NVMe Over Fabrics: Scaling Up With The Storage Performance Development Kit

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Agenda

- Background
- Design Overview
- Benchmarking
  - Connections
  - Memory
  - CPU cores
Background

- Storage Performance Development Kit
  - BSD Licensed collection of C libraries
  - User-space drivers, storage targets
  - http://www.spdk.io
Requirements

- User-space NVMe-oF Target
  - Leverage SPDK user-space drivers
- Zero copy
- Polled-mode
- Linear scaling (w/ CPU, network, storage)
Linear Scaling

- Avoid locks and atomics
  - Ok to make management operations more time consuming to avoid interrupting I/O path
- Avoid cache contention
  - Keep each core focused on an independent job, as much as possible
- NUMA awareness
NVMe-oF Primitives

- `spdk_nvmf_tgt`
  - `spdk_nvmf_subsystem`
  - `spdk_nvmf_transport`
NVMe-oF Subsystems

- Subsystems are **global**
  - Subsystems have states
    - Inactive
    - Paused
    - Active
  - `spdk_nvmf_subsystem` may only be modified while not in the active state.
- Contains controllers and namespaces
NVMe-oF Primitives

- spdk_nvme_poll_group
  - spdk_nvme_subsystem_poll_group
  - spdk_nvme_transport_poll_group
NVMe-oF Transport Poll Groups

- Per-thread collection of transport data
  - Uses a transport-specific mechanism to efficiently poll the group
    - RDMA: Shared completion queue
    - FC: Shared hardware queue pair
    - TCP: epoll/kqueue
  - The queue pairs are not necessarily related to one another
NVMe-oF Subsystem Poll Groups

- Per-thread collection of subsystem data
  - Contains thread-unique I/O channels for each namespace in the subsystem.
  - Think of an I/O channel as an NVMe queue pair for the local device.
Accepting a New Connection

spdk_nvmf_tgt_accept()

new_qpair_fn(qpair)

spdk_nvmf_poll_group_add(qpair)

When does a queue pair identify which subsystem it belongs to?
Performing an I/O

- No Locks!
- Touches only thread-local data (cache friendly)!
- Lookups are all array math!

Poll group checks for incoming requests associated with a subsystem and targets a namespace.

Look up I/O channel for subsystem + namespace in subsystem.

Use I/O channel to submit I/O to bdev layer.
Scaling: Active Connections

Single Core

Number of Active Connections (Queue Depth 32)

System Configuration: 2x Intel® Xeon® Platinum 8180 CPU @ 2.50 GHz, Intel® Speed Step enabled, Intel® Turbo Boost Technology enabled, 4x 2GB DDR4 2666 MT/s, 1 DIMM per channel, Ubuntu* Linux 17.10, Linux kernel 4.13.0, SPDK 18.04, DPDK 18.01, Mellanox® ConnectX-4 MT27700
Scaling: Idle Connections

System Configuration: 2x Intel® Xeon® Platinum 8180 CPU @ 2.50 GHz, Intel® Speed Step enabled, Intel® Turbo Boost Technology enabled, 4x 2GB DDR4 2666 MT/s, 1 DIMM per channel, Ubuntu* Linux 17.10, Linux kernel 4.13.0, SPDK 18.04, DPDK 18.01, Mellanox® ConnectX-4 MT27700
Memory Usage vs Number of Connections

System Configuration: 2x Intel® Xeon® Platinum 8180 CPU @ 2.50 GHz, Intel® Speed Step enabled, Intel® Turbo Boost Technology enabled, 4x 2GB DDR4 2666 MT/s, 1 DIMM per channel, Ubuntu* Linux 17.10, Linux kernel 4.13.0, SPDK 18.04, DPDK 18.01, Mellanox® ConnectX-4 MT27700
Performance vs Number of CPU cores

System Configuration: 2x Intel® Xeon® Platinum 8180 CPU @ 2.50 GHz, Intel® Speed Step enabled, Intel® Turbo Boost Technology enabled, 4x 2GB DDR4 2666 MT/s, 1 DIMM per channel, Ubuntu® Linux 17.10, Linux kernel 4.13.0, SPDK 18.04, DPDK 18.01, Mellanox® ConnectX-4 MT27700

4K Read I/O Per Second

 Millions

Number of CPU Cores (Target)

1 2 3 4

1 1.5 2 2.5 3 3.5 4 4.5

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5

1 2 3 4