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Supporting SPDK in Oracle RDBMS

Akshay Shah, Zahra Khatami, Bang Nguyen, Avneesh Pant, Rajarshi Chowdhury and Sumanta Chatterjee

Oracle, VOS Group
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Program Agenda

1. **Challenges**
2. SPDK and Oracle Database Architecture
3. OraEnv
4. Oracle Dispatcher
5. Oracle Database Support Model

Challenges

1. **Memory Management**: Oracle instance must manage all the resource allocations within the SPDK libraries.

2. **Security**: There is no read/write access security policy provided for the memory shared across all the secondary processes spawned in SPDK:

   I. Allocates private/shared memory from same area.
   II. Shares memory map with both primary/secondary processes.

Challenges

3. **Recoverability**: We want to prevent memory leaks, detect, and isolate memory corruption incidents.

4. **Restartability**: We want SPDK processes to be restartable.

5. **Scalability**:

✓ Modern RDMA NICs have known scaling limitations in presence of large number of connections and memory regions due to the limited caches on the device.

✓ Limited number of the I/O queues on NVMe devices precludes in-band dispatch of the local I/Os from Oracle processes.

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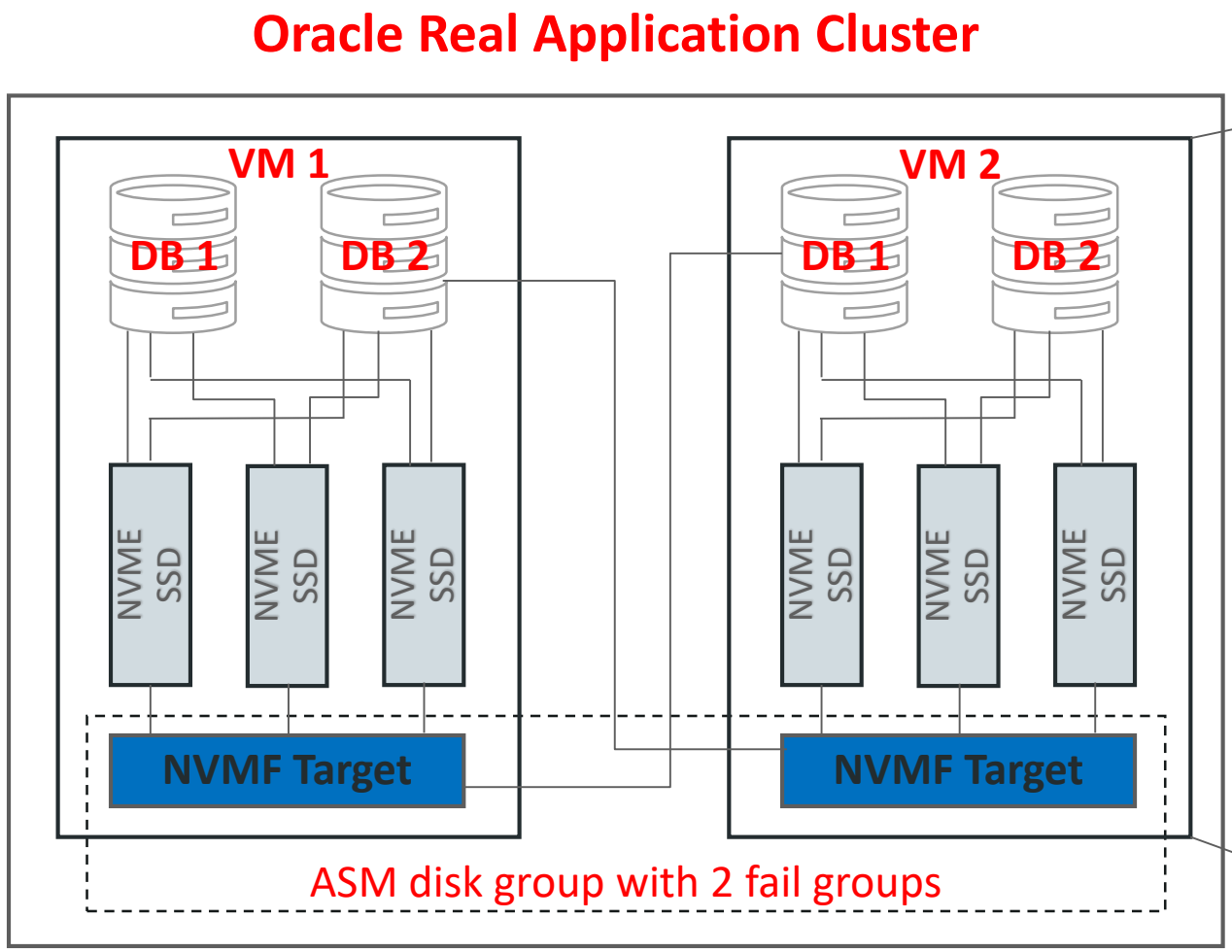
SPDK and Oracle Database Architecture



Database NVM I/O module		
Device Management	**Local I/O**	**Remote I/O**
Oracle EAL	Oracle NVM dispatcher	Oracle NVM library
Enumerate PCIe devices	SPDK I/O to PCIe ns	SPDK I/O to NVMe-oF ns
Memory Management		Zero-copy RDMA for IB and RoCEE. bcopy for TCP
Rkey/ lkey Management		

SPDK and Oracle Database Architecture

- High-performance I/O subsystem capable of delivering millions of IOPS.
- Guarantees low latency by eliminating overheads in I/O code path.
- Enables multiple databases to securely access the same devices.
- Provides fault tolerance from software bugs and malicious workloads.
- Provides scalable RDMA capability with large number of connections.
- High availability using Oracle RAC, ASM and NVMe-oF technologies.

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OraEnv

- ✓ Getting rid of DPDK (Sorry! ☹)
- ➢ In spdk/lib/Makefile

```
# If CONFIG_ENV is pointing at a directory in lib, build it.
# Out-of-tree env implementations must be built separately by the user.
ENV_NAME := $(notdir $(CONFIG_ENV))
ifeq ($(abspath $(CONFIG_ENV)),$(SPDK_ROOT_DIR)/lib/$(ENV_NAME))
DIRS-y += $(ENV_NAME)
endif
```

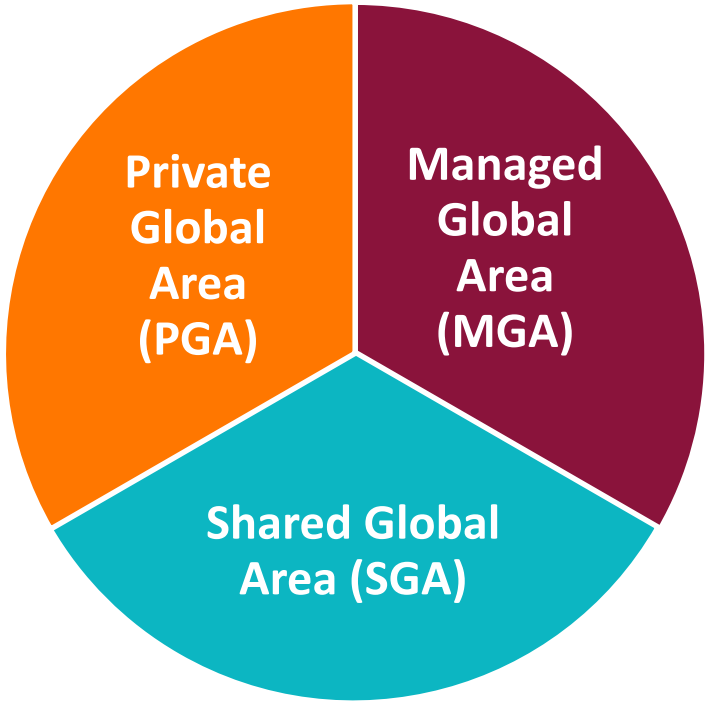
- ✓ Introducing OraEnv: Complete implementation of SPDK Env

```
struct spdk_env_opts {
        const char *name;
        const char *core_mask;
        int shm_id;
        int mem_channel;
        int master_core;
        int mem_size;
        bool no_pci;
        bool hugepage_single_segments;

        bool unlink_hugepage;
        size_t num_pci_addr;
        const char *hugedir;
        struct spdk_pci_addr *pci_blacklist;

        struct spdk_pci_addr *pci_whitelist;


        /** Opaque context for use of the env implementation. */

         void *env_context;
};
```

OraEnv

- Memory managements (allocations/deallocations/physical addresses)
- Providing rkeys/lkeys
- PCIe scanning/enumerations
- lcore initialization
- Enhancements for RDMA transfers with NVMe-oF

OraEnv: Memory Managements



Kgh

- Space is organized into Heaps.
- A heap can either be allocated in space that is private to a particular process or space that is shared by many processes.
- When a user asks for a chunk of space, that chunk will come from a particular heap.
- A heap is composed of a set of contiguous chunks.
- Returns the set of extents contained in the heap.

OraEnv: Memory Managements

Shared memory:

1. Globally shared areas
   - Controllers pages
2. Managed global areas (MGA)
   - Data path

```
/**
* Memory is dma-safe.
*/
#define SPDK_MALLOC_DMA 0x01

/**
* Memory is sharable across process boundries.
*/
#define SPDK_MALLOC_SHARE 0x02
```

```
void *spdk_malloc(size_t size, size_t align, uint64_t *phys_addr, int socket_id, uint32_t flags);
```

```
void *spdk_zmalloc(size_t size, size_t align, uint64_t *phys_addr, int socket_id, uint32_t flags);
```

OraEnv: Memory Managements

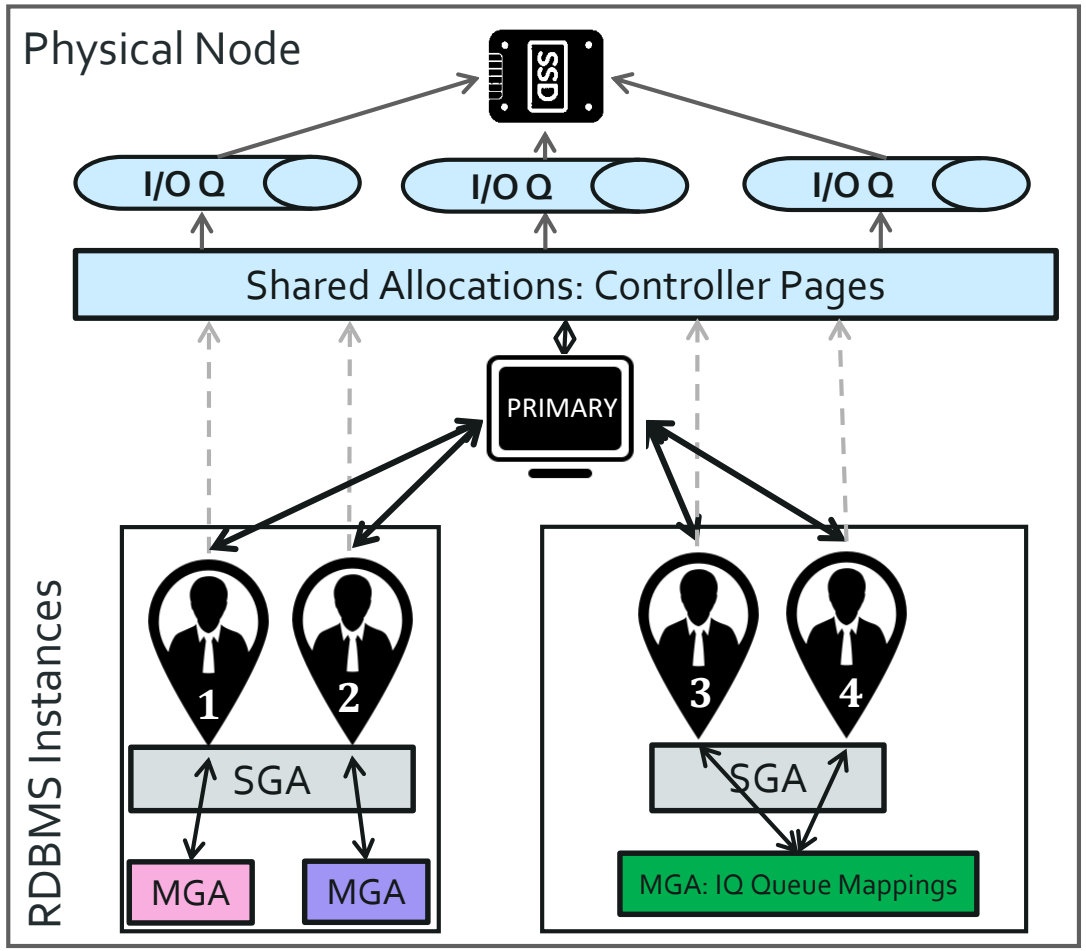
Two types of processes:

1. Primary

✓ The shared memories are requested from a primary process and all the clients have same accesses to them.

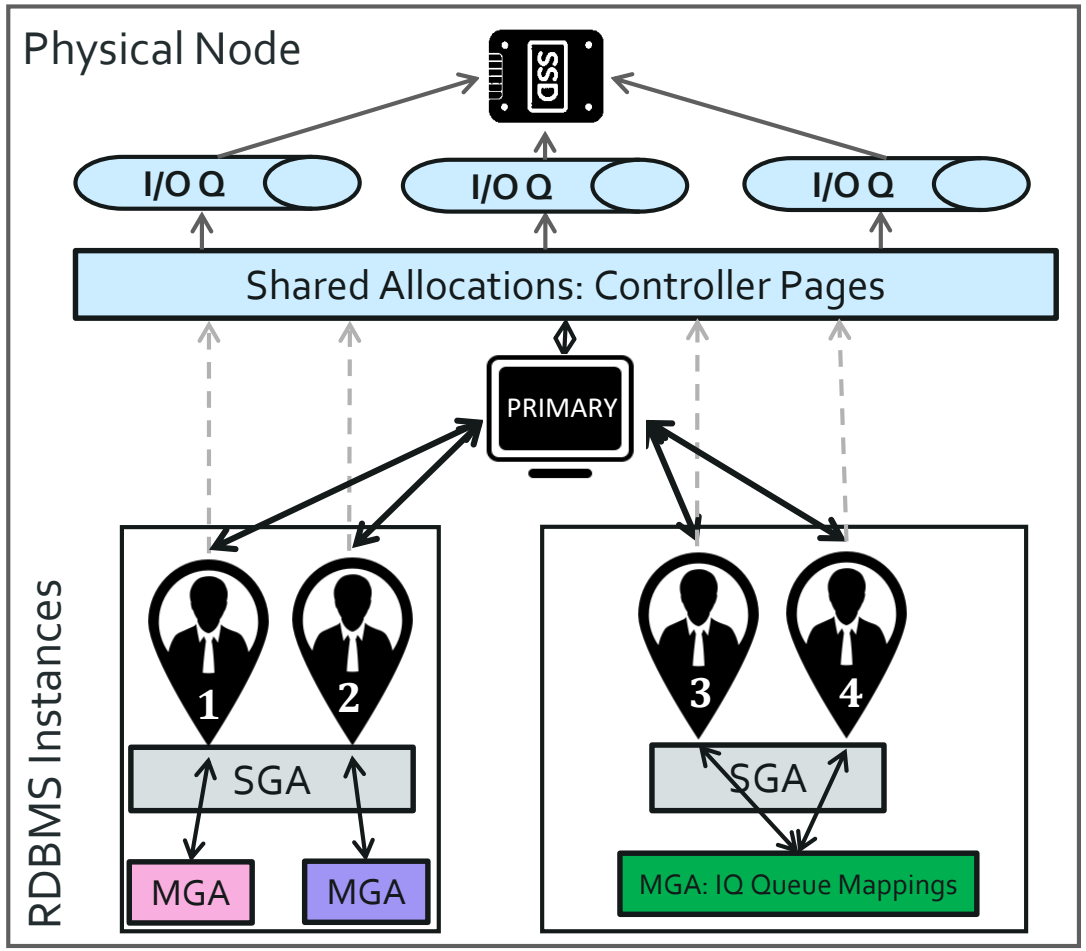
2. Secondary

✓ MGA can be configured to be shared between specific processes



OraEnv: Memory Managements

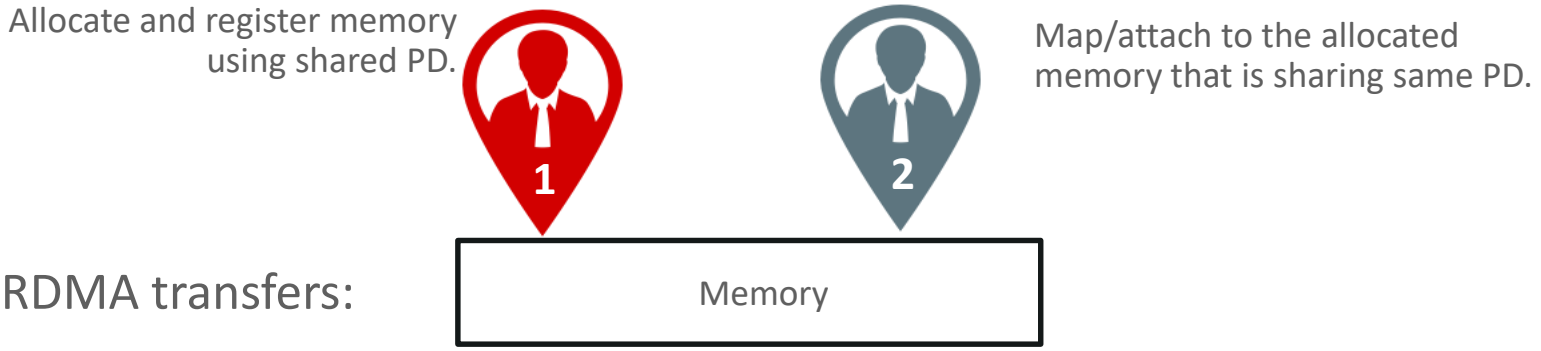
- ✓ **Security**: Clients 3 and 4 are attached to the same MGA section that is isolated from clients 1 and 2. It allows us to share DMA resources across instances.
- ✓ **Recoverability**: Preventing memory leakages and data loss.
- ✓ **Restartability:** For both primary and target processes



OraEnv: Enhancements for RDMA transfers

Registering entire memory ... ch process is not scalable

Using shared PD



- MGA allocations are optimized for RDMA transfers: using shared PD registration.
- Providing lkey/rkeys
- It utilize a single RDMA Protection Domain across all Oracle processes.
- PD is valid as long as one user process attached to it.

OraEnv: Enhancements for RDMA transfers

- New hooks in nvme.h
- An interface for users to provide their own pd/mr/rkeys in both nvme and nvmf libraries.

RDMA Transport Hooks

```
struct spdk_nvme_rdma_hooks {
    struct ibv_pd *(*get_ibv_pd)(const struct spdk_nvme_transport_id *trid,
                                 struct ibv_context *verbs);

    uint64_t (*get_rkey)(struct ibv_pd *pd, void *buf, size_t size);

};
```

Getting pd

```
rctrlr->pd = g_nvme_hooks.get_ibv_pd(&rctrlr->ctrlr.trid, rqpair->cm_id->verbs);
```

```
rc = spdk_mem_map_set_translation(map, (uint64_t)vaddr, size, g_nvme_hooks.get_rkey(pd, vaddr, size));
```

Getting rkey

OraEnv Performance

1. 2 node RoCEE setup with 2x 18-core Xeon Gold 6154 CPU.
2. 1x Intel P4500 PCIe SSD

	OraEnv IOPS	OraEnv MB/s	DPDK IOPS	DPDK MB/s	%	Faster
Perf with PCIe	646422	2525	639311	2497	1.1	OraEnv
Perf with Target (loopback)	623225	2434	623448	2435	--	SAME
Perf with Target (Remote)	388854	3037	397176	3102	2	DPDK

*Performance data is still WIP.

OraEnv: Target

- Fully enterprise secured
- Highly resilient and recoverable
- High availability (HA)

- Getting name spaces
- Analyzing memory consumption and resource utilizations
- Getting the number of clients connected to nvmf_tgt

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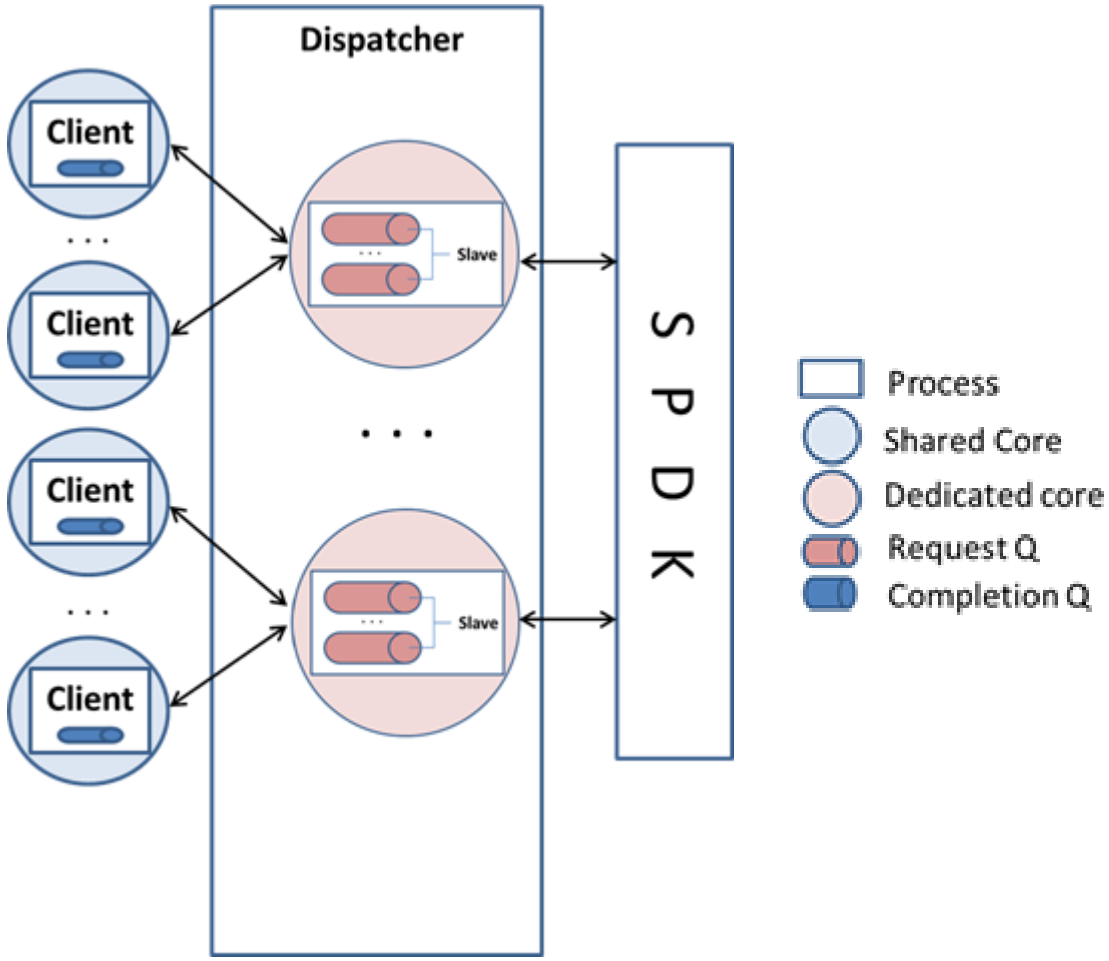
Oracle SPDK I/O stack

- NVMe devices are discovered as ASM disks.
- ASM fail groups created using local (PCIe) and remote (NVMe-oF) NVMe devices.
- Writes are mirrored to local and remote devices.
- Reads are always issued to local fail group when available.
- Local SGA I/Os are handled by Oracle dispatcher slave using PCIe name space.
- Local PGA I/Os are submitted directly to SPDK using the NVMe-oF name space.
- Remote I/Os are submitted directly to SPDK using the NVMe-oF name space.

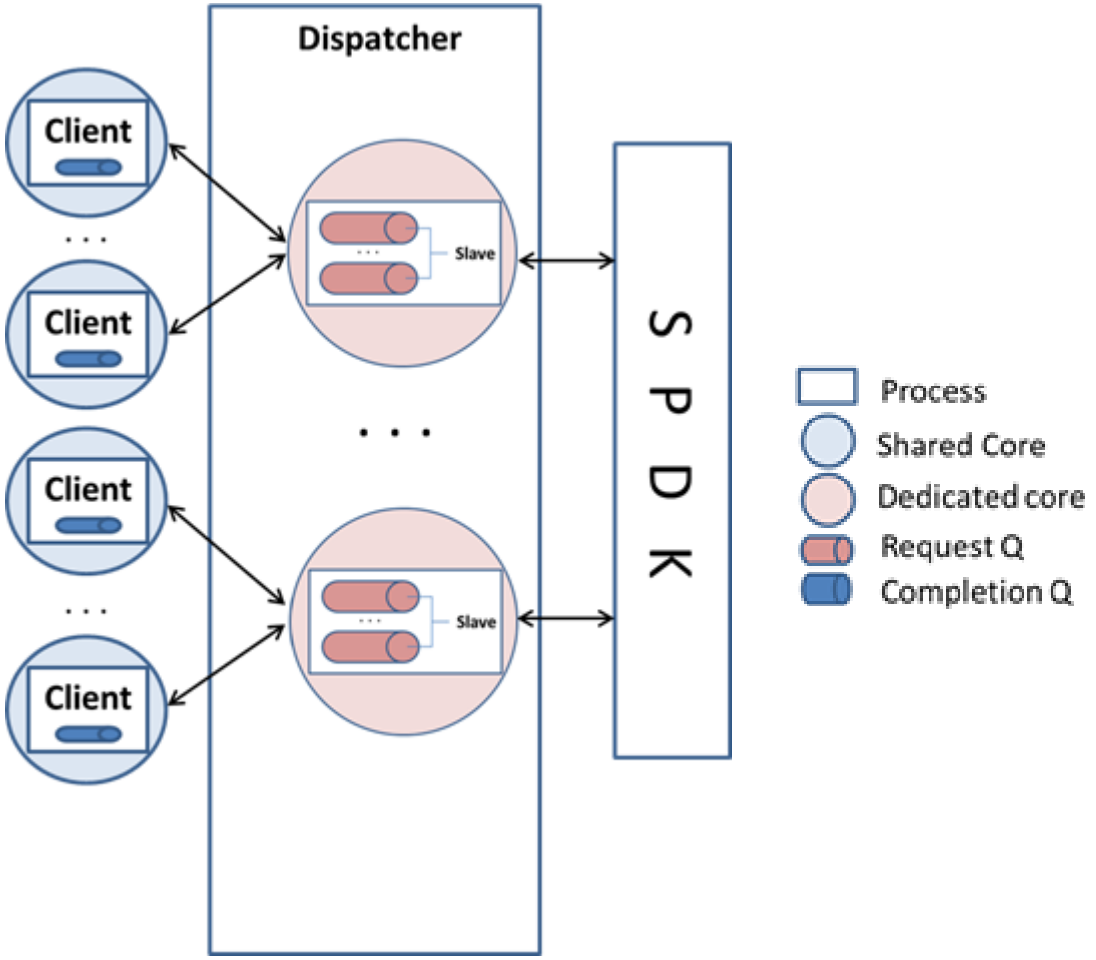
Oracle Dispatcher

- Local IO proxy that runs one or more slaves.
- Each Slave gets its own core.
- Each Slave has one or more request queues.
- Request queue implemented as a lock-free ring.
- Slave processes IO requests from clients.
- Queues IO completions to client completion queues.
- Runs as secondary process to Oraenv primary.



Oracle Client

- Bound to specific Dispatcher Slave/Request queue
- Clients bound to the same Request queue must run on separate cores.
- Clients bound to different Request queues can run on the same core.
- Each client has its own completion queue.
- Submits I/O requests to the Slave request queue.
- Polls I/O completions from its completion queue.



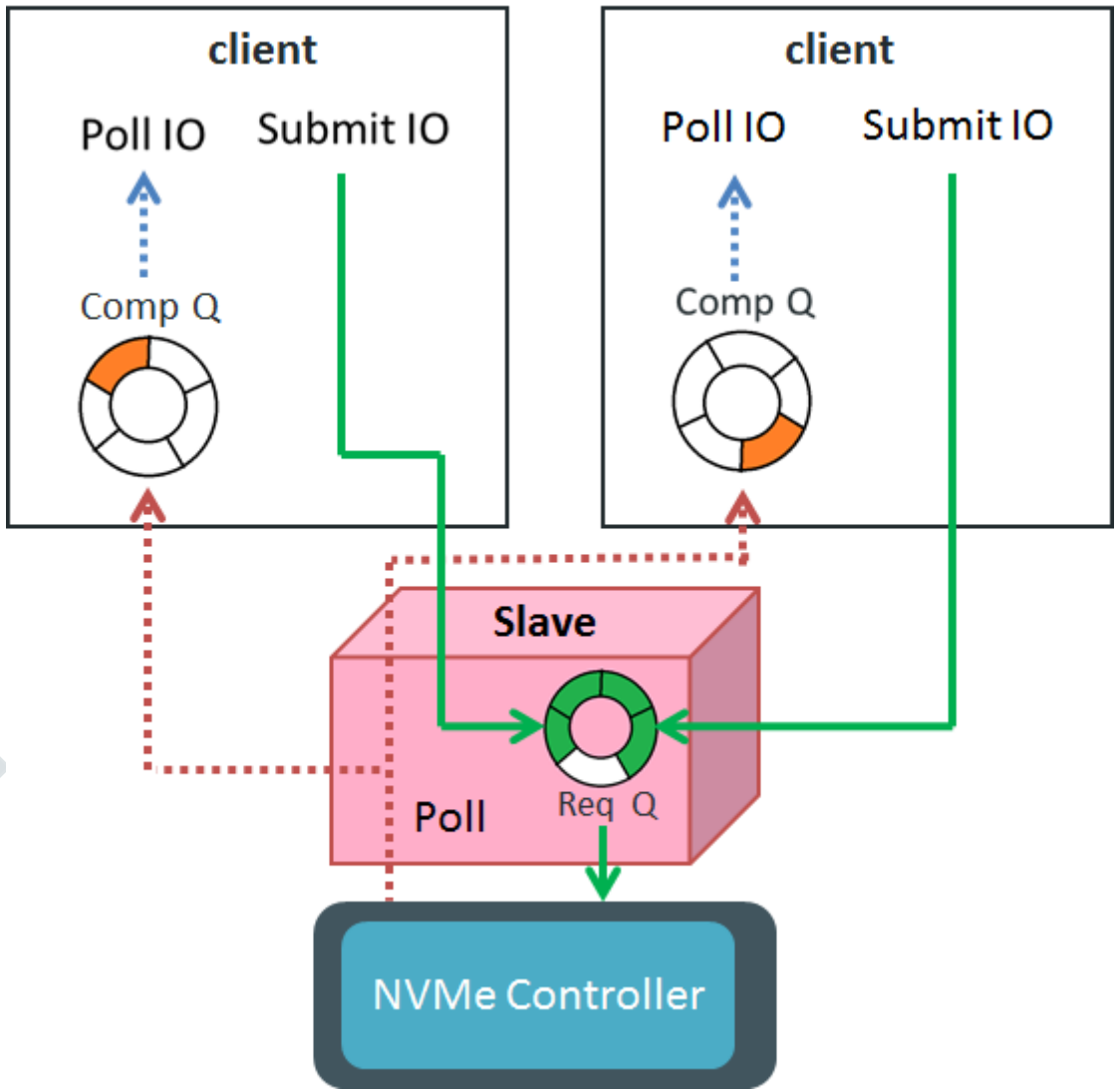
Lock-free Queues

Request Queue

- Multiple producers Single consumer queue.
- IO clients submit requests and Dispatcher Slave processes them.

Completion Queue

- Single producer Single consumer queue.
- Dispatcher Slave queue IO completions and Client reaps them.



Oracle NVM Dispatcher Performance

- 3 node Oracle X6 server based RAC setup.
- 2x 10-core Xeon E5- 2630 v4 processors.
- 6x Samsung PM1725 NVMe PCIe SSDs.
- High redundancy ASM disk group with preferred local (PCIe) fail group.
- Database I/O calibration workload.
- 1.7M random 8 KB read IOPS with 4 dispatcher slaves*
- 2.25M random 8 KB read IOPS with 8 dispatcher slaves*

*Performance data is still WIP.

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Oracle Database Deployment Model

- Traditionally deployed on-premise in customer data centers.
- Long term release (LTR) supported for multiple (5-7) years.
- Grid Infrastructure (GI) software manages the cluster.
- GI is backward compatible for older database (DB) software releases.
- ASM and Oraenv will be included as part of GI.
- Customers can run multiple DB software versions with the same GI.

SPDK Compatibility and Support

- How do SPDK releases fit into the database deployment model?
- SPDK LTS release is a good start.
- How will critical and security bug fixes be backported to LTS release?
- API and ABI stability is essential to minimize client disruption.
- API and ABI stability limits the complexity involved in backporting fixes.
- How do we achieve the above with SPDK new feature development?


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