SDC 19

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SPDK based user space NVMe over TCP transport solution

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DCG, **Intel**

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Agenda

- Why NVMe-oF & SPDK solution?
- SPDK NVMe-oF development status
- SPDK NVMe-oF TCP transport introduction
- Conclusion

Why NVMe-oF & SPDK solution?

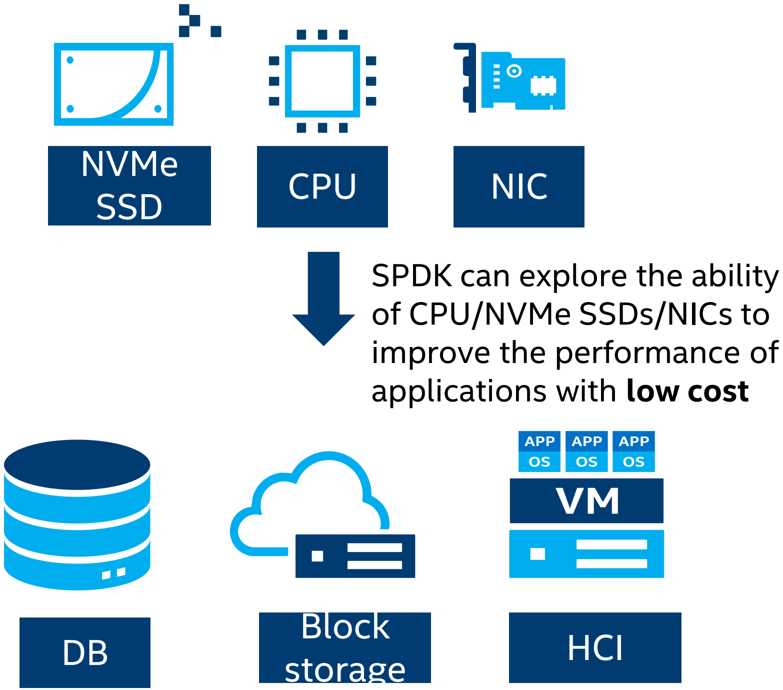
Why NVMe-oF fabrics

- NVMe over Fabrics project Goals: **Simplicity**, **Efficiency**, and **End-to-End** NVMe model
- Scale NVMe remotely, beyond limitation of local PCIe
- Provide remote NVMe performance equivalent to local PCIe
  - Take advantage of inherent parallelism of deep multi-Q model (64 commands/queue, up to 64K queues)
  - Avoid translation to or from other protocols (e.g., SCSI)
  - NVMe commands and structures are transferred end-to-end
- Maintain architecture and software consistency between fabric types by standardizing a **common abstraction** and **encapsulation definition.**
- Storage computing disaggregation VS Storage computing aggregation

Why SPDK based solution?

What is SPDK (storage performance development kit: http://spdk.io)

- *User Space, High Performance, Scalable Library*
- *End-to-End storage accelerated Solution*
- *Extensible Framework and Component*



Why SPDK based user space NVMe-oF solution?

Ingredients	Linux Kernel	SPDK solution
Deployment	Need to upgrade the kernel or backporting (Most cloud storage providers' kernel is old)	Easy to deploy (Because it is in user space)
Performance	Currently, worse than SPDK NVMe-oF solution in per CPU core aspect	Currently Better than Linux kernel solution in IOPS and latency in per CPU core apsect
Spec compliance and functionality	Follow NVMe-oF spec	Follow NVMe-oF spec
Service recovery	Reload the kernel module or reboot kernel	Restart SPDK NVMe-oF target application
Further development challenge for programmers	Need to development the kernel module, difficulty (*****)	Need to develop based on SPDK framework, difficulty (***)

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SPDK NVMe-oF development status ?

SPDK NVMe-oF target timeline

19.04-NOW: 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

19.04-NOW : CONTINUING IMPROVEMENT

19.01: TCP TRANSPORT RELEASED

17.11 – 18.11: RDMA TRANSPORT IMPROVEMENTS

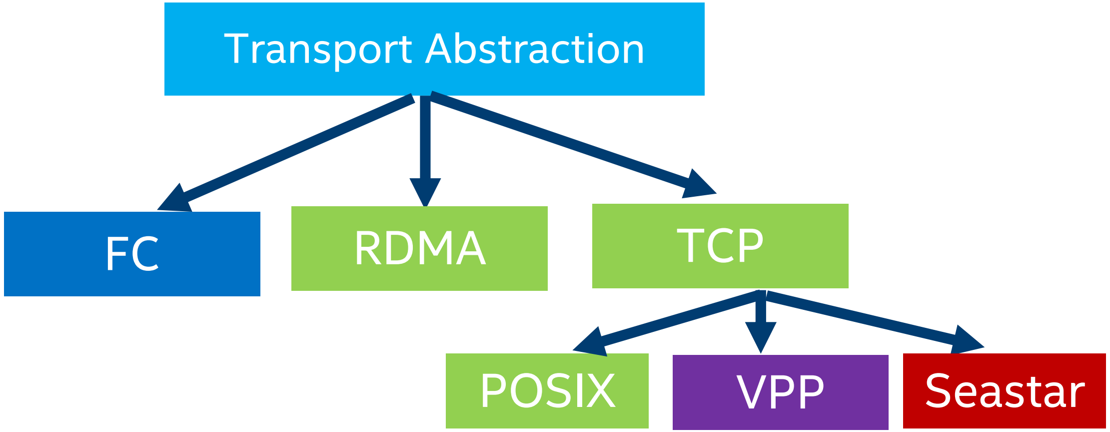
17.03 – 17.07 : FUNCTIONAL HARDENING (E.G., INTEROPERABILITY TEST WITH KERNEL TARGET)

DEC 2016: RELEASED WITH RDMA TRANSPORT SUPPORT

SPDK NVMe-oF target design highlights

NVMe* over Fabrics Target Features	Performance Benefit
Utilizes user space NVM Express* (NVMe) Polled Mode Driver	Reduced overhead per NVMe I/O
Group polling on each SPDK thread (binding on CPU core) for multiple transports	Efficient Parallelism among different CPU cores
Each connection pinned to dedicated SPDK thread	No synchronization overhead among connections.
Asynchronous NVMe CMD handling in whole life cycle	No locks in NVMe CMD data handling path

General design and implementation



Merged, code is available after **19.07** release

Already released

Integrated, but performance tuning is still needed

In investigate phase

SPDK NVMe-oF TCP transport introduction

Comparison between TCP and RDMA Transport ?

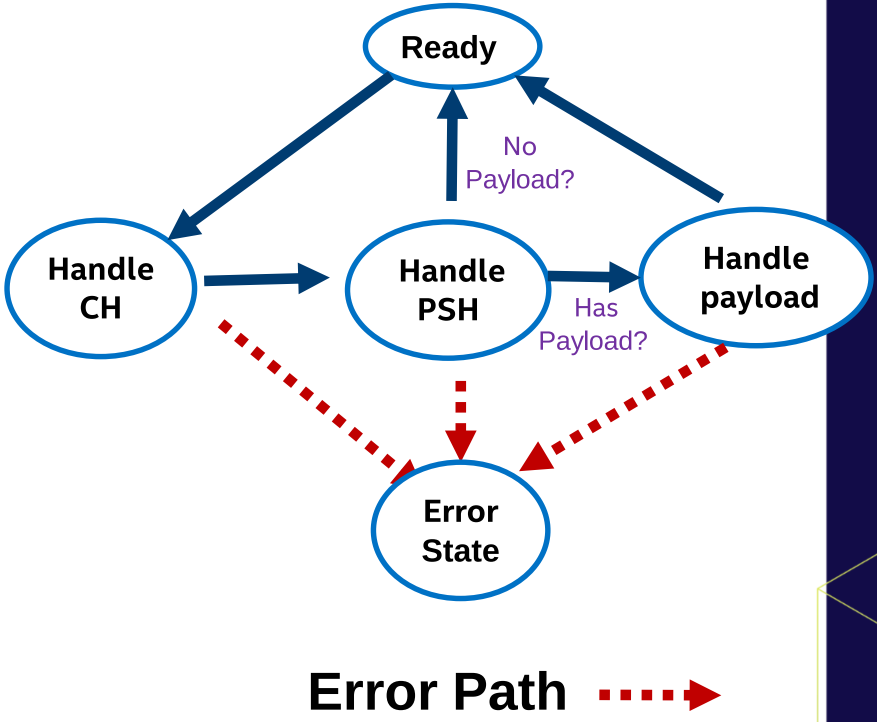
Ingredients	RDMA transport	TCP transport
Performance	High performance	Low performance
Hardware dependency	RDMA capable NICs (supporting RoceV2 or iwarp)	No dependency on NICs (It can reuse the existing NICs in data center)
Physical distance restriction	May only be suitable in a small data center	No distance requirements (suitable for general cloud storage interface)
Programming skills requirements	Must be familiar with RDMA related primitives. (High requirements for developers for debugging)	Relatively easy to debug (Since most programmers are familiar with TCP)
Usage scope	Especially for high performance usage	Can be applied into any usage scenarios due to its flexibility

Performance design consideration for TCP transport on target side

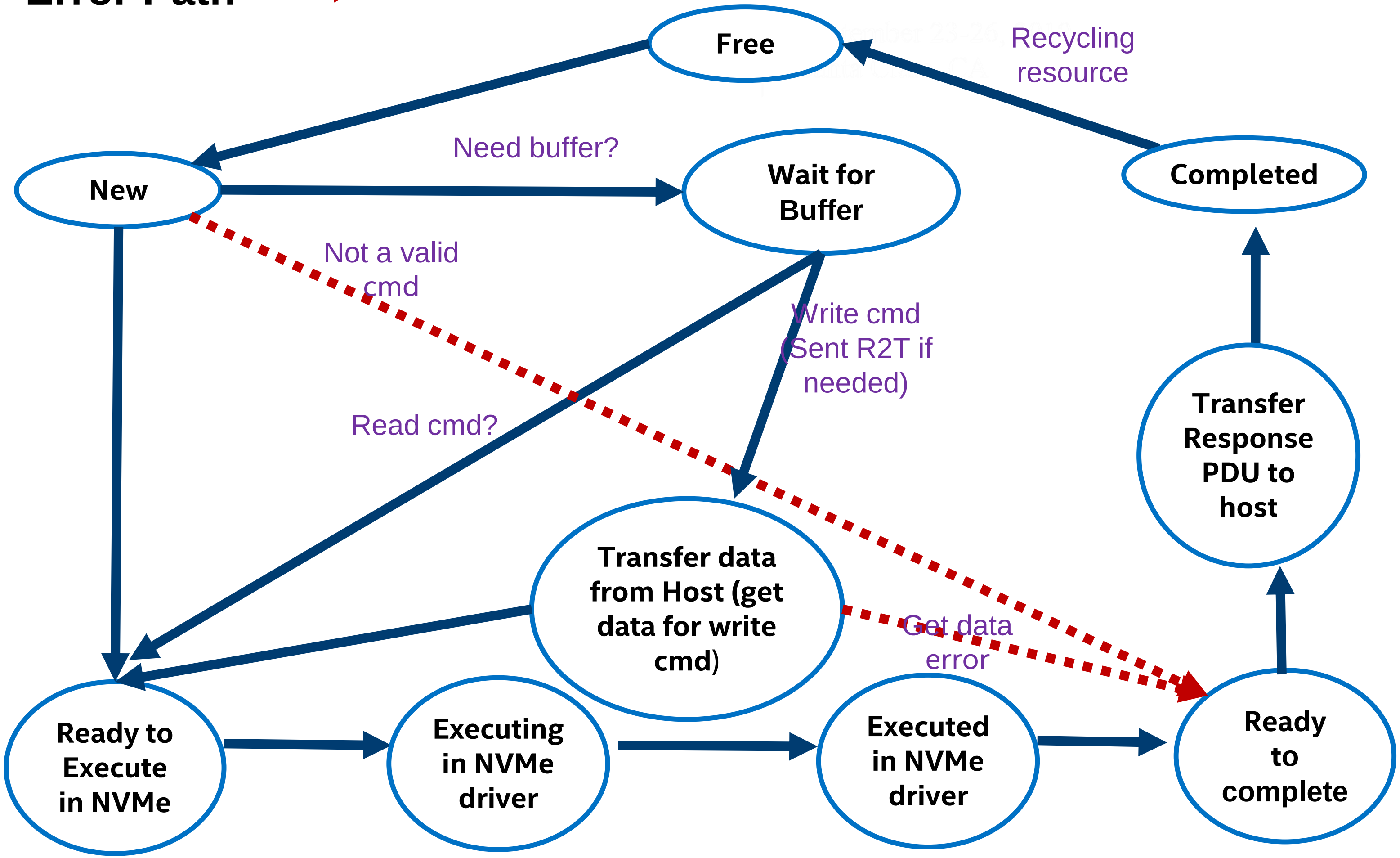
Ingredients	Methodology
Design framework	Follow the general SPDK NVMe-oF framework (e.g., polling group)
TCP connection optimization	Use the SPDK encapsulated Socket API (preparing for integrating other stack, e.g., VPP)
NVMe/TCP PDU handling	Use state machine to track
NVMe/TCP request life time cycle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

TCP PDU Receiving handling for each connection

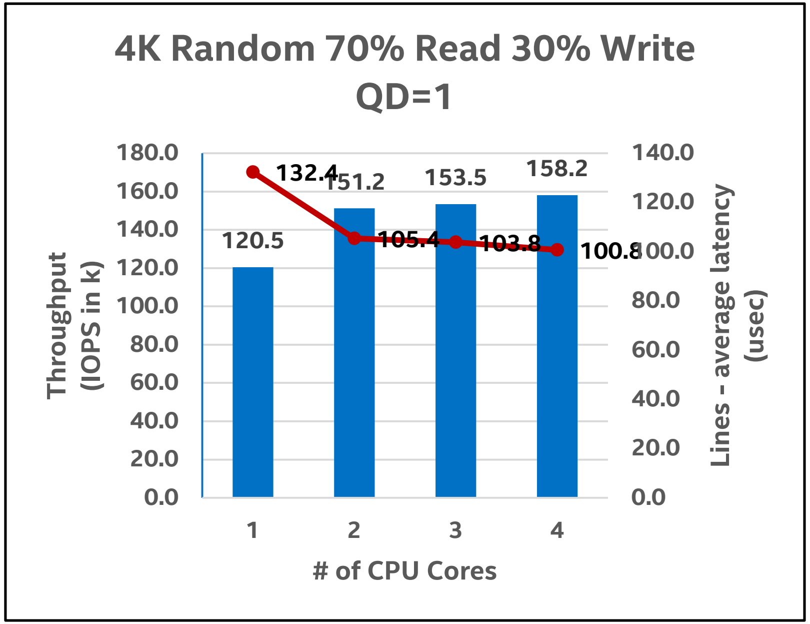
```
enum nvme_tcp_pdu_recv_state {
        /* Ready to wait PDU */
        NVME_TCP_PDU_RECV_STATE_AWAIT_PDU_READY,

        /* 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,
};
```

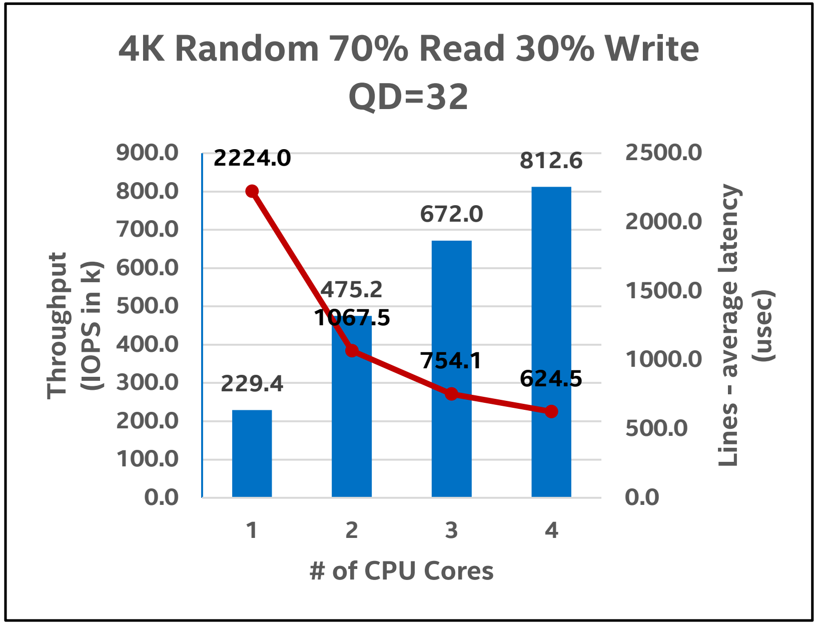


Error Path


Free
Recycling resource
Need buffer?
New
Wait for Buffer
Completed
Not a valid cmd
Write cmd (Sent R2T if needed)
Read cmd?
Transfer Response PDU to host
Transfer data from Host (get data for write cmd)
Get data error
Ready to Execute in NVMe
Executing in NVMe driver
Executed in NVMe driver
Ready to complete

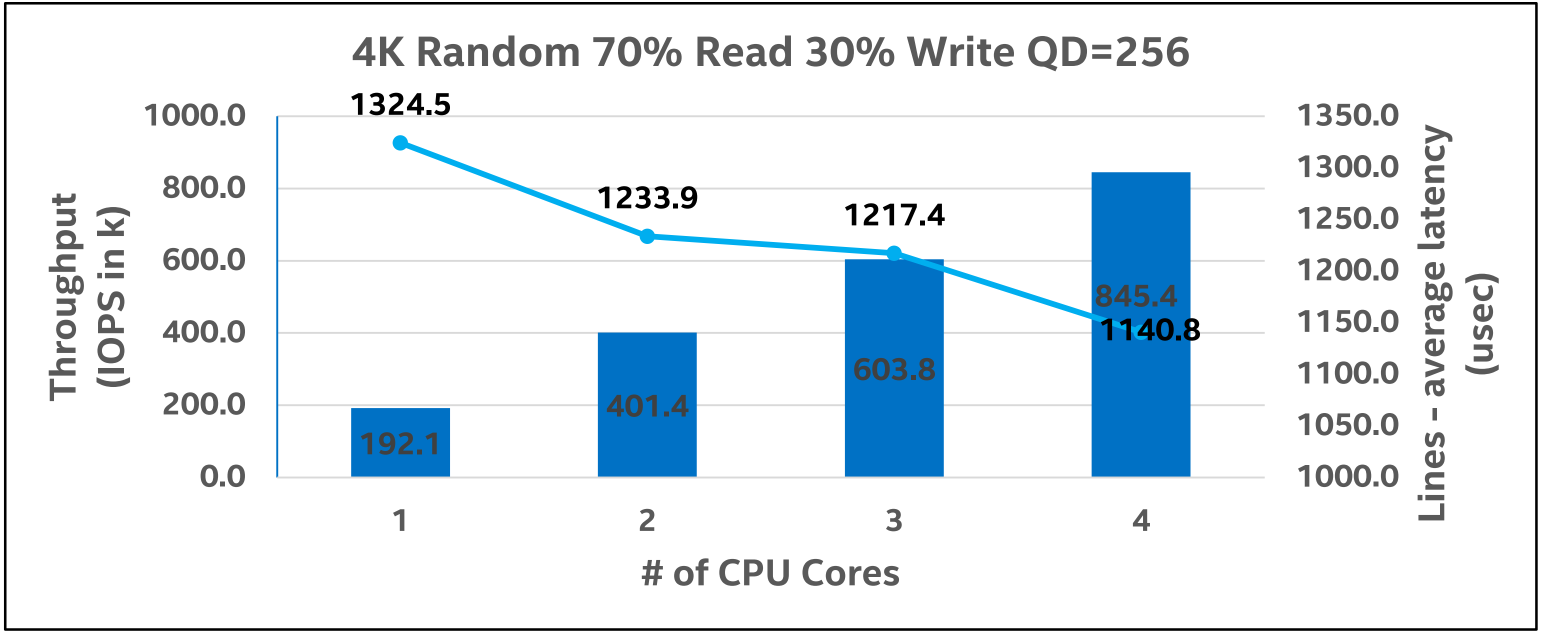
SPDK TCP transport target side I/O scaling





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 TCP transport host side I/O scaling



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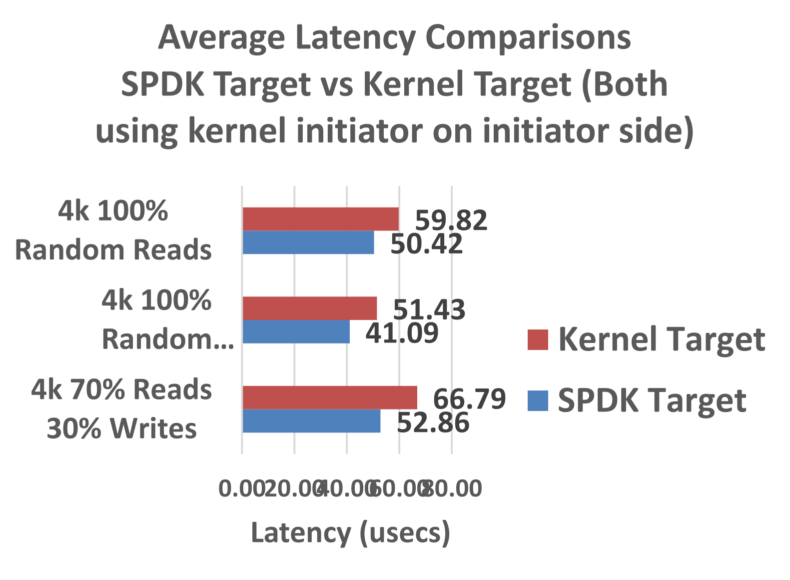
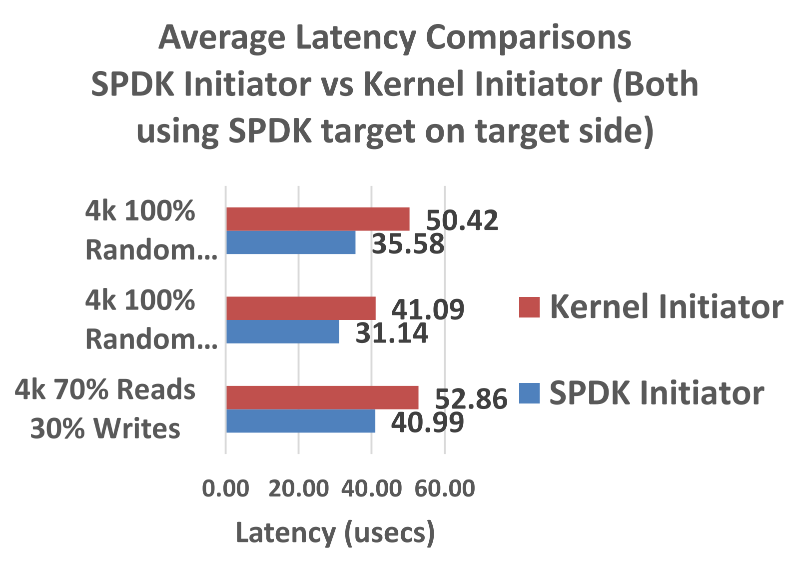
Latency comparison between SPDK and Kernel (NULL block dev is used)





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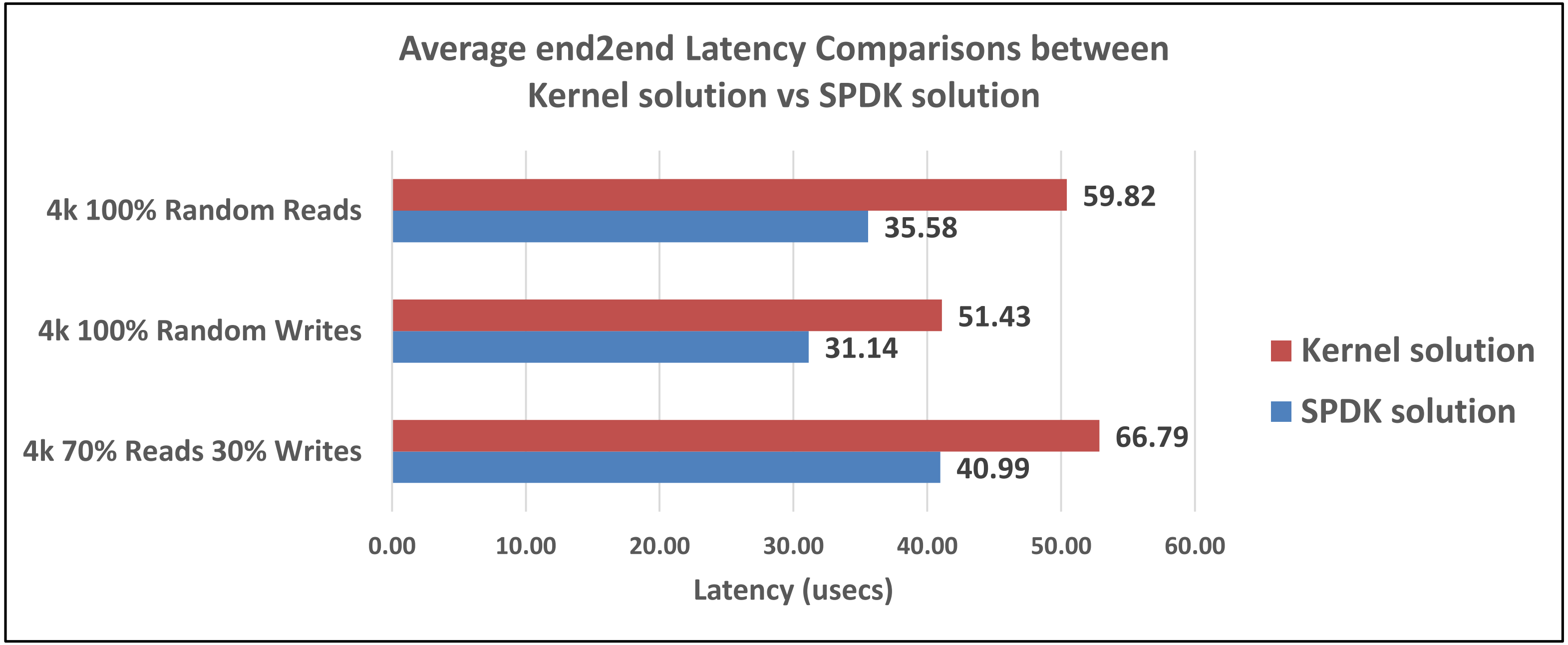

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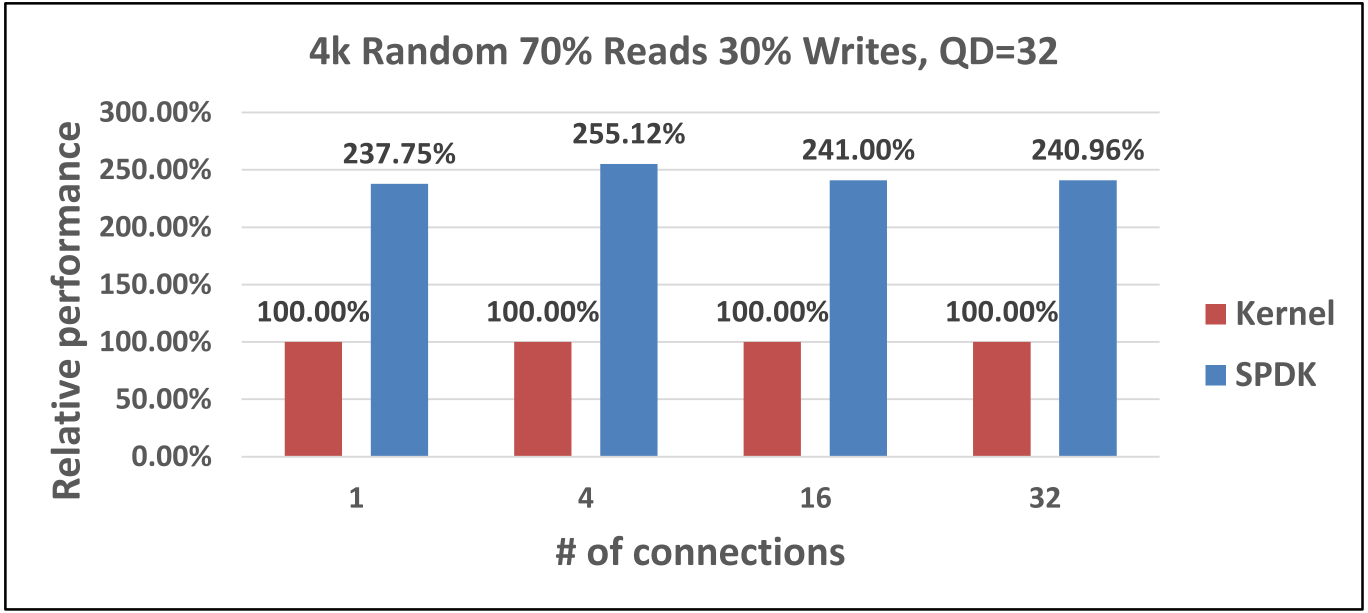
IOPS/CPU core comparison between SPDK and kernel on target side



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SPDK NVMe/TCP transport: Further development plan

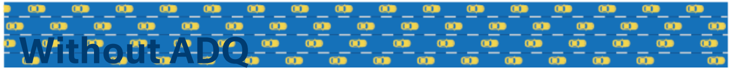
- Continue enhancing the functionality
  - Including the compatible test with Linux kernel solution.
- Performance tuning
  - Integration with third party software
    - Deep integration with user space stack, e.g., VPP/Seastar + DPDK, need the stability and performance tuning.
  - Leveraging hardware features
  - Use existing hardware features of NICs for performance improvement, e.g., VMA from Mellanox's NIC; ADQ from Intel's 100Gbit NIC.
  - Figuring out offloading methods with hardware, e.g., FPGA, Smart NIC, and etc.

To integrate ADQ feature of Intel 800 E800 series NIC into SPDK

- Try to Leverage the ADQ (application device queue) feature of Intel's NIC (i.e., E810 100Gbps NIC). Benefit: **High IOPS with improved (tail) latency.**
  - ADQ is an application specific queuing and steering technology that **dedicates and isolates** application specific hardware NIC queues.
  - These queues are then connected optimally to application specific threads of execution.

With ADQ

Application traffic to a dedicated set of queues



Without ADQ

Application traffic intermixed with other traffic types

ADQ integration requirements

- **Kernel & driver**: (a) Busy polling; (B) socket option for NAPI_ID (SO_INCOMING_NAPI_ID); (c) symmetric polling; ….
- **Application**: Epoll threads watch the socket with same NAPI_ID
- **Hardware**: (a) Application level filtering & traffic shaping; (b) Flow based queue steering and load balance.

Conclusion

Conclusion

- SPDK NVMe-oF solution is well adopted by the industry. In this presentation, followings are introduced, i.e.,
  - The development history of SPDK NVMe-oF solution.
  - SPDK TCP transport status introduction & some further development plan.
- Call for activity in spdk community
  - Welcome to bug submission, idea discussion and patch submission.

Conclusion: Further development plan for NVMe-oF in SPDK

Ingredients	Goal
Spec compliance	Continue following the NVMe-oF spec
Interoperability with kernel	Continue the interoperability test with Linux kernel solution.
Performance	Continue performance enhancements and integration with other solutions.
Advanced feature	Continuing extracting the common features from customers and put in the roadmap

Q & A