Open-Channel Solid State Drives

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Vault

Solid State Drives

- Thousand of IOPS and low latency (<1ms)
- Hardware continues to improve
  - Parallel architecture
  - Larger flash chips

- Replaceable for traditional harddrives
- Embedded software maintains complexity

Embedded FTLs: No Future

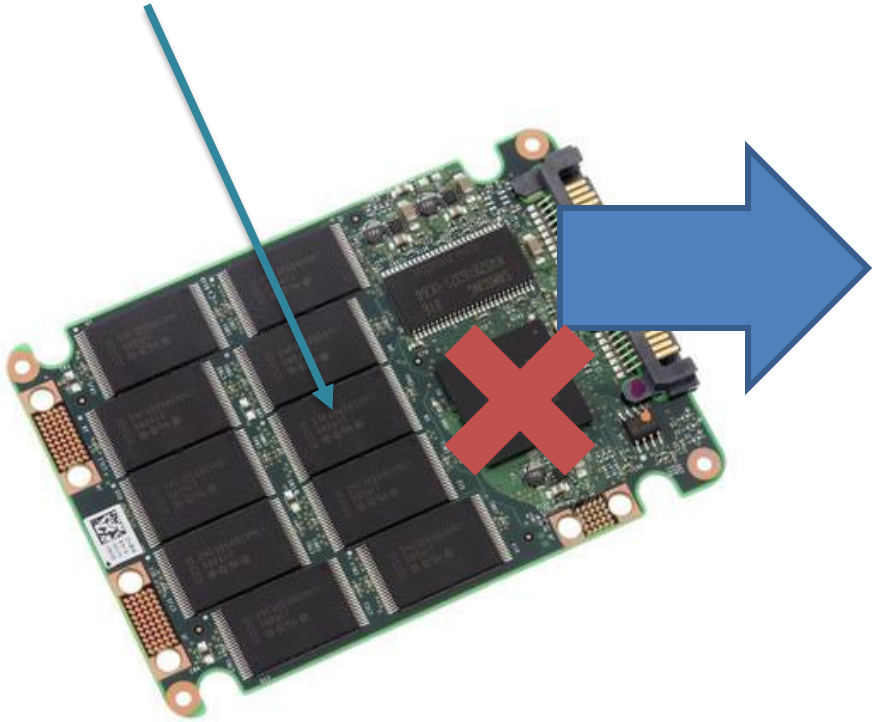
- Dealing with flash chip constraints is a necessity
  - No way around some form of FTL
- Embedded FTLs were great to guarantee adoption, but have critical limitations:
  - Hardwire design decisions about data placement, overprovisioning, scheduling, garbage collection and wear leveling
  - Based on more or less explicit assumptions about the application workload
  - Resulting in redundancies, missed optimizations and underutilization of resources

Market Specific FTLs

- SSDs on the market with embedded FTLs targeted at specific workloads (90% reads) or applications (SQL Server, KV store)
- FTL is no longer in the way of a given application
- What if the workload or application changes?
- What about the other workloads or applications?

Open-Channel SSDs

Physical flash exposed to the host (Read, write, erase)



Host

- Data placement
- IO Scheduling
- Over-provisioning
- Garbage collection
- Wear levelling

Where are Open-Channel SSDs useful?

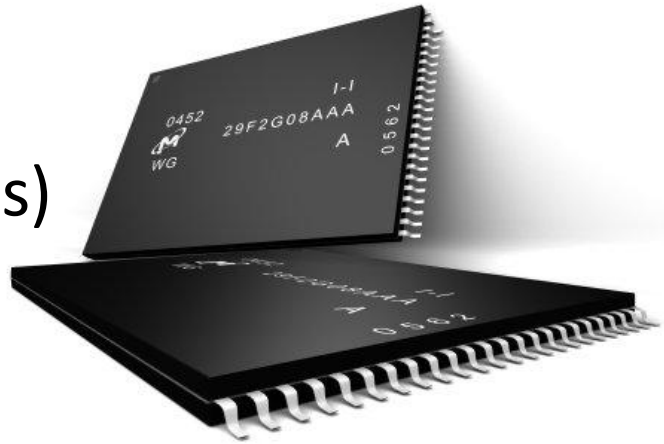
- Data centers with multi-tenancy environments
- Software-defined SSDs
  - Managed storage centrally across open-channel SSDs.
  - NAND flash shared at fine-granularity
- Applications that have specific needs can be serviced by a FTL tailored to their needs (Application-driven FTLs).

New Logical Abstractions

- How is flash exposed to the host?
  - Traditional Flash Translation Layer
    - Both metadata and data are managed by the host
  - New interfaces
    - LUNs (The parallel unit of SSDs)
    - Key-value database (e.g. LevelDB and RocksDB)
    - Object-store (OSSD)
    - Application-driven (New research area)
    - File-system (NVMFS)
    - Hybrid FTL (Traditional FTL is expensive, offload metadata consistency to device)
  - Manage multiple devices under a single address space
    - Including garbage collection (Global FTL)

What should the host know?

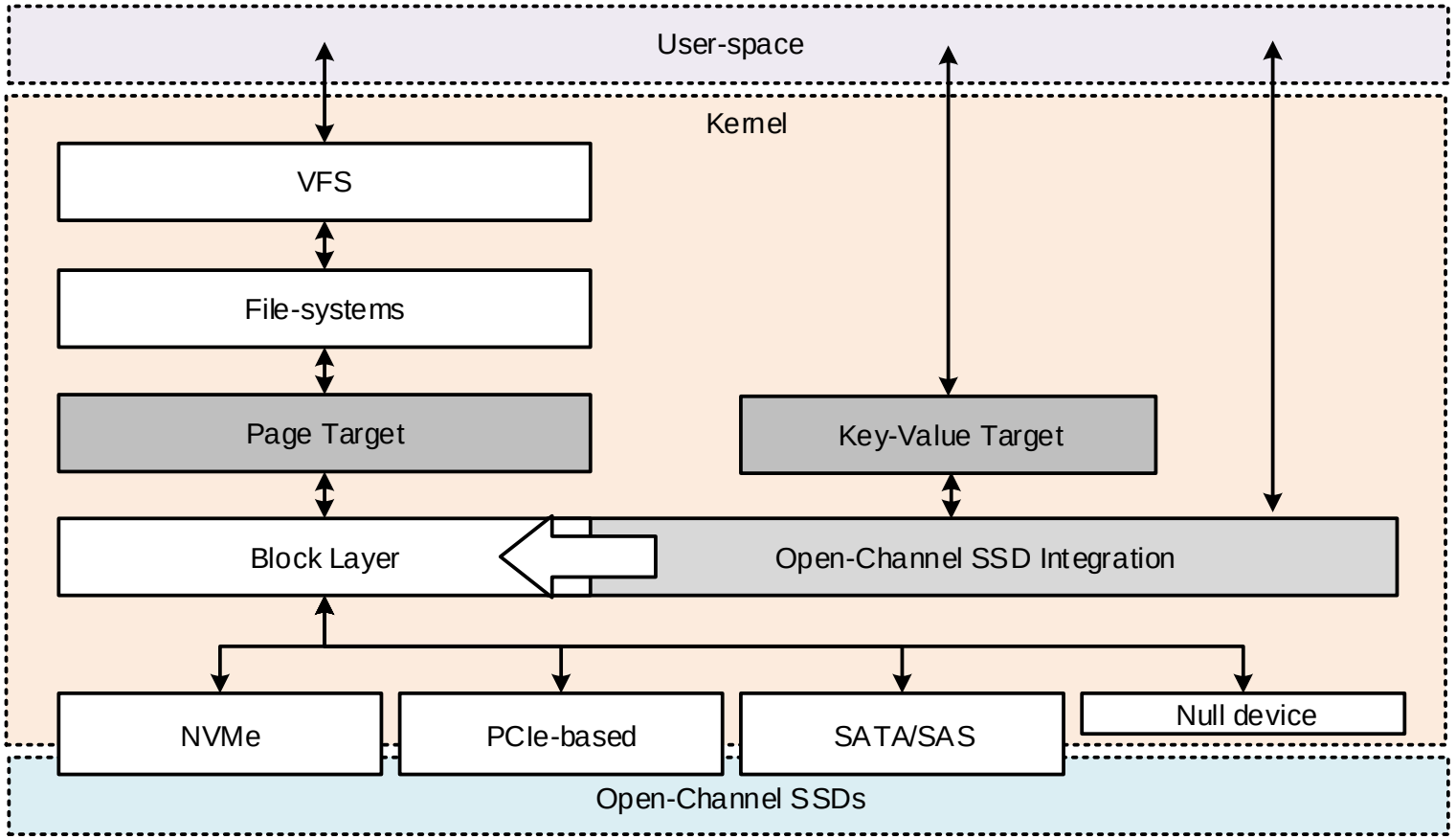
- SSD Geometry
  - NAND idiosyncrasies
  - Die geometry (Blocks & Pages)
  - Channels, Timings, Etc.
  - Bad blocks
  - Error-Correcting Codes (ECC)
- Features and Responsbilities



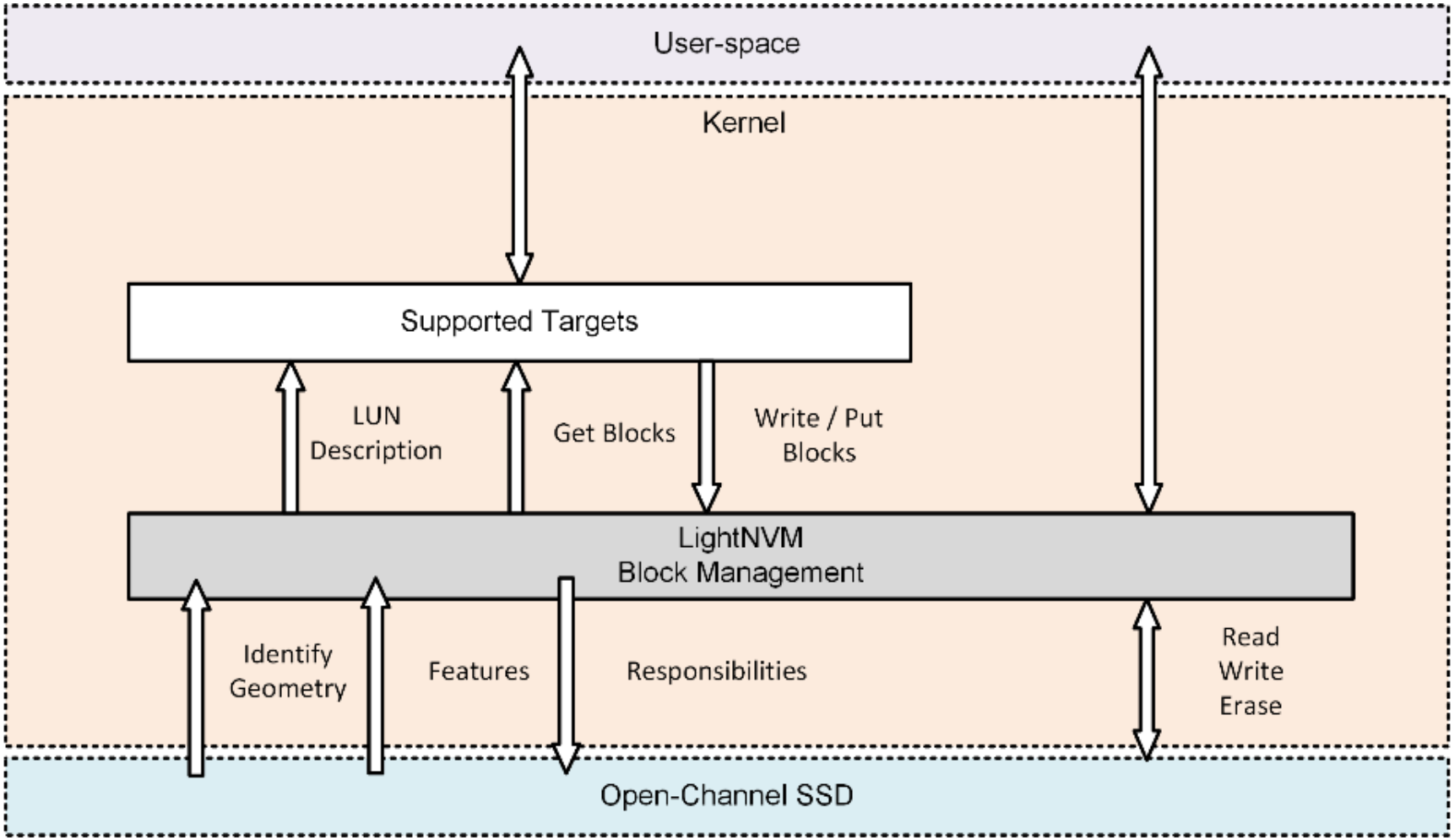
Kernel Integration

- Generic core features for flash-based SSD management such as:
  - List of free and in-use blocks, handling of flash characteristics, and global state.
- Targets that expose a logical address space, possibly tailored for the needs of a class of applications (e.g., key-value stores or file systems)

Architecture



Responsibilities



Hybrid Target

- Host-side Translation table and reverse mapping table (for GC) in host
- Device maintains metadata consistency
  - Offloads metadata overhead at the cost of disk also maintaining translation table
- Sequential mapping of pages within a block
- Cost-based garbage collection
- Inflight tracking
  - Guarantee atomicity of writes

Hybrid Target per Request

Component	Description	Native Latency(us)		LightNVM Latency(us)	
		Read	Write	Read	Write
Kernel and fio overhead	Submission and completion	1.18	1.21	1.34 (+0.16)	1.44 (+0.23)
Completion time for devices	High-performance SSD	10us (2%)			
	Null NVMe hardware device	35us (0.07%)			
	Common SSD	100us (0.002%)			

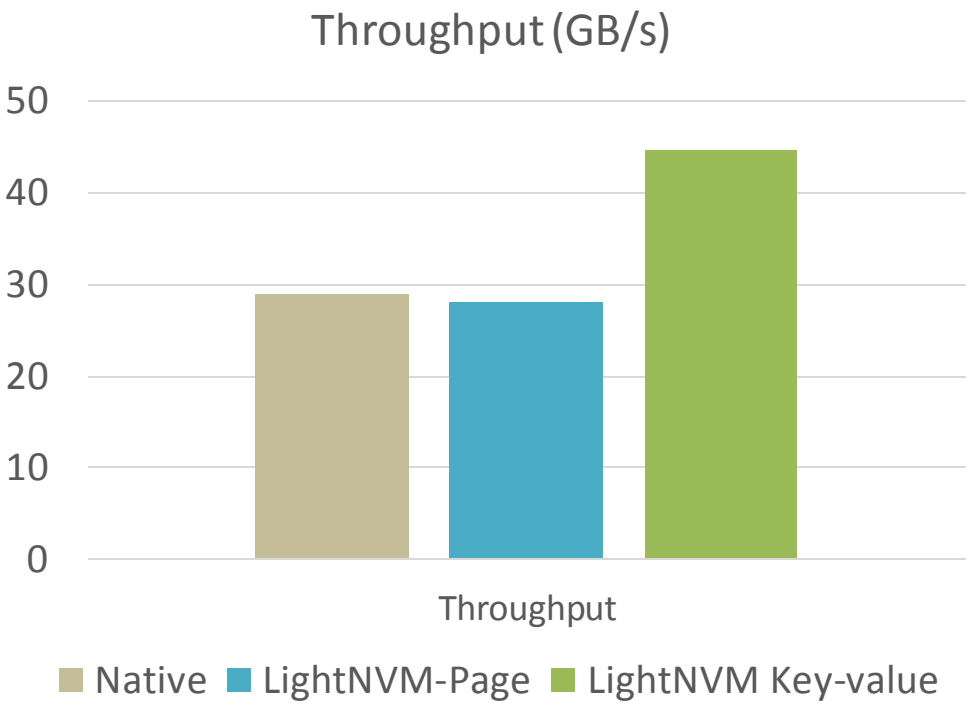
System: i7-3960K, 32GB 1600Mhz – 4K IOs

Low overhead compared to hardware overhead
0.16us on reads and 0.23us on writes

Key-value Target

1 MB Writes

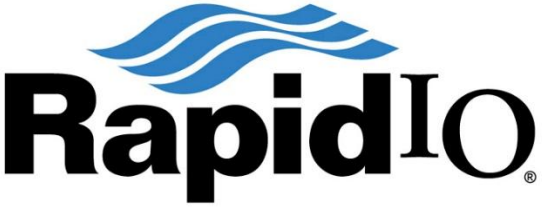
Metric	Native	LightNVM -Page	LightNVM Key-value
Throughput	29GB/s	28.1GB/s	44.7GB/s
Latency	32.04µs	33.02µs	21.20µs
Kernel Time	66.03%	67.20%	50.01%



Kernel time overhead 30% serving 1MB writes.
Opportunities for application-driven FTLs

Industry Vendors

- MemBlaze
  - Available hardware
- PMC Sierra
  - Builds support in user-space
- IIT Madras
  - Builds HW using RapidIO SRIO
- Stealth startups and others
  - Storage Arrays
  - Applications



Source Layout

- Open-channel SSD initialization
  - /block/blk-nvm.c – Initialization/Registration
  - /include/linux/blkdev.h – Common NVM structures
- Targets
  - /drivers/nvm
    - Round-robin page-based with cost-based GC FTL (rrpc)

Open-channel SSD initialization

- Device drivers register the block device as an Open-channel SSD device
  - Device is queried for geometry and configured
- `blk_nvm_register(struct request_request *, struct blk_nvm_ops *)`
- `struct blk_nvm_ops`
  - `identify`
  - `get_features`
  - `set responsibility`
  - `get l2p`
  - `erase_block`

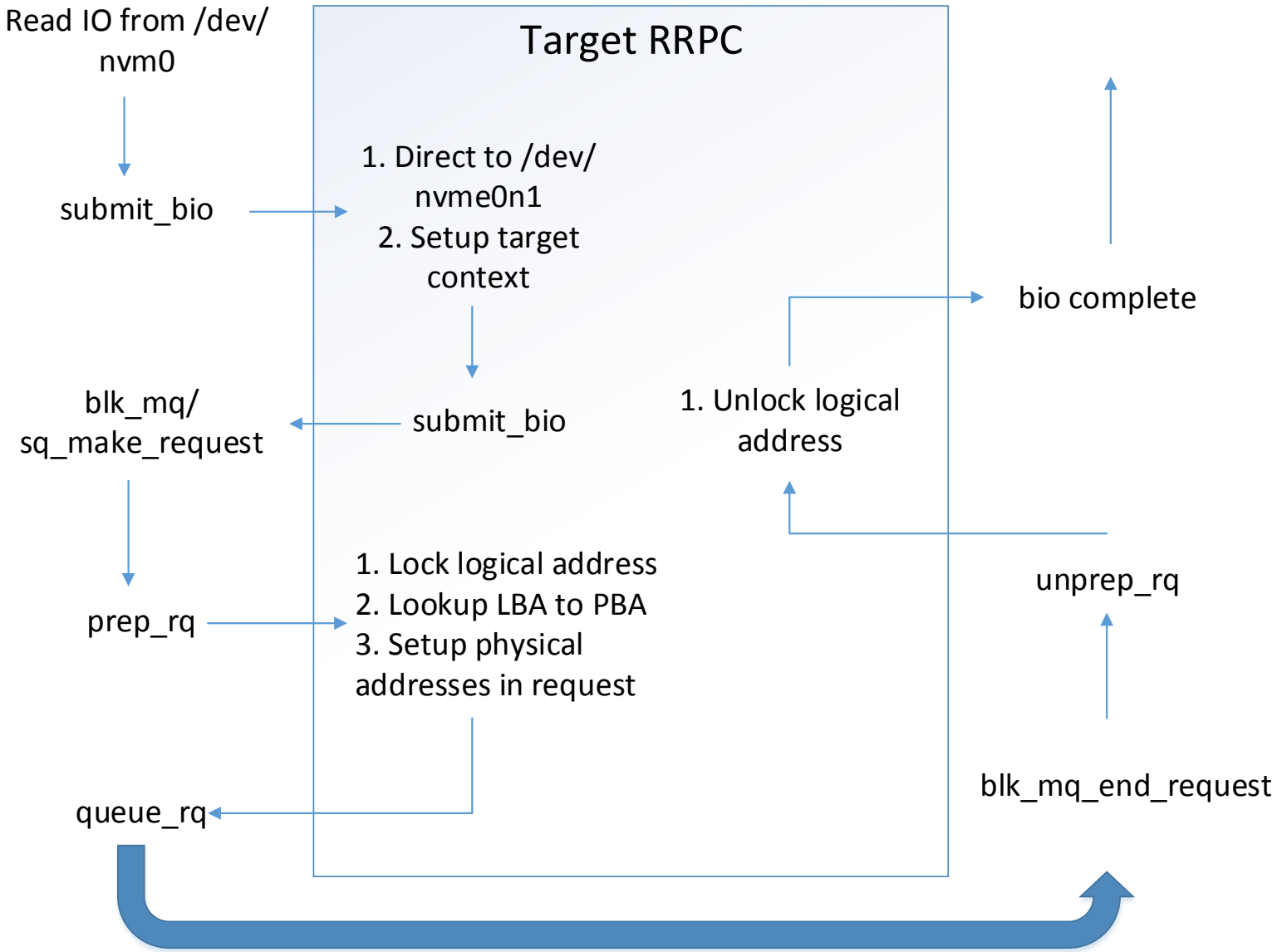
Block Layer Structures /includes/linux/blkdev.h

- struct nvm_dev (1 per device)
  - Describes the characteristics of the device
- struct nvm_lun (N per device, 8-16)
  - Information about luns and status of flash blocks
- struct nvm_block (M per device, 1024+)
  - Information about each flash block state

Target Interface

- Uses the interface provided by the block layer
  - blk_nvm_get_blk(struct nvm_lun *)
  - blk_nvm_put_blk(struct nvm_block *)
- Target reserves flash blocks and writes data
- Reads can either be resolved by device or physical LBAs
- Implements target_type interface
  - make_request, prep_rq/unprep_rq, init/exit

RRPC Flow


Read IO from /dev/ nvm0
submit_bio
Target RRPC
1. Direct to /dev/ nvme0n1
2. Setup target context
bio complete
blk_mq/ sq_make_request
submit_bio
1. Unlock logical address
prep_rq
1. Lock logical address
2. Lookup LBA to PBA
3. Setup physical addresses in request
unprep_rq
queue_rq
blk_mq_end_request

Future

- Integrate with
  - Ceph
  - RocksDB
  - Percona
  - Openstack
  - And many others

- Kernel upstream
- Finalize interface specification together with vendors

https://github.com/OpenChannelSSD

Thanks for Listening

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