PASTE: A Networking API for Non-Volatile Main Memory

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More details at our HotNets paper: https://goo.gl/Ssreei

Motivation

SSICLOPS

- Non-Volatile Main Memories (NVMMs)
  - Persistent
  - Byte-addressable
  - Low latency
    - 10s-1000s of ns

https://www.hpe.com/us/en/servers/persistent-memory.html

- A lot of work in databases and file systems
  - NVHeap [ASPLOS'11], NOVA [FAST'16], NVWal [ASPLOS'16], HiKV [ATC'17] etc

What are implications for networking?

Review: Today's Stack with NVMM

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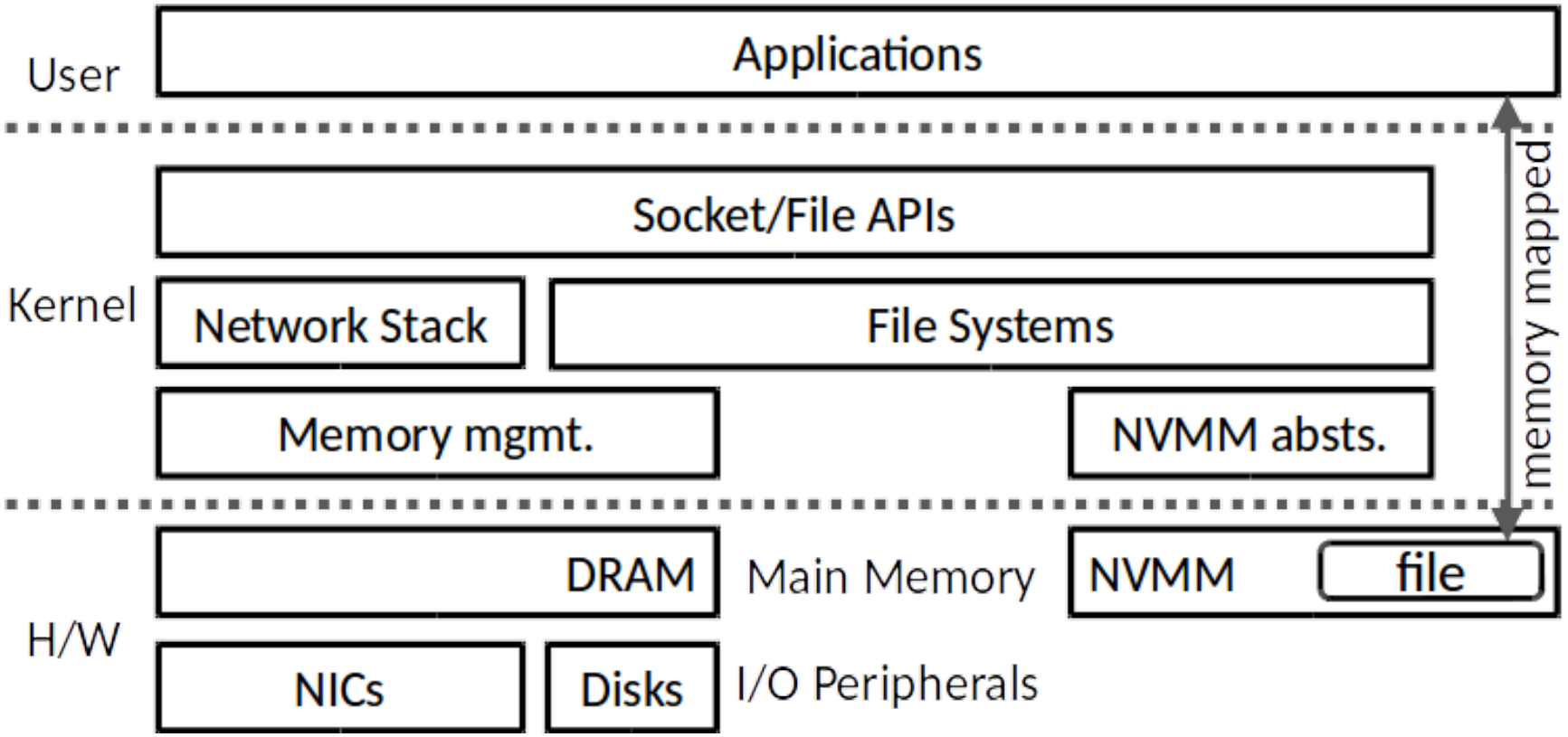

Review: Today's Stack with NVMM – How data move from the network to the storage

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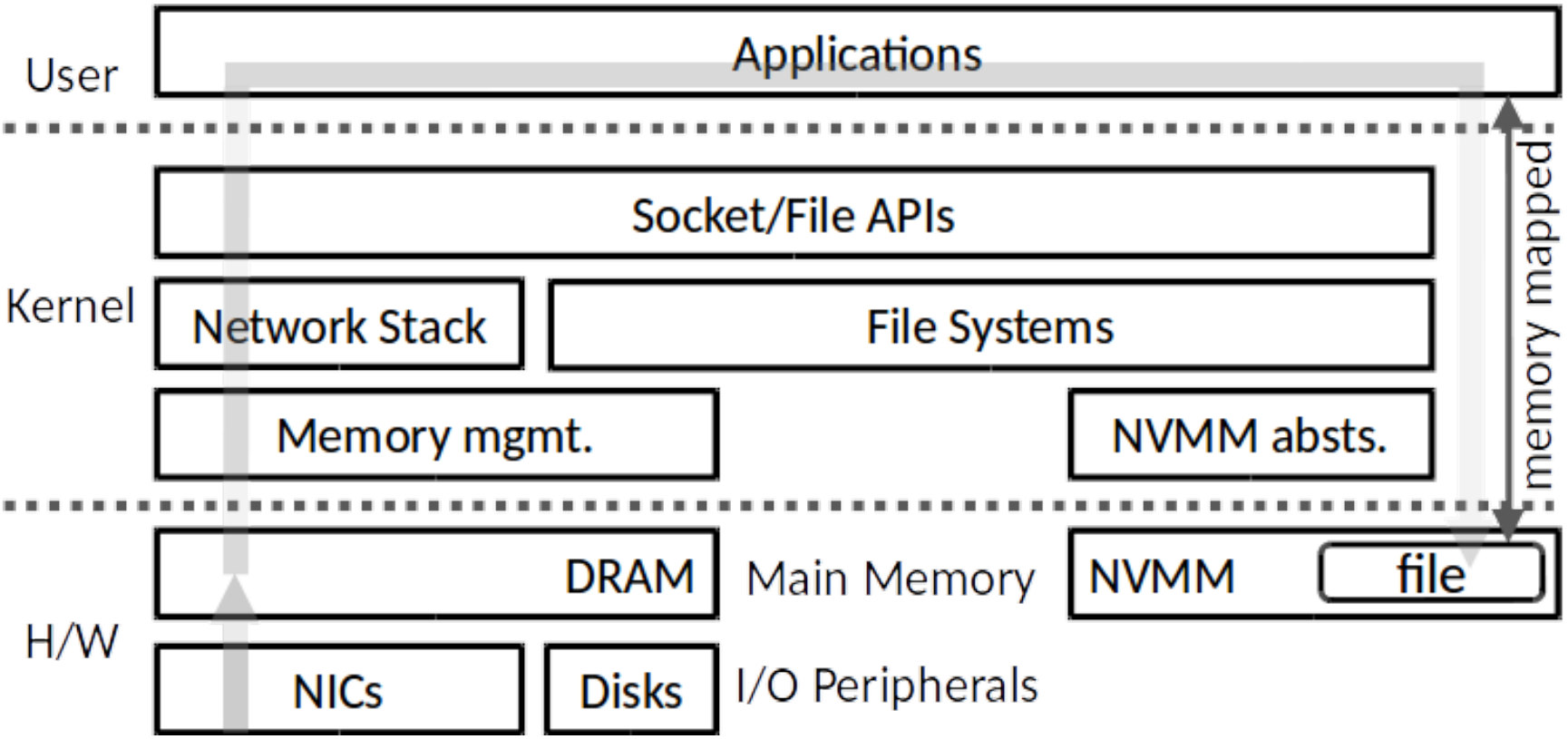

Case Study: Careful Data Transfer

- Server persists client's request prior to acknowledgment
- e.g., 1KB commit:

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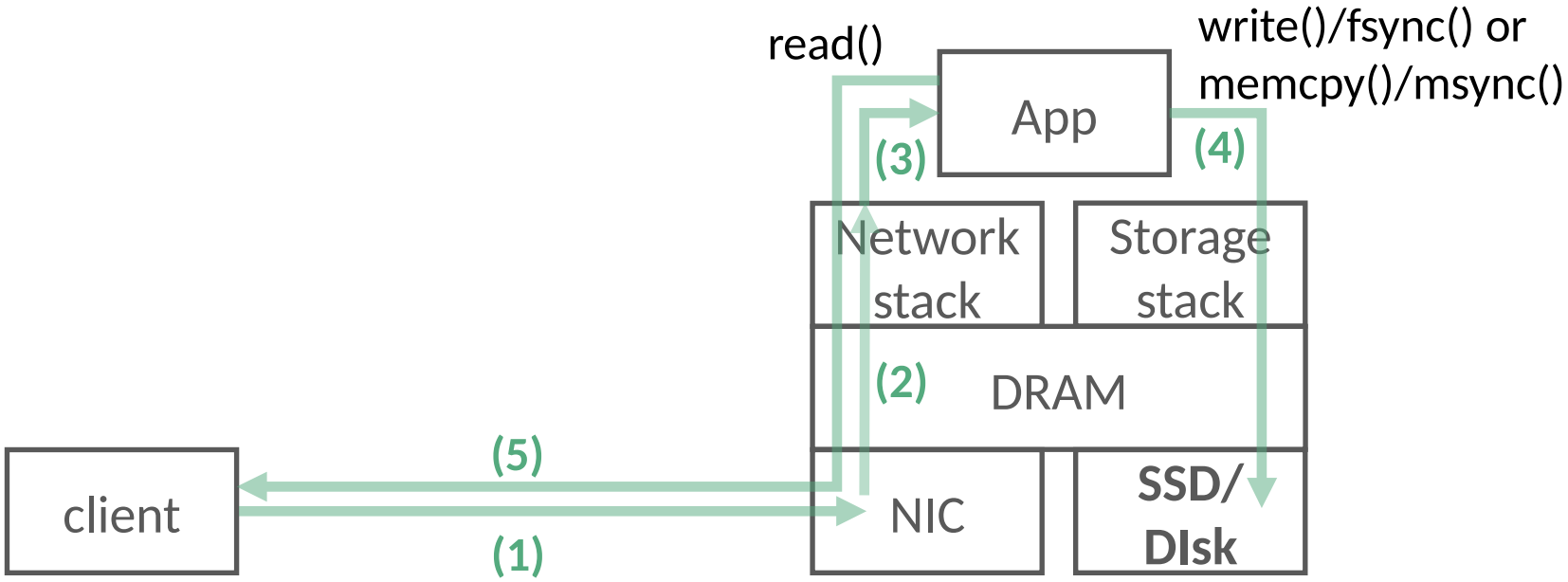

- 2030 us
  - Networking (w/o step (4)) takes 40 us

Case Study: Careful Data Transfer

SSICLOPS

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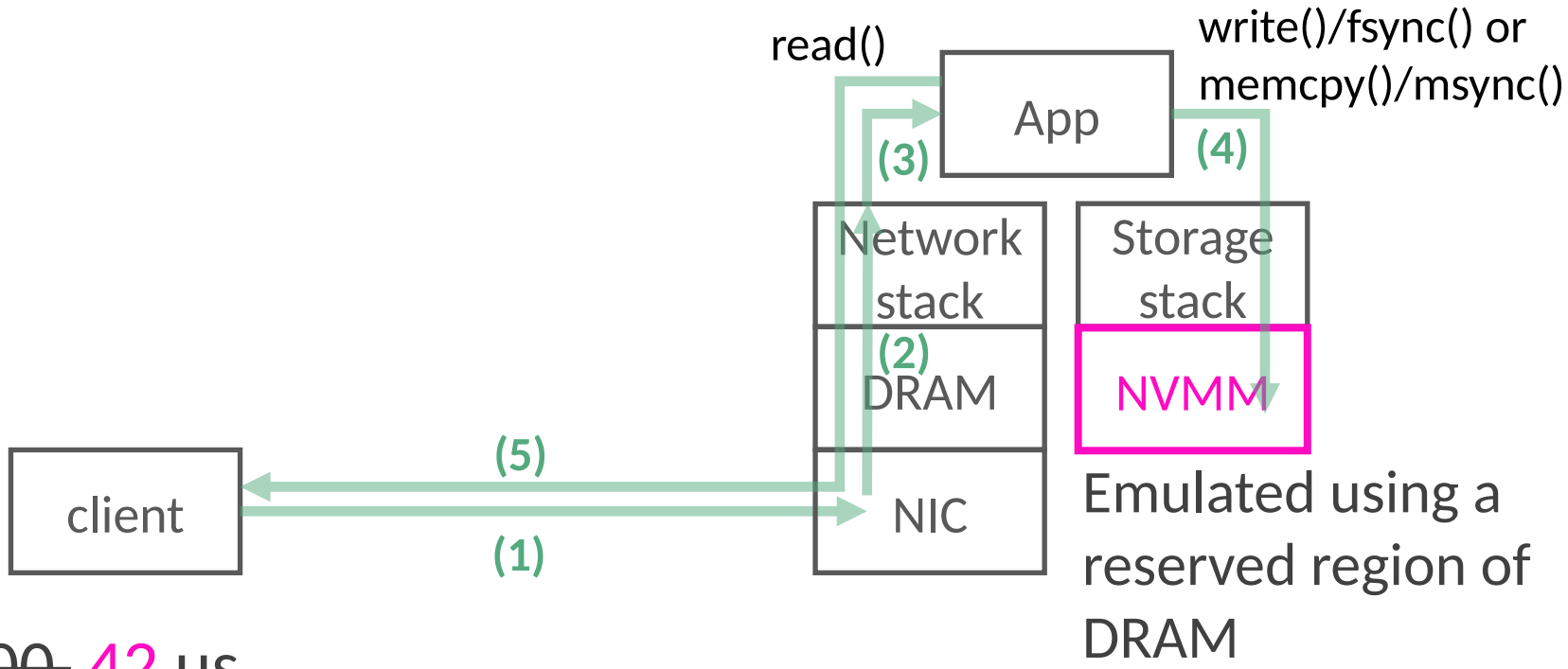
- e.g., 1KB commit:

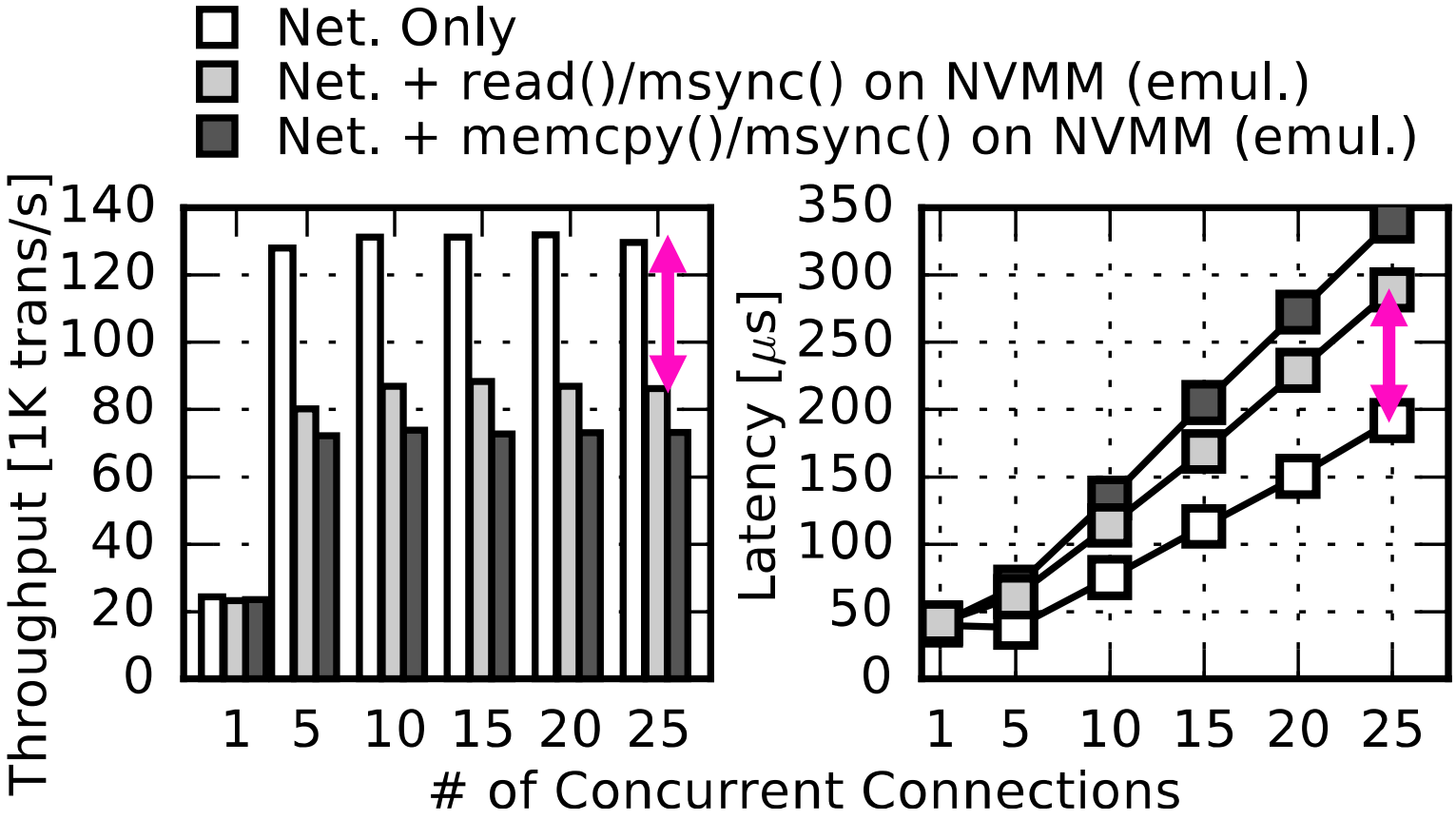


- ~~2000~~ 42 us
  - Networking takes 40 us
- This 2 us is not small

Case Study: Careful Data Transfer

SSICLOPS

- Parallel requests are serialized on each core

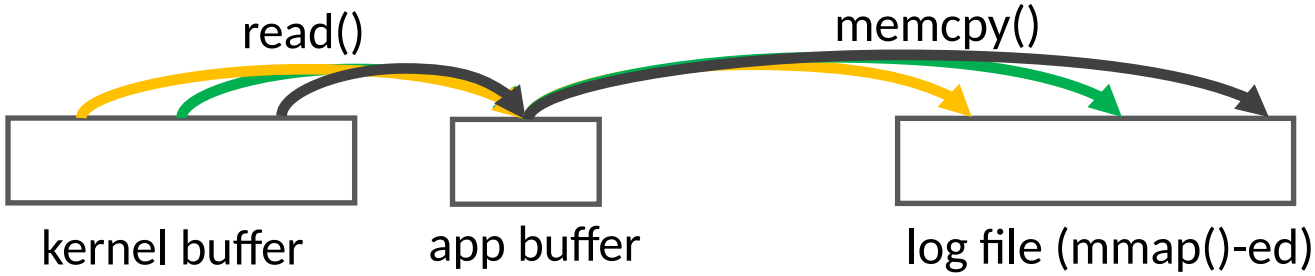


33 % throughput decrease, 50 % latency increase

Data Copies Matter

SSICLOPS

- **Cache Misses**
  - **Persisting data (e.g., to a log) always happens to a different destination**



	Overall cache misses	Major Contributor
Networking only	0.0004 %	net_rx_action() (84%)
Networking + NVMM (read() + memcpy() + msync())	**4.4121** %	**memcpy() (98%)**

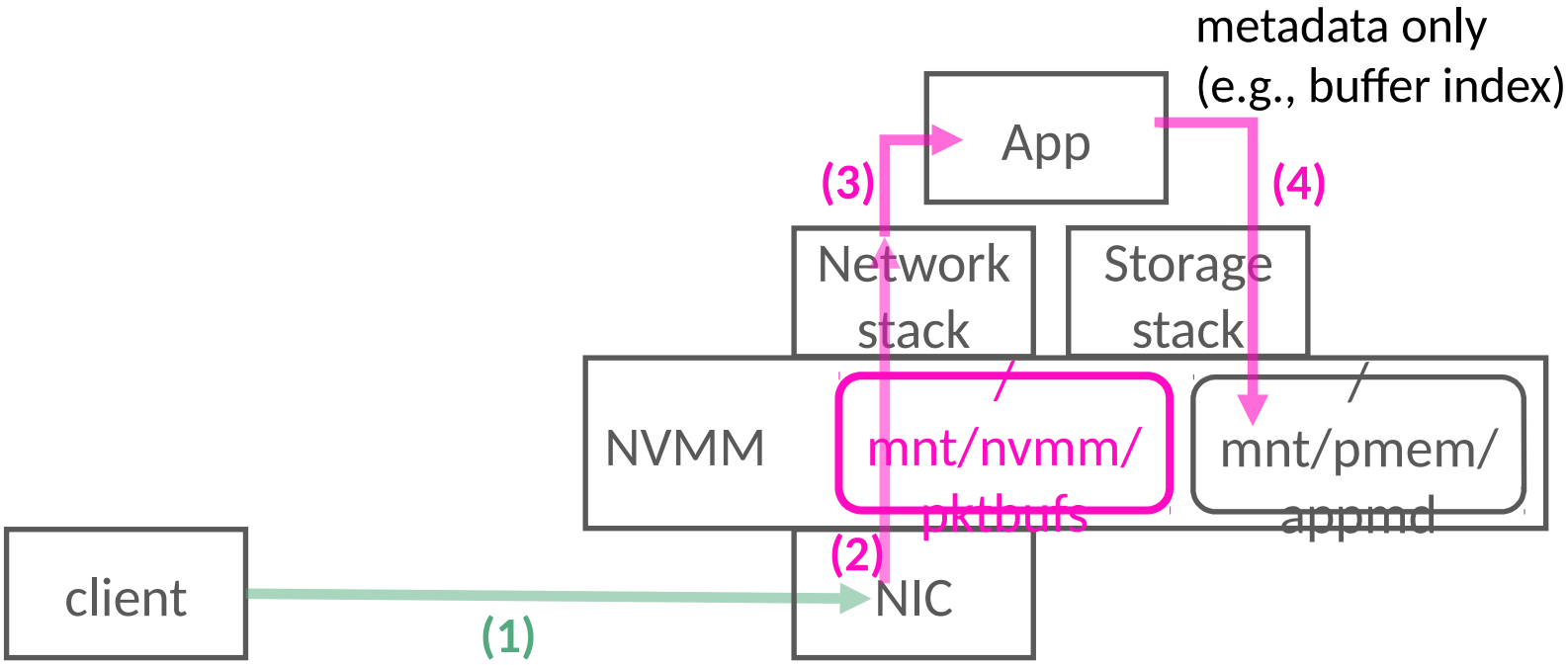
Reported by Linux perf

We must avoid data copy!

Packet Store (PASTE) Overview

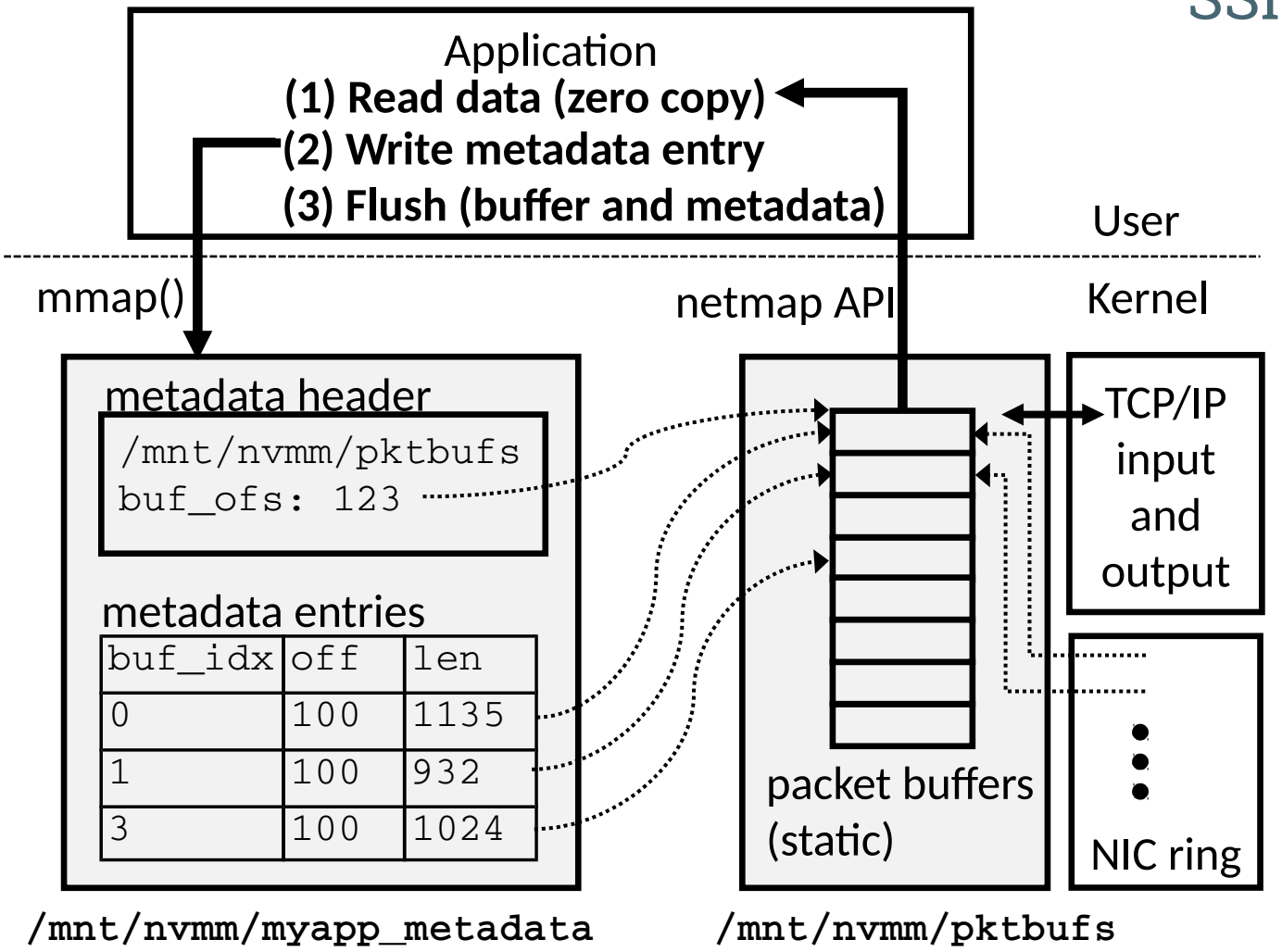
SSICLOPS

- **Packet buffers on a named NVMM region**
  - DMA to NVMM
- **Zero-copy APIs**



Fast Persistent Write with PASTE

SSICLOPS



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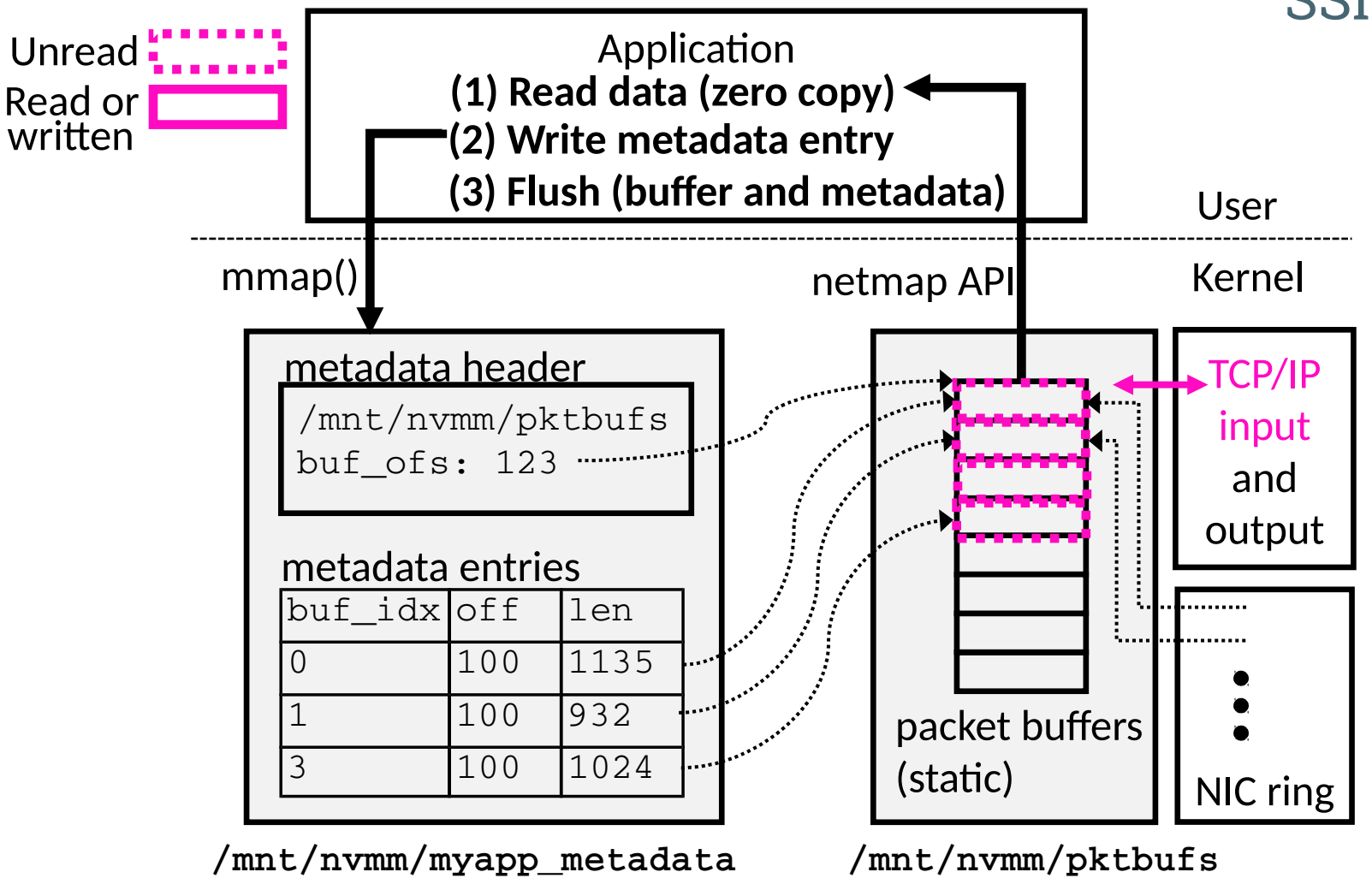

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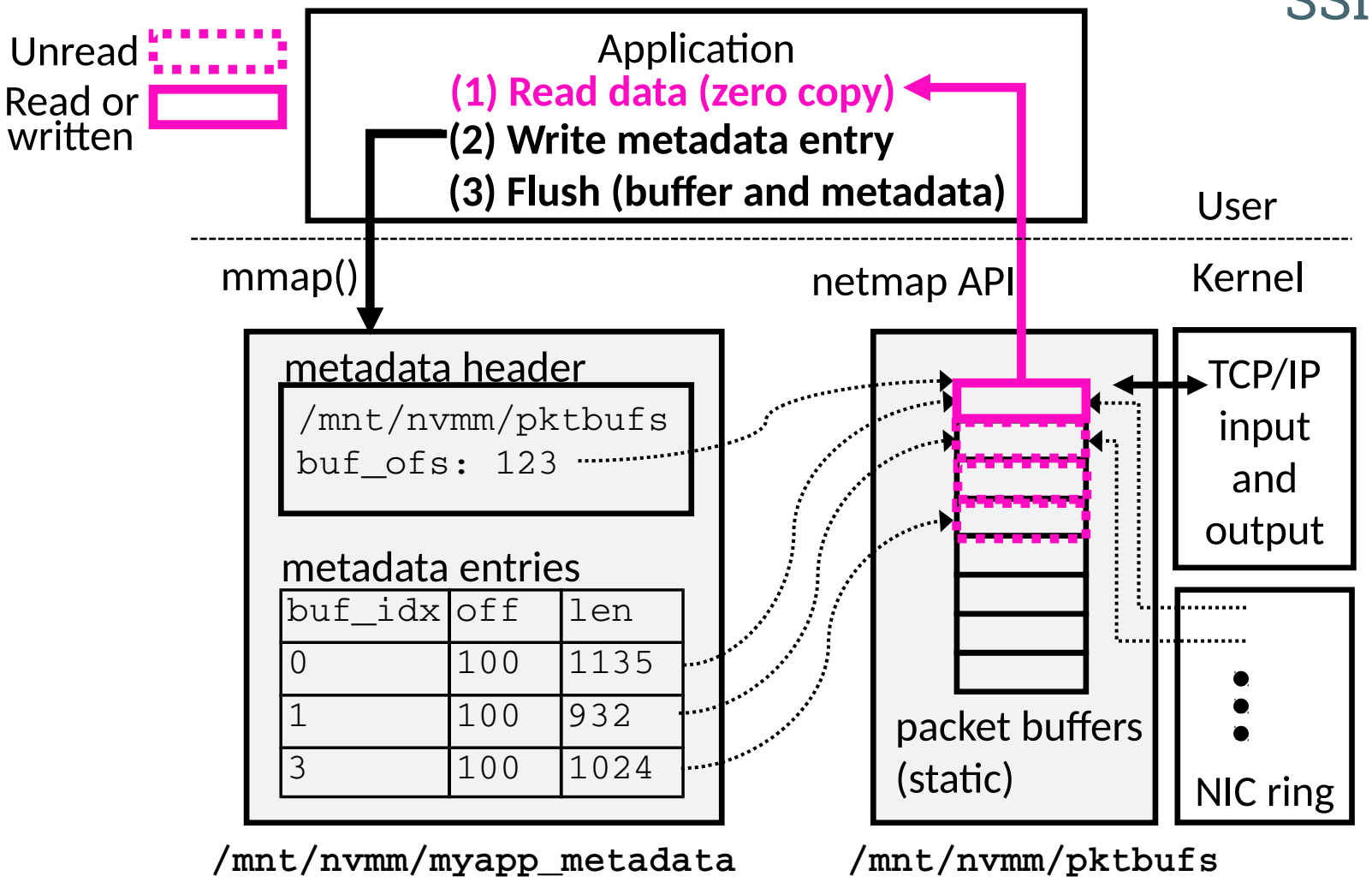

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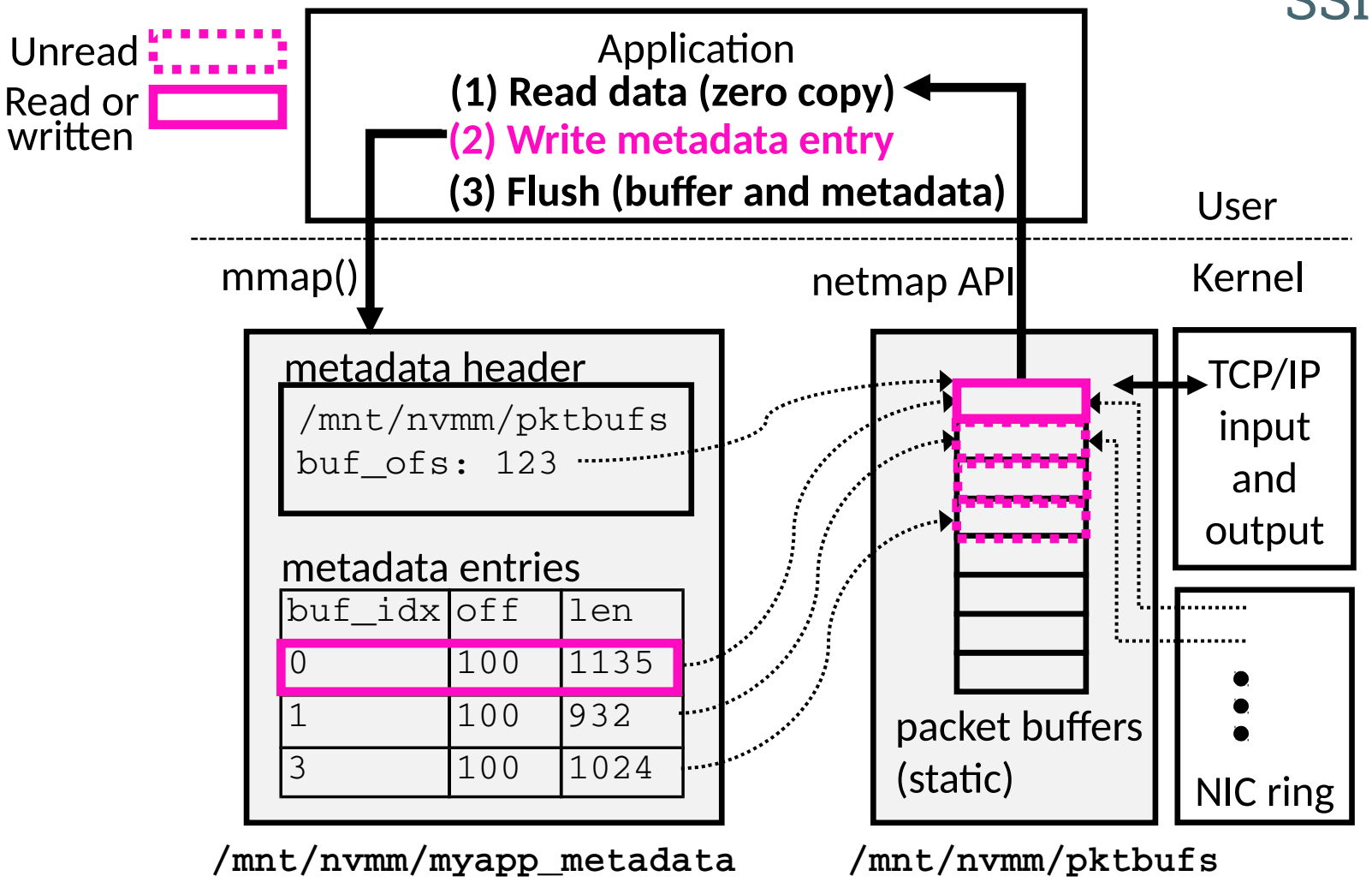

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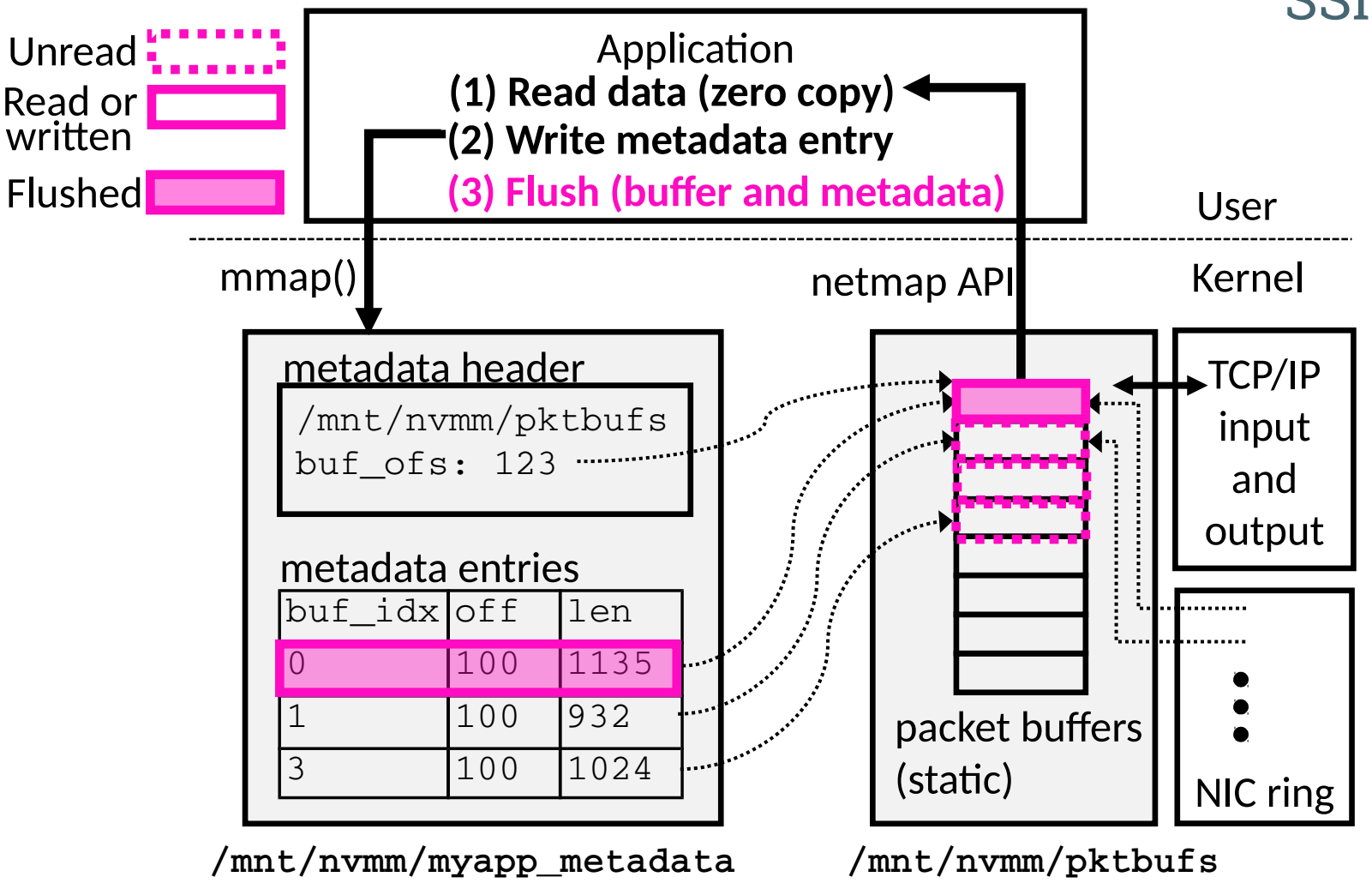

DMA is performed to L3 cache (DDIO)

Fast Persistent Write with PASTE

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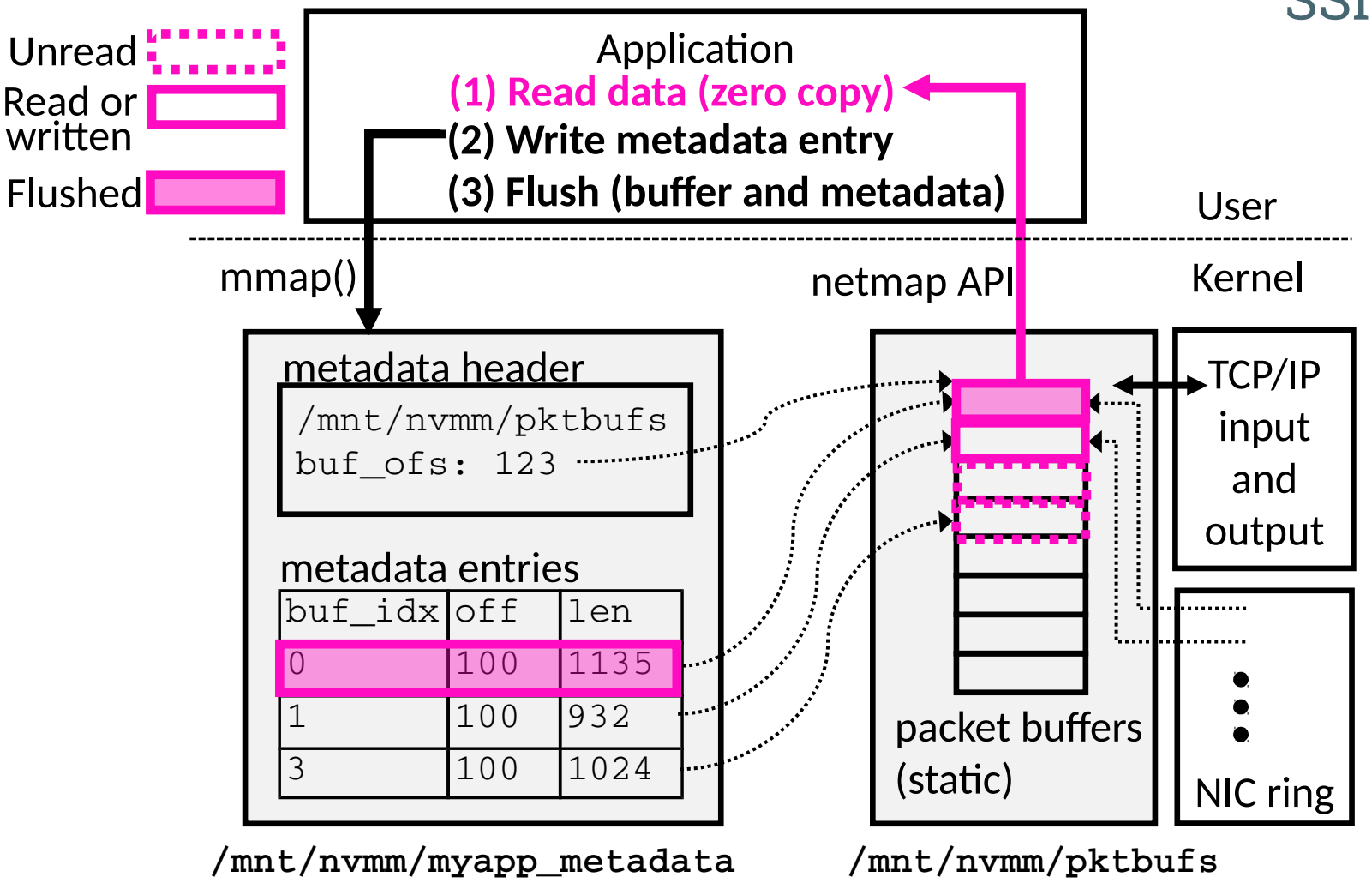

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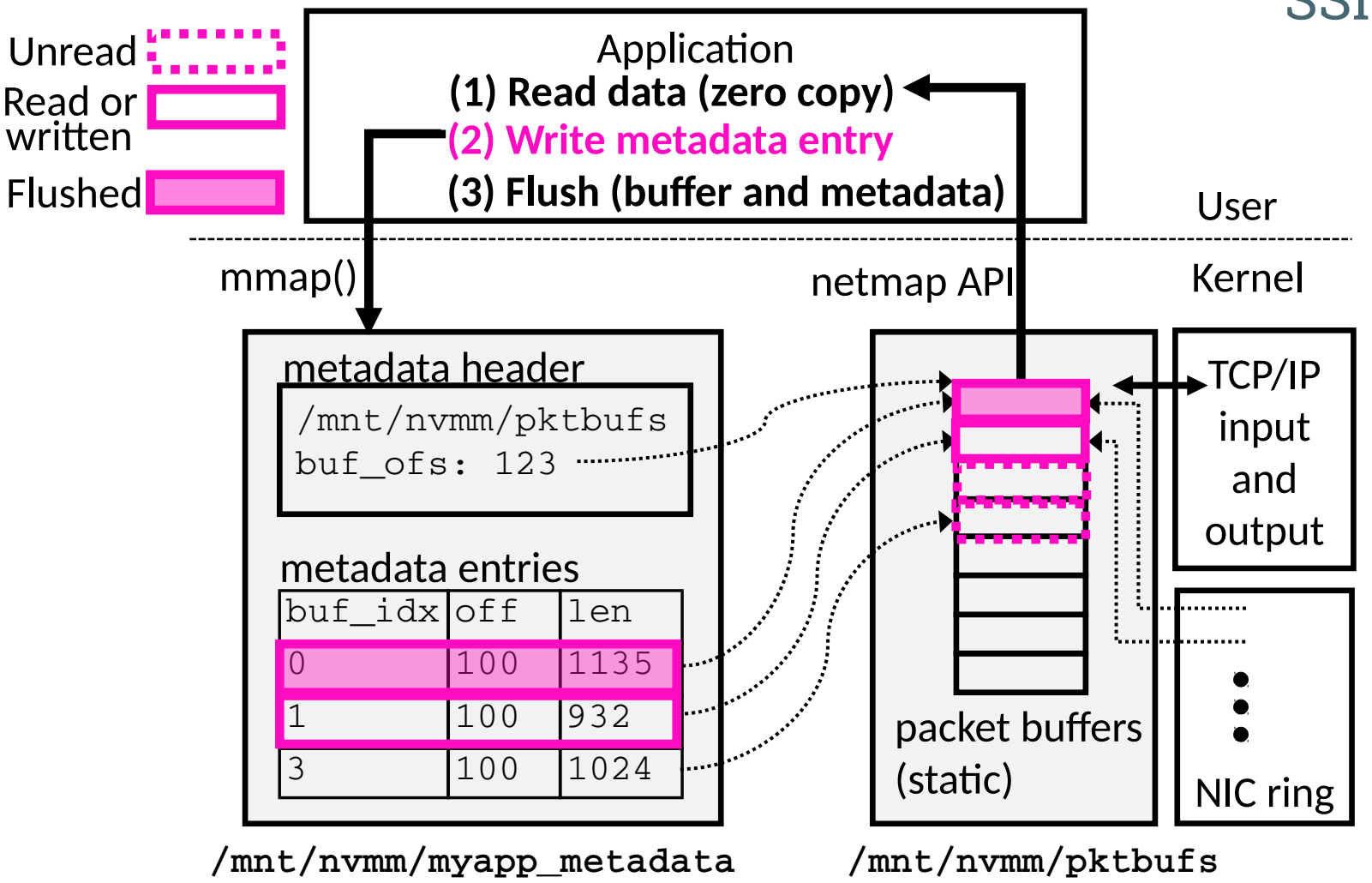

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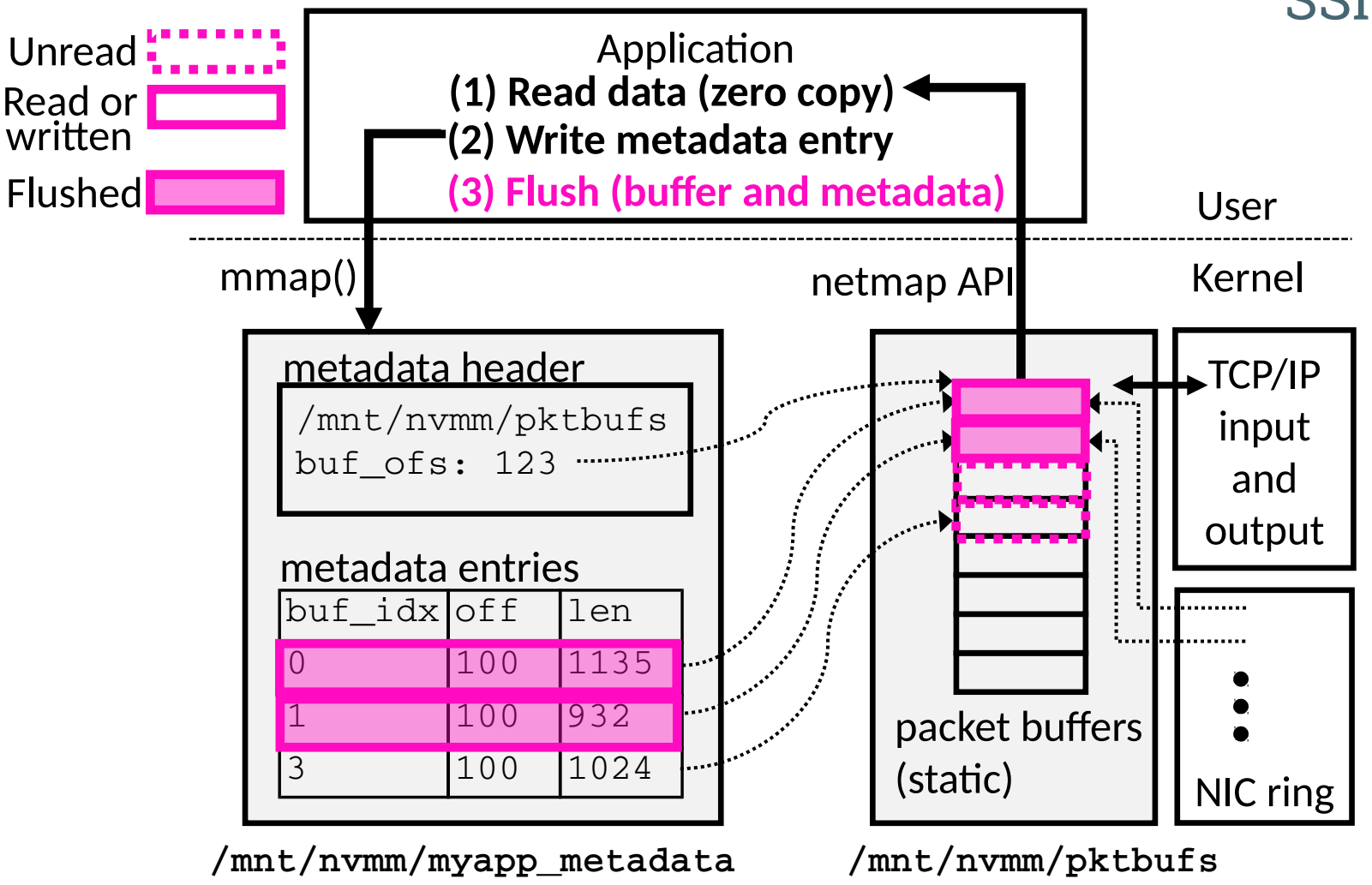

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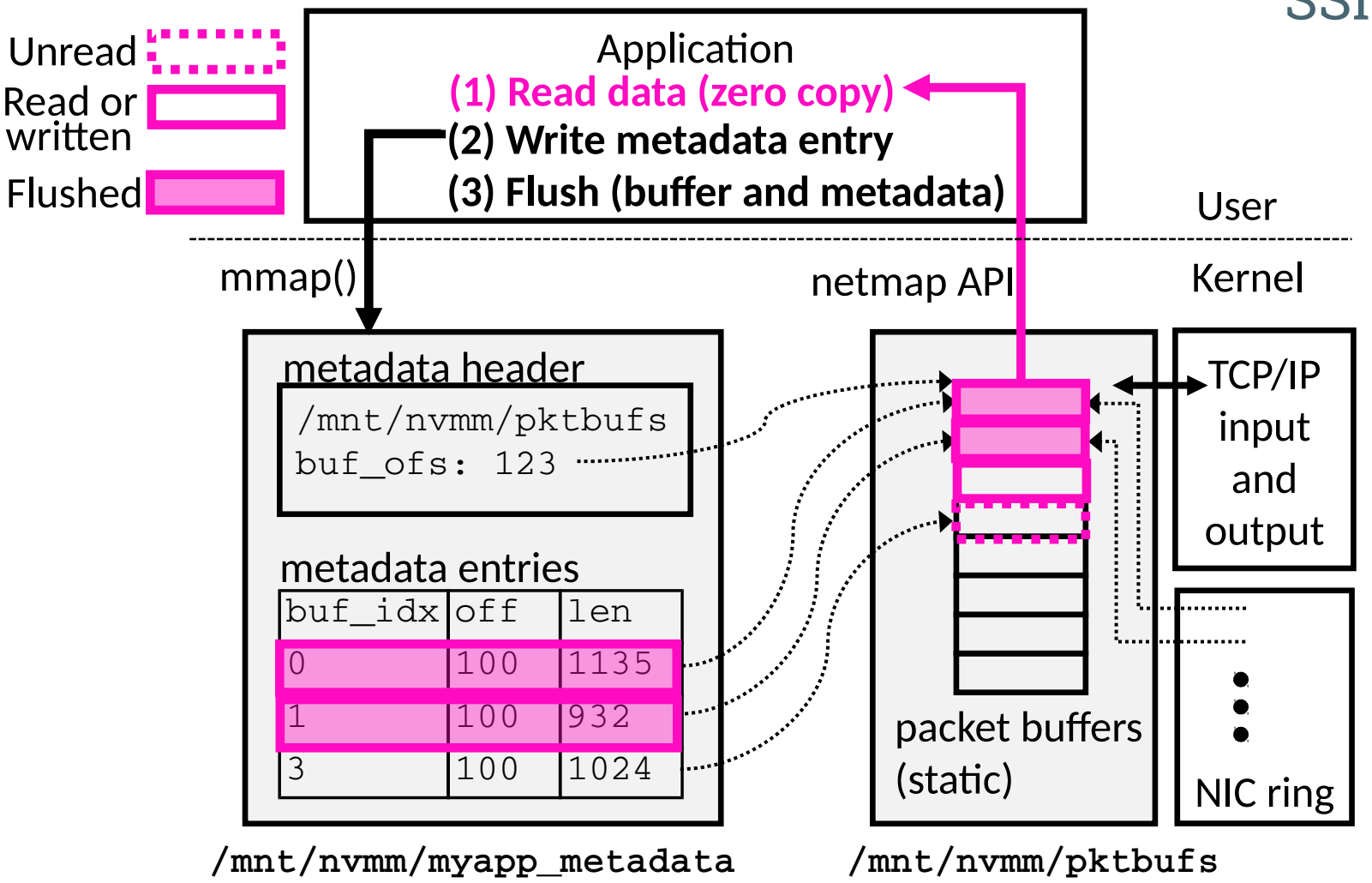

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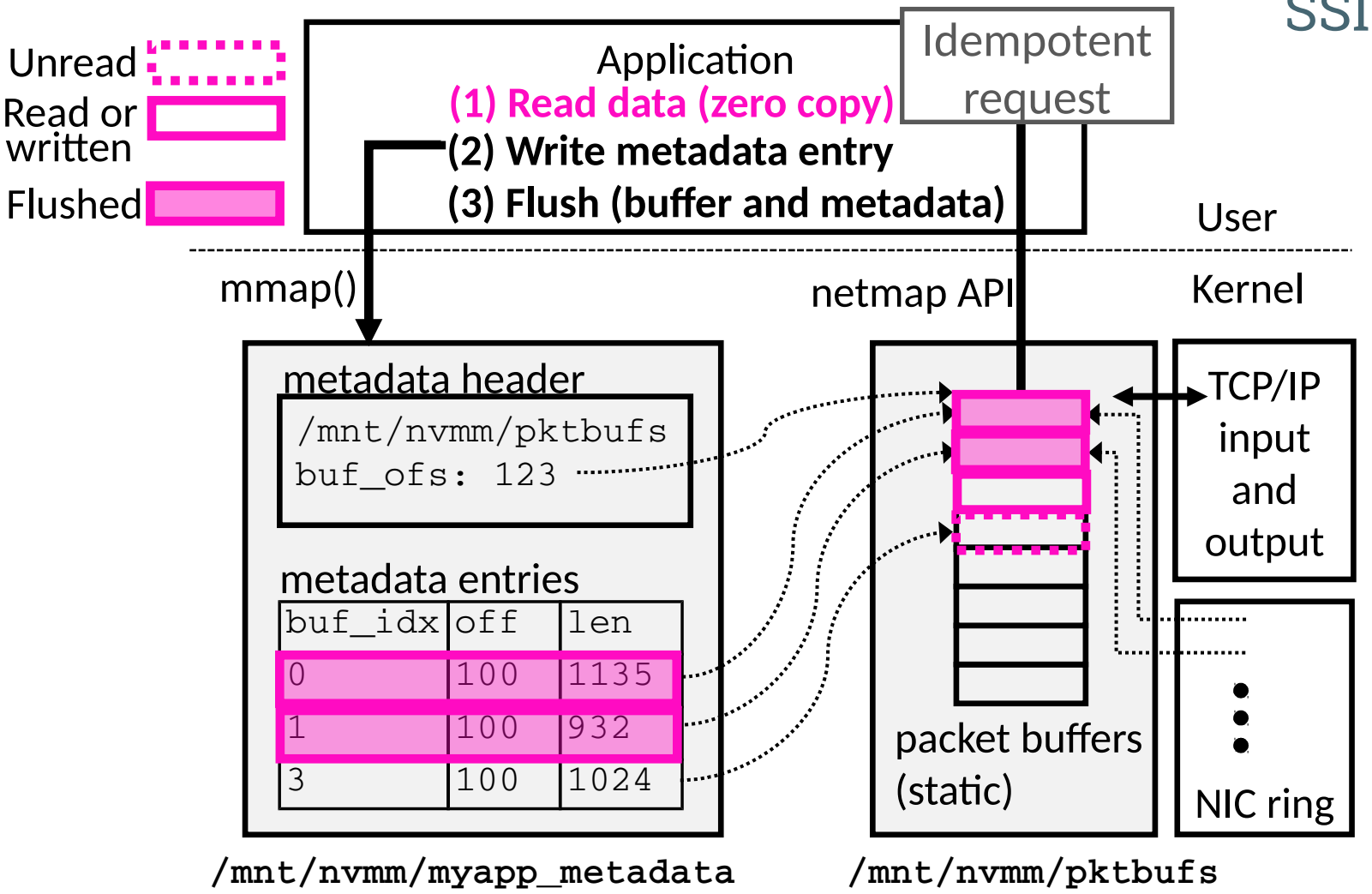
Fast and Selective Persistent Write with PASTE

SSICLOPS

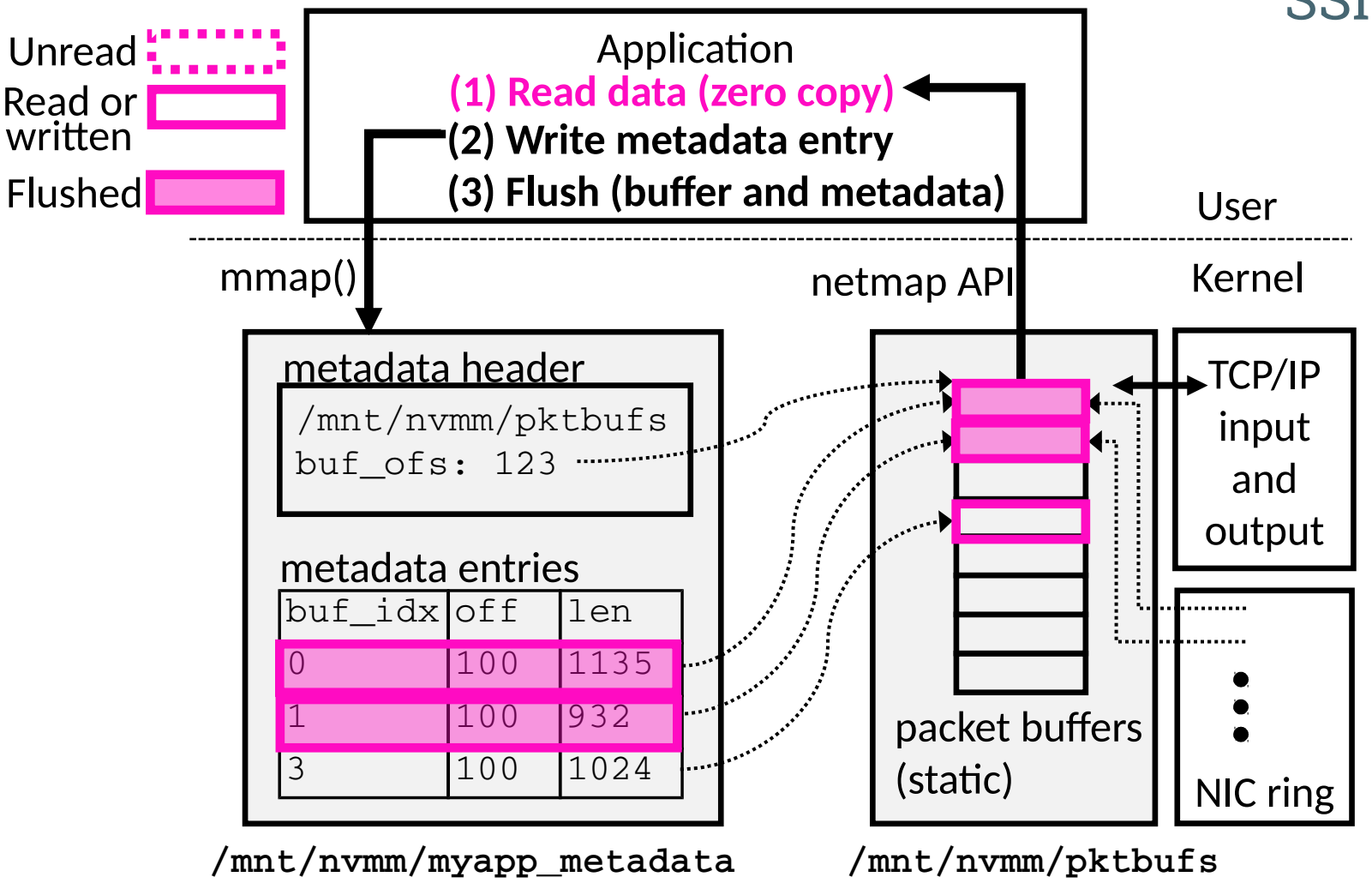


DMA is performed to L3 cache (DDIO)

Unnecessary data is not flushed to DIMM

Fast and Selective Persistent Write with PASTE

SSICLOPS



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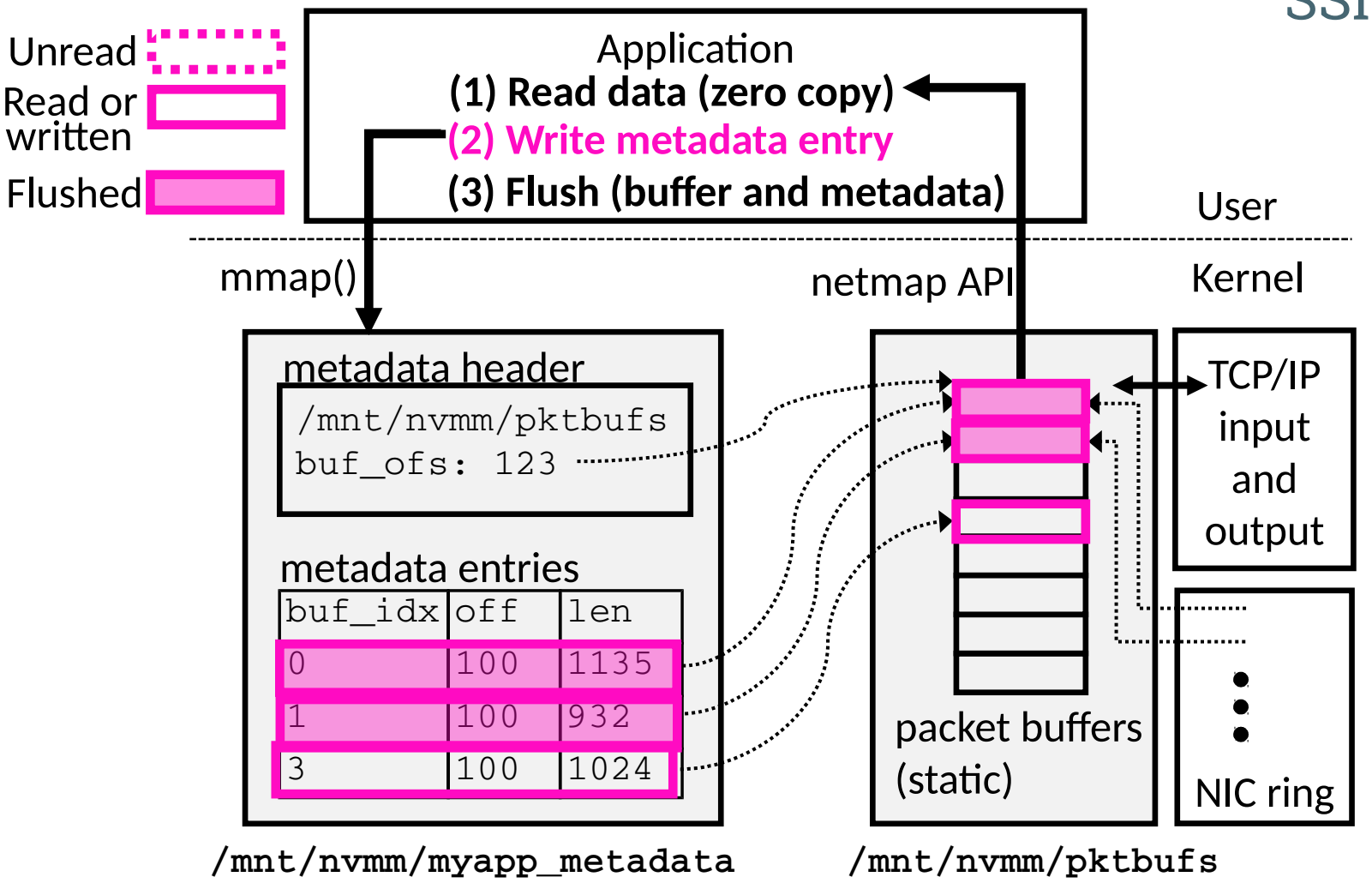

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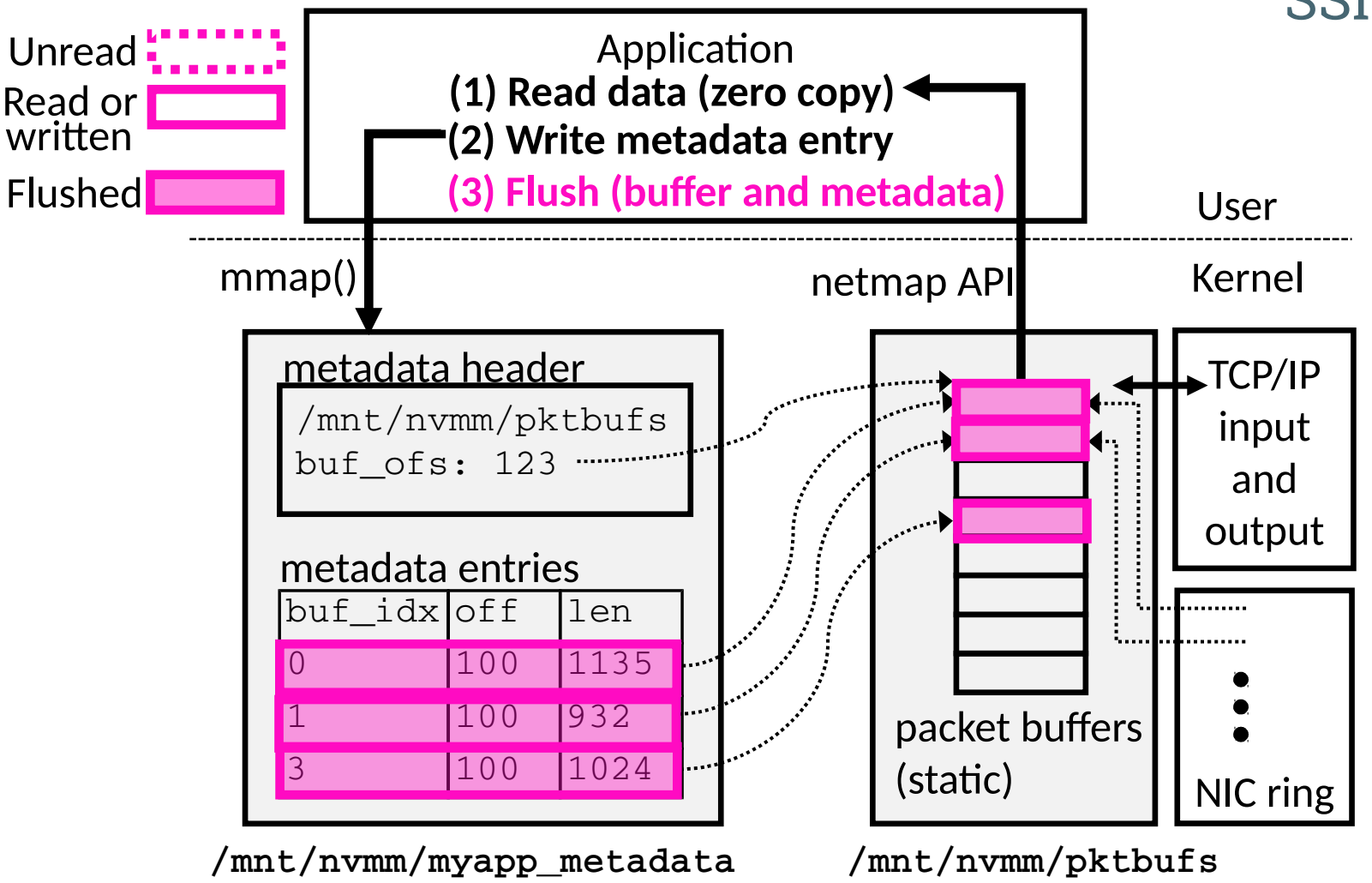

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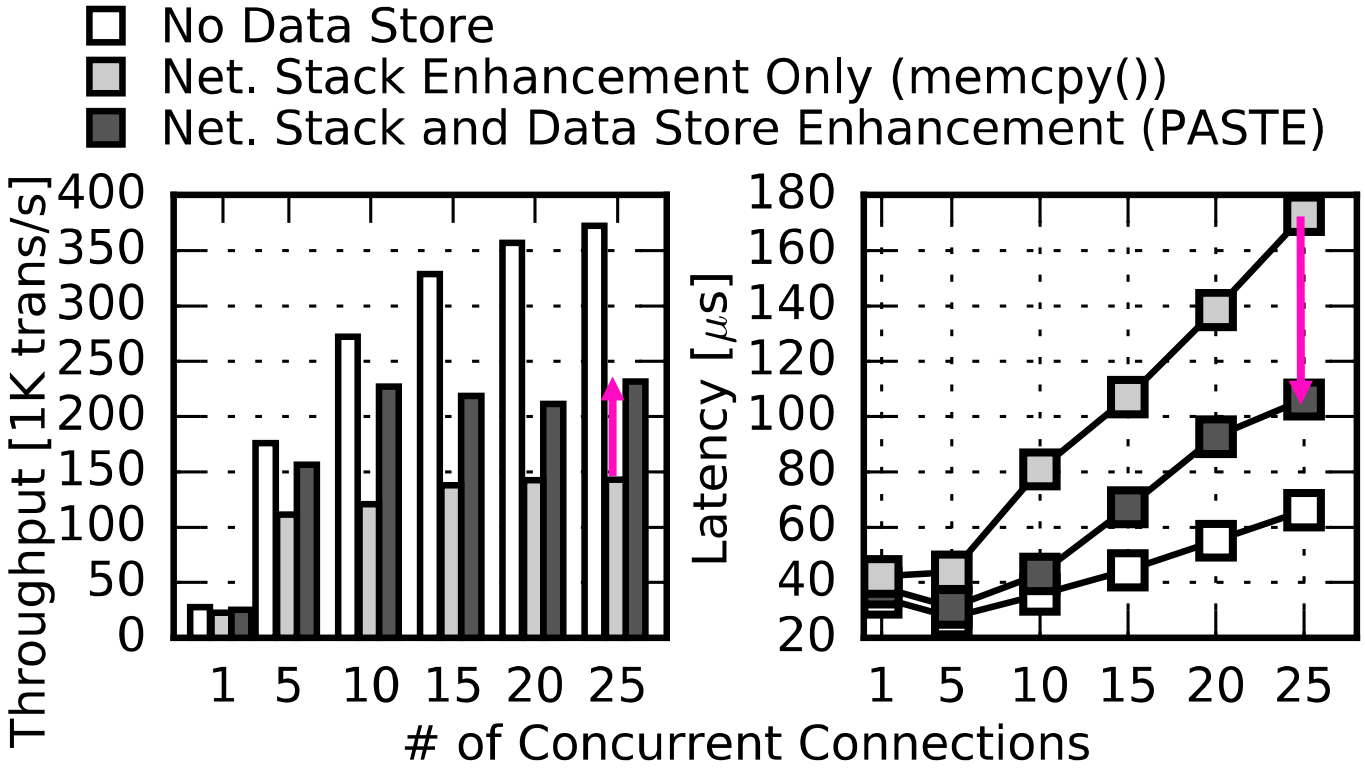
Preliminary Results

SSICLOPS

- Implementation
  - Extend the netmap framework
    - TCP/IP is also supported



10-88 % throughput increase, 9-46 % latency reduction

Related Work

- Enhanced network stacks
  - MegaPipe (OSDI'12), Stackmap (ATC'16), Fastsocket (ASPLOS'16)
  - IX and Arrakis (OSDI'14), mTCP (NSDI'13), Sandstorm (SIGCOMM'14), MICA (NSDI'14)

No NVMM aware

- NVMM filesystems
  - BPFS (SOSP'09), NOVA (FAST'15)
- NVMM databases
  - NVWAL (ASPLOS'15), REWIND (VLDB'15), NV-Tree (FAST'15)

No networking aware

Conclusion

SSICLOPS

- Networking APIs are now a bottleneck for durably storing data
- Ongoing work
  - Brushing up APIs
    - Smooth integration with netmap API
  - Forming a filesystem with packet buffers
    - Fast data movement between files
  - Use case applications