Creating Flash-Aware Applications

Nisha Talagala

NVM (Flash, other) is different from Disk

Area	Hard Disk Drives	Flash Devices
Logical to Physical Blocks	Nearly 1:1 Mapping	Remapped at every write
Read/Write Performance	Largely symmetrical	Heavily asymmetrical. Additional operation (erase)
Sequential vs Random Performance	100x difference. Elevator scheduling for disk arm	<10x difference. No disk arm – NAND die
Background operations	Rarely impact foreground	Regular occurrence. If unmanaged - can impact foreground
Wear out	Largely unlimited writes	Limited writes
IOPS	100s to 1000s	100Ks to Millions
Latency	10s ms	10s-100s us

I/O and Memory Access for Flash Aware Applications

I/O

I/O semantics examples:

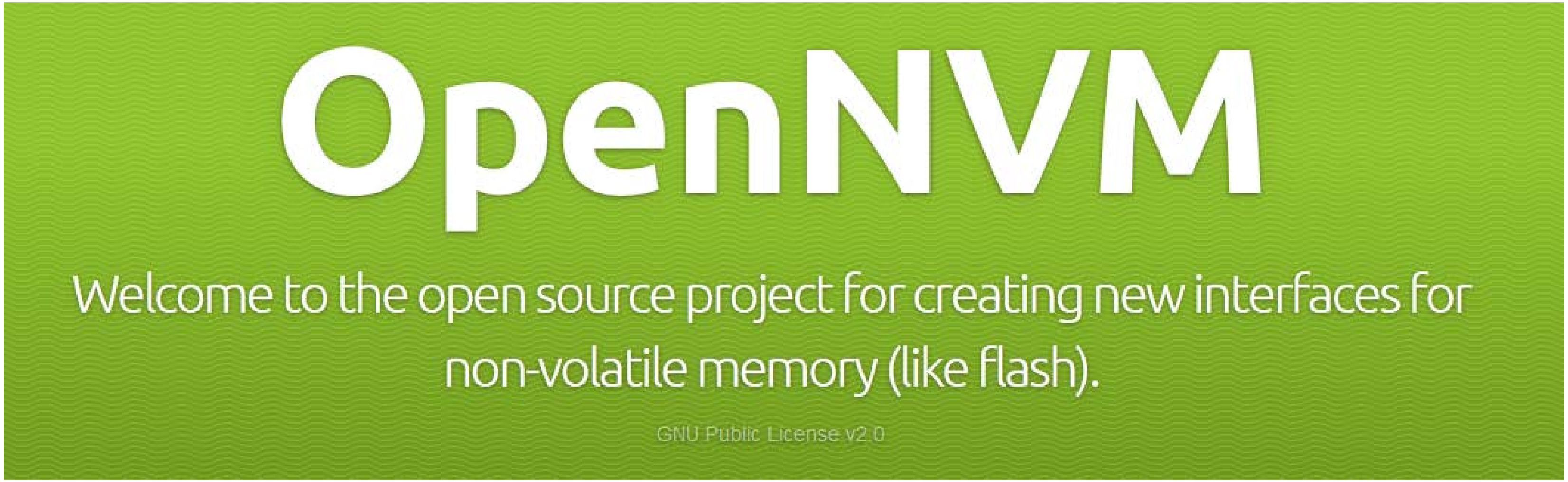
- Open file descriptor – open(), read(), write(), seek(), close()
- (New – presented today) NVM Primitives
- (New – presented today) NVM KV Store

Memory

Volatile memory semantics example:

- Allocate virtual memory, e.g. malloc()
- memcpy/pointer dereference writes (or reads) to memory address
- (Improved – presented today) Page-faulting transparently loads data from NVM into memory

https://opennvm.github.io



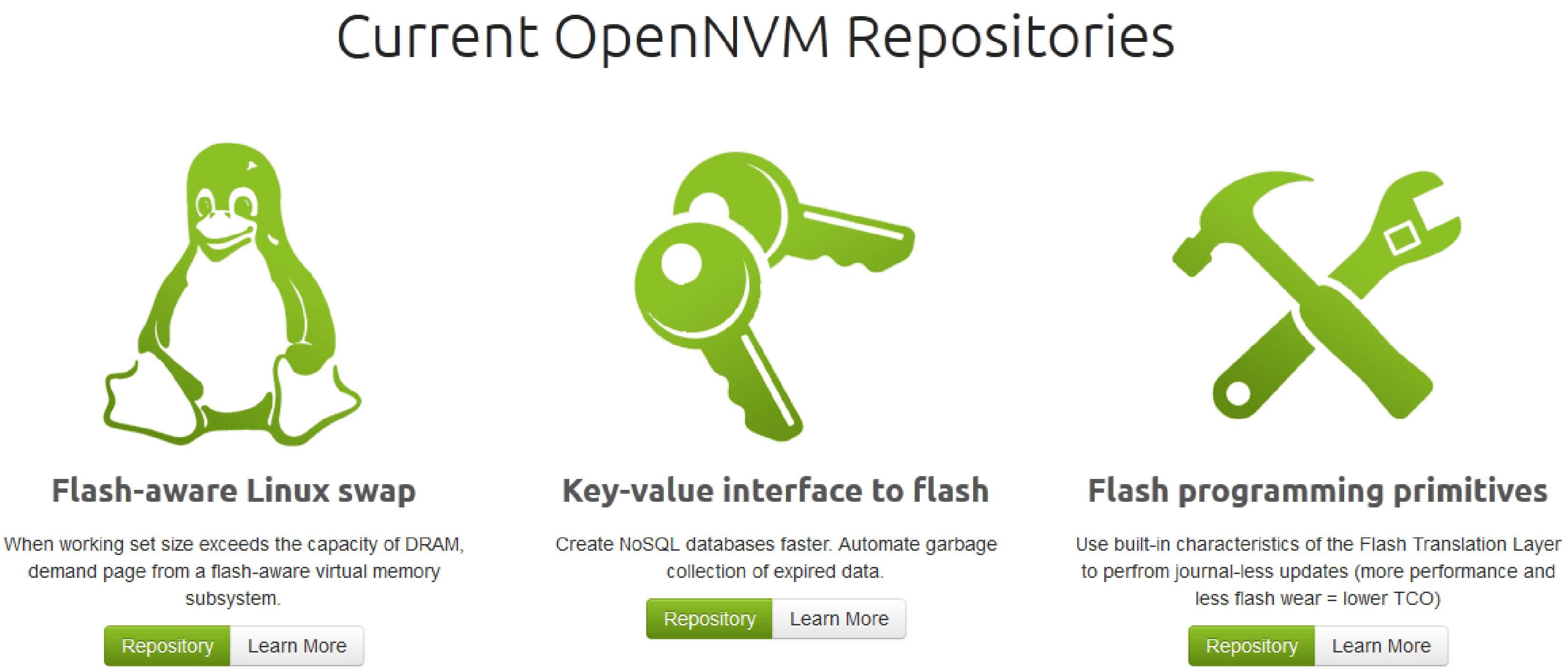
OpenNVM

Welcome to the open source project for creating new interfaces for non-volatile memory (like flash).

GNU Public License v2.0

http://www.opencompute.org/projects/storage/

3 Contributions to the Community



Current OpenNVM Repositories

Flash-aware Linux swap

When working set size exceeds the capacity of DRAM, demand page from a flash-aware virtual memory subsystem.

Key-value interface to flash

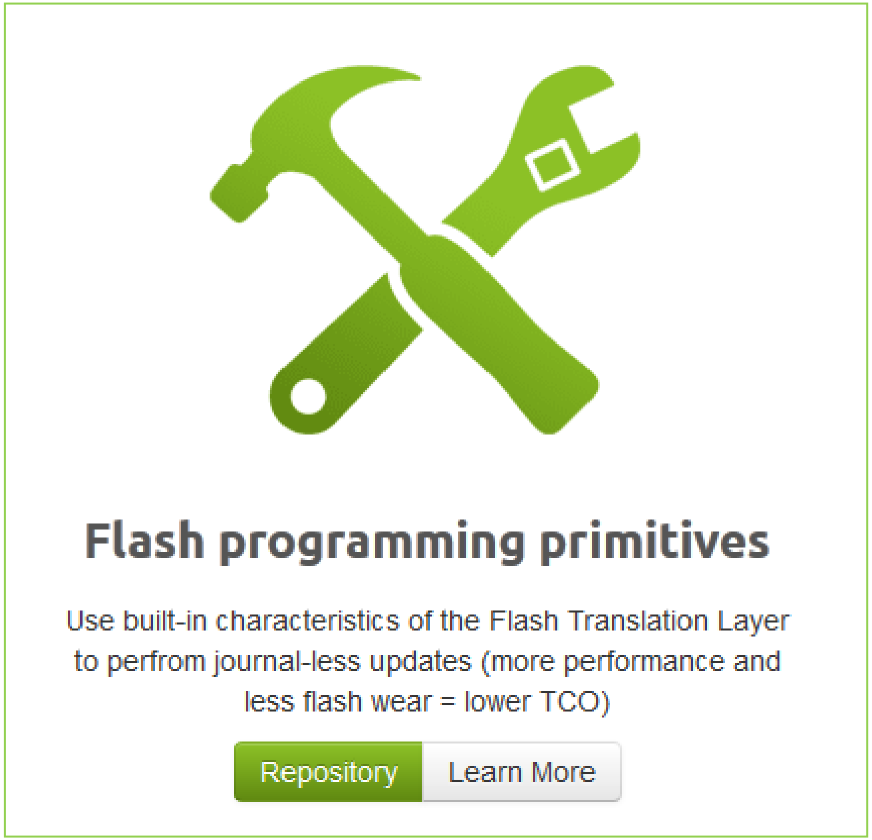
Create NoSQL databases faster. Automate garbage collection of expired data.

Flash programming primitives

Use built-in characteristics of the Flash Translation Layer to perfrom journal-less updates (more performance and less flash wear = lower TCO)

https://opennvm.github.io

1st Contribution: Flash Primitives



Flash programming primitives

Use built-in characteristics of the Flash Translation Layer to perfrom journal-less updates (more performance and less flash wear = lower TCO)

https://opennvm.github.io

On GitHub:

- API specifications, such as:
  - *nvm_atomic_write()*
  - *nvm_batch_atomic_operations()*
  - *nvm_atomic_trim()*
- Sample program code

Flash Primitives: Sample Uses and Benefits

FUSION-IO

- Databases

  Transactional Atomicity:
  Replace various workarounds implemented in database code to provide write atomicity (MySQL double-buffered writes, etc.)

- Filesystems

  File Update Atomicity:
  Replace various workarounds implemented in filesystem code to provide file/directory update atomicity (journaling, etc.)

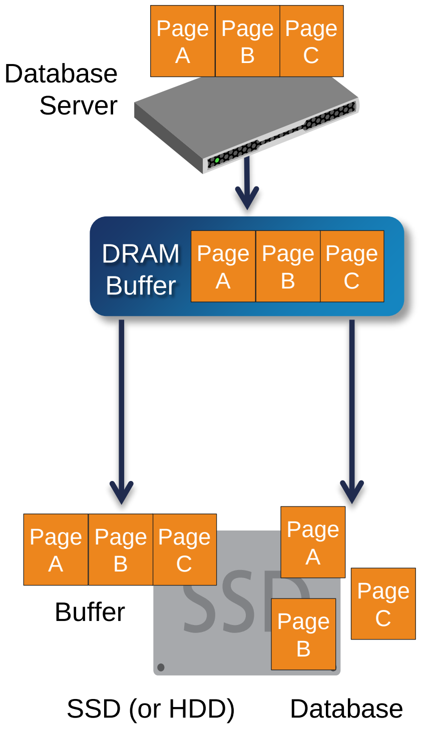
- 98% performance of raw writes
  Smarter media now natively understands atomic updates, with no additional metadata overhead.

- 2x longer flash media life
  Atomic Writes can increase the life of flash media up to 2x due to reduction in write-ahead-logging and double-write buffering.

- 50% less code in key modules
  Atomic operations dramatically reduce application logic, such as journaling, built as work-arounds.

Atomic Writes – MySQL Example

Traditional MySQL Writes



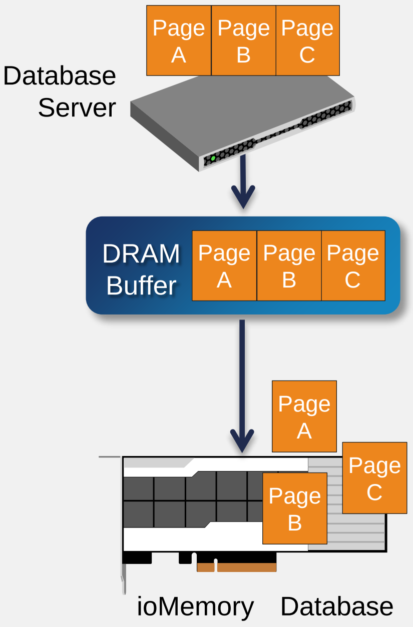
1 Application initiates updates to pages A, B, and C.

2 MySQL copies updated pages to memory buffer.

3 MySQL writes to double-write buffer on the media.

4 Once step 3 is acknowledged, MySQL writes the updates to the actual tablespace.

MySQL with Atomic Writes



1 Application initiates updates to pages A, B, and C.

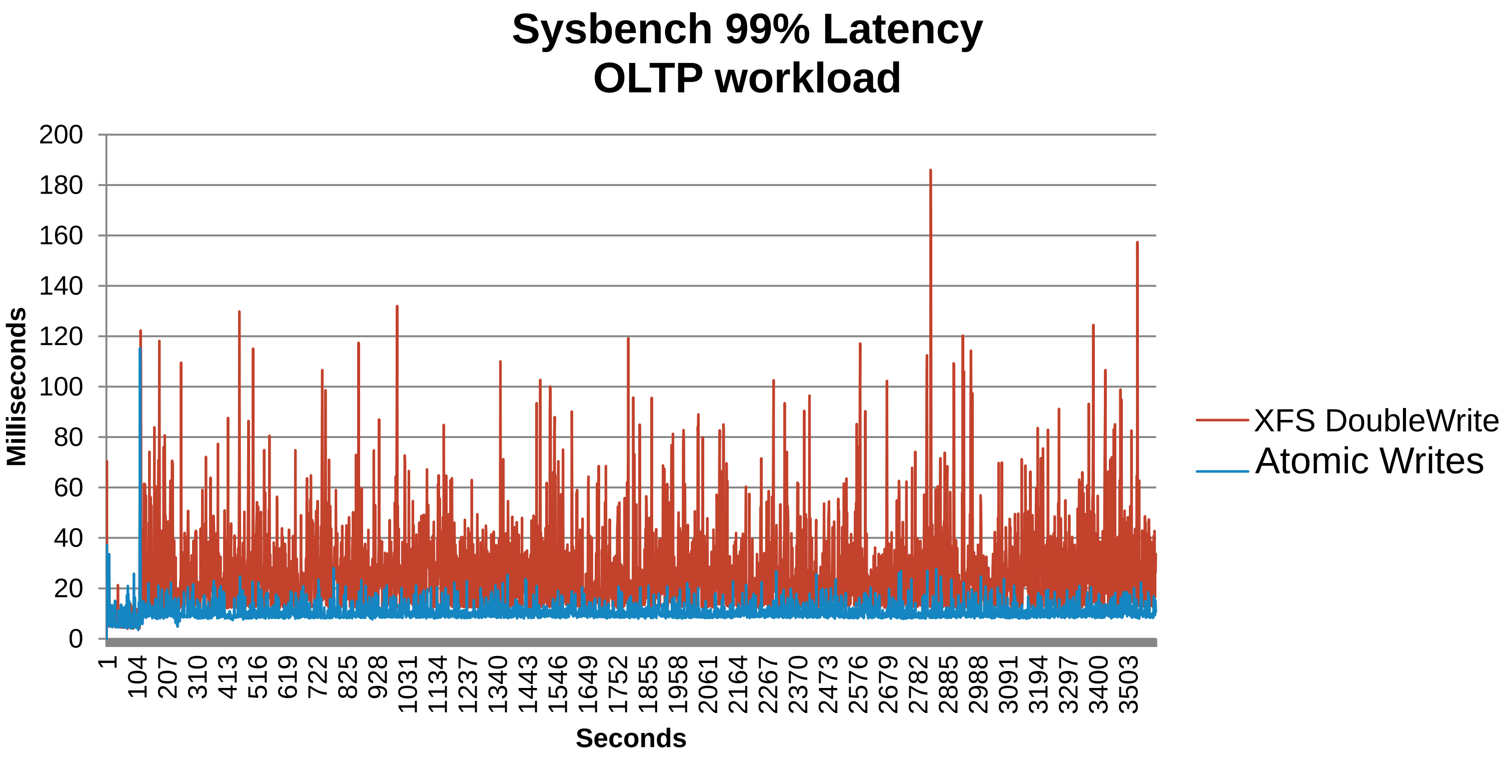
2 MySQL copies updated pages to memory buffer.

3 MySQL writes to actual tablespace, bypassing the double-write buffer step due to inherent atomicity guaranteed by the (intelligent) device.

MySQL Example: Latency Improvement

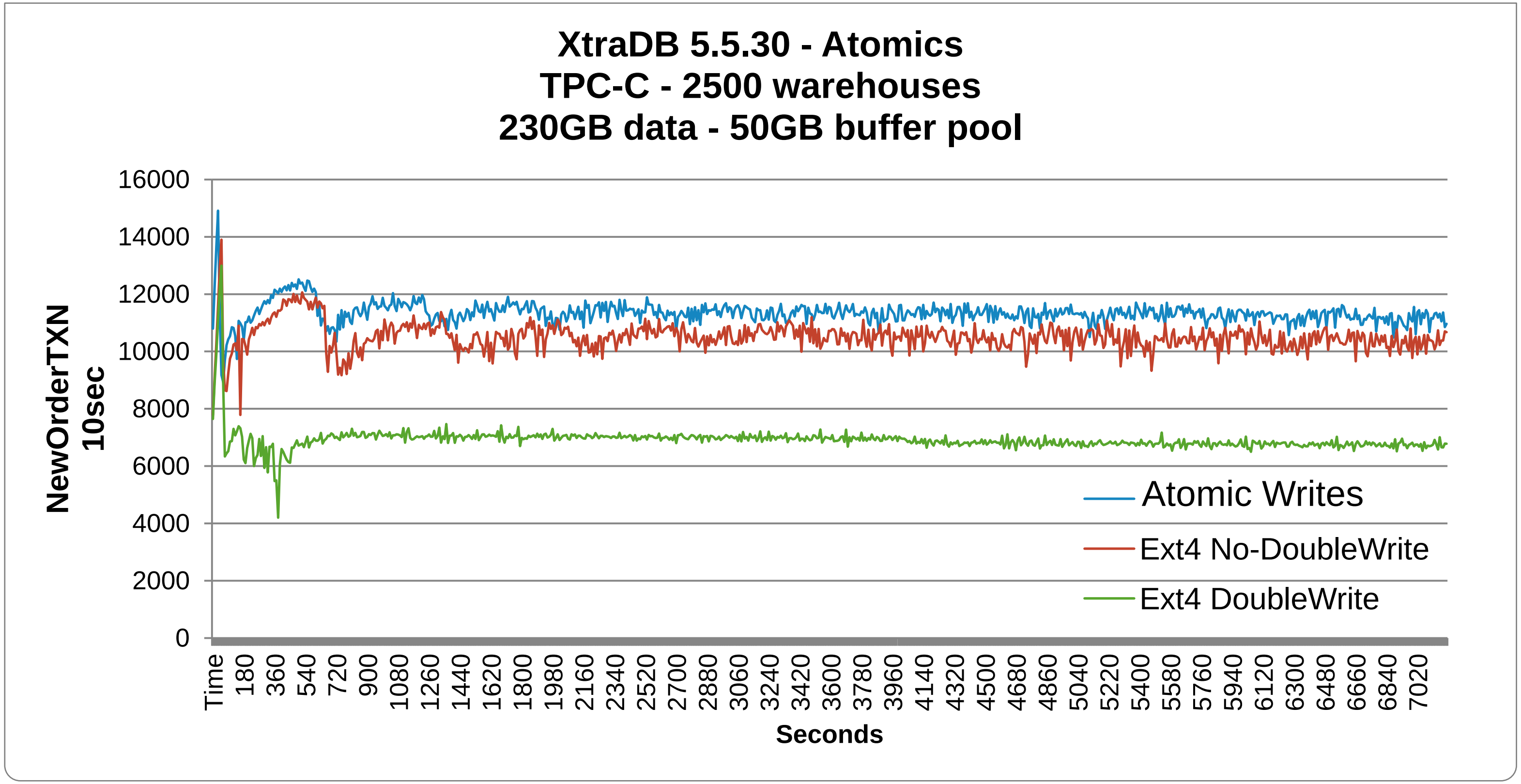
FUSION-IO

2-4x Latency Improvement on Percona Server

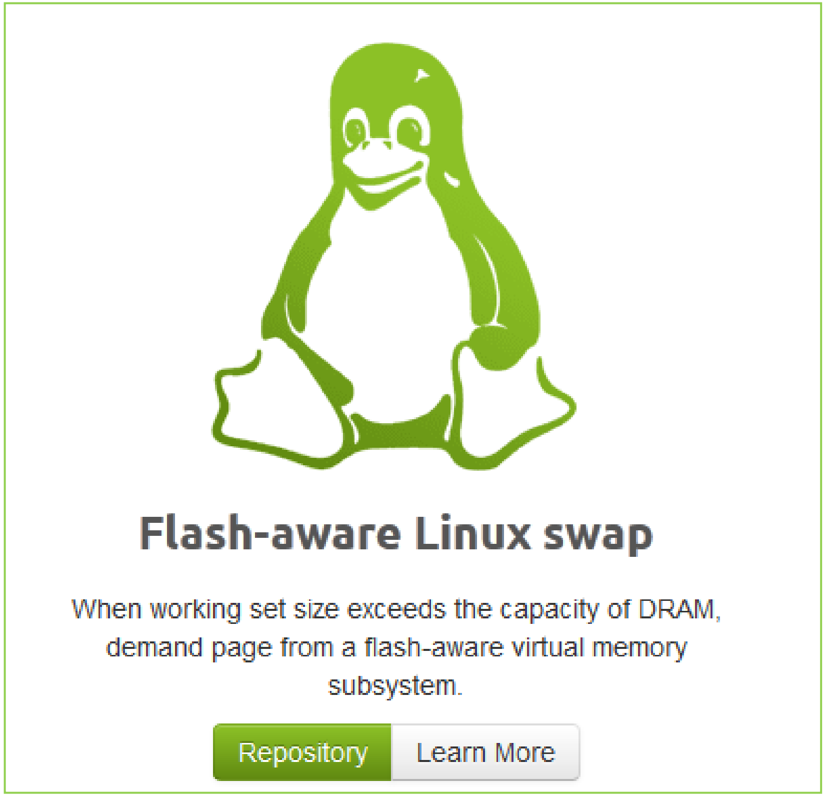


MySQL Example: Throughput Improvement

70% Transactions/sec Improvement on MariaDB Server



2nd Contribution: Linux Fast-Swap



Flash-aware Linux swap

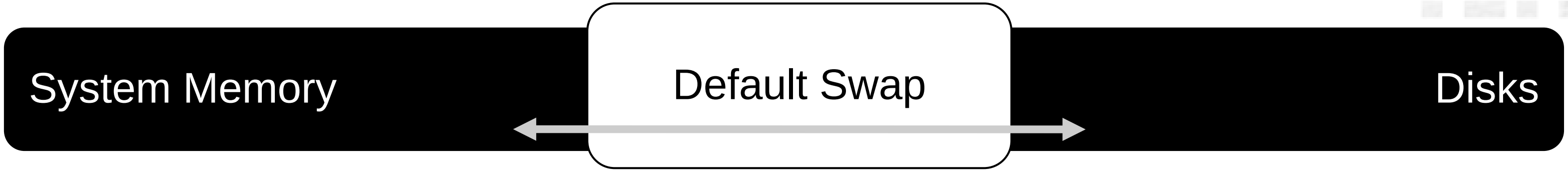
When working set size exceeds the capacity of DRAM, demand page from a flash-aware virtual memory subsystem.

https://opennvm.github.io

On GitHub:

- Documentation
- Experimental Linux kernel with virtual memory swap patch (3.6 kernel)
- Benchmarking utility

Improving Linux Swap (Demand-paging)



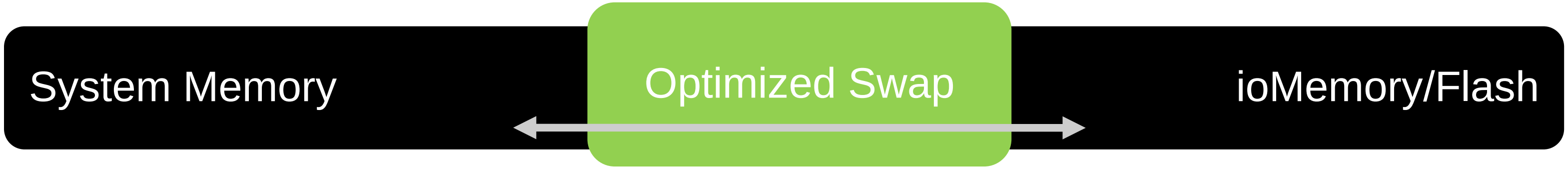
System Memory

Default Swap

Disks

Originally designed as a last resort to prevent OOM (out-of-memory) failures

- Never tuned for high-performance demand-paging
- Never tuned for multi-threaded apps
- Poor performance



System Memory

Optimized Swap

ioMemory/Flash

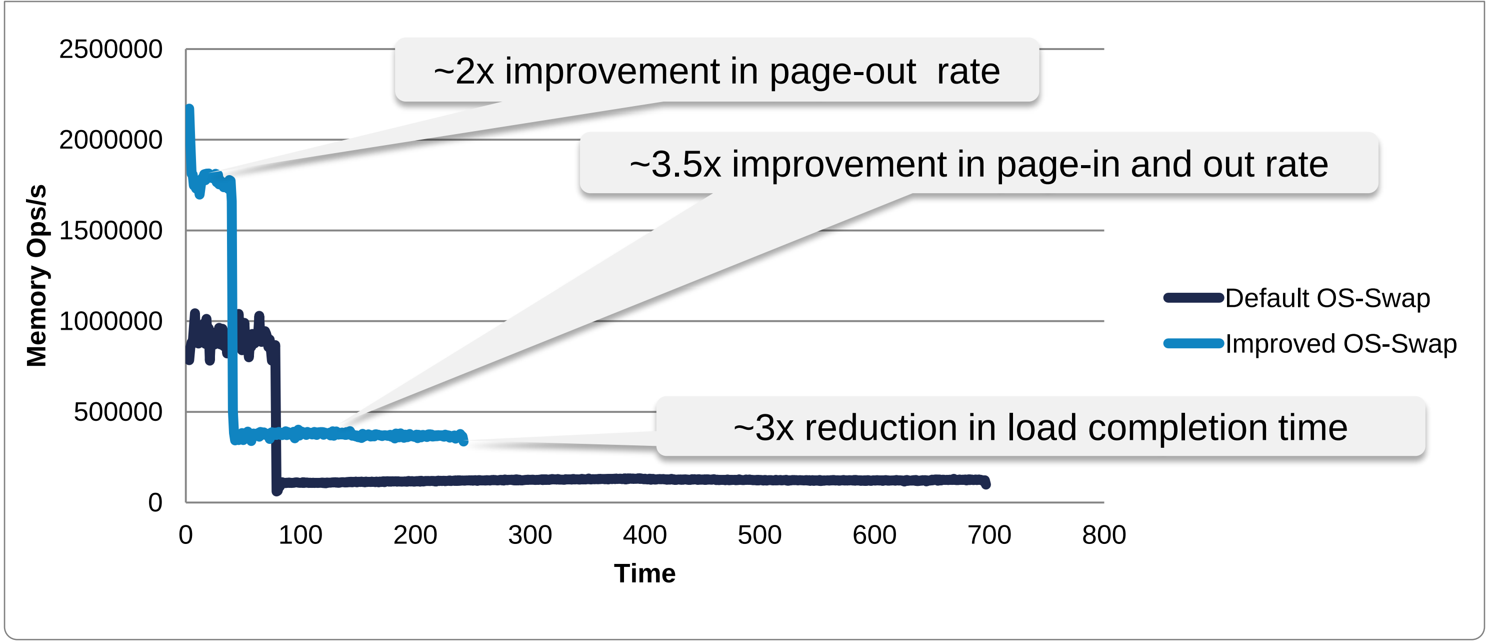
Tuned for flash (leverages native characteristics)

- O(1) algorithm for swap_out – reduce algorithm time and leverage fast random I/O
- Per CPU reclaim – greater throughput for multi-threaded environments
- Intelligent read-ahead on swap-in – cut legacy, disk-era cruft for rotational latency

Fast Swap - Performance

FUSION-IO

3x reduction in load completion time with fast swap

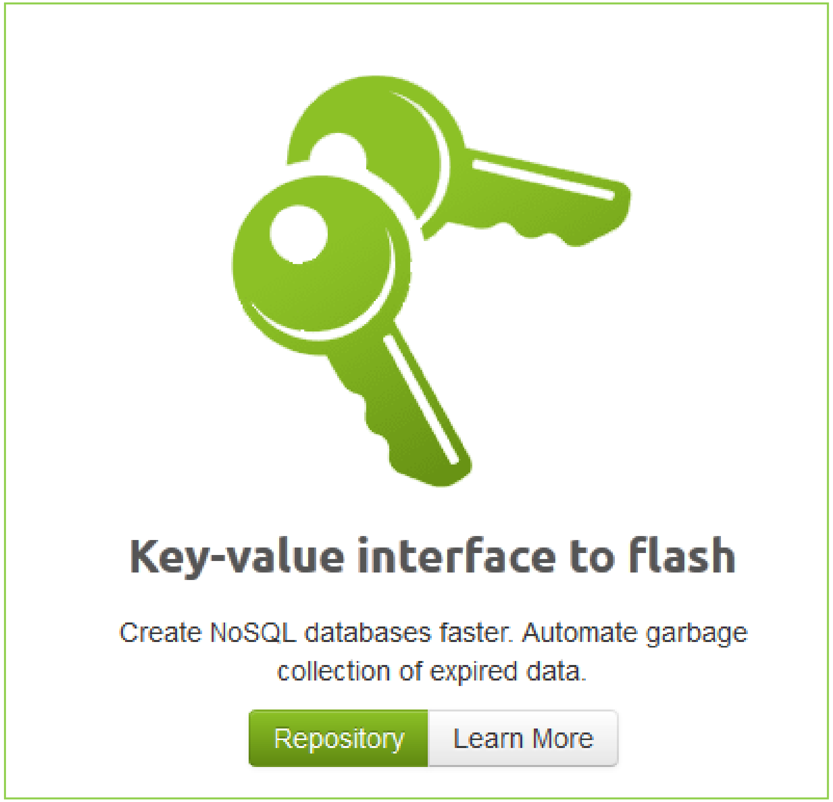


~2x improvement in page-out rate

~3.5x improvement in page-in and out rate

~3x reduction in load completion time

3rd Contribution: Key-Value Interface



Key-value interface to flash

Create NoSQL databases faster. Automate garbage collection of expired data.

https://opennvm.github.io

On GitHub:

- API specifications, such as:
  nvm_kv_put()
  - *nvm_kv_get()*
  - *nvm_kev_batch_put()*
  - *nvm_kv_set_global_expiry()*
- Sample program code
- Benchmarking utility
- Source code (30 Aug)

Key-Value Interface: Sample Uses and Benefits

FUSION-IO

- NoSQL Applications

  Increase performance by eliminating packing and unpacking blocks, defragmentation, and duplicate metadata at app layer.

  Reduce application I/O through batched operations.

  Reduce overprovisioning due to lack of coordination between two-layers of garbage collection (application-layer and flash-layer). Some top NoSQL applications recommend over-provisioning by 3x due to this.

- Near performance of raw device

  Smarter media now natively understands a key-value I/O interface with lock-free updates, crash recovery, and no additional metadata overhead.

- 3x throughput on same SSD

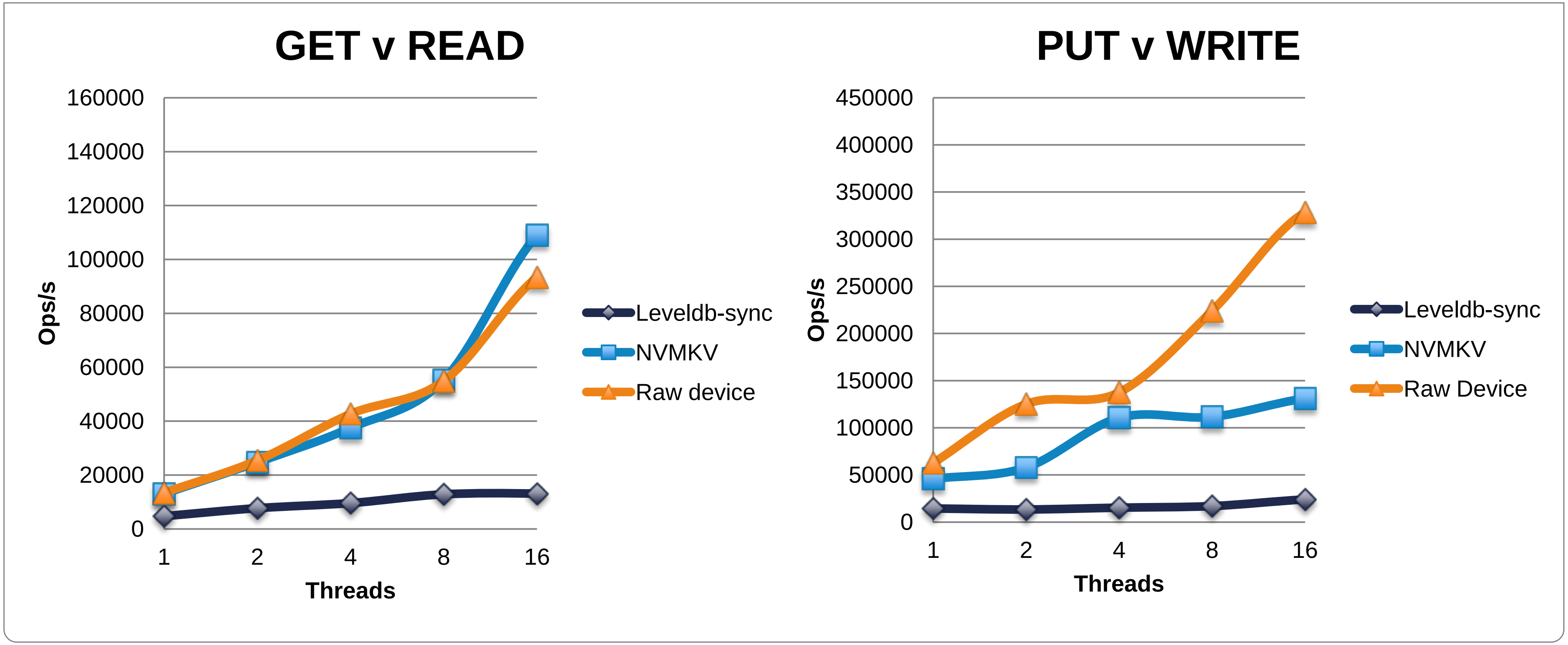
  Early benchmarks comparing against synchronous levelDB show over 3x improvement.

- Up to 3x capacity increase

  Dramatically reduces over-provisioning through coordinated garbage collection and automated key expiry.

Key-Value Interface - Performance

Key-Value get/put vs. Raw read/write vs. levelDB read/write



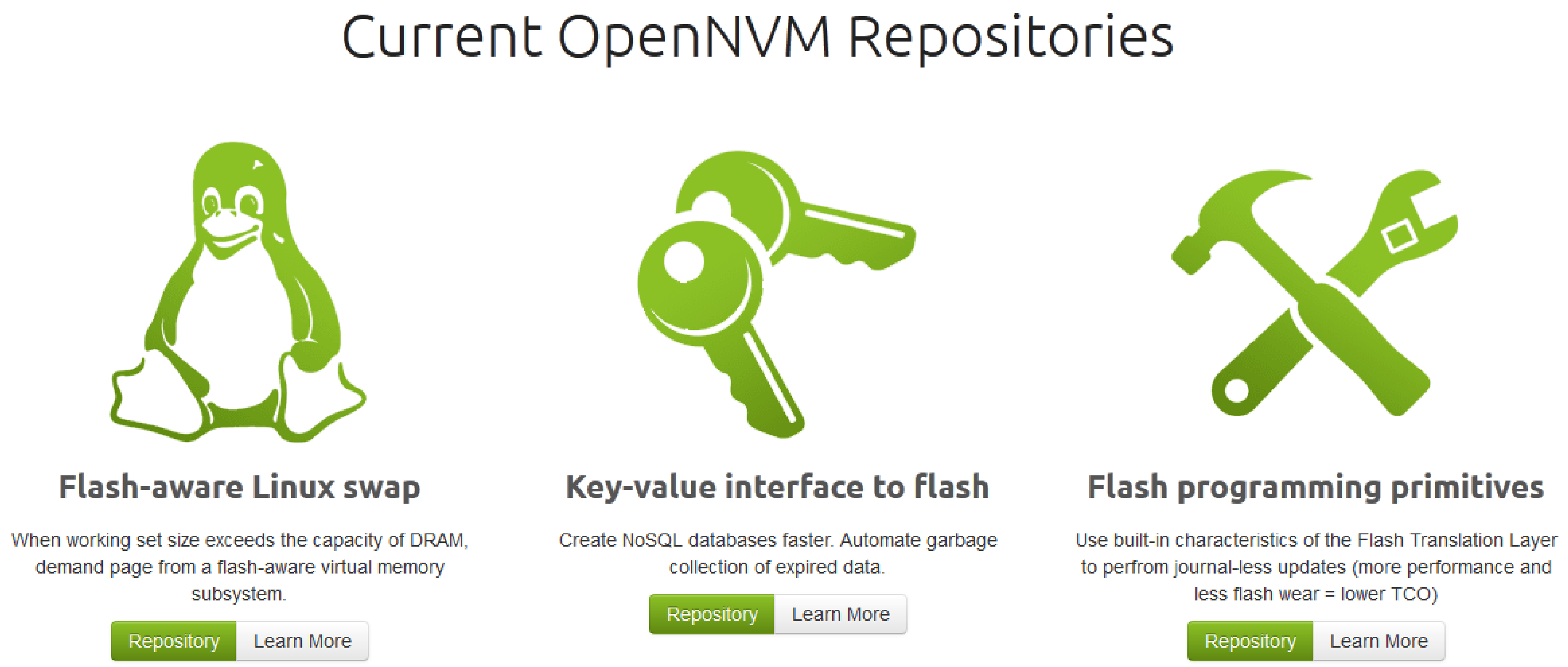
OpenNVM, Standards, and Consortiums

- opennvm.github.io
  - Primitives API specifications, sample code
  - Linux swap kernel patch and benchmarking tools
  - key-value interface API library, sample code, benchmark tools
- INCITS SCSI (T10) active standards proposals:
  - SBC-4 SPC-5 Atomic-Write http://www.t10.org/cgi-bin/ac.pl?t=d&f=11-229r6.pdf
  - SBC-4 SPC-5 Scattered writes, optionally atomic http://www.t10.org/cgi-bin/ac.pl?t=d&f=12-086r3.pdf
  - SBC-4 SPC-5 Gathered reads, optionally atomic http://www.t10.org/cgi-bin/ac.pl?t=d&f=12-087r3.pdf
- SNIA NVM-Programming TWG draft guide: http://snia.org/forums/sssi/nvmp

Apps Using OpenNVM technology

https://opennvm.github.io

Join us at opennvm.github.io



Current OpenNVM Repositories

Flash-aware Linux swap

When working set size exceeds the capacity of DRAM, demand page from a flash-aware virtual memory subsystem.

Key-value interface to flash

Create NoSQL databases faster. Automate garbage collection of expired data.

Flash programming primitives

Use built-in characteristics of the Flash Translation Layer to perfrom journal-less updates (more performance and less flash wear = lower TCO)

THANK YOU

fusionio.com | REDEFINE WHAT’S POSSIBLE