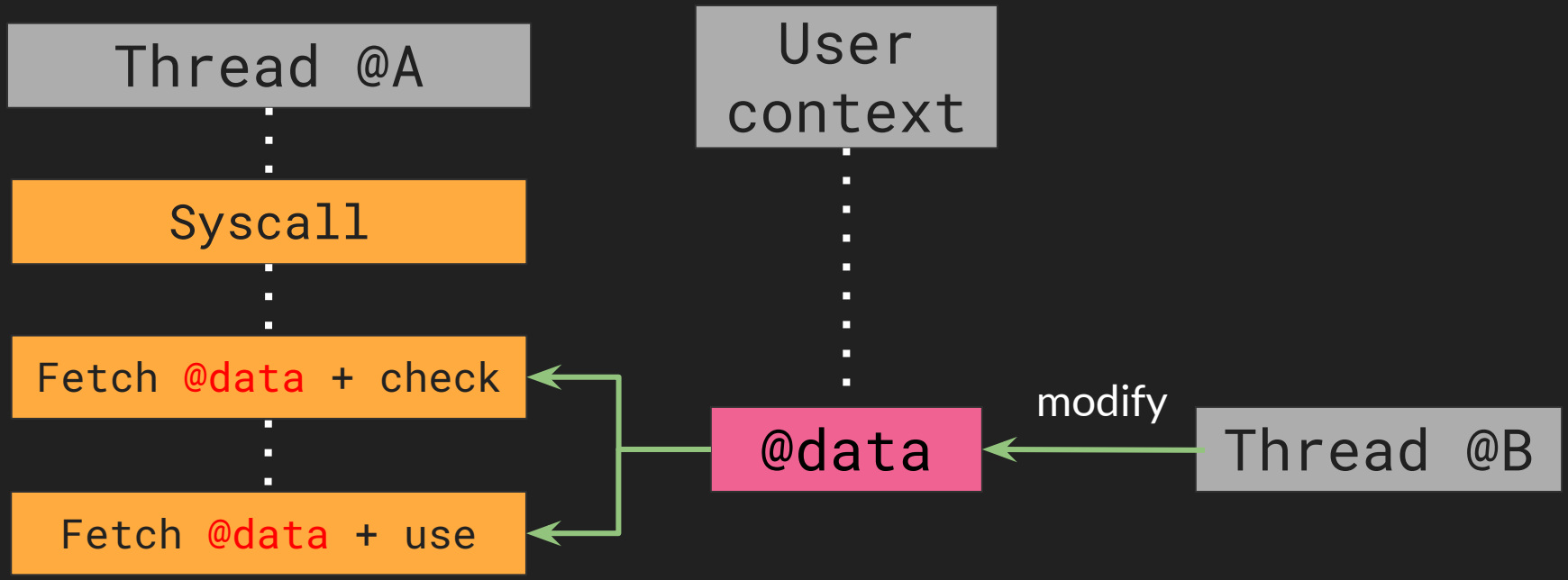


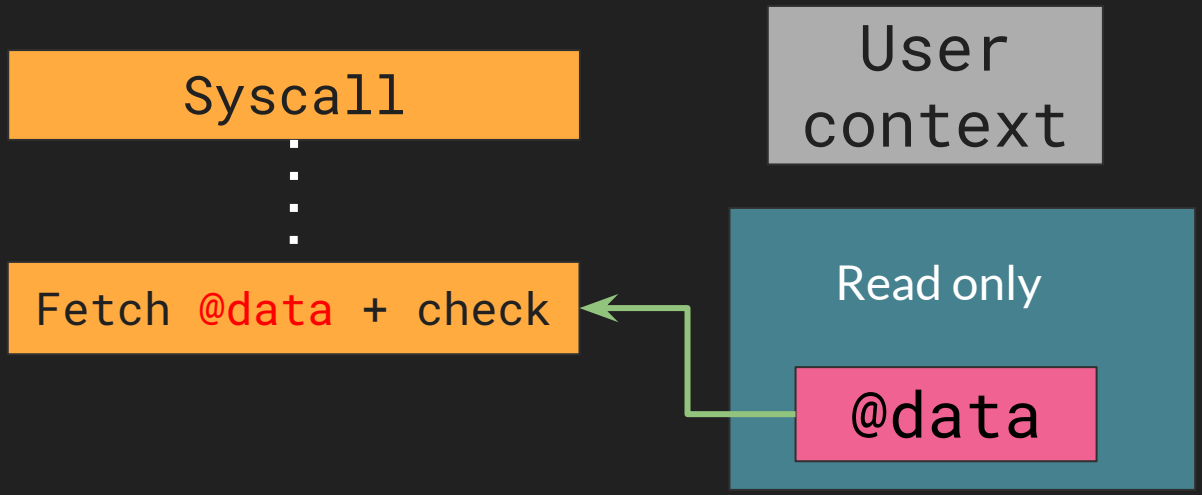
Midas

Syscall

User context

@data

Midas



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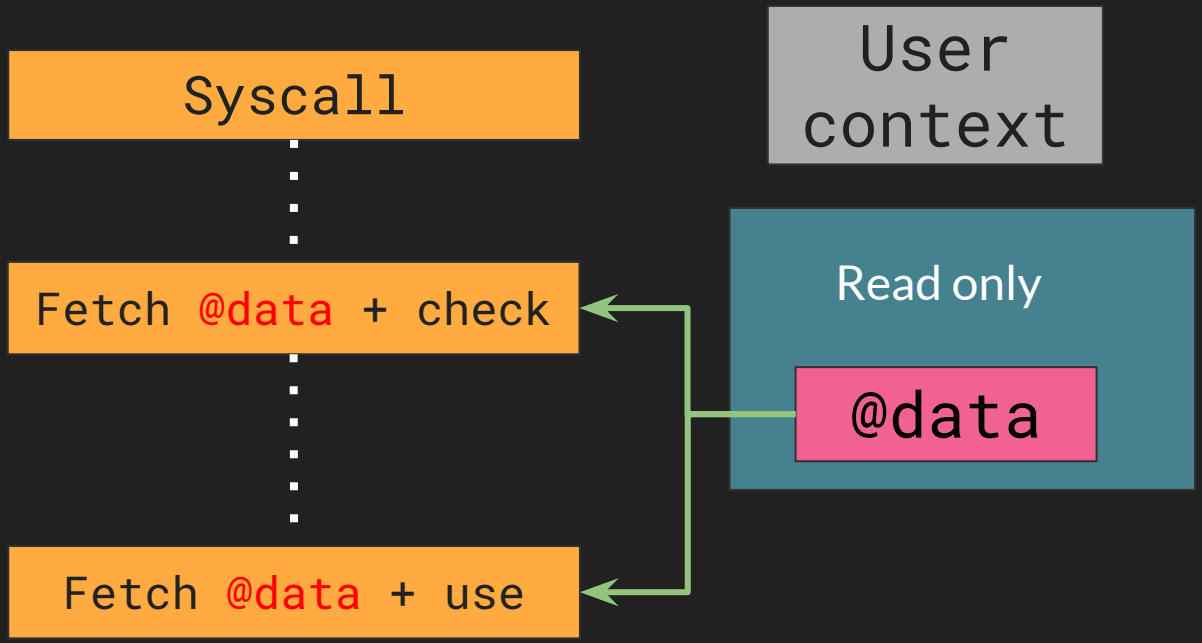
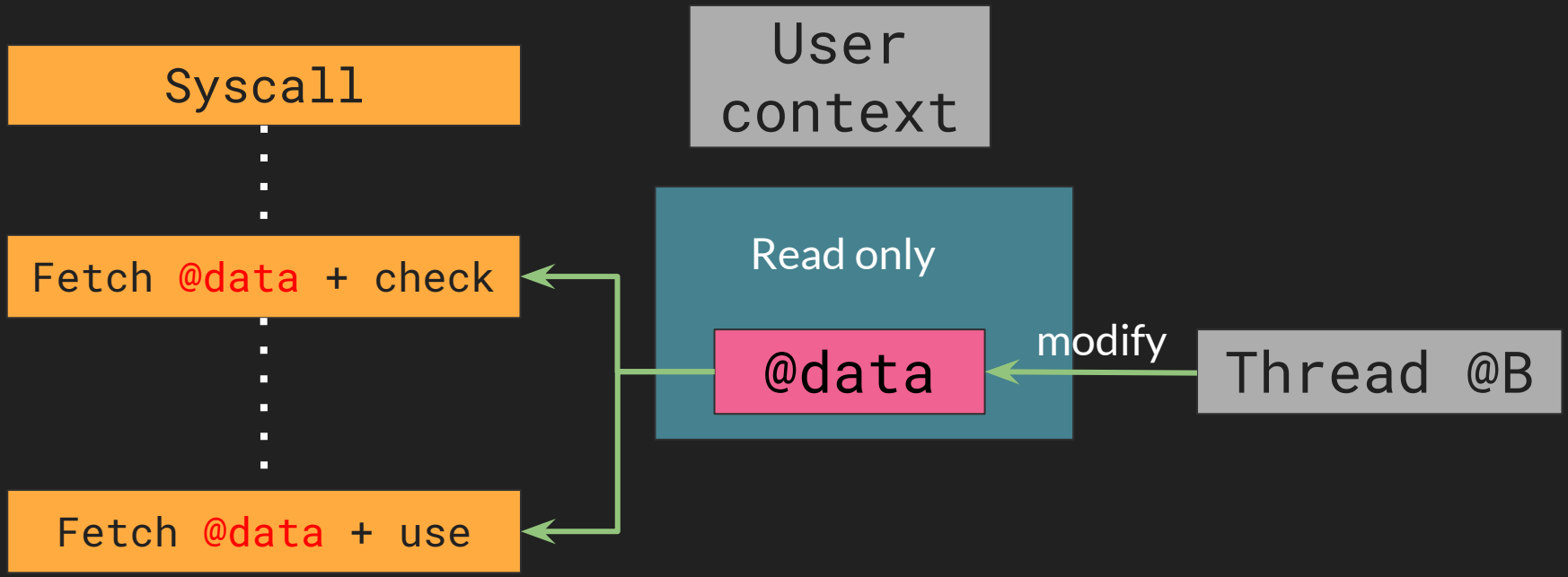

Syscall
Fetch @data + check
Fetch @data + use
User context
Read only
@data

Midas


Syscall
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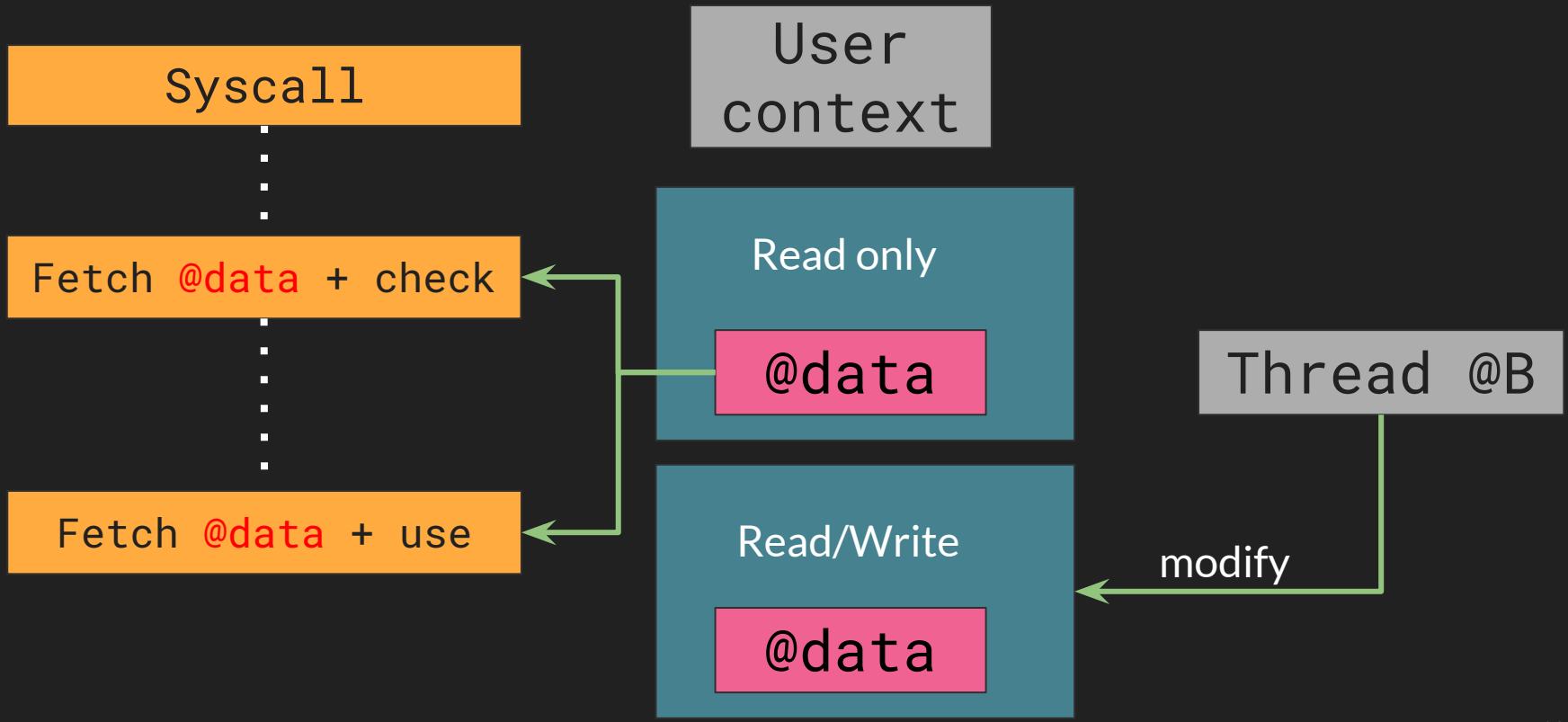
User context
Read only
@data
modify
Thread @B

Midas


Syscall
Fetch @data + check
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User context
Read only
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Read/Write
@data
Thread @B
modify

Key Insights

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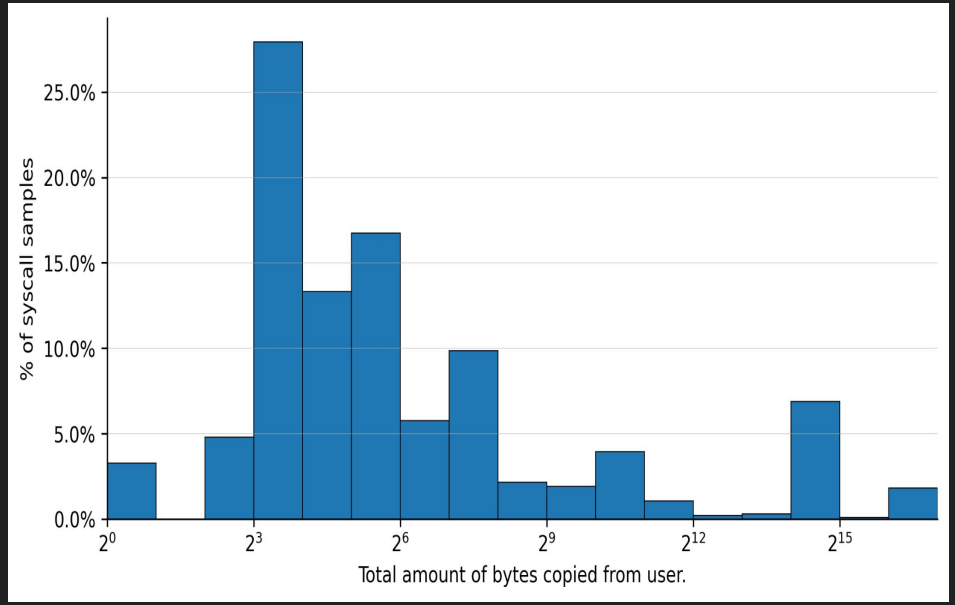

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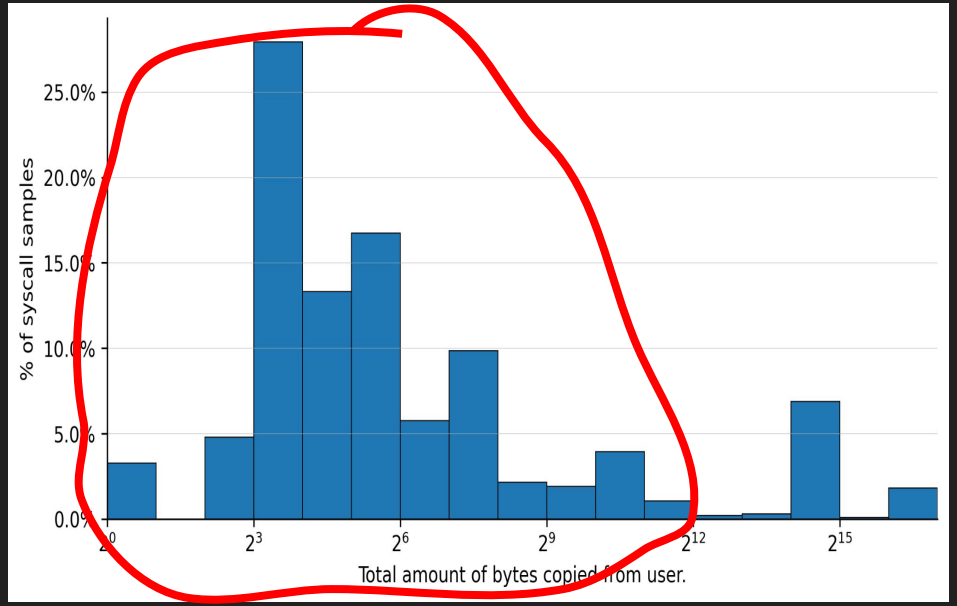
90% of syscalls fetch <= 1 Page of user data



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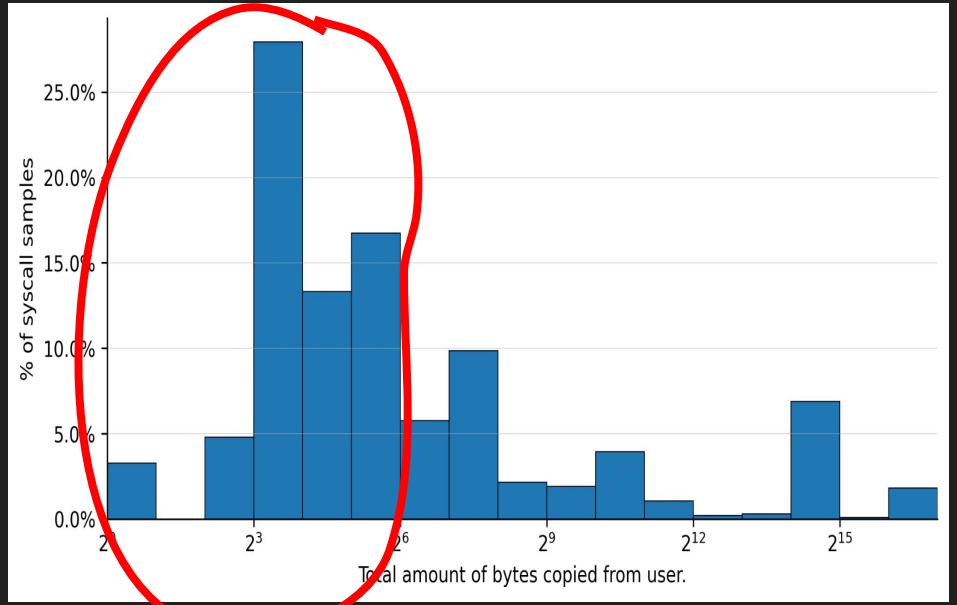

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- On average syscalls fetch far less than a page of data
- Caching is more efficient

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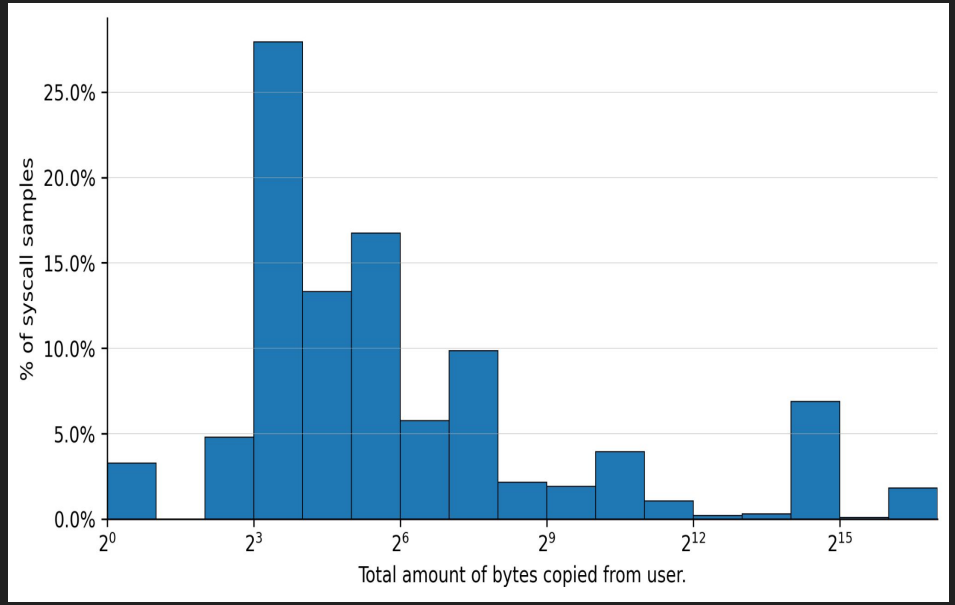

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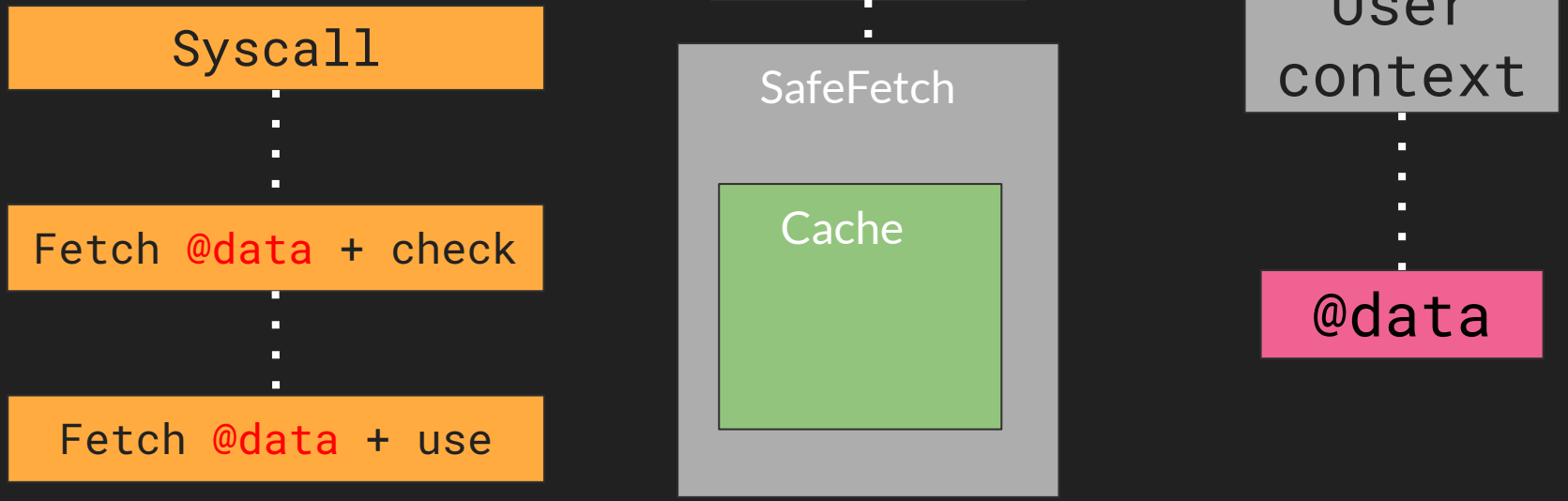
SafeFetch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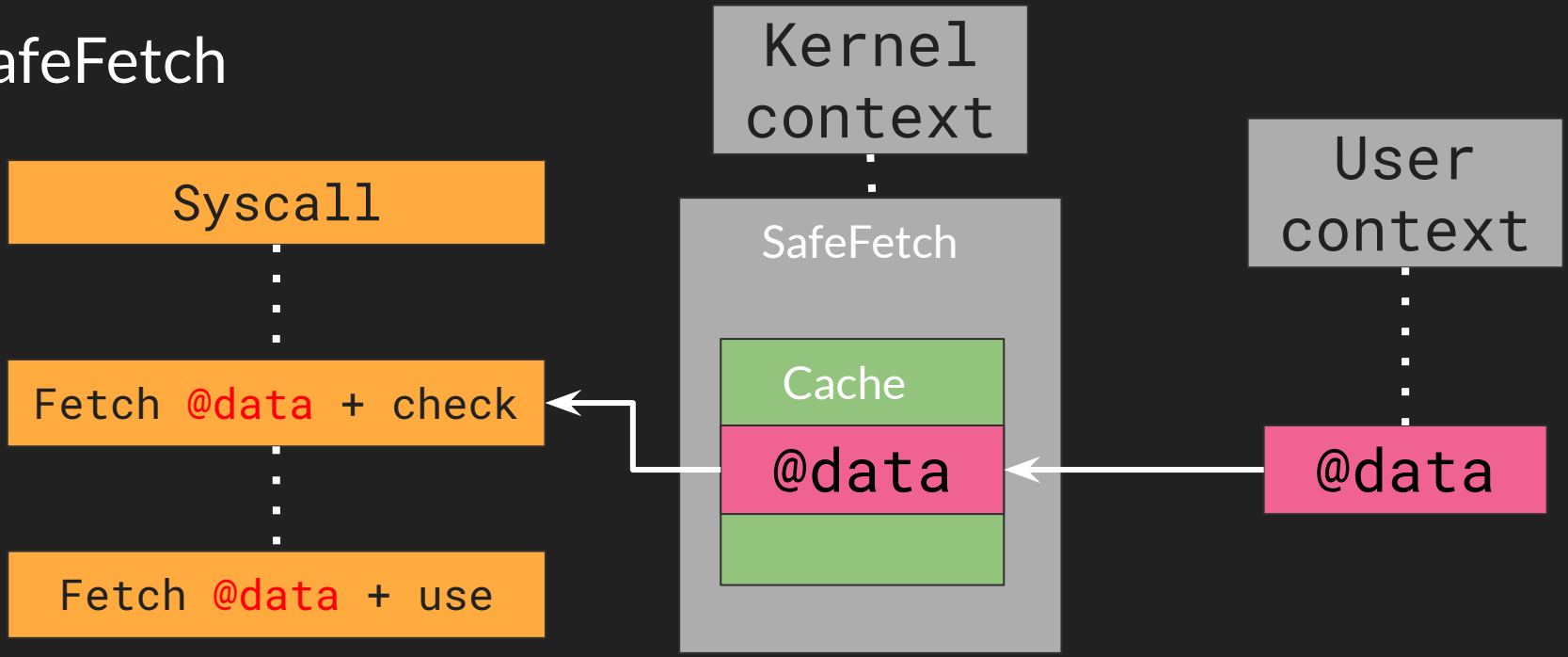
Fetch @data + use
Kernel context
SafeFetch
Cache
User context
@data

SafeFetch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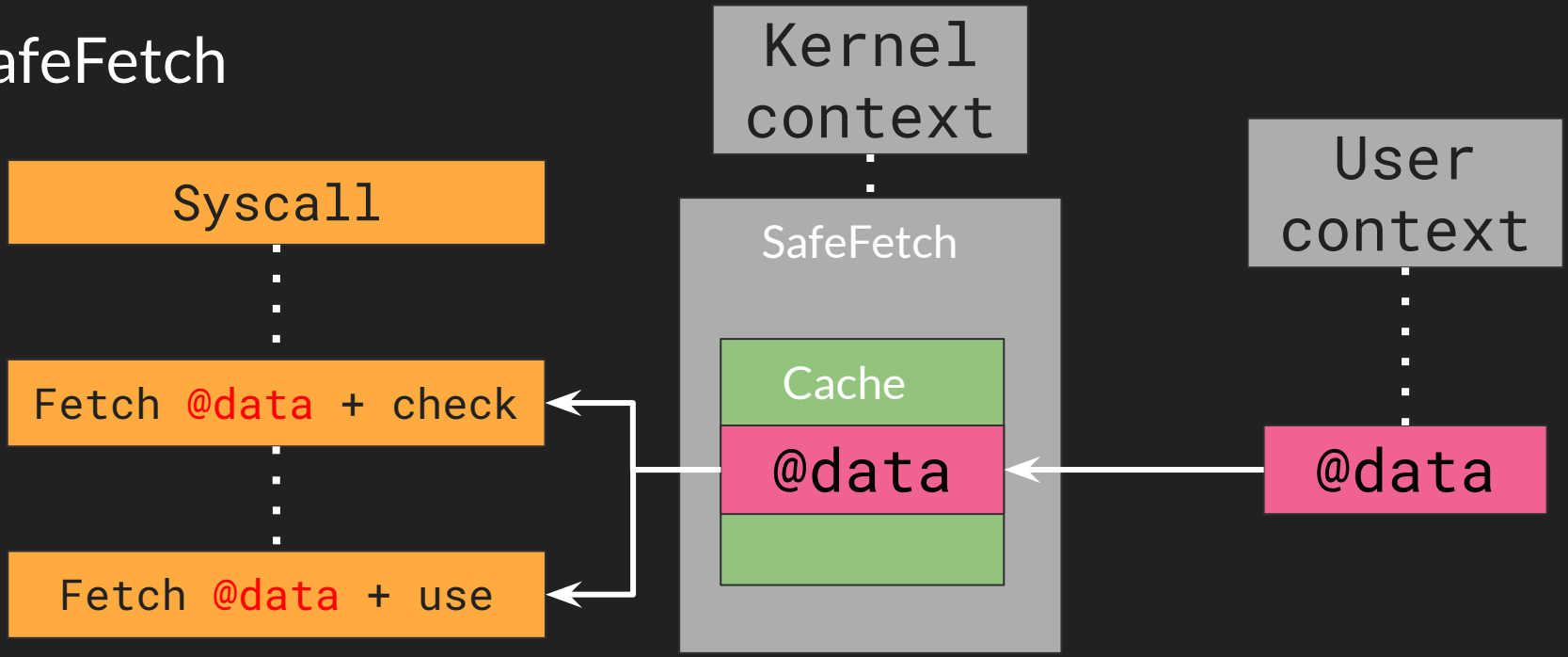
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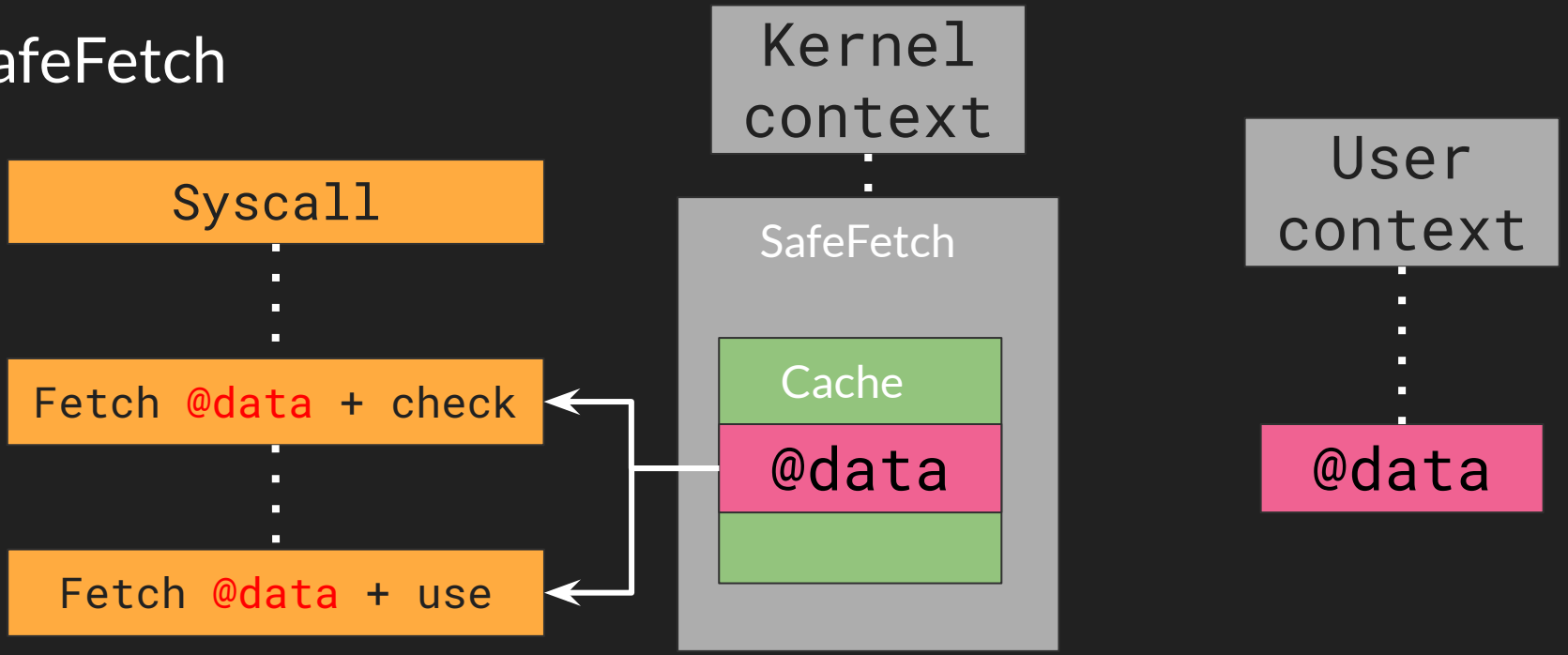
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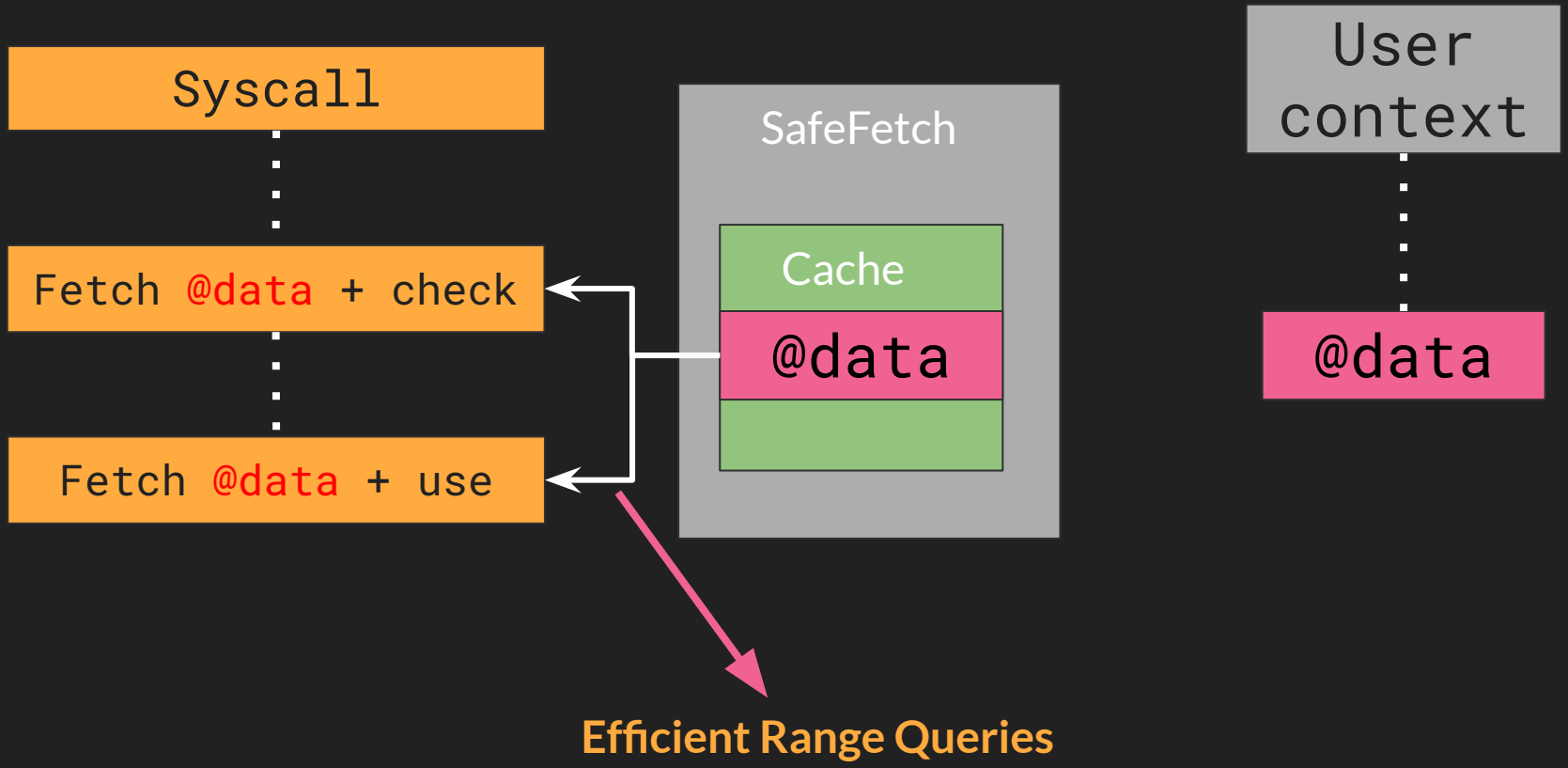
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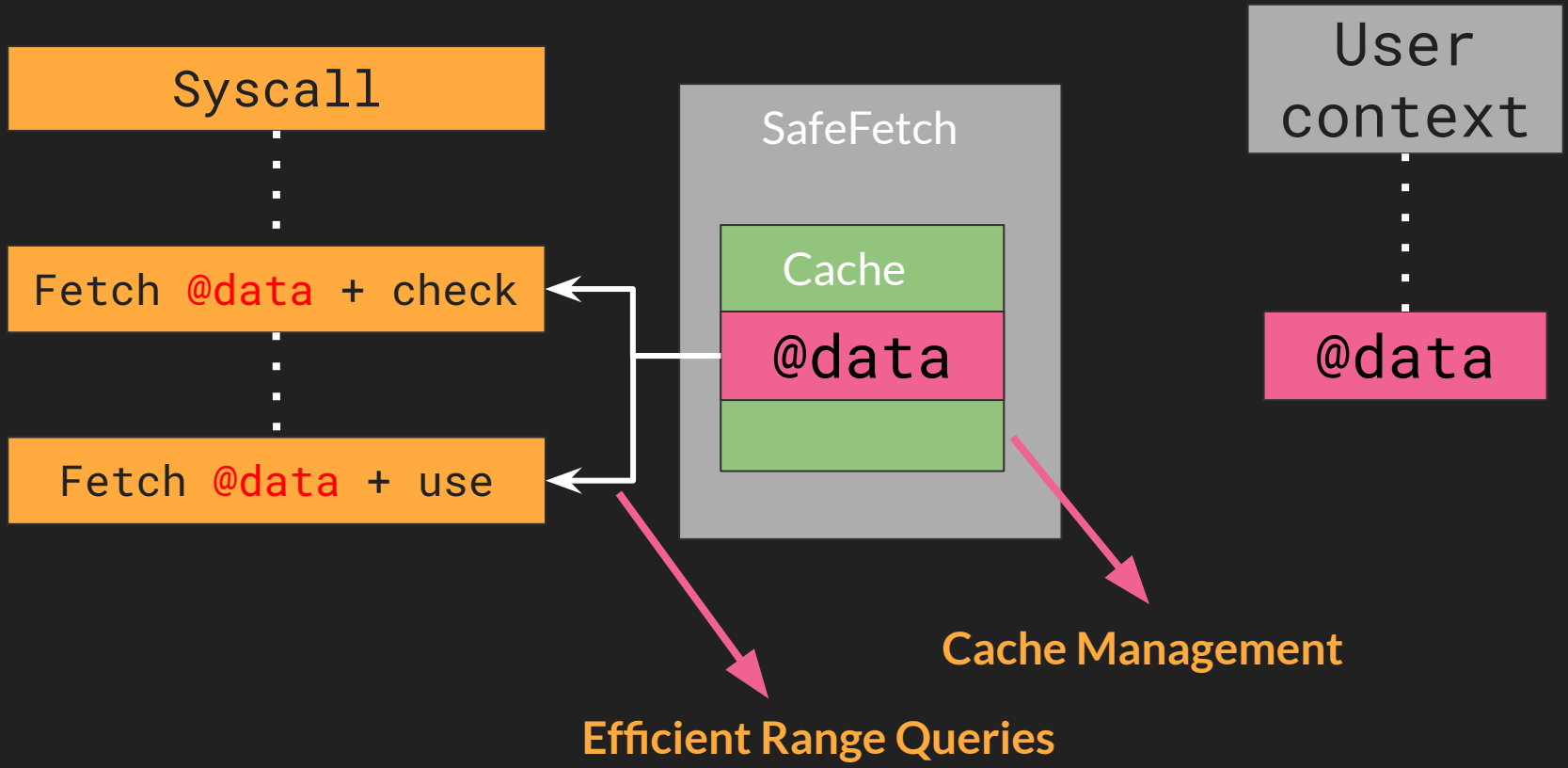
Efficient Range Queries

SafeFetch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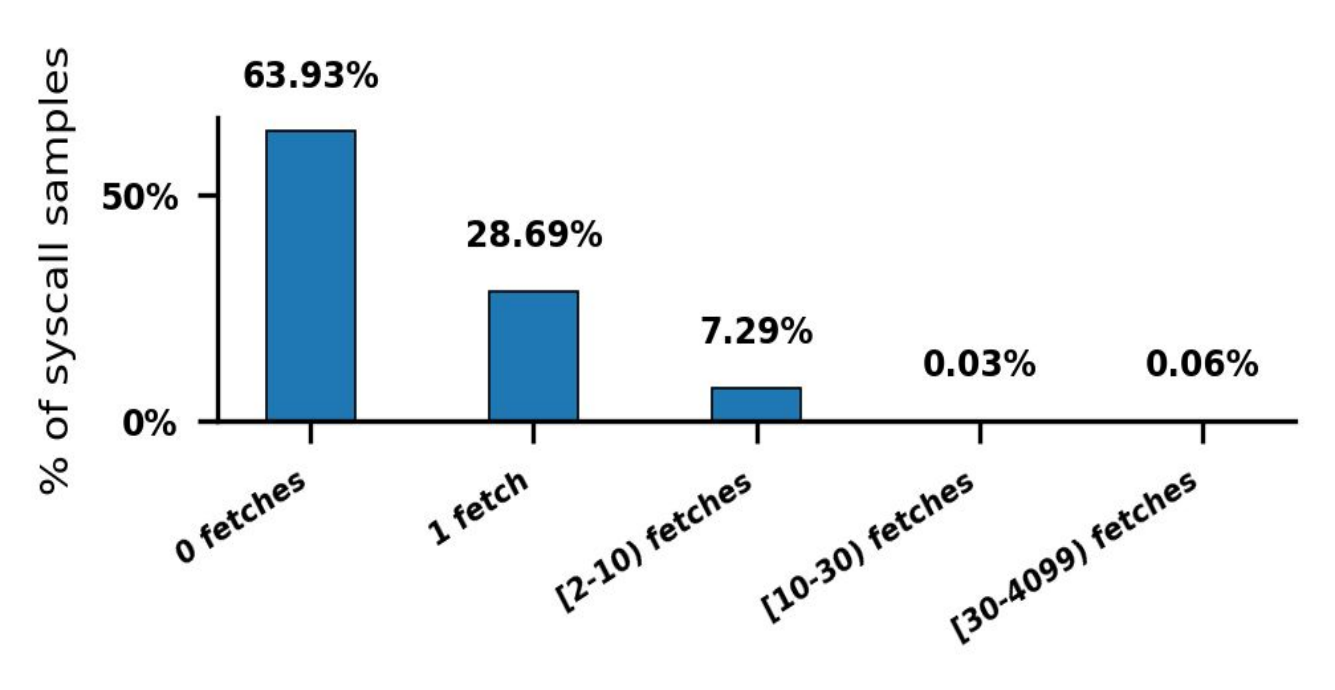
Cache Management
Efficient Range Queries

Efficient queries



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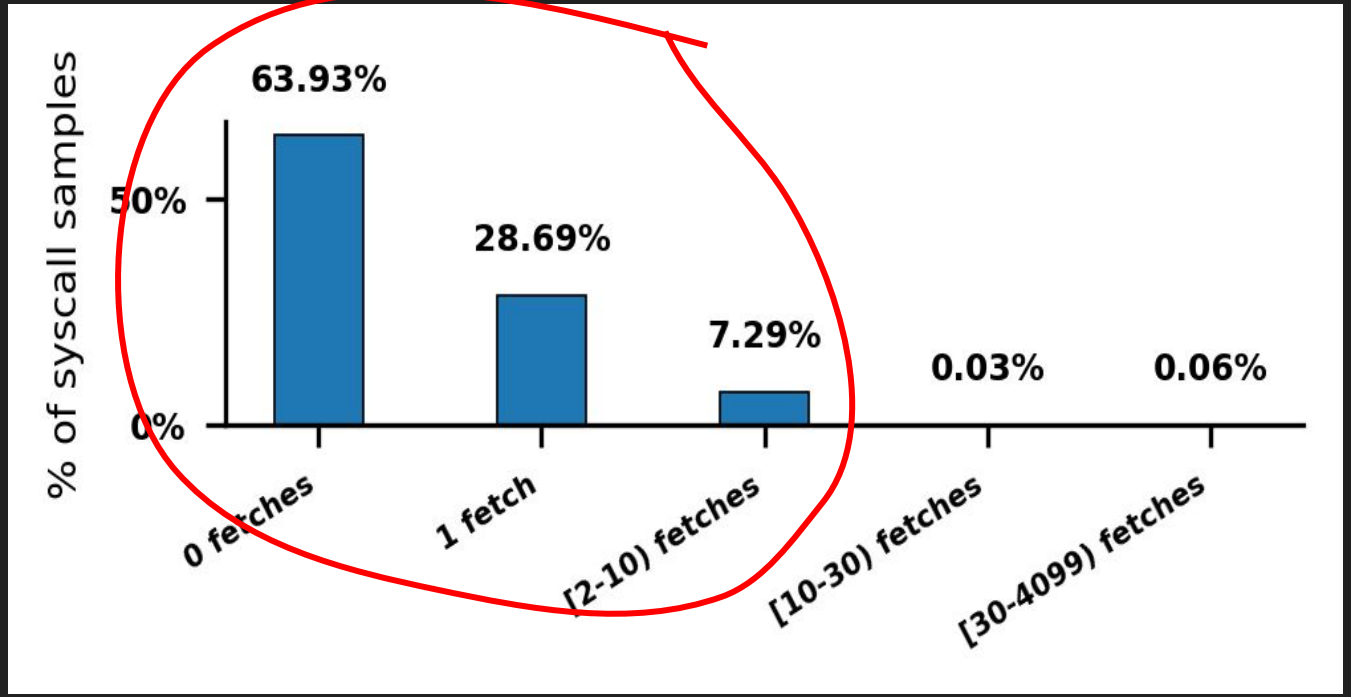

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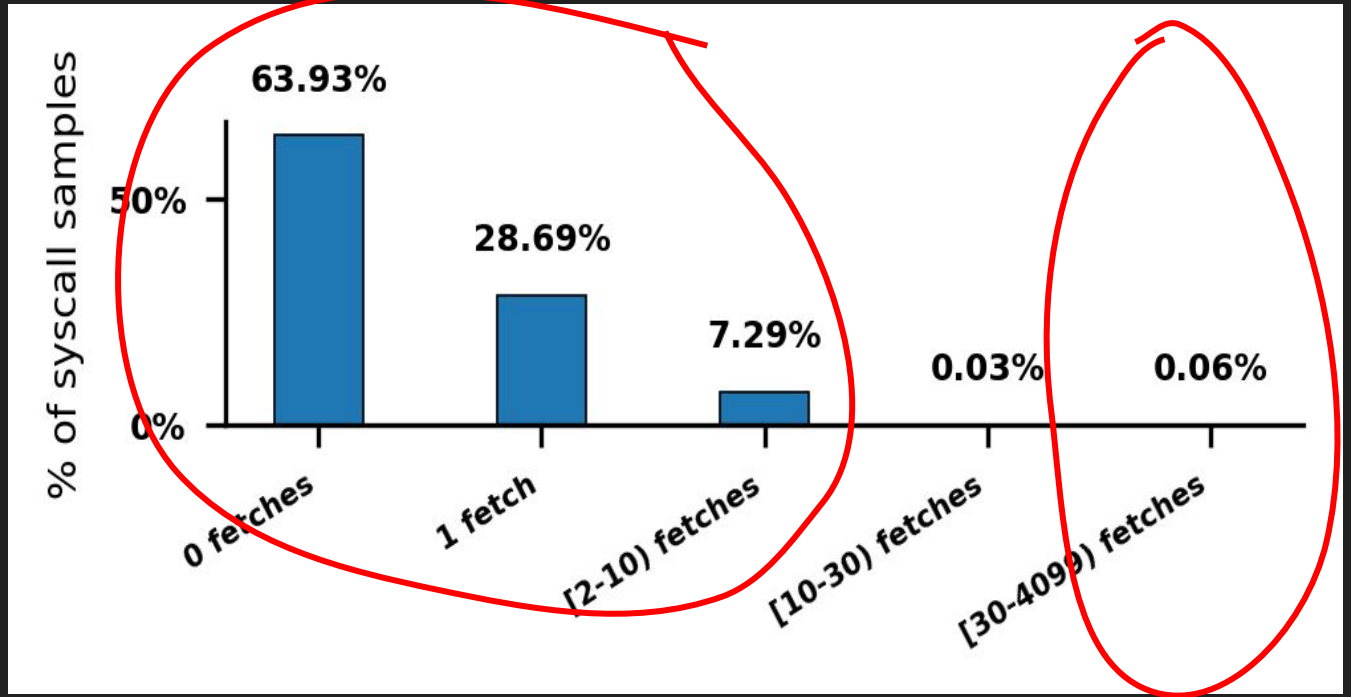
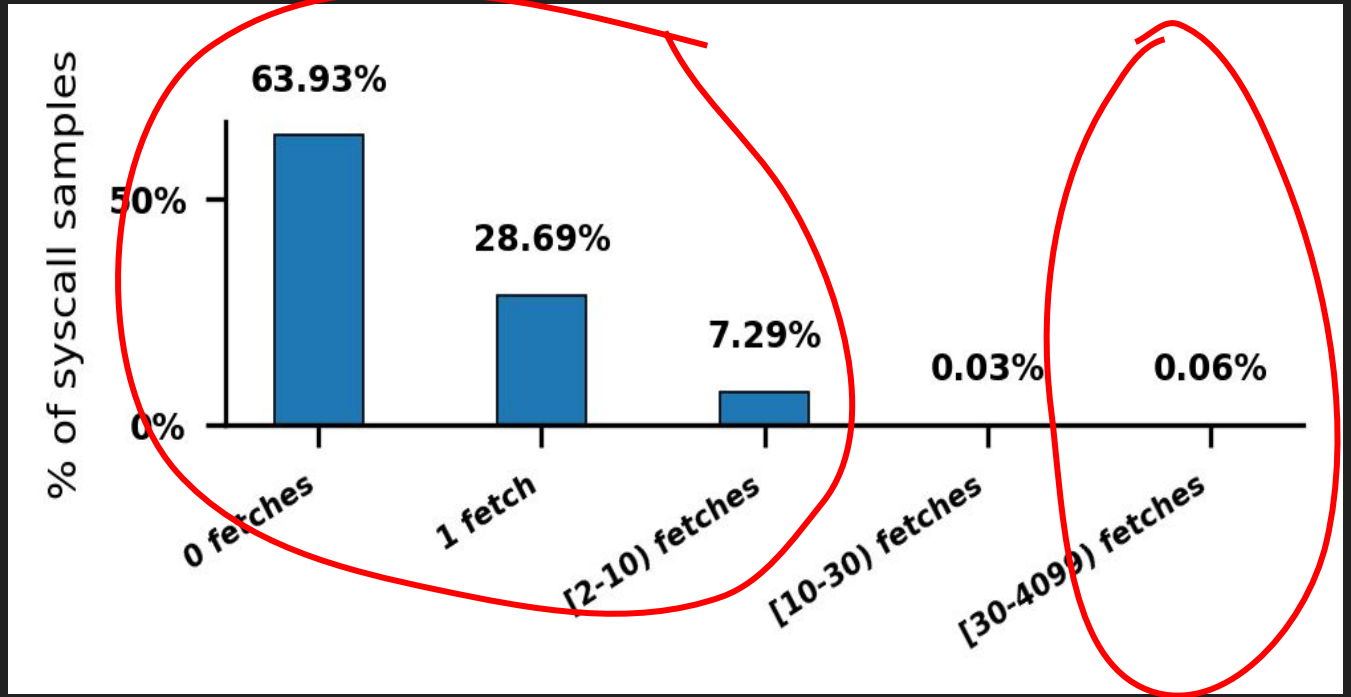


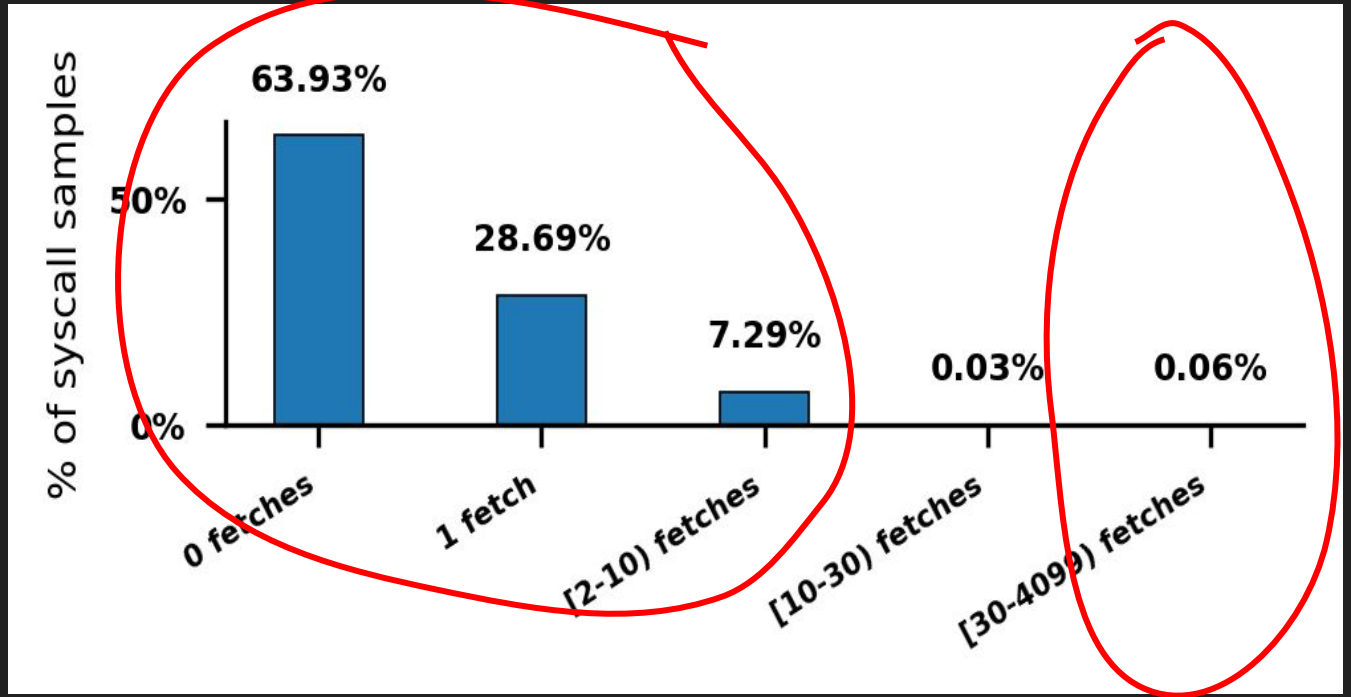
Efficient queries

linked list



Efficient queries

linked list → rb-tree



Cache Management

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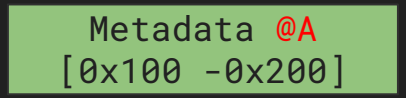

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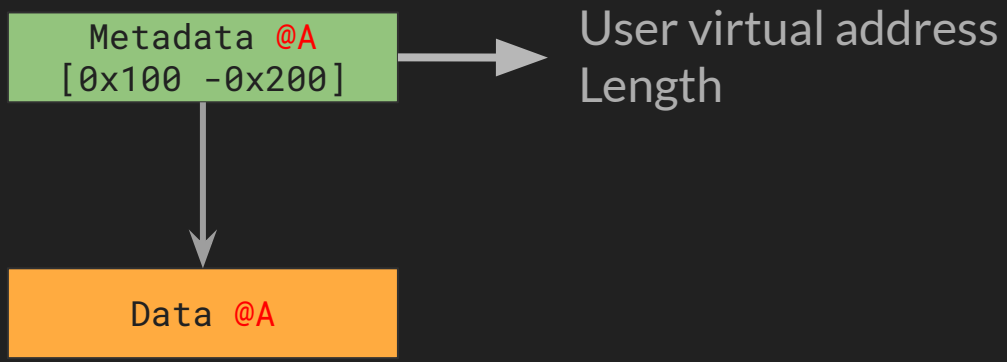

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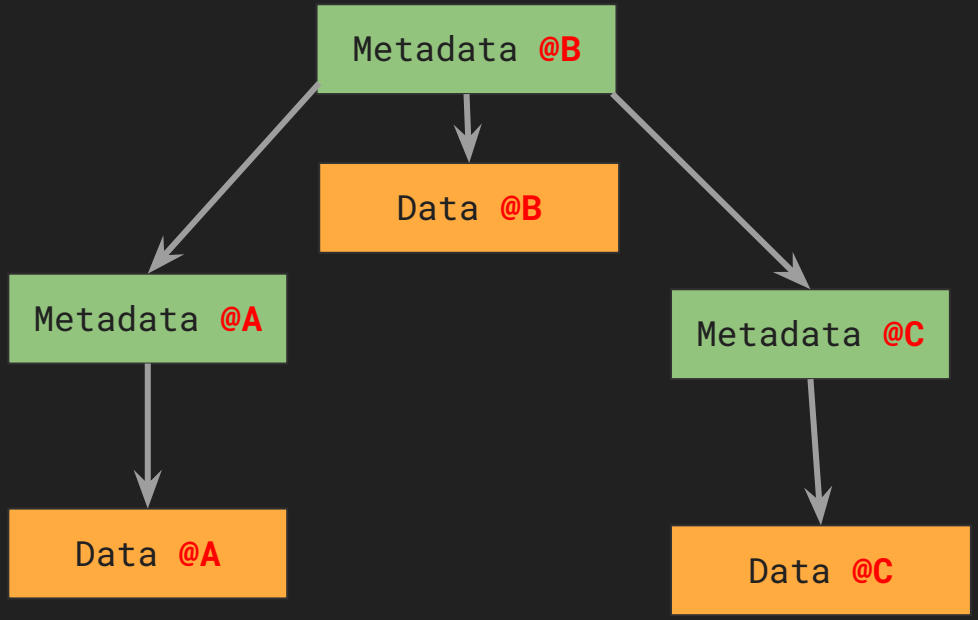

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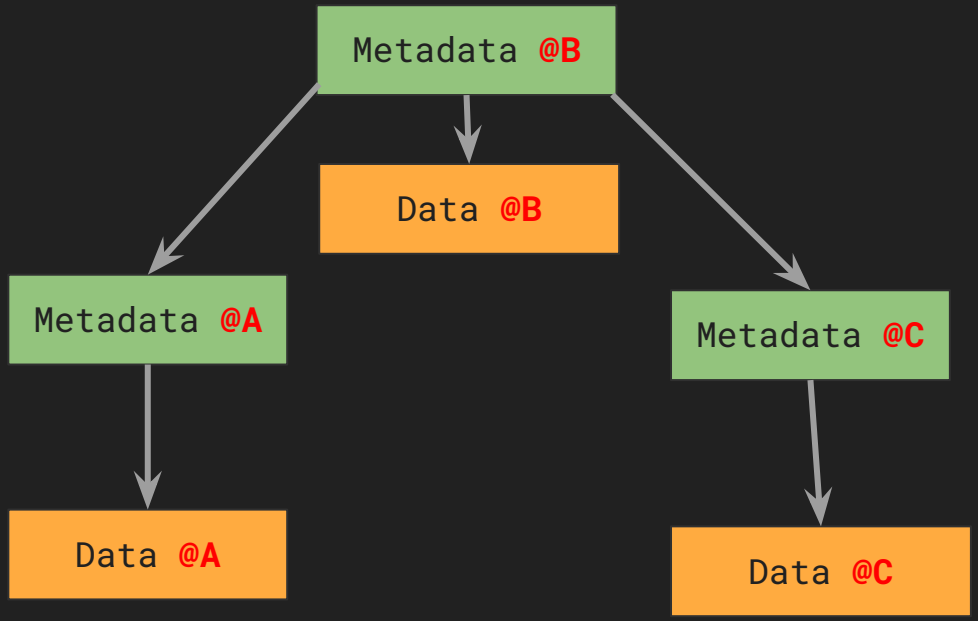
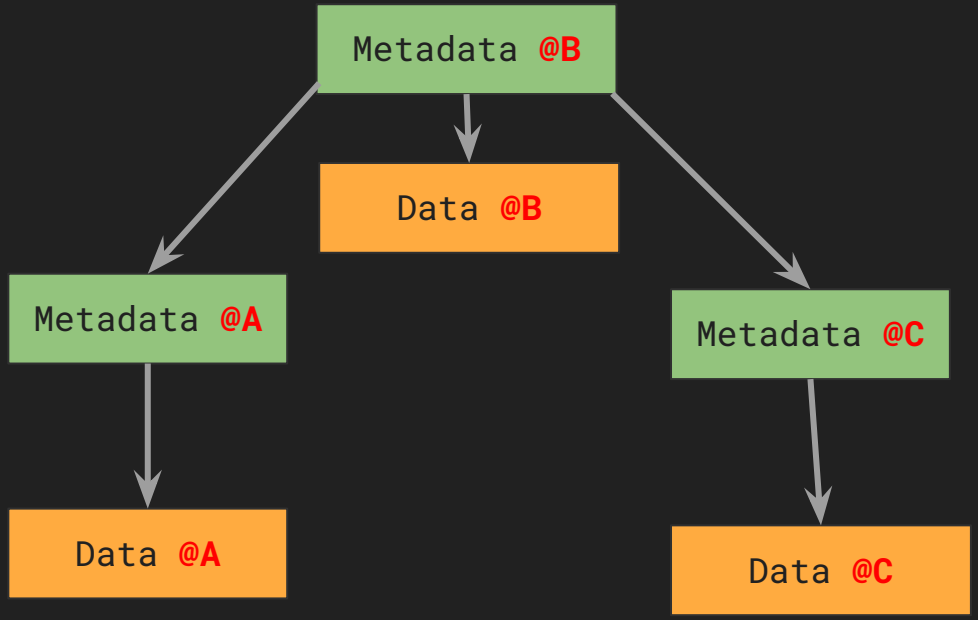
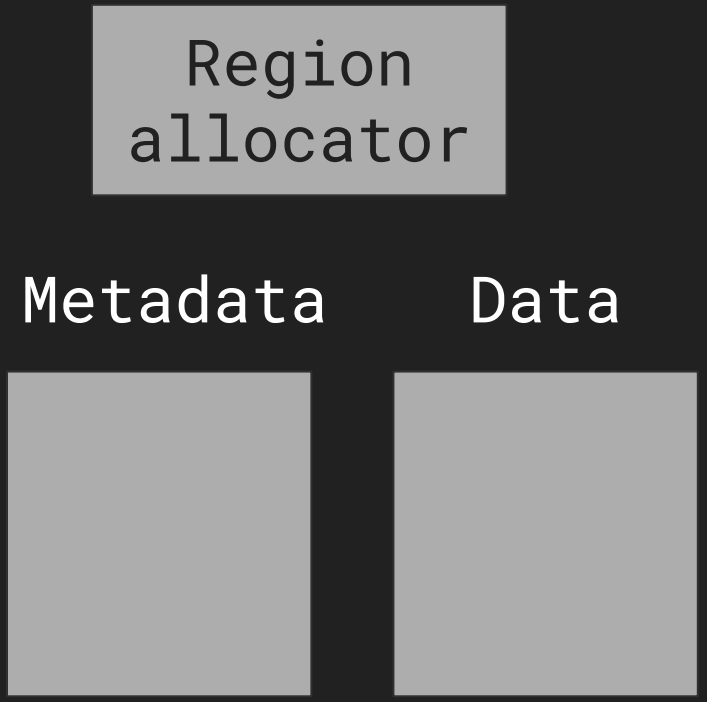


Region allocator

Cache management





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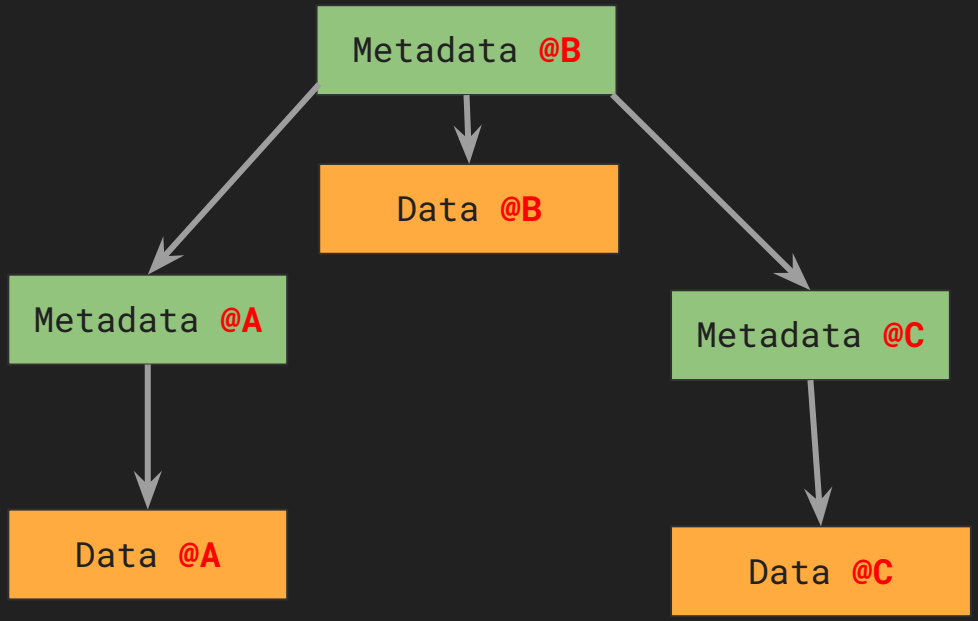


Region allocator

Metadata

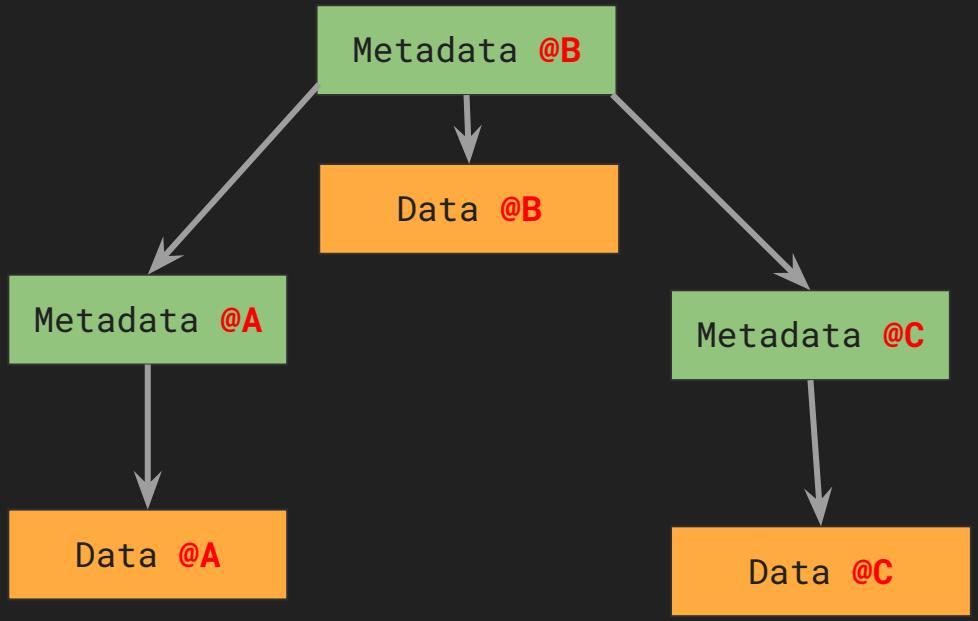
Metadata @A

Metadata @B

Metadata @C

Data

Cache management



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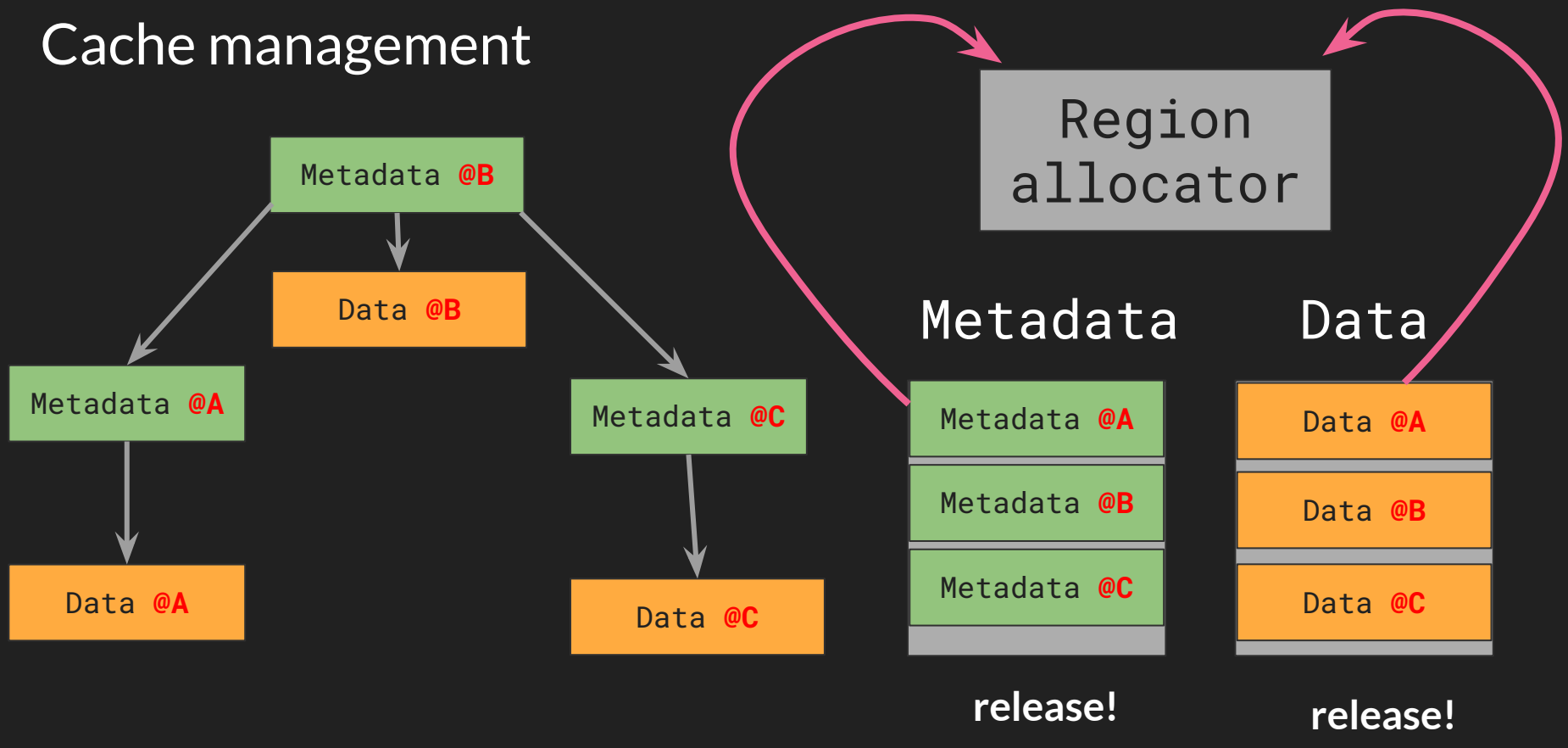

Results

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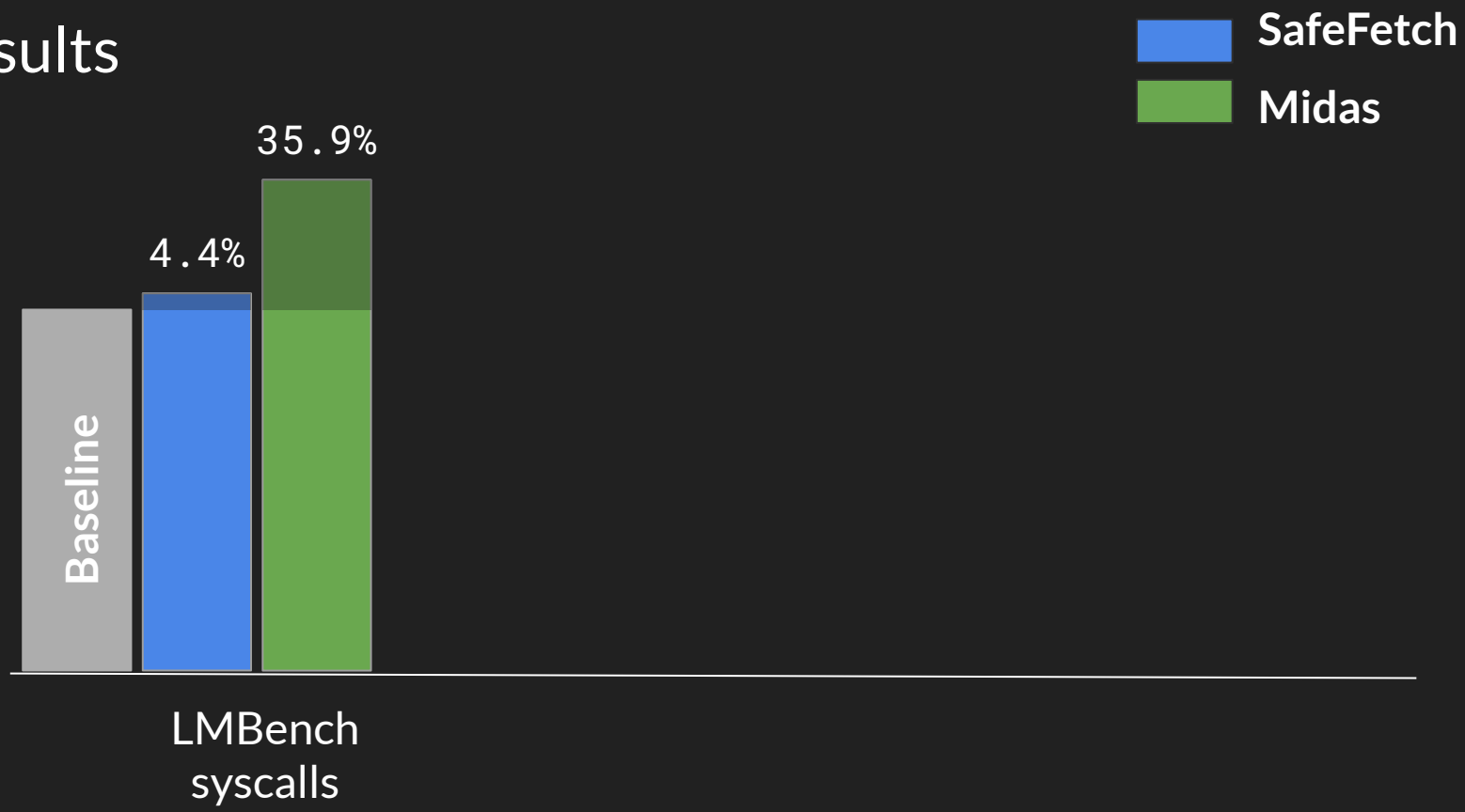

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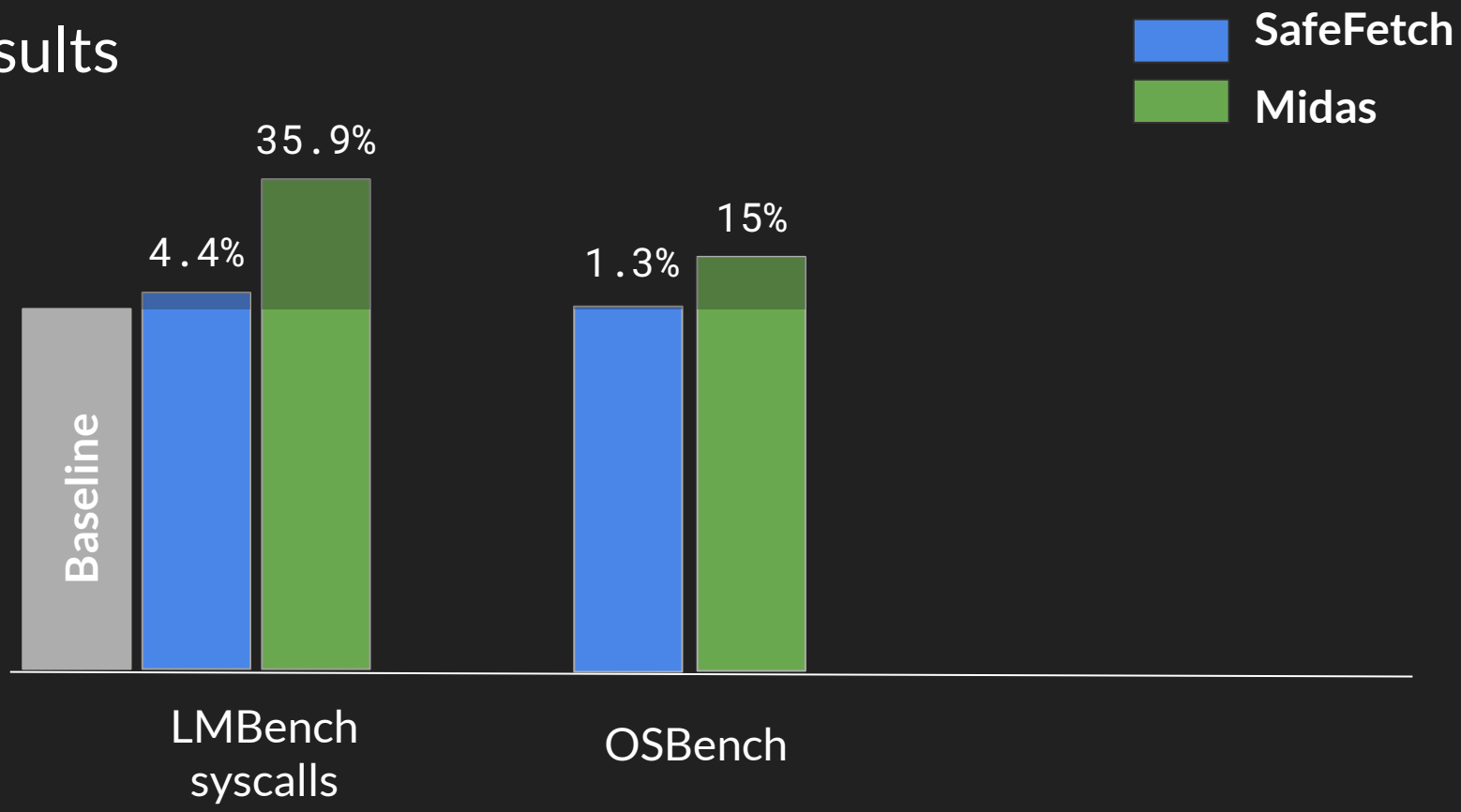
SafeFetch
Midas
35.9%
4.4%
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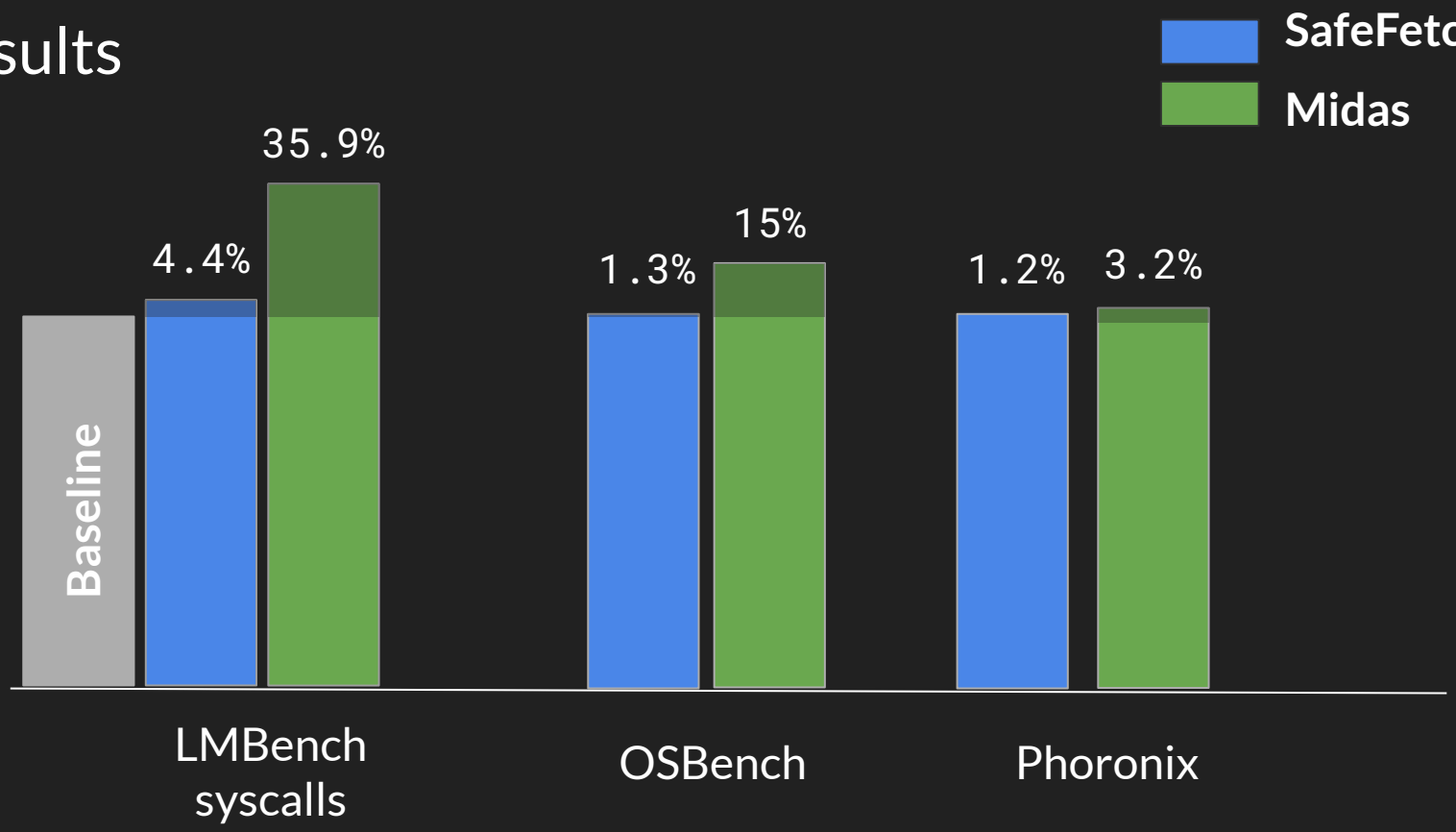
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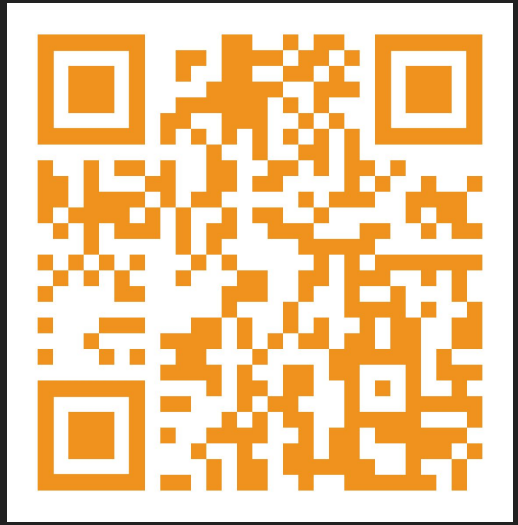
Conclusion

- Comprehensive protection against double-fetch bugs
- Less than 5% geometric overhead across a variety of benchmarks
- CVE-2016-6516

Questions?



Github Repository

Memory utilization

Table 3: `SafeFetch`-induced memory utilization.

Benchmark	SafeFetch raw memory utilization					
	cache provisioning			zero-copy pins		
	avg.	99^{th}	peak	avg.	99^{th}	peak
LMBench	**8.02 KB**	**8 KB**	**236 KB**	**0.65 KB**	**0 KB**	**9.6 MB**
OSBench	**8.04 KB**	**12 KB**	**12 KB**	**0 KB**	**0 KB**	**0 KB**
Phoronix	**8.04 KB**	**8 KB**	**44 KB**	**5.82 KB**	**16 KB**	**128 KB**

(Double-)Fetch Rate

Table 5: Statistics for (double) fetch rates.

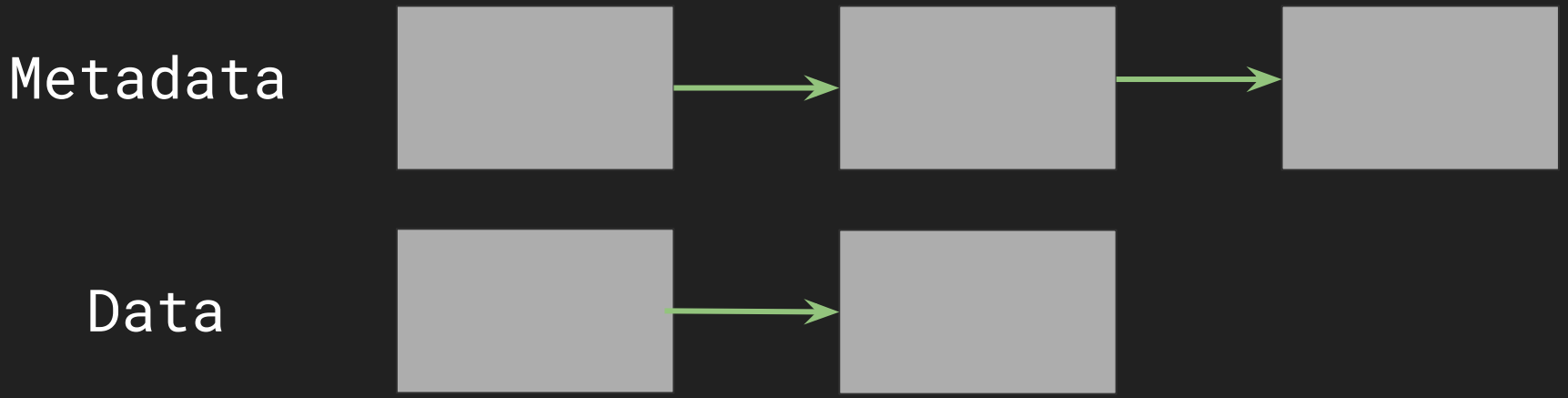
Benchmark	Statistic	Fetches	Double Fetches
LMBench	Rate	1/2	1/273457
	Syscalls	38	7
	Min/Avg/Max	1/1/459	1/50/67
OSBench	Rate	1/3	1/80
	Syscalls	17	5
	Min/Avg/Max	1/6/134	1/42/43
Phoronix	Rate	1/4	1/5993
	Syscalls	47	21
	Min/Avg/Max	1/1/661	1/1/218
Background	Rate	1/2	1/644
	Syscalls	93	20
	Min/Avg/Max	1/2/4099	1/130/467

Optimization benefits

Table 4: `SafeFetch`-induced throughput degradation.

Benchmark	SafeFetch /wo zero-copy (%)	SafeFetch /w zero-copy (%)
AF_UNIX	39.1%	8.4%
Pipe	16.1%	5.1%
Nginx	5.9%	1.3%
Apache	9.3%	1.8%

Cache management



Cache management

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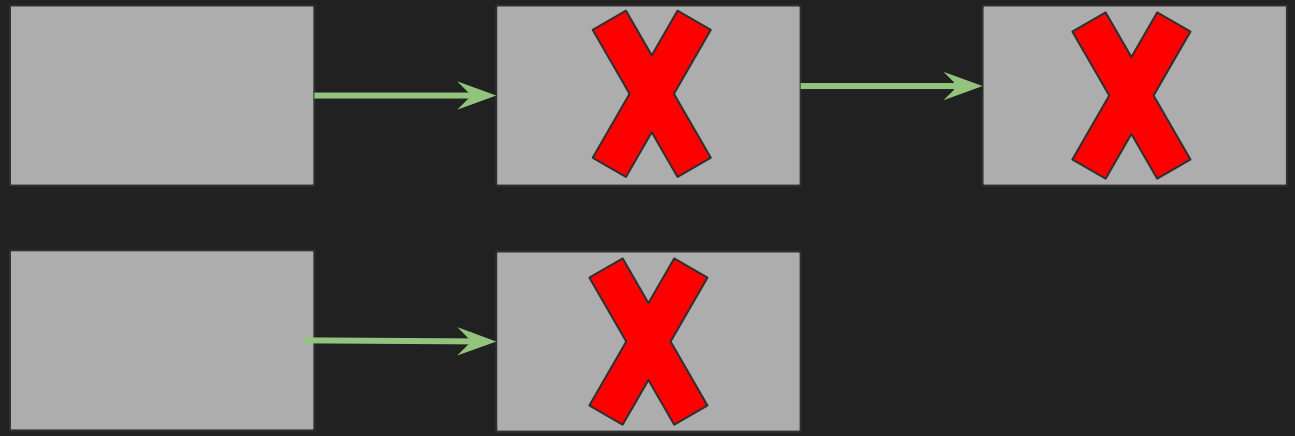

Cache management

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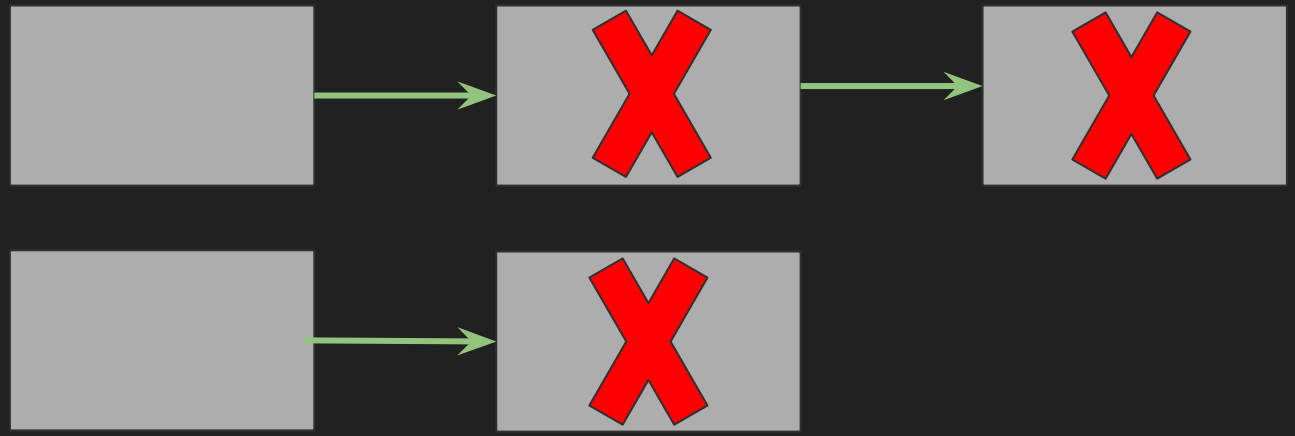


2 page allocations + 2 page releases + extra writes

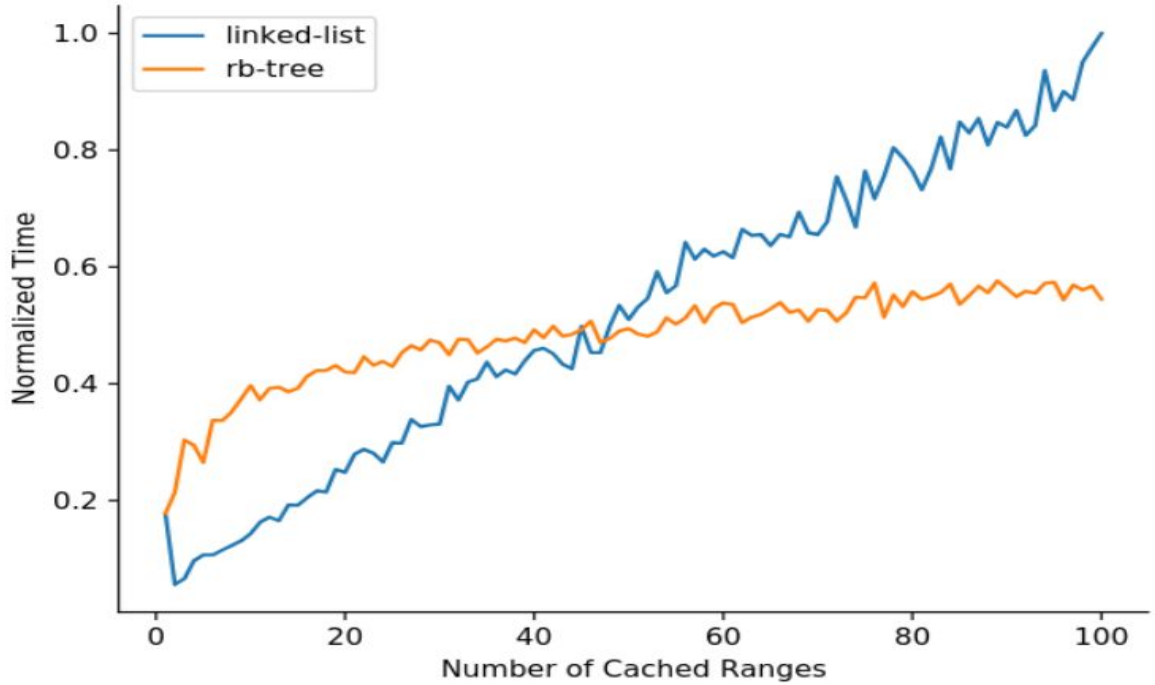
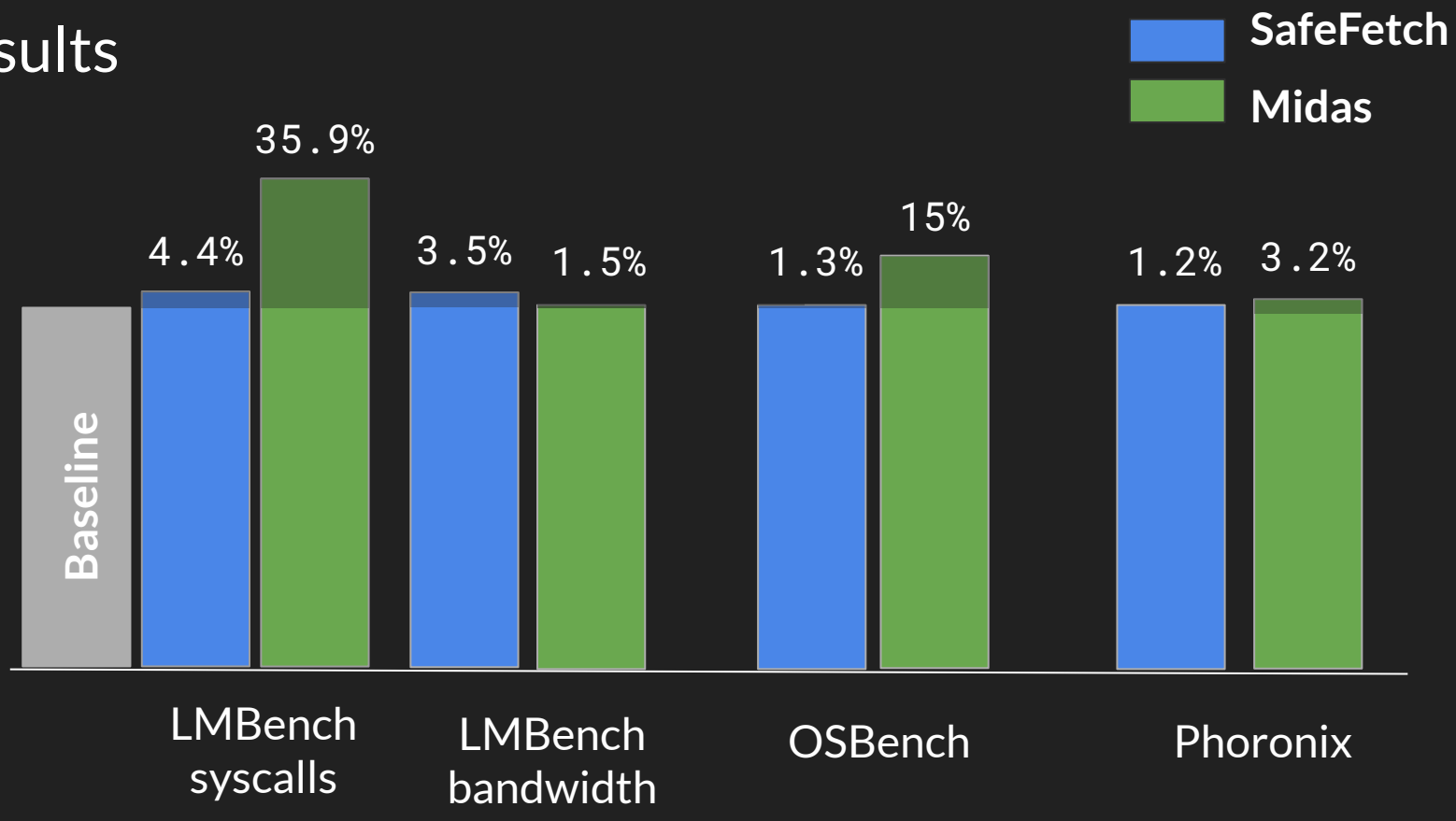


Figure 13: Average normalized time for each fetch vs. number of cached ranges.

Results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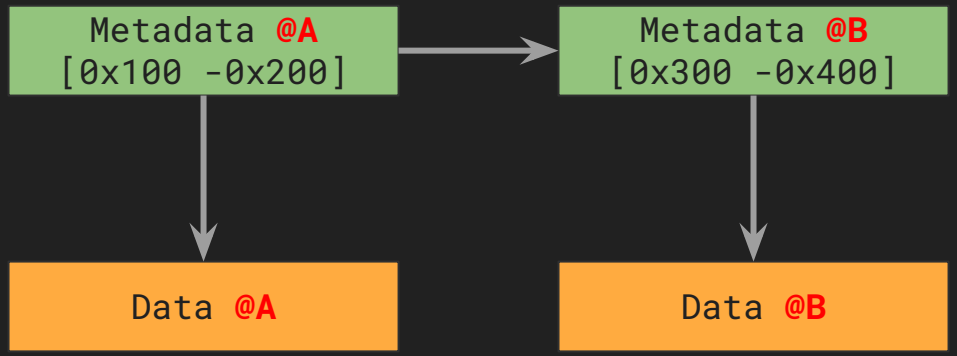

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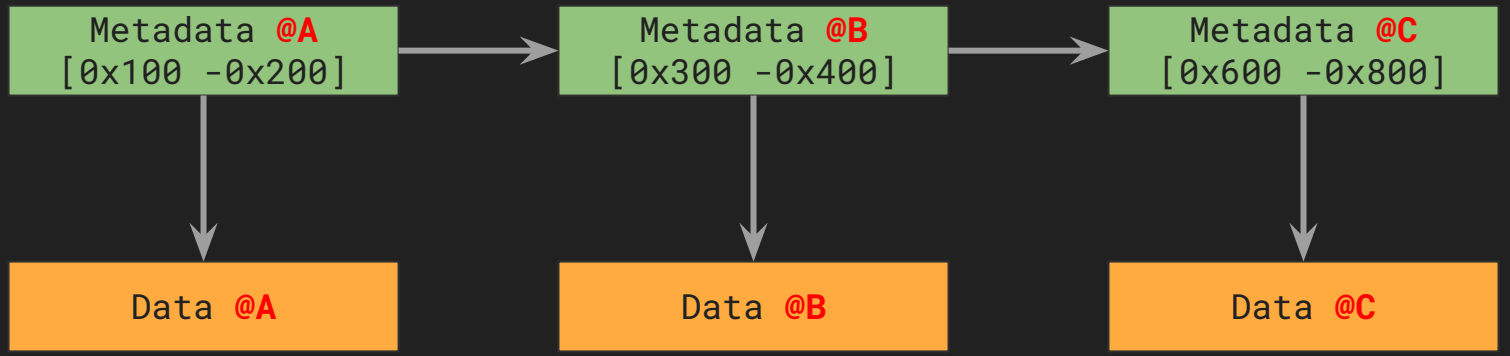

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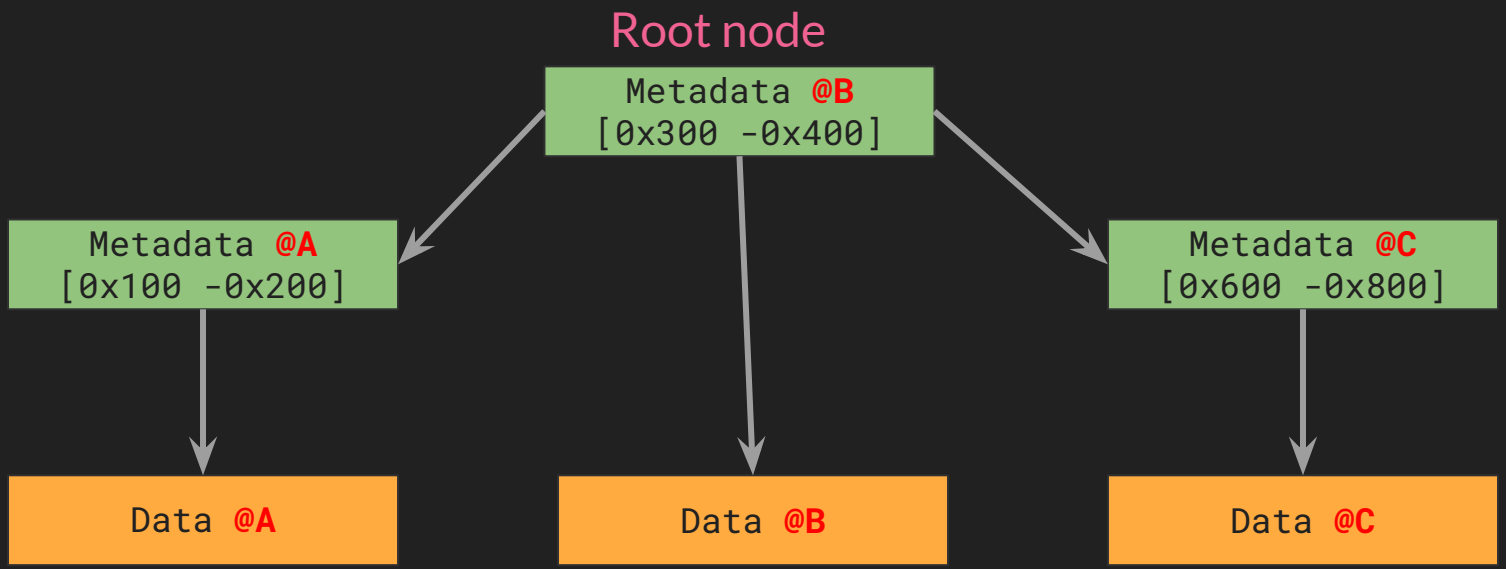

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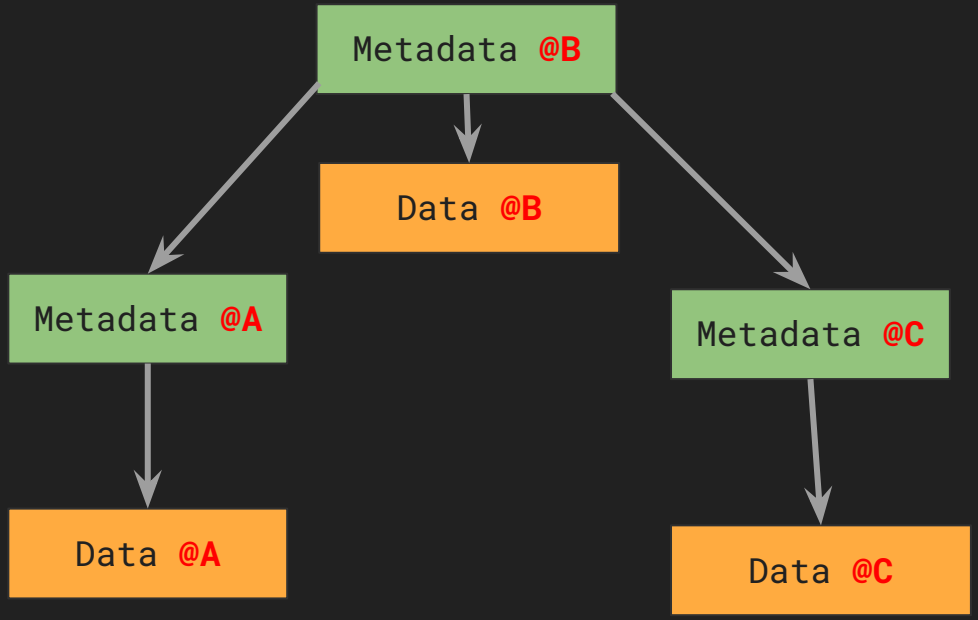

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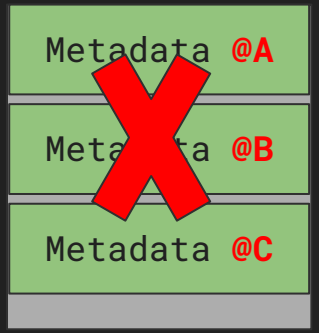

Data