Flash Memory Summit

SOLIDIGM

New Developments in Cloud Storage Acceleration Layer (CSAL), an FTL in SPDK

Kapil Karkra, Sr. Principal Engineer, Storage Platform Architect

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Imagine if we had…

A sandbox to explore, add capabilities, and drive down data center TCO…

Agenda

1. TCO Benefits of large capacity (D5-P5536 61.44TB) QLC
2. How to Further Expand the Reach of QLC?

Motivation and Problem

3. Creating an Easy Button with CSAL and a Reference Storage Platform (RSP)
4. Performance Results and TCO Benefits

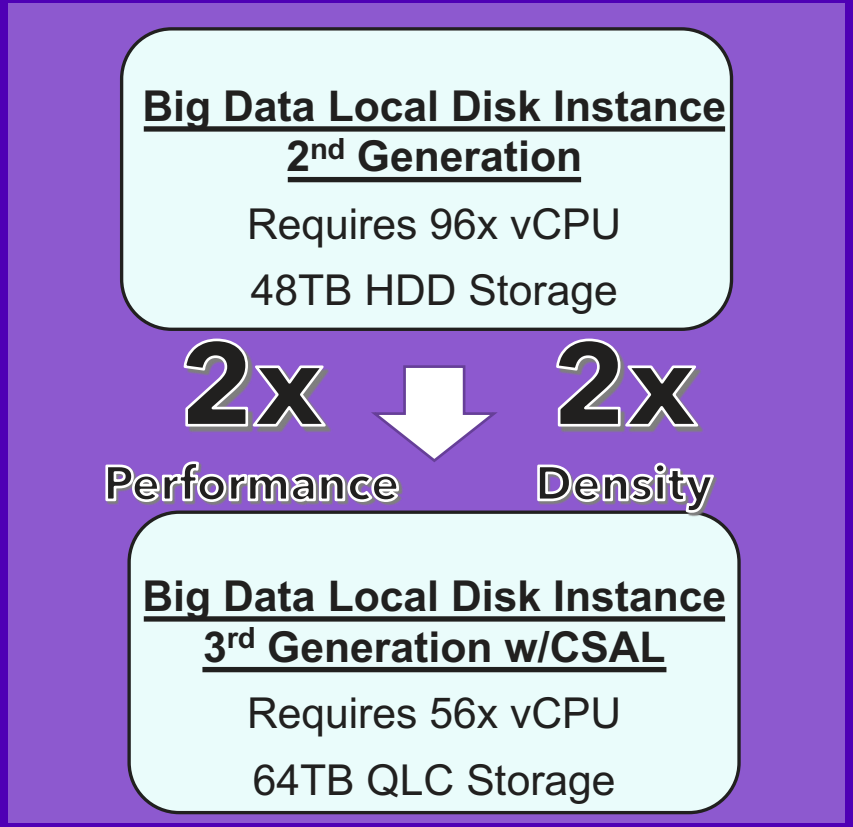
Solution

5. Summary and Call to Action

Wide Range of Use Cases/Customers Adopting QLC

Example: Alibaba Local Disk Use Case

- Alibaba replaced HDDs with Solidigm's QLC D5-P5316 QLC SSDs in their 3rd generation big data local disk ECS instances to double the performance vs. 2nd generation while holding the price to their customers constant.
- TCO was the same between the two generations
  - While the CAPEX was higher, the 2x density led to rack tax (building, personnel, land, etc.) and OPEX savings to offset the higher CAPEX.



Please see reference #1 under Sources, References and Test configs section on slide 19

Deep collaboration with Alibaba, as one of the foundational QLC customers, resulted in co-development of CSAL

Even Greater TCO Benefits with 61.44TB P5336 SSD

- Applied CSAL to Solidigm's D5-P5336 61.44TB QLC SSD with Solidigm's first generation SLC.

Config	8xOptane+ 8xQLC Optane = 400GB QLC = 15.36TB	8xSLC + 8xQLC SLC= 1600GB QLC = 61.44TB
1x Drive capacity (GB)	15360	61440
Total storage cap per node (TB)	128	442
Incremental CAPEX for compute (vCPU + host DRAM) and storage (SLC + QLC)	base	+$18K
OPEX per node (5 years)	base	- ($0.5K)
Data center tax per node (5 years)	base	- ($0.3K)
Virtual drive capacity (GB)	16000	16000
Virtual drives per node	8	27
% TCO savings per virtual drive (5 years)	base	**2x**

Based on Solidigm internal analysis

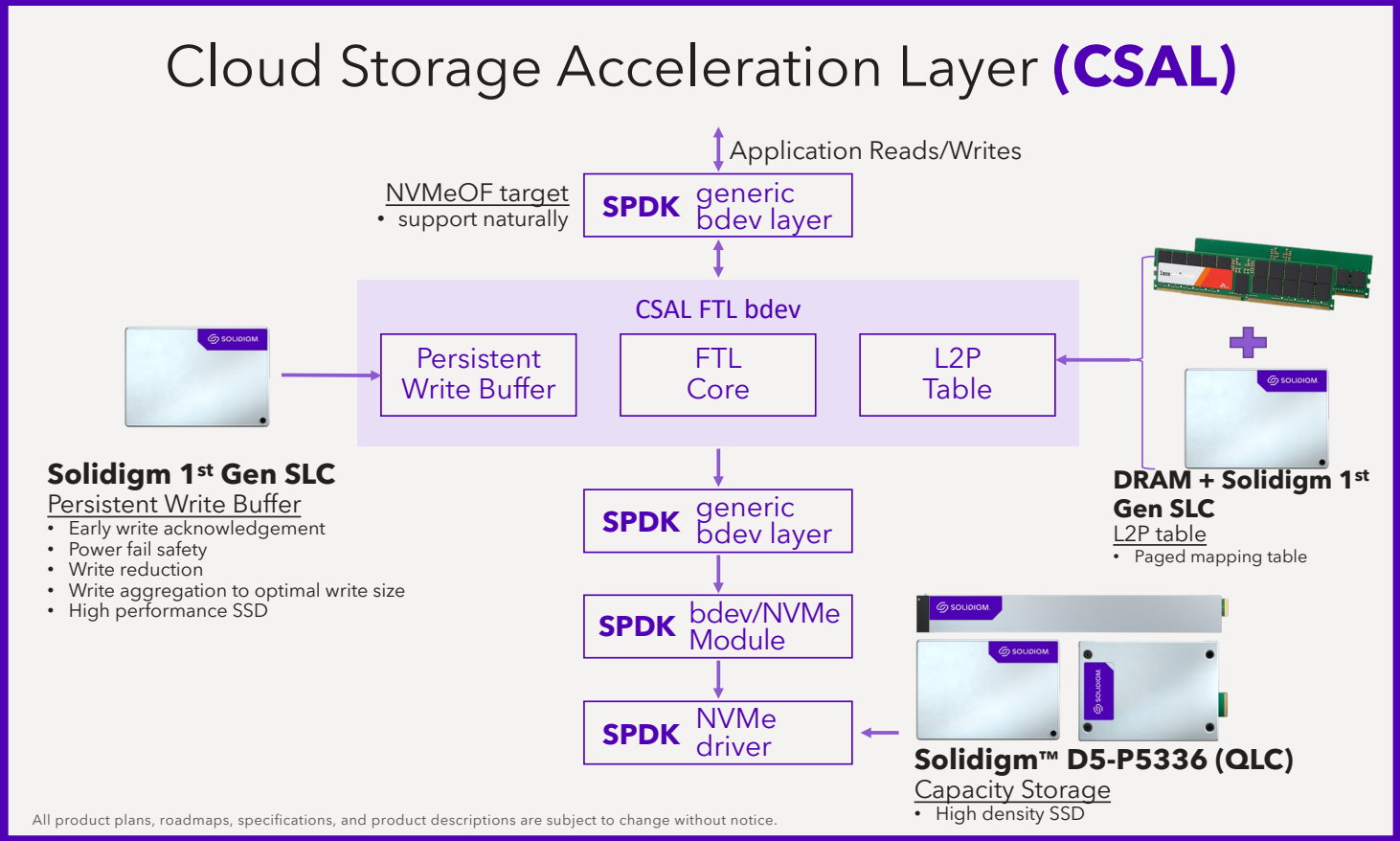
How can we bring these TCO benefits of hyper-dense QLC to everyone?

Open-source CSAL is part of the answer!

Refresher from last FMS: What is Cloud Storage Acceleration Layer (CSAL)

What is CSAL*?*

- Open-source cloud-scale shared-nothing Flash Translation Layer (FTL bdev) in Storage Performance Development Kit (SPDK)
- Ultra fast cache and write shaping tier to improve performance and endurance to scale QLC value
- Consistent performance in multi-tenant environment
- Flexible scaling of NAND performance and capacity to the user/workload needs



What Changed in CSAL since last FMS

- CSAL open sourced (SPDK v22.09)
- Solidigm acquired CSAL team (Feb. 2023)
- New CSAL capabilities:
  - SLC as Optane Replacement
  - Mitigated in CSAL the need for VSS for crash consistency and power fail safety
  - RAID5F (in progress)
  - ZNS (in progress)

CSAL's Core Capabilities Expand the QLC Benefits

Capability #1: Write shaping to enable a reduced DRAM footprint with Large IU drives and SLC caching tier can provide additional ~2x endurance and perf benefit for locality workloads vs. TLC

	1xTLC	1xSLC + 1xQLC	Unit
64k rand write zipf 1.2	1875	3317	MiB/s

Please see Test Configuration #2 under Sources, References and Test configs section on slide 22

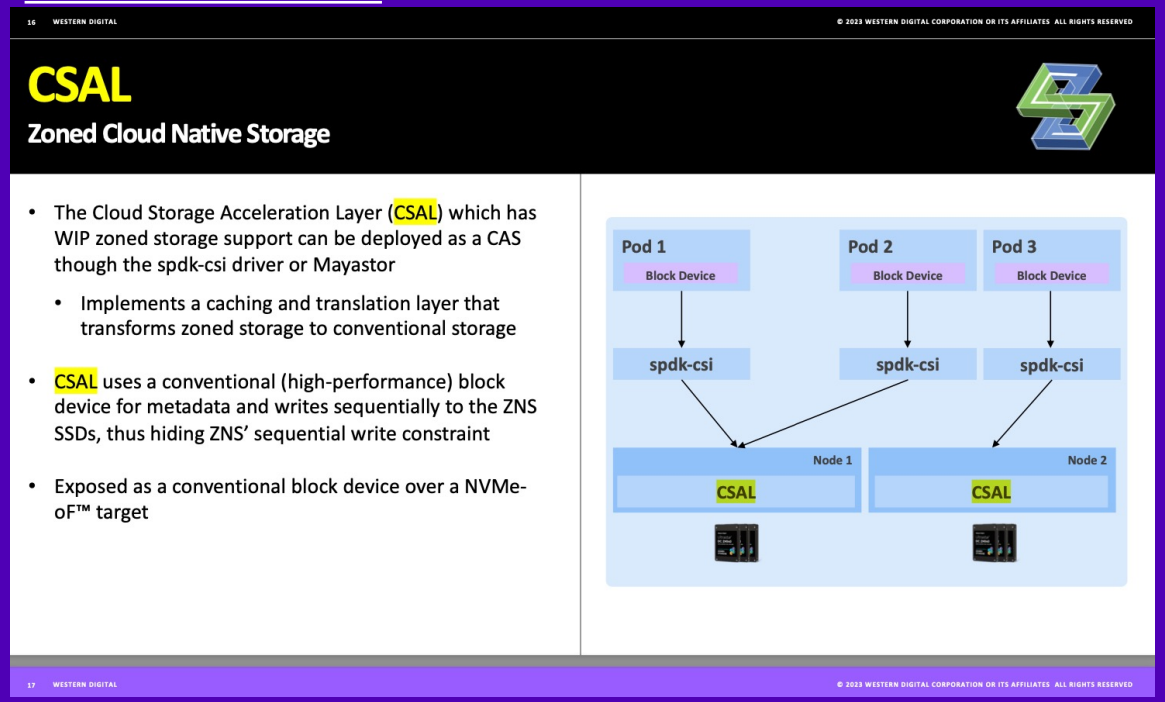
Capability #2: CSAL tiered arch enables full-stripe RAID5F ~2x more efficient than traditional RAID5 to improve system fault tolerance

$$raid5fWritePerf = (N-1) \times diskWritePerf$$

$$raid5WritePerf = N \times \frac{diskWritePerf}{(2 + 2 \times \frac{diskWritePerf}{diskReadPerf})} \rightarrow \frac{raid5fWritePerf}{raid5WritePerf} = \sim 2$$

Capability #3: CSAL enables pooling a large QLC capacity that can be shared across multiple cloud tenants to increase capacity and performance utilization.

Capability #4: CSAL writes sequentially to QLC to adapt to emerging interfaces e.g., ZNS to a regular 4k block, and enable multi-tenant isolation.



Please see reference #2 under Sources, References and Test configs section on slide 19

Workload	CSAL on Standard SSD WAF	CSAL on ZNS SSD WAF
1 write job: 4K/seq/qd128, 1 write job1: 4K/rand/qd128, 1 write job:4K/zipf0.8/qd128, 1 write job:4K/zipf1.2/qd128	3.8	2.3

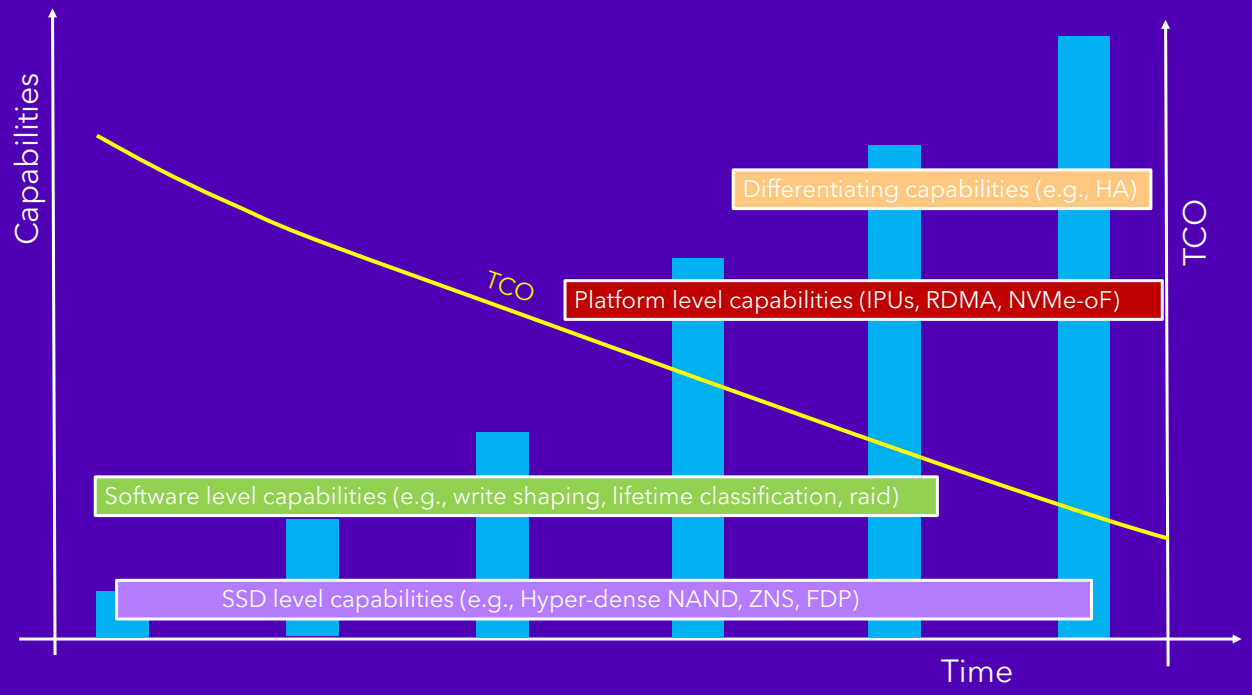
Please see Test Configuration #3 under Sources, References and Test configs section on slide 24

CSAL has key abstractions to extend the use of high-density QLC NAND and adapt the emerging interfaces (ZNS) to 4k block interface

In addition to CSAL, we are taking a community-driven approach to create a Reference Storage Platform (RSP) for everyone

Why A Reference Storage Platform & Community-driven Approach?

- Open-source building blocks are a complex mix of parts, often challenging to assemble
- This hampers rapid development, assessment, and deployment of storage technologies
- A Reference Storage Platform brings it all together into a turnkey solution
- A community-driven approach enables faster innovation, transparency, and easy evaluation and adoption of “part” technologies inside a unified “whole” solution



The first instantiation of the reference platform already done!

First Reference Storage Platform Instantiation – NVMe-oF Target for Disaggregation

- Thanks to our **Reference Storage Platform (RSP) partners**, we have created the first instantiation of an open-source Reference Storage Platform sandbox
- Reference Storage Platform provides an easy button
  - SPDK NVMe-oF TCP target packaged in a turnkey VM image
  - SPDK NVMe-oF TCP target packaged in a turnkey Container
  - GUI to manage a pool of high-density NAND
  - Reference hardware platform is an off the shelf commodity server from typical OEMs (Dell and Supermicro to start) with Intel CPUs.
  - Getting started guide on spdk.io
- We have a demo at the Solidigm booth

RSP Partners:

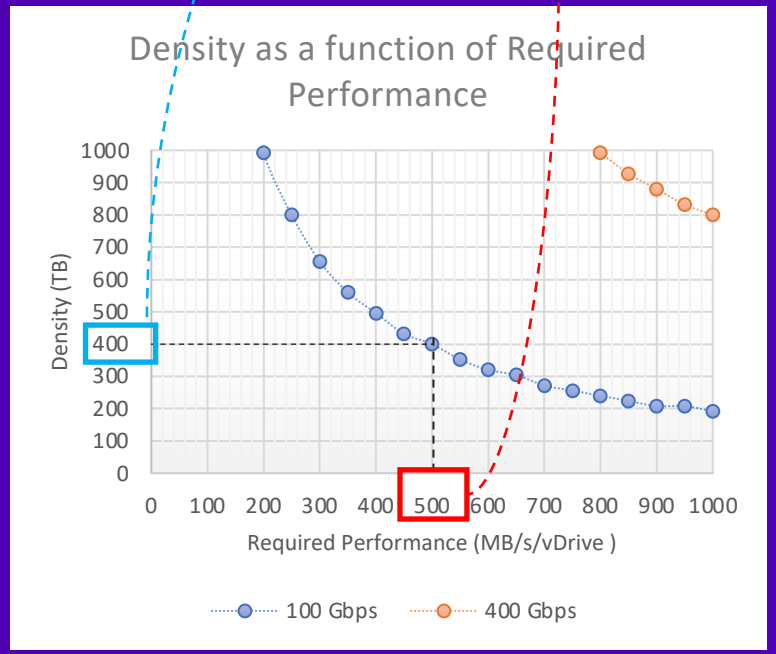
StarWind HYPERCONVERGENCE, intel, SOLIDIGM, Western Digital, SPDK

Next, we used this reference storage platform to illustrate the benefit of our hyper-dense QLC P5336 61.44 TB

Disaggregated CSAL+SLC+QLC Perf/TCO vs. Incumbent TLC

	10x TLC	3xSLC + 7xQLC	Unit
Total available capacity	138	344	TB
Raw aggregate R/W BW	14	10.3	GB/s
Network Bound	11.4		GB/s
vDrive Capacity	16000		GB
vDrive Count per server	8	21	
Min(Demanded, Delivered) Perf/vDrive	500	500	MiB/s/16TB

Please see Test Configuration #1 under Sources, References and Test configs section on slide 20



Based on Solidigm internal analysis

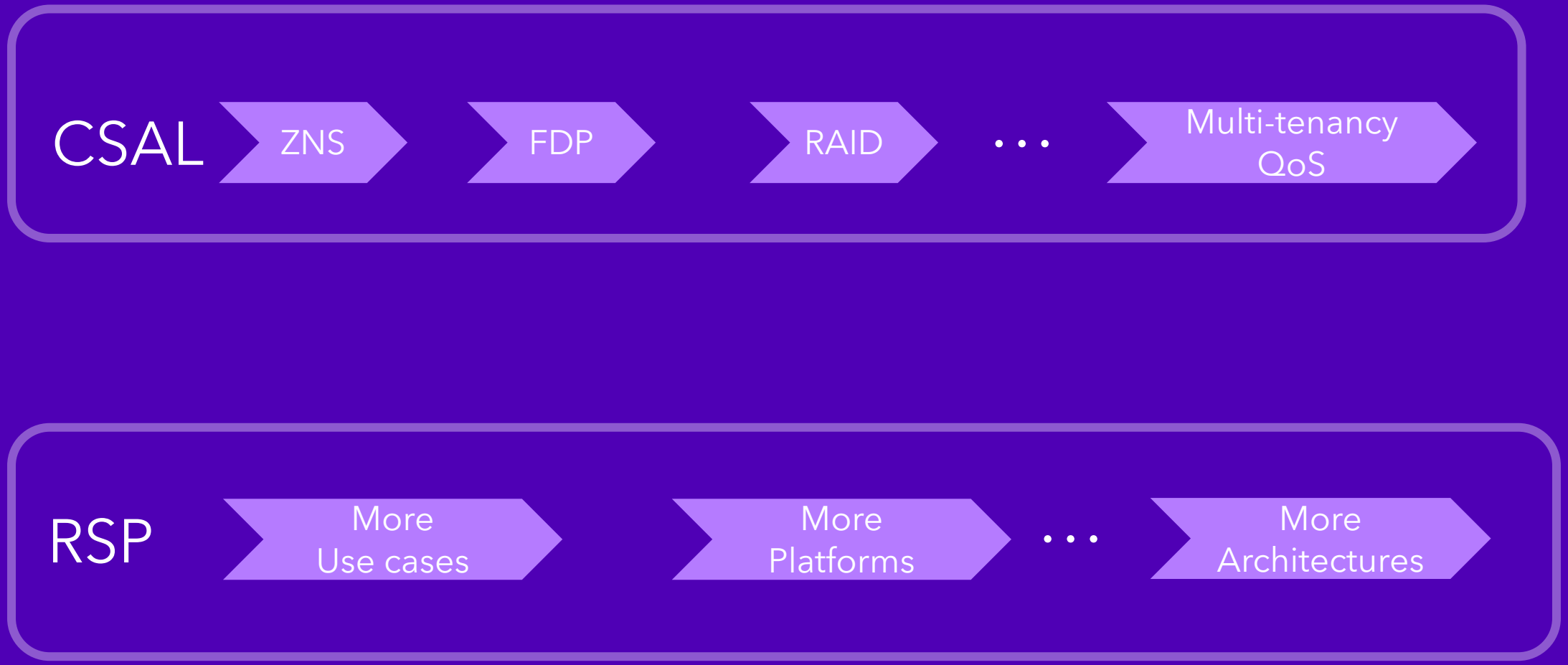
Config	10x TLC TLC = 15.36TB	3xSLC + 7xQLC SLC = 800GB, QLC = 61.44TB
1x Drive capacity (GB)	15360	61440
Total storage capacity per node (TB)	138	344
Incremental CAPEX for compute (vCPU + host DRAM) and storage (SLC + QLC)	base	+$14K
OPEX per node (for 5 years)	base	base
Data center tax per node (for 5 years)	base	base
Virtual drive capacity (GB)	16000	16000
Virtual drives per node	8	21
% TCO savings per virtual drive (for 5 years)	base	**35%**

Based on Solidigm internal analysis

Both TLC and QLC saturate the 80% of the 100Gbps network, but CSAL+SLC+QLC does it with 35% better TCO with D5-P5336

The 35% TCO gain is attributable only to greater density; disaggregation, caching, raid5f, ZNS/FDP, etc. capabilities further the TCO reduction…

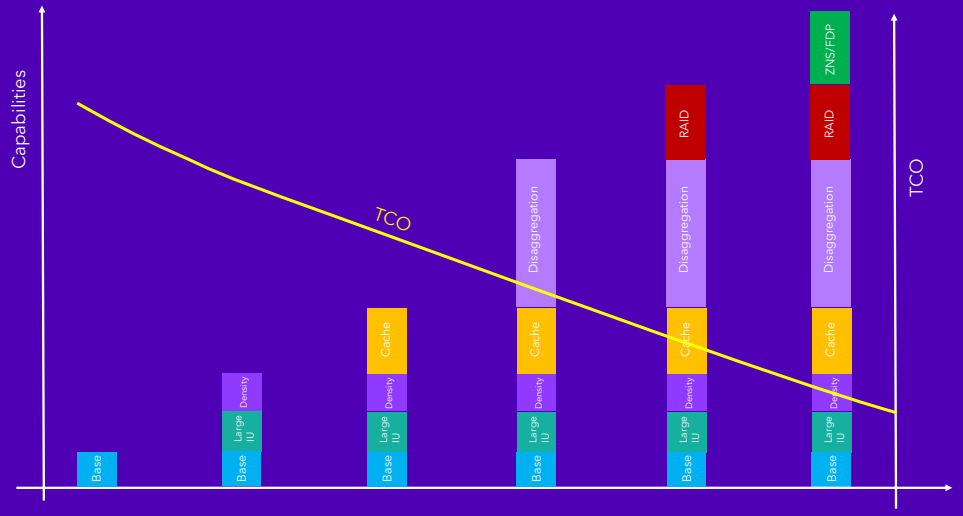
CSAL and Reference Storage Platform (RSP) Add Capabilities Over Time



Summary and Call to Action

Summary:

- CSAL has the necessary host-based FTL abstractions you need for the emerging SSD interfaces and high-density NAND
- We have provided a turnkey open-source disaggregated NVMe-oF TCP target as our first instantiation of the Reference Storage Platform
- CSAL and Reference Storage Platform provide an easy way to adopt new technologies
- Continuing technology additions drive TCO lower



Call to Action:

- Develop CSAL with us in the SPDK open source
- Use the NVMe-oF target we've provided and see the great things you can do with it.
- Add your own capabilities and create more reference implementations
- Let's grow this community for the benefit of the entire storage industry!

We invite you to come, play with us in the sandbox!

Sources and References

1. CSAL whitepaper – A Media-Aware Cloud Storage Acceleration Layer (CSAL)
2. CSAL+ZNS presentation – Zoned Storage in the Cloud
3. CSAL solution brief – A CSAL-Based Reference Storage Platform
4. Reference Storage Platform – Main Download Page

Author Contact: kapil.karkra@solidigm.com

Test Configuration #1

Storage Server – SuperMicro SYS-220U-TNR System Configuration	
BIOS Version	1.4b
OS	Fedora 37 (Server Edition)
Kernel	6.3.8-100.fc37.x86_64
CPU Model	Intel(R) Xeon(R) Platinum 8380 CPU @ 2.30GHz
NUMA Node(s)	2
DRAM Installed	756GB (16x16GB DDR4 3200MT/s [3200MT/s])
Huge Pages Size	2048 kB
NIC Summary	Ethernet Controller X710 for 10GBASE-T, Ethernet Controller X710 for 10GBASE-T
Drive Summary	**3x SLC+ 7x QLC**: SLC is Solidigm's first generation SLC for cache device; QLC is a P5336 D5-P5336 61TB
SPDK	22.09
CSAL	1.0
FIO	3.29

Test Configuration #1: Example FIO job file

```
[global]
ioengine=spdk_bdev
spdk_json_conf=${FTL_JSON_CONF}
filename=${FTL_BDEV_NAME}
# SPDK cores, FTL core mask should avoid core 0
spdk_core_mask=${SPDK_CORE_MASK}
# CPUS allowed fio threads cannot interleave with SPDK cores
cpus_allowed=12
cpus_allowed_policy=split
direct=1
thread=1
buffered=0
time_based
norandommap=1
randrepeat=0
scramble_buffers=1
rw=randrw

[POR]
bs=4k
rwmixread=70
numjobs=1
iodepth=128
runtime=3600s
time_based=1
```

Test Configuration #2

Storage Server – SuperMicro SYS-220U-TNR System Configuration	
BIOS Version	1.4b
OS	Fedora 37 (Server Edition)
Kernel	6.3.8-100.fc37.x86_64
CPU Model	Intel(R) Xeon(R) Platinum 8380 CPU @ 2.30GHz
NUMA Node(s)	2
DRAM Installed	756GB (16x16GB DDR4 3200MT/s [3200MT/s])
Huge Pages Size	2048 kB
NIC Summary	Ethernet Controller X710 for 10GBASE-T, Ethernet Controller X710 for 10GBASE-T
Drive Summary	1. **TLC** is a Solidigm TLC SSD D7-P5520 15.36 TB 2. **1x SLC+ 1x QLC:** SLC is Solidigm's first generation SLC for cache device; QLC is a P5336 D5-P5336 61TB
SPDK	22.09
CSAL	1.0
FIO	3.29

Test Configuration #2: Example FIO job file

```
[global]
ioengine=spdk_bdev
spdk_json_conf=${FTL_JSON_CONF}
filename=${FTL_BDEV_NAME}
# SPDK cores, FTL core mask should avoid core 0
spdk_core_mask=${SPDK_CORE_MASK}
# CPUS allowed fio threads cannot interleave with SPDK cores
cpus_allowed=12
cpus_allowed_policy=split
direct=1
thread=1
buffered=0
time_based
norandommap=1
randrepeat=0
scramble_buffers=1
rw=randrw

[POR]
bs=64k
numjobs=1
rw=randwrite
random_distribution=zipf:1.2
iodepth=128
runtime=3600s
time_based=1
```

Test Configuration #3

Storage Server – SuperMicro SYS-220U-TNR System Configuration	
BIOS Version	1.4b
OS	Fedora 37 (Server Edition)
Kernel	6.3.8-100.fc37.x86_64
CPU Model	Intel(R) Xeon(R) Platinum 8380 CPU @ 2.30GHz
NUMA Node(s)	2
DRAM Installed	756GB (16x16GB DDR4 3200MT/s [3200MT/s])
Huge Pages Size	2048 kB
NIC Summary	Ethernet Controller X710 for 10GBASE-T, Ethernet Controller X710 for 10GBASE-T
Drive Summary	CSAL ZNS POC branch (not yet upstream) with P5800X + **WDC ZN540 ZNS TLC SSD**
SPDK	22.09
CSAL	1.0
FIO	3.29

Test Configuration #3: Example FIO job file

```
[global]
ioengine=spdk_bdev
spdk_json_conf=${FTL_JSON_CONF}
filename=${FTL_BDEV_NAME}
# SPDK cores, FTL core mask should avoid core 0
spdk_core_mask=${SPDK_CORE_MASK}
# CPUS allowed fio threads cannot interleave with SPDK cores
cpus_allowed=12
cpus_allowed_policy=split
direct=1
thread=1
buffered=0
norandommap=1
randrepeat=0
scramble_buffers=1
```

```
[WRITE_SEQ]
bs=4k
numjobs=1
rw=write
iodepth=128
size=100%
exitall

[WRITE_RAND]
bs=4k
numjobs=1
rw=randwrite
iodepth=128
runtime=1000d

[WRITE_ZIPF_0_8]
bs=4k
numjobs=1
rw=randwrite
random_distribution=zipf:0.8
iodepth=128
runtime=1000d
time_based=1

[WRITE_ZIPF_1_2]
bs=4k
numjobs=1
rw=randwrite
random_distribution=zipf:1.2
iodepth=128
runtime=1000d
time_based=1
```

Test Configuration #4

Storage Server – SuperMicro SYS-220U-TNR System Configuration	
BIOS Version	1.4b
OS	Fedora 37 (Server Edition)
Kernel	6.3.8-100.fc37.x86_64
CPU Model	Intel(R) Xeon(R) Platinum 8380 CPU @ 2.30GHz
NUMA Node(s)	2
DRAM Installed	756GB (16x16GB DDR4 3200MT/s [3200MT/s])
Huge Pages Size	2048 kB
NIC Summary	Ethernet Controller X710 for 10GBASE-T, Ethernet Controller X710 for 10GBASE-T
Drive Summary	6xP5800X + 6x3DR5F (i.e., 3 disk RAID5F, with each disk being P5316) md raid5 performance numbers are the saturation achieved using nullblk
SPDK	22.09
CSAL	An internal CSAL POC branch based on CSAL 1.0, please contact your Solidigm sales rep for details.
FIO	3.29