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Eviction Notice:
Reviving and Advancing Page Cache Attacks

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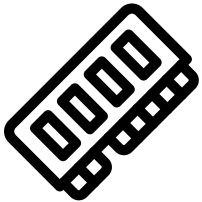
The Linux Page Cache



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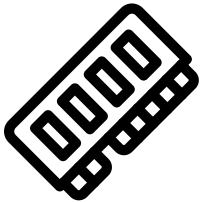

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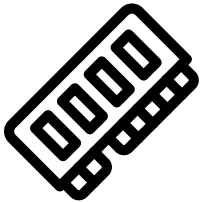

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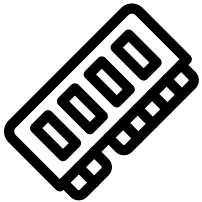

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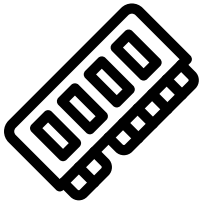

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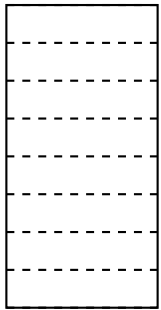

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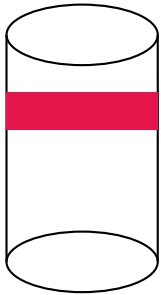

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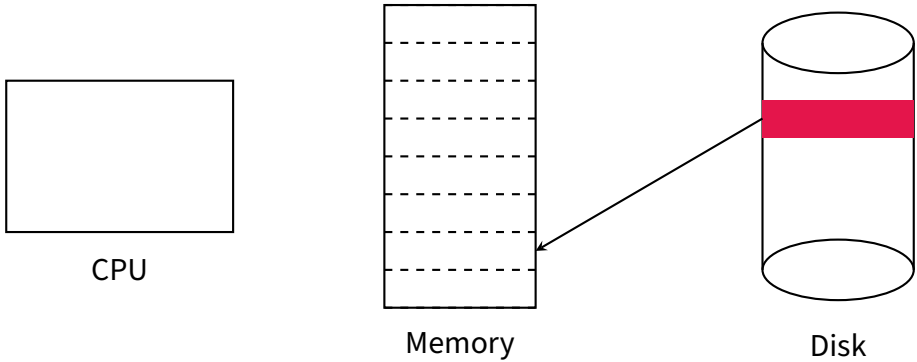

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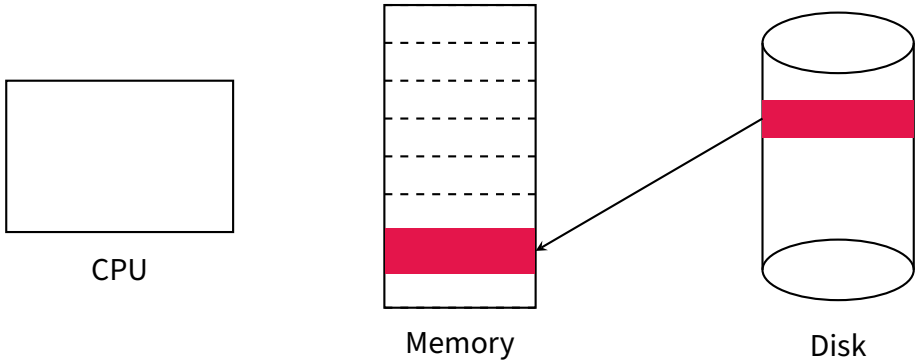

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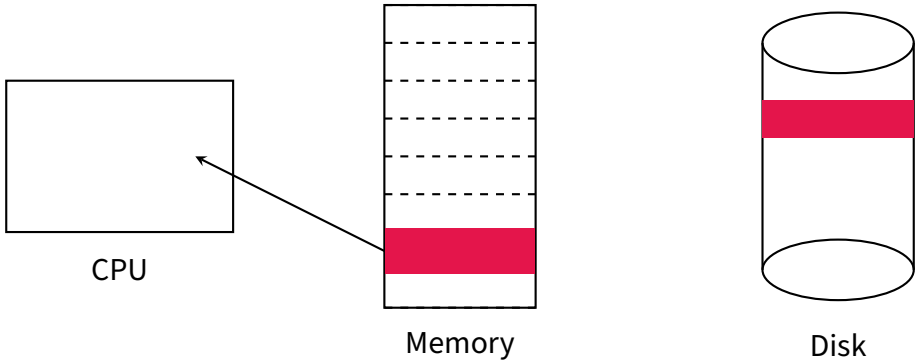

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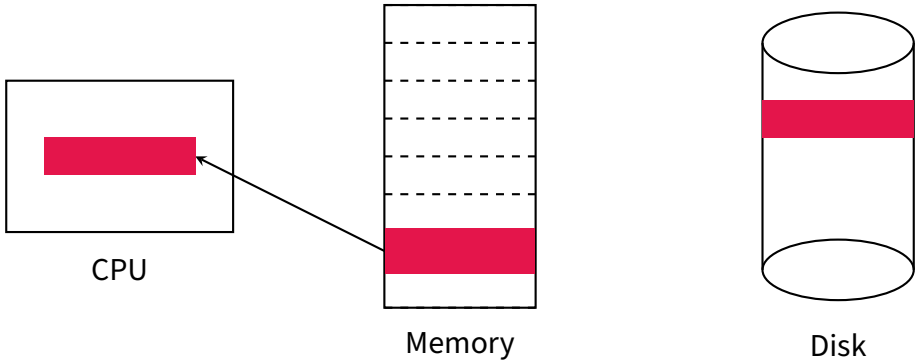

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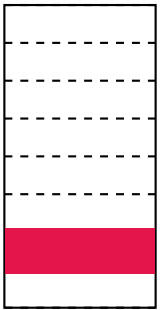

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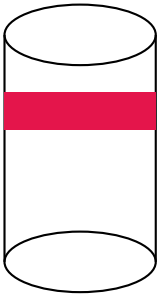

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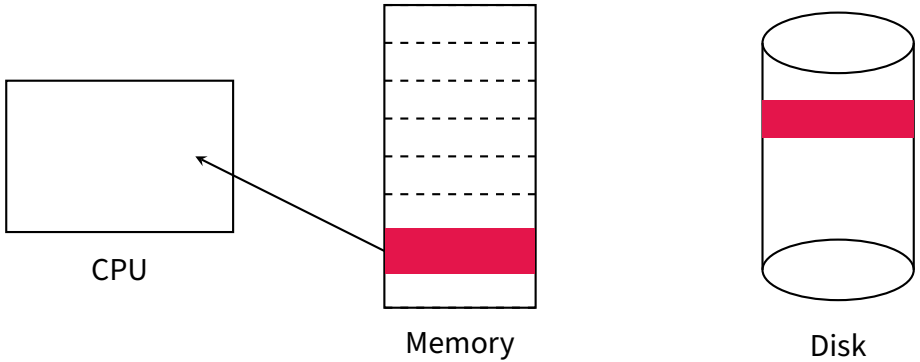

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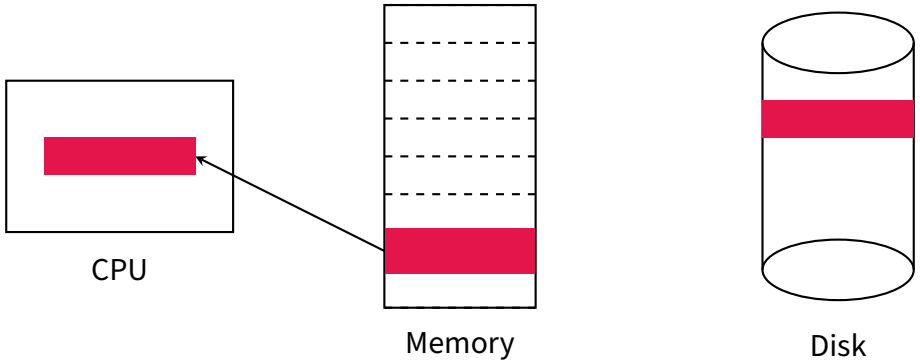

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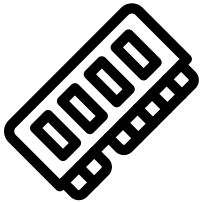

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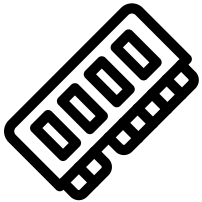

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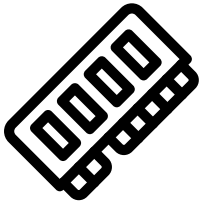

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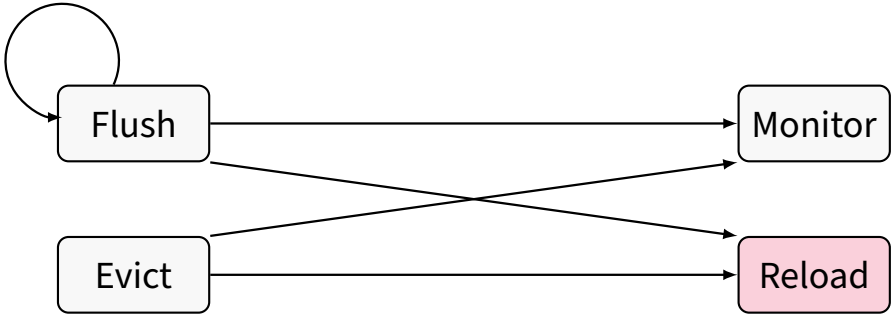
- Local Cross-User Threat Model
- How to interact with the page cache?

The Four Primitives



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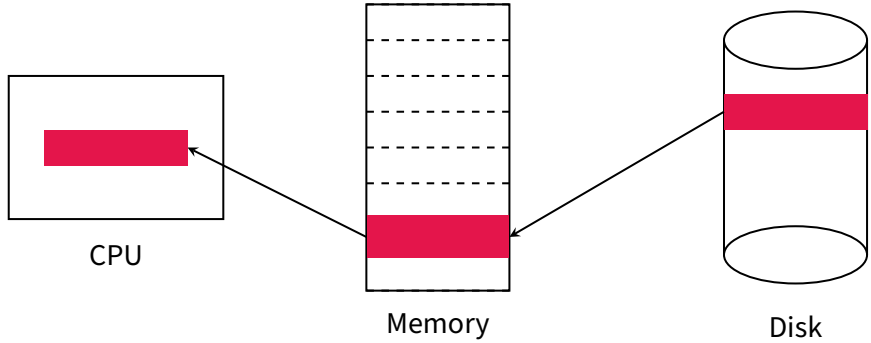

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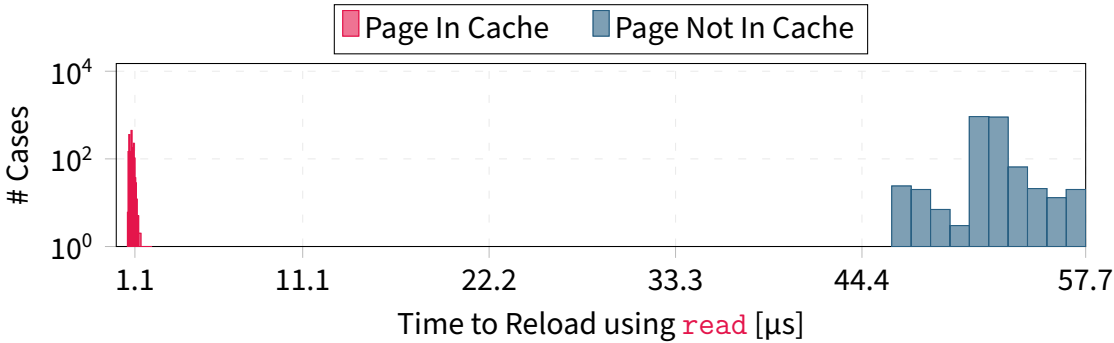
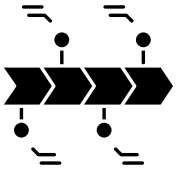
- 5.7–147.1× slower than cache
- `copy_file_range`, `mmap` (access), `posix_fadvise` + `POSIX_FADV_WILLNEED`, `pread`, `preadv`, `preadv2`, `read`, `readahead`, `readv`, `sendfile`, `splice`

Reload Timings



The Readahead Problem



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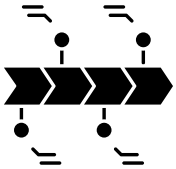

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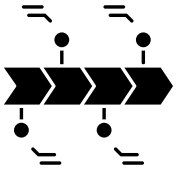

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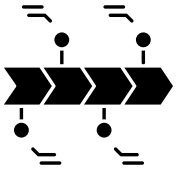

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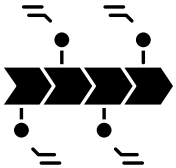

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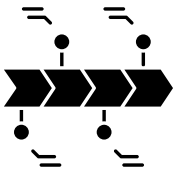

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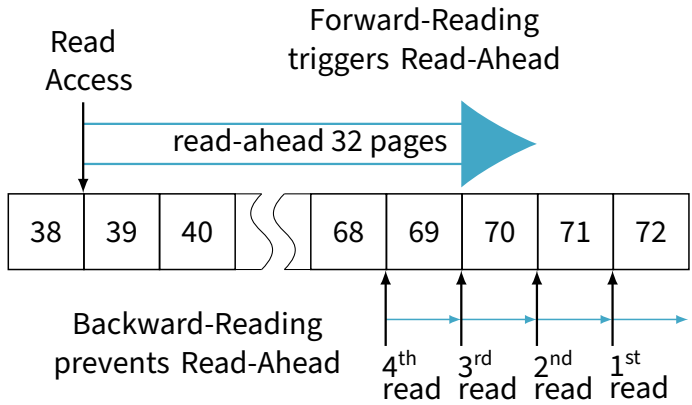
- Our work: 2 novel methods to completely bypass readahead

Backward Reading



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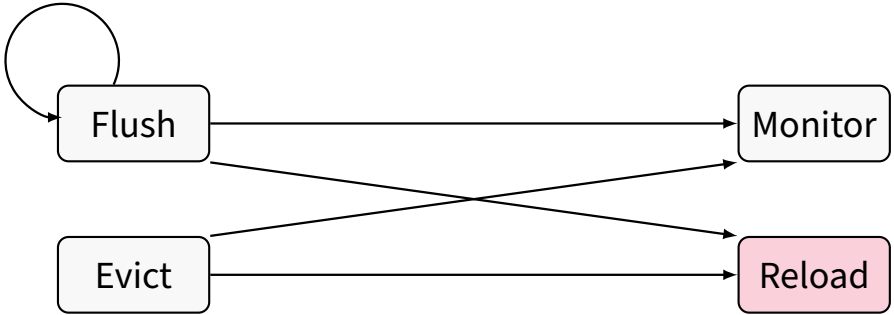

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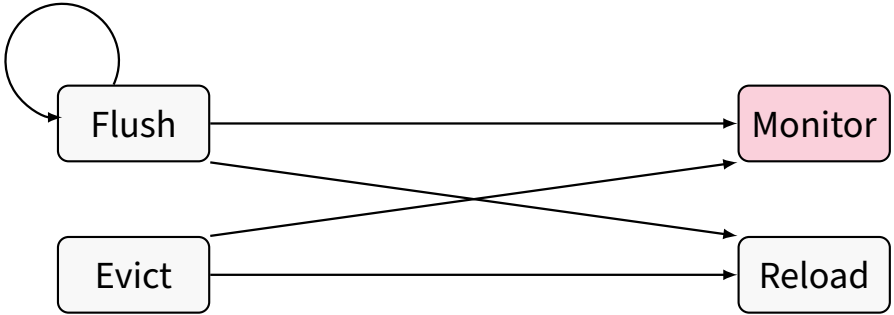

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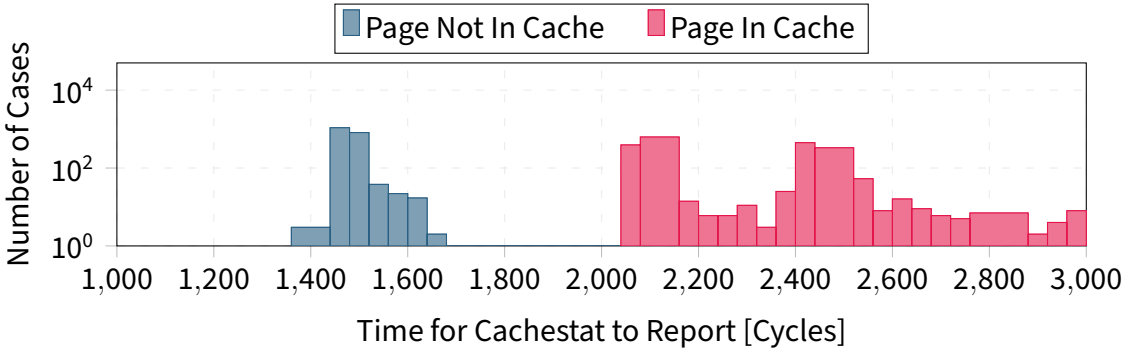
Monitor Timings



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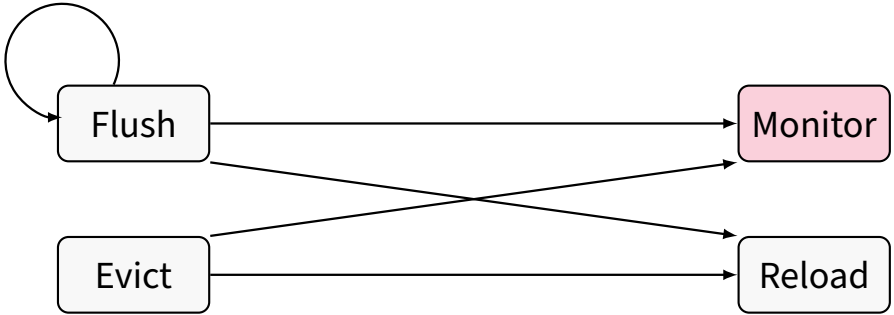

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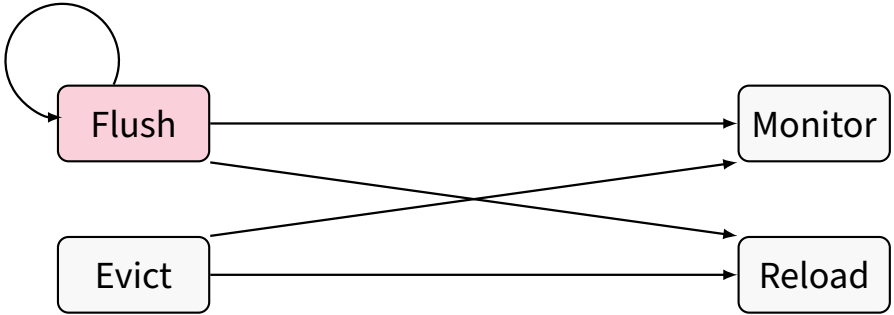
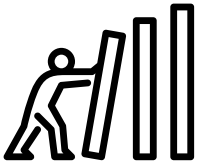


Flush



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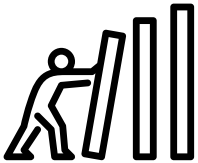

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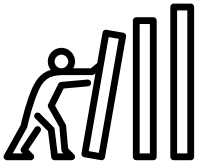

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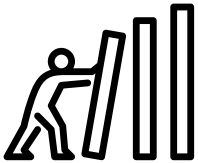

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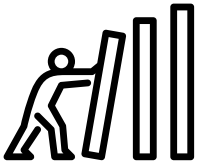

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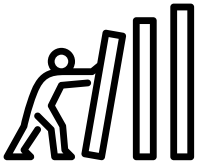

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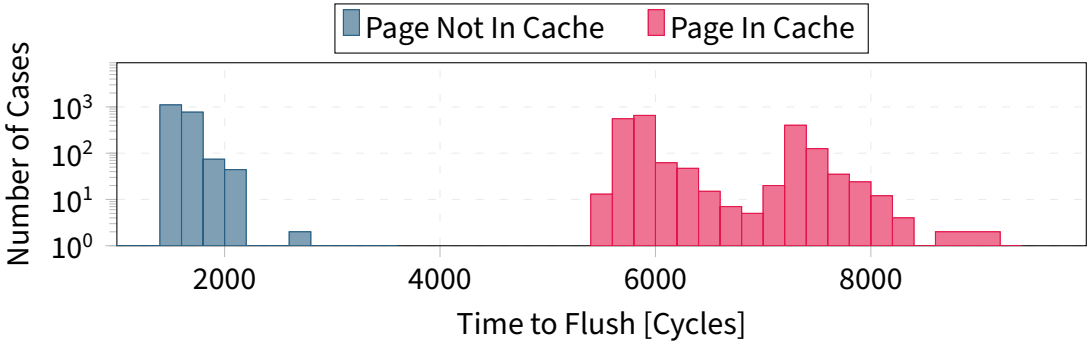

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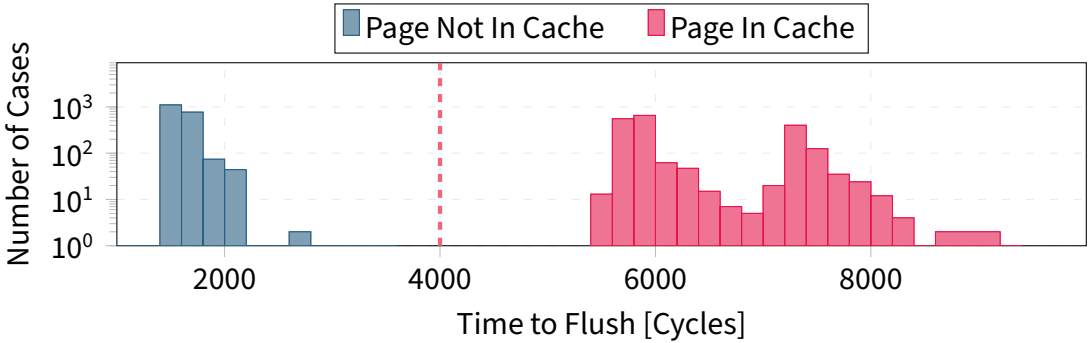

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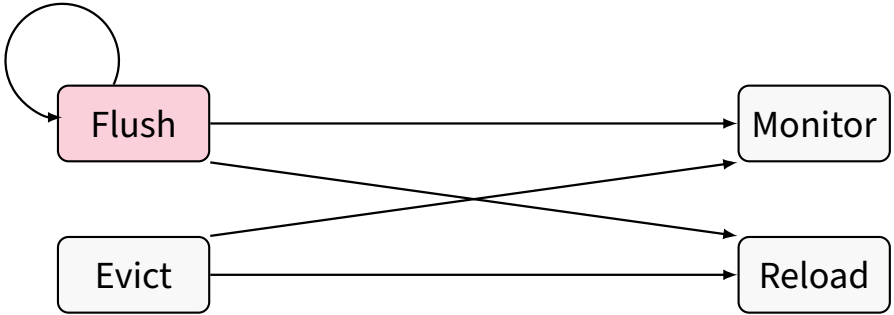

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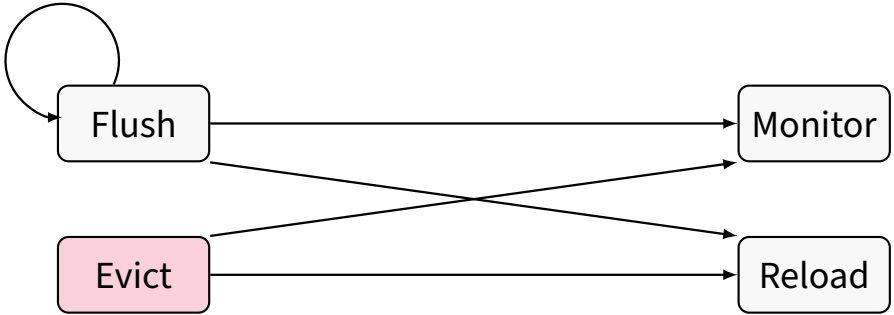
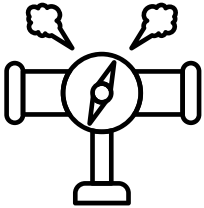
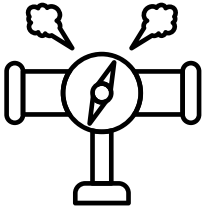


Eviction



- Flush: Unprivileged, deterministic method to remove page from cache

Eviction



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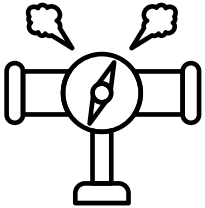

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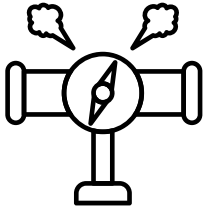

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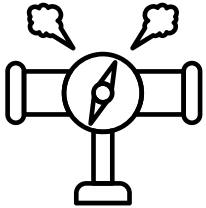

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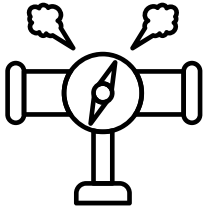

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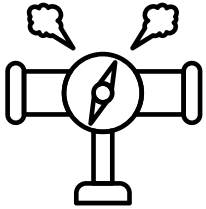

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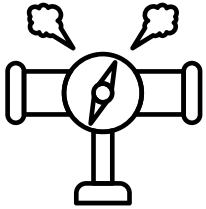

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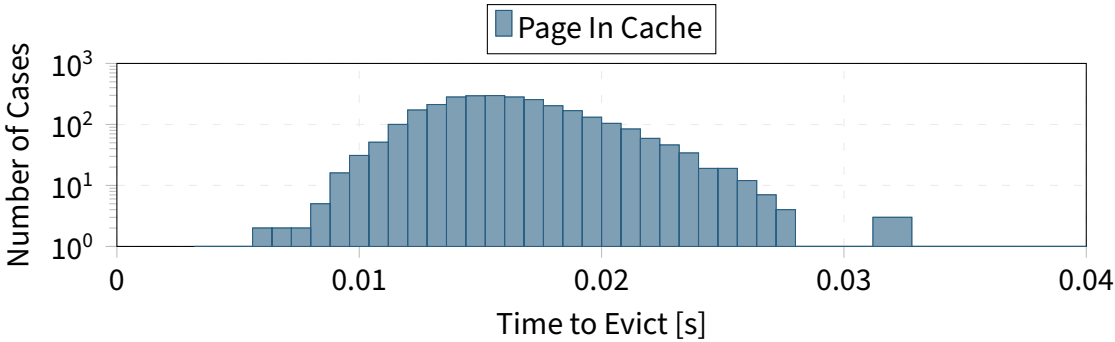
Eviction Timings



The Four Primitives

Flush

Monitor

Evict

Reload

The Five Attacks

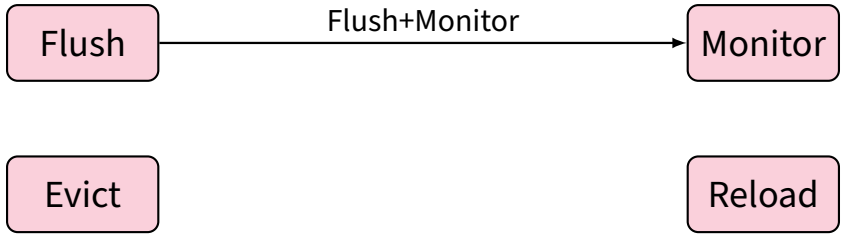
Flush

Monitor

Evict

Reload

The Five Attacks



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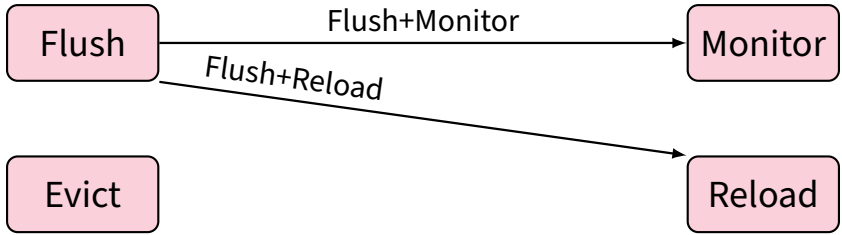

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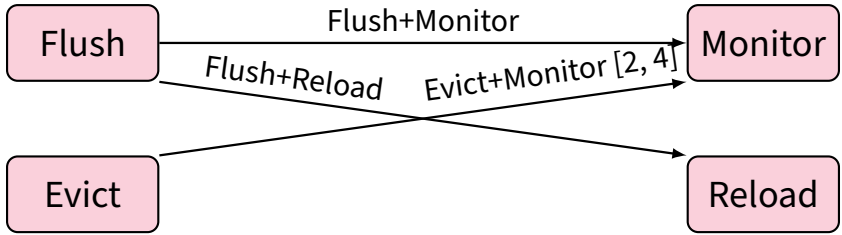

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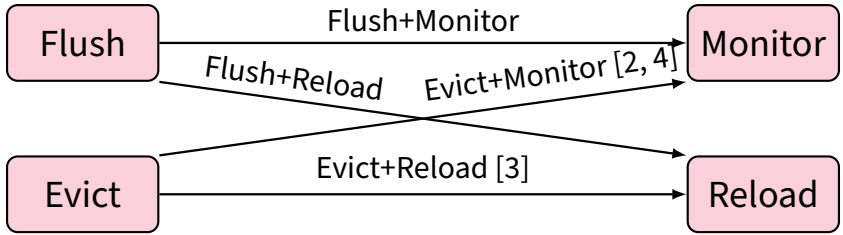

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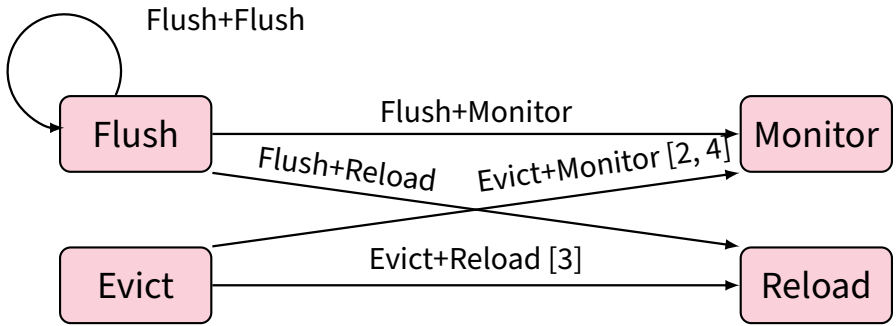

Covert Channels

Attack Technique	Error Rate	Channel Capacity
Flush+Monitor	$< 3 \times 10^{-4}\%$	$37.7\,\mathrm{kB/s}$
Flush+Flush	$1.8\,\%$	$33.9\,\mathrm{kB/s}$
Flush+Reload	$< 2.9 \times 10^{-3}\%$	$4.3\,\mathrm{kB/s}$
Evict+Monitor	$< 8.9 \times 10^{-3}\%$	$1.4\,\mathrm{kB/s}$
Evict+Reload	$6 \times 10^{-4}\%$	$1.2\,\mathrm{kB/s}$

Covert Channel: Hardware and Filesystem

CPU	OS	Kernel	RAM	Capacity
Intel Ultra 7 265K	Ubuntu 24.04	6.14.0	8 GB	73.1 kB/s
Intel i9 13900KF	Ubuntu 22.04	6.8.0	64 GB	71.5 kB/s
Intel i5-11300H	Debian 13	6.12.43	16 GB	55.0 kB/s
Intel i5-8265U	Ubuntu 22.04	6.8.0	16 GB	35.9 kB/s
AMD Epyc 7313P	Ubuntu 22.04	6.11.0	64 GB	31.8 kB/s

Flush+Monitor Across Hardware

Covert Channel: Hardware and Filesystem

CPU	OS	Kernel	RAM	Capacity
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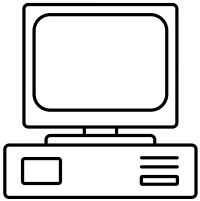
Flush+Monitor Across Hardware

File System	btrfs	ext4	ext3	ext2	ntfs
Channel Capacity	64.3 kB/s	54.99 kB/s	43.8 kB/s	44.4 kB/s	48.3 kB/s

Flush+Monitor Across Filesystems

Covert Channels



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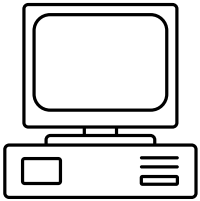

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  - Flush+Monitor (`preadv2`): 69.1 $\mathrm{kB/s}$
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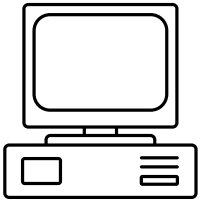

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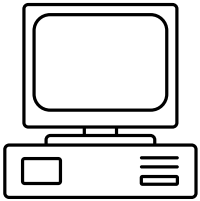

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Inter-Keystroke Timing

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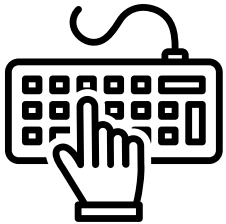
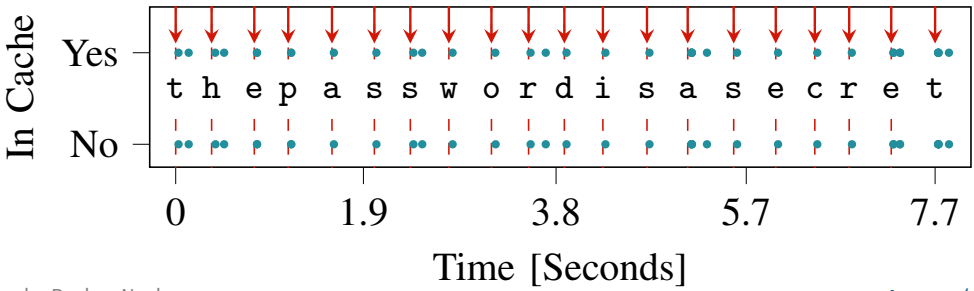
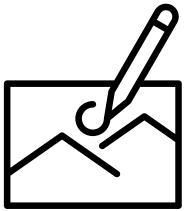


- Evict+Monitor on Gedit: Page 32 of `libgedit-41.so`
- Accessed upon any keypress (monitor), removed after keypress (evict); cannot flush!
- 5.5 keys/s, F_1 score: 96.7%



Authentication UI Redress



- Flush+Monitor: detect when `pkexec` is run

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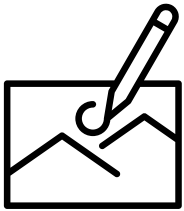

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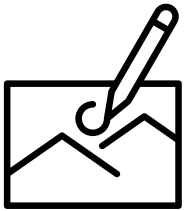

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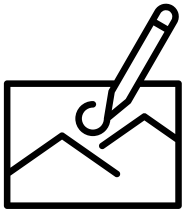

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- Detect the first page of pkexec in 800 ns

Cross-Container

- Across containers of the same image

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- Flush+Reload: detect when shared pages are accessed (OverlayFS)

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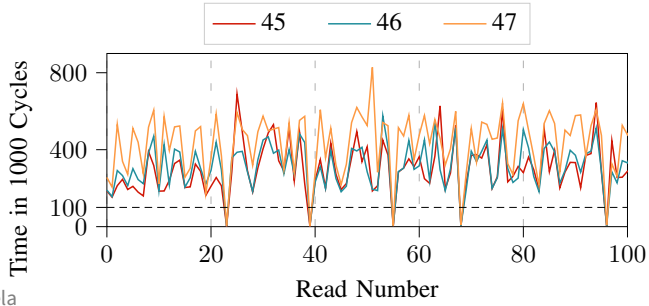
- Pages 45-47 of libtinfo.so: When a shell is launched in another container



Website Fingerprinting

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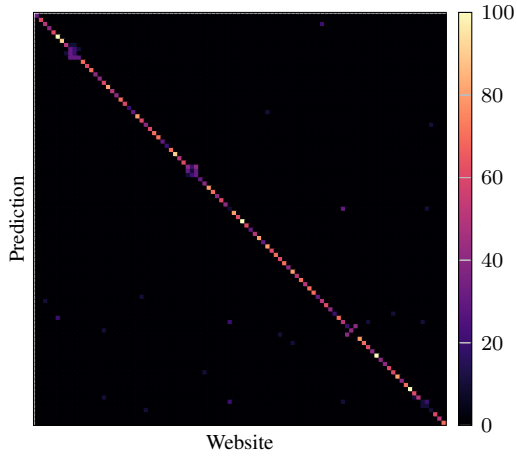
Website Fingerprinting F_1 Scores

Attack Technique	F_1 Score
Flush+Monitor	90.5 %
Flush+Reload	88.1 %
Flush+Flush	86.1 %
Evict+Monitor	79.5 %
Evict+Reload	37.9 %



Responsible Disclosure & What Remains

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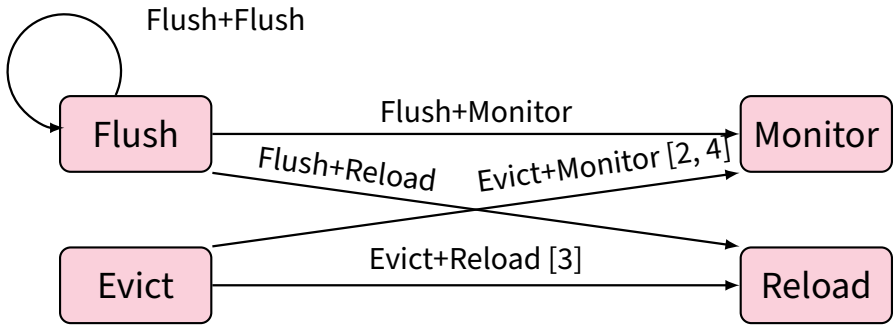

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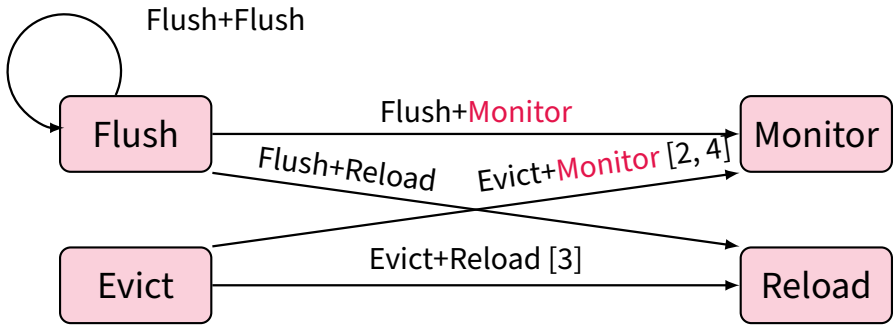

Conclusion

- In this work: revived and advanced page cache attacks (thought to be mitigated or impractical since 2019)
- Flush, Reload, Evict, Monitor: combine into 5 attacks
- Keystroke Detection, Covert Channels, Website Fingerprinting, Cross-Container Leaks
- Attacks remain possible

sudheendra.neela@tugraz.at
Website: https://snee.la
Mastodon: @vmcall@infosec.exchange
Bluesky: @snee.la
Available, Functional, Reproducible:
https://github.com/isec-tugraz/Eviction-Notice

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