SPDK BASED USER SPACE NVME OVER TCP TRANSPORT SOLUTION

Presenters: Ziye Yang
Company: Intel
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AGENDA

• SPDK NVMe-oF development history & status
• SPDK TCP transport introduction
• Conclusion
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SPDK NVMe-oF Target Timeline

19.04: CONTINUING IMPROVEMENT
19.01: TCP TRANSPORT RELEASED
17.11 - 18.11: RDMA TRANSPORT IMPROVEMENTS
17.03 - 17.07: FUNCTIONAL HARDENING
JULY 2016: RELEASED WITH RDMA TRANSPORT SUPPORT
SPDK NVMe-oF Host Timeline

- DEC 2016: Released with RDMA transport support
- 17.11 - 18.11: RDMA transport improvements
- 17.03 - 17.07: Functional hardening (e.g., interoperability test with kernel target)
- 19.01: TCP transport released
- 19.04: Continuing improvement
### SPDK NVMe-oF target design highlights

<table>
<thead>
<tr>
<th>NVMe* over Fabrics Target Features</th>
<th>Performance Benefit</th>
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<tbody>
<tr>
<td>Utilizes user space NVM Express* (NVMe) Polled Mode Driver</td>
<td>Reduced overhead per NVMe I/O</td>
</tr>
<tr>
<td>Group polling on each SPDK thread (binding on CPU core) for multiple transports</td>
<td>No interrupt overhead</td>
</tr>
<tr>
<td>Connections pinned to dedicated SPDK thread</td>
<td>No synchronization overhead</td>
</tr>
<tr>
<td>Asynchronous NVMe CMD handling in whole life cycle</td>
<td>No locks in NVMe CMD data handling path</td>
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General design and implementation

- Follow the SPDK transport abstraction:
  - Host side code: `lib/nvme/nvme_tcp.c`
  - Target side code: `lib/nvmf/tcp.c`
Performance design consideration for TCP transport in target side

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Methodology</th>
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<tr>
<td>Design framework</td>
<td>Follow the general SPDK NVMe-oF framework (e.g., polling group)</td>
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<tr>
<td>TCP connection optimization</td>
<td>Use the SPDK encapsulated Socket API (preparing for integrating other stack, e.g., VPP )</td>
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<tr>
<td>NVMe/TCP PDU handling</td>
<td>Use state machine to track</td>
</tr>
<tr>
<td>NVMe/TCP request life time cycle</td>
<td>Use state machine to track (Purpose: Easy to debug and good for further performance improvement)</td>
</tr>
</tbody>
</table>
TCP PDU Receiving handling for each connection

```c
enum nvme_tcp_pdu_recv_state {
    /* Ready to wait PDU */
    NVME_TCP_PDU_RECV_STATE_AWAIT_PDU_READY,

    /* Active tqpair waiting for any PDU common header */
    NVME_TCP_PDU_RECV_STATE_AWAIT_PDU_CH,

    /* Active tqpair waiting for any PDU specific header */
    NVME_TCP_PDU_RECV_STATE_AWAIT_PDU_PSH,

    /* Active tqpair waiting for payload */
    NVME_TCP_PDU_RECV_STATE_AWAIT_PDU_PAYLOAD,

    /* Active tqpair does not wait for payload */
    NVME_TCP_PDU_RECV_STATE_ERROR,
};
```
SPDK NVMe-oF TCP request life cycle of each connection in target side

/* spdk nvmf related structure */
enum spdk_nvmf_tcp_req_state {
    /
    /* The request is not currently in use */
    TCP_REQUEST_STATE_FREE = 0,
    /
    /* Initial state when request first received */
    TCP_REQUEST_STATE_NEW,
    /
    /* The request is queued until a data buffer is available. */
    TCP_REQUEST_STATE_NEED_BUFFER,
    /
    /* The request is currently transferring data from the host to the controller. */
    TCP_REQUEST_STATE_TRANSFERRING_HOST_TO_CONTROLLER,
    /
    /* The request is ready to execute at the block device */
    TCP_REQUEST_STATE_READY_TO_EXECUTE,
    /
    /* The request is currently executing at the block device */
    TCP_REQUEST_STATE_EXECUTING,
    /
    /* The request finished executing at the block device */
    TCP_REQUEST_STATE_EXECUTED,
    /
    /* The request ready to send a completion */
    TCP_REQUEST_STATE_READY_TO_COMPLETE,
    /
    /* The request is currently transferring final pdus from the controller to the host. */
    TCP_REQUEST_STATE_TRANSFERRING_CONTROLLER_TO_HOST,
    /
    /* The request completed and can be marked free. */
    TCP_REQUEST_STATE_COMPLETED,
    /
    /* Terminator */
    TCP_REQUEST_NUM_STATES,
};
SPDK TARGET SIDE (TCP TRANSPORT): I/O SCALING

System configuration: (1) Target: server platform: SuperMicro SYS2029U-TN24R4T; 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; 2x 100GbE Mellanox ConnectX-5 NICs; Fedora 28, Linux kernel 5.05, SPDK 19.01.1; 6x Intel® P4600TM P4600x 2.0TB; (2) Initiator: Server platform: SuperMicro SYS-2028U TN24R4T+; 44x Intel(R) Xeon(R) CPU E5-2699 v4 @ 2.20GHz (HT off); 1x 100GbE Mellanox ConnectX-4 NIC; Fedora 28, Linux kernel 5.05, SPDK 19.0.1. (3) Fio ver: fio-3.3; Fio workload: blocksize=4K, iodepth=1, iodepth_batch=128, iodepth_low=256, ioengine=libaio or SPDK bdev engine, size=10G, ramp_time=0, run_time=300, group_reporting, thread, direct=1, rw=read/write/rw/randread/randwrite/randrw
**SPDK HOST SIDE (TCP TRANSPORT): I/O SCALING**

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Latency comparison between SPDK and Kernel (null bdev is used)

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IOPS/CORE COMPARISON BETWEEN SPDK AND KERNEL ON TARGET SIDE

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Further development plan

• Continue enhancing the functionality
  • Including the compatible test with Linux kernel solution.

• Performance tuning

• Integration with third party software
  • Deep integration with user space stack: VPP + DPDK

• Leveraging hardware features
  • Use existing hardware features of NICs for performance improvement, e.g., VMA from Mellanox's NIC; load balance features (ADQ) from Intel's 100Gbit NIC.
  • Figuring out offloading methods with hardware, e.g., FPGA, Smart NIC, and etc.
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Conclusion

• SPDK NVMe-oF solution is well adopted by the industry. In this presentation, followings are introduced, i.e.,
  • The development status of SPDK NVMe-oF solution
  • SPDK TCP transport development status.
• Further development
  • Continue following the NVMe-oF spec and adding more features.
  • Continue performance enhancements and integration with other solutions.
• Call for activity in community
  • Welcome to bug submission, idea discussion and patch submission for NVMe-oF