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上海科技大学
ShanghaiTech University

Sync+Sync: A Covert Channel Built on `fsync` with Storage

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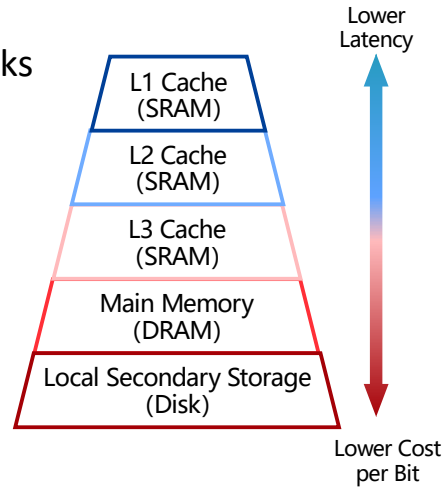
Background

- Covert Channel and Side-Channel Attacks
  - Memory Hierarchy



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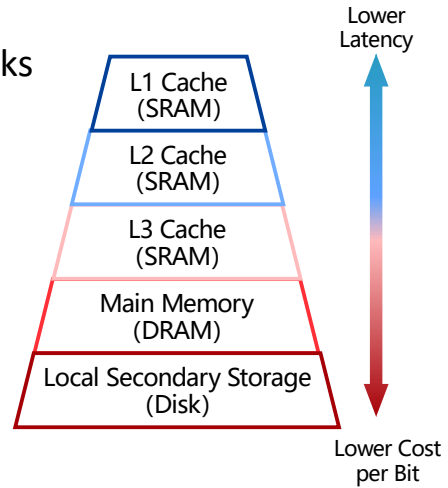

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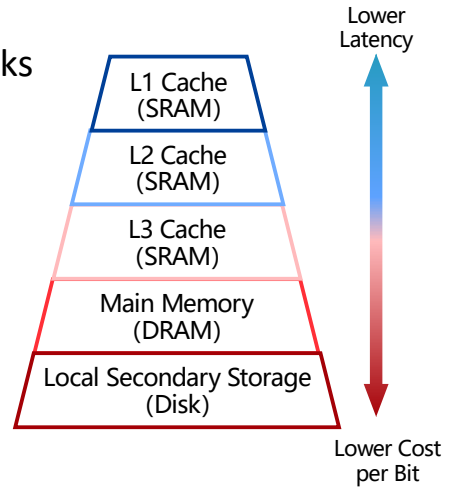
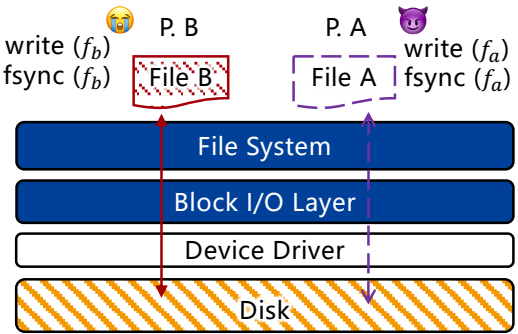
- **`fsync`** contention
  - Multiple files
  - Even longer response latency



fsync Contention

- Program A and Program B
  - **`ftruncate`** / write / idle + **`fsync`**
- Only measure the **`fsync`** latency of Program A
  - A+B: about 2x A-only



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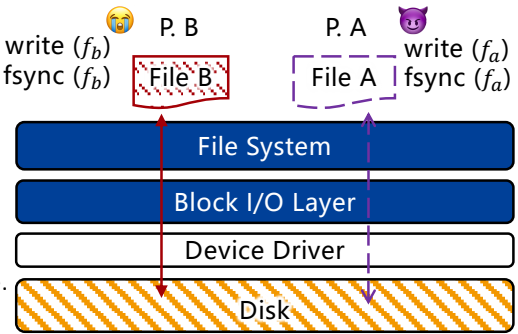

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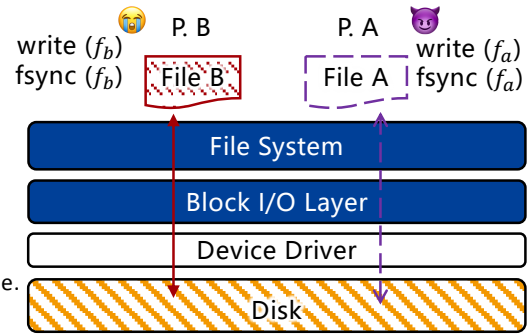

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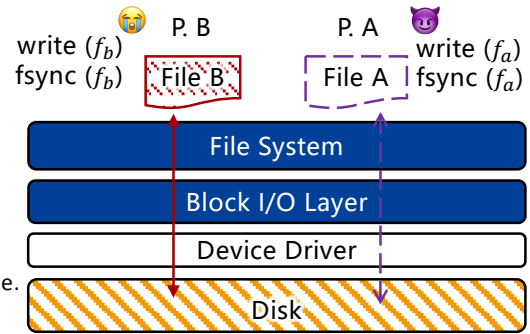
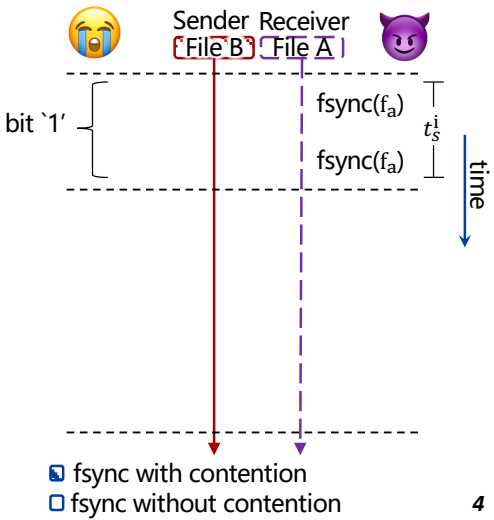
A good fit for timing-based channel



Sync+Sync - Covert Channel



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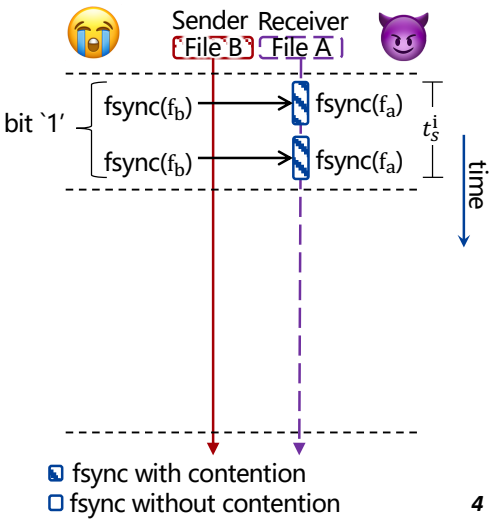

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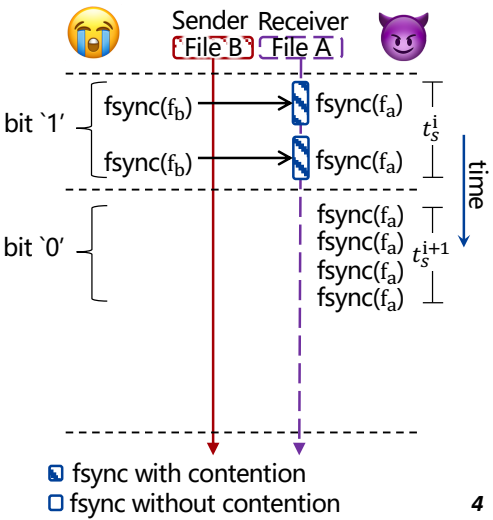

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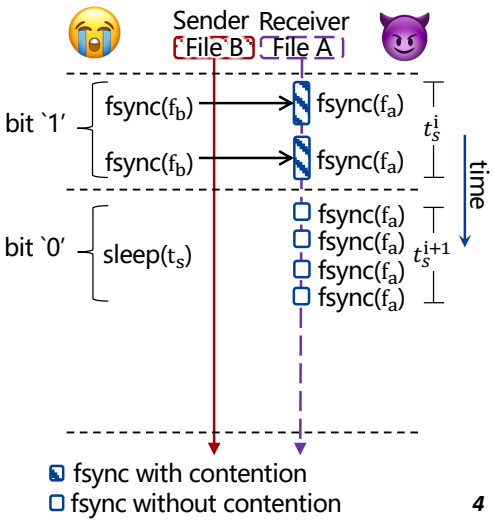

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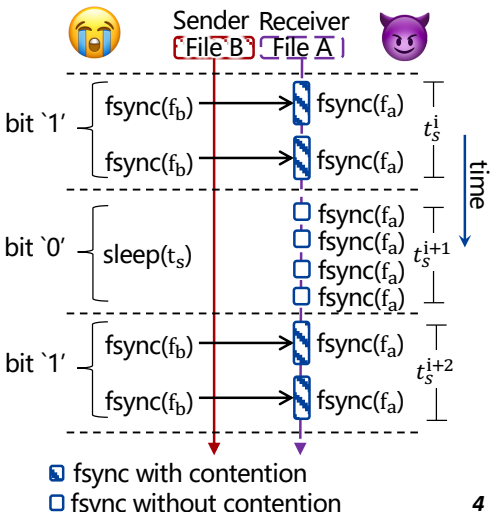

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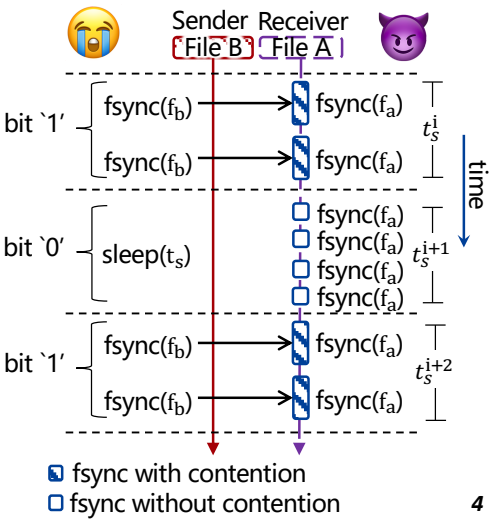
  - Cross-file
    - 20,000 bps at an error rate of about 0.40%
  - Cross-container
    - Overlay file system
  - Cross-VM: disk images



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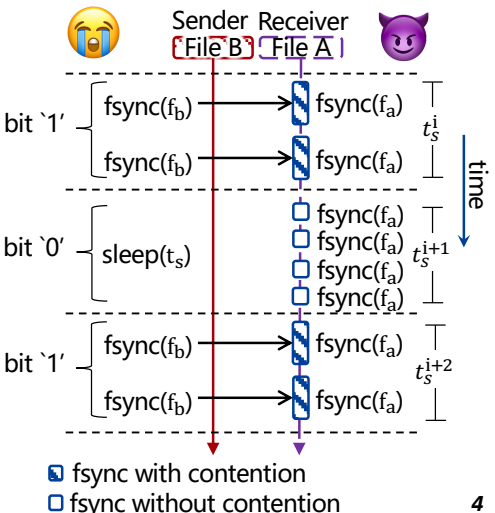
- Positions of two sides
  - Intra-partition
  - Inter-partition
- Various storage devices
  - SATA SSDs
  - NVMe SSDs



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- Principle
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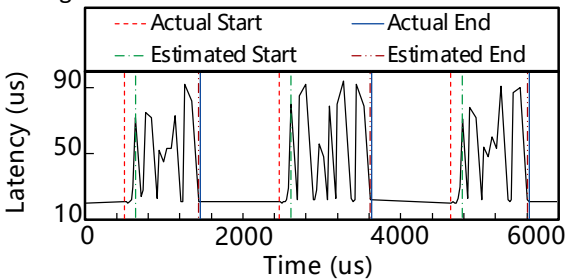
- Observation
  - Different applications exhibit varying patterns of **`fsync`** calls
    - Frequency
    - Data volume to be flushed
  - The attacker can recognize different patterns of **`fsync`** calls

Database Operations Speculation

- Attack Design
  - Victim database
    - SQLite, Invoking **`fsync`** when committing



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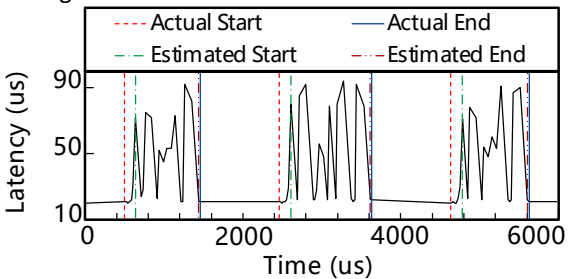

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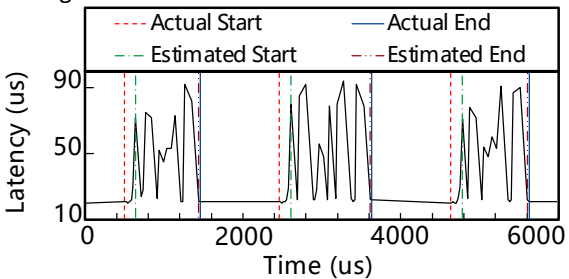
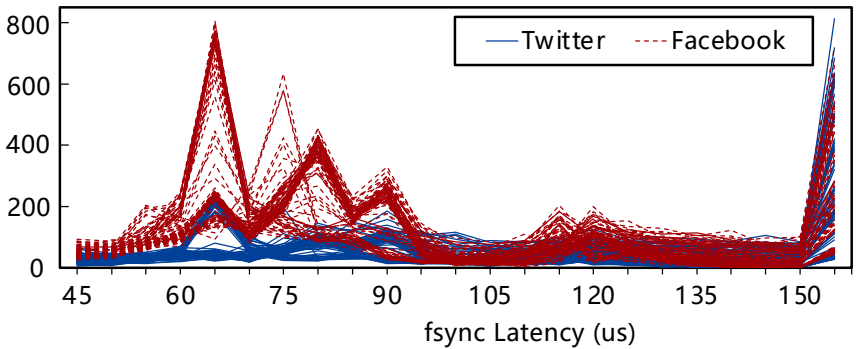
- Information Leakage
  - Insert/Update Ratio over Time
  - B-Tree Split Detection
  - Database Operation Leakage



Application Information Leakage

- Application Fingerprinting
  - e.g., Twitter and Facebook



Application Information Leakage

- Website Fingerprinting
  - Most websites do not commonly use **`fsync`**.
  - Some websites invoke **`fsync`** more frequently and exhibit different I/O behaviors.
    - Due to the use of Indexed Database

Website	Average # fsync	Accuracy	F1-score
360.cn	10.6	3.3%	0.04
adobe.com	11.5	0.0%	0.00
amazon.com	16.2	13.3%	0.08
apple.com	11.5	16.7%	0.17
baidu.com	14.4	6.7%	0.03
bing.com	15.0	6.7%	0.08
booking.com	15.9	0.0%	0.00
cnn.com	15.2	6.7%	0.10
detik.com	10.1	10.0%	0.13
github.com	12.1	13.3%	0.18

Website	Average # fsync	Accuracy	F1-score
imdb.com	16.1	13.3%	0.19
jd.com	14.9	56.7%	0.65
live.com	10.6	13.3%	0.14
microsoft.com	12.1	3.3%	0.04
qq.com	**264.6**	**100.0%**	**1.00**
sina.com.cn	**40.8**	**96.7%**	**0.98**
sohu.com	14.4	46.7%	0.44
taobao.com	10.6	23.3%	0.16
tmall.com	11.4	3.3%	0.03
yahoo.co.jp	11.4	6.7%	0.06

Keystroke Attack

- Attack Design
  - Victim
    - For every keystroke typed by the victim, the service program auto-commits the user input by storing it in a file with an **`fsync`**
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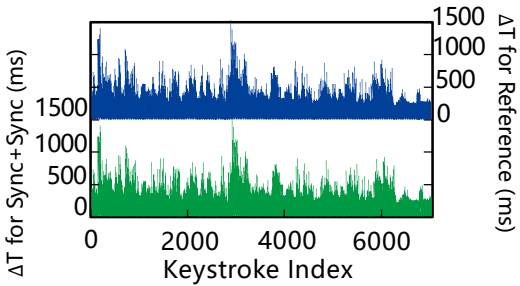
- Inter-keystroke Timings
  - Inter-keystroke latency (> 100ms)
  - Attacker's fsync latency (< 100us)
  - An accuracy of 99.2%



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A full version of the paper is available at https://arxiv.org/abs/2309.07657
Source code of Sync+Sync covert channel is available at https://github.com/toast-lab/sync-sync
Should you have any question, drop an email to toast-lab@outlook.com

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ShanghaiTech University

Thanks :-)

Toast Lab in ShanghaiTech (June 1st, 2024)

Jian Zhang is on the job market

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