Flash Memory Summit Session:

Benefits of ZNS in Datacenter Storage Systems

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RocksDB, F2FS with ZNS SSD

Summary

Introduction: Zoned Namespaces Proposal

- **Previous proposals are not a complete solution for data center storage system**
- **New proposal, Zoned Namespaces (ZNS), appears to be an optimal solution**

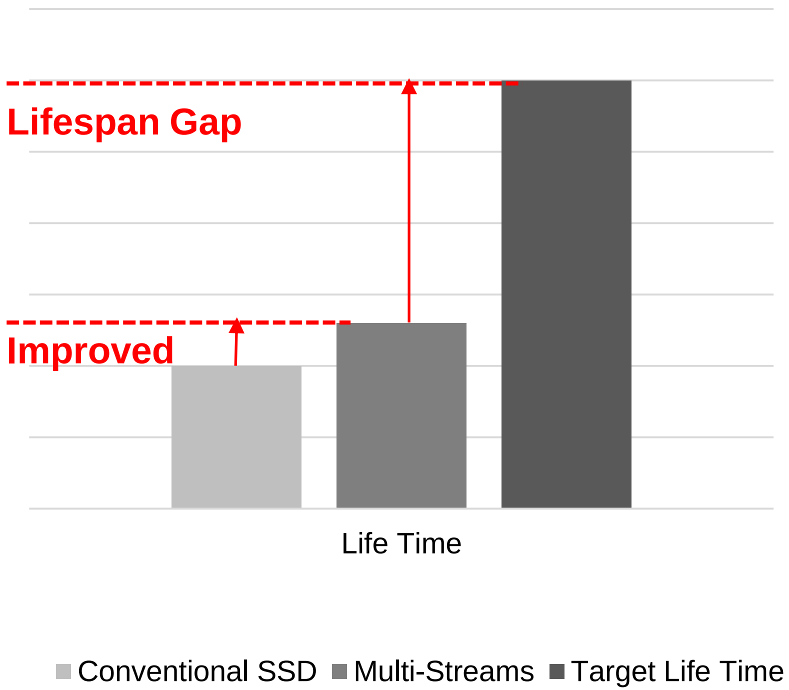
✓ Available
● Incomplete
✗ Not planned

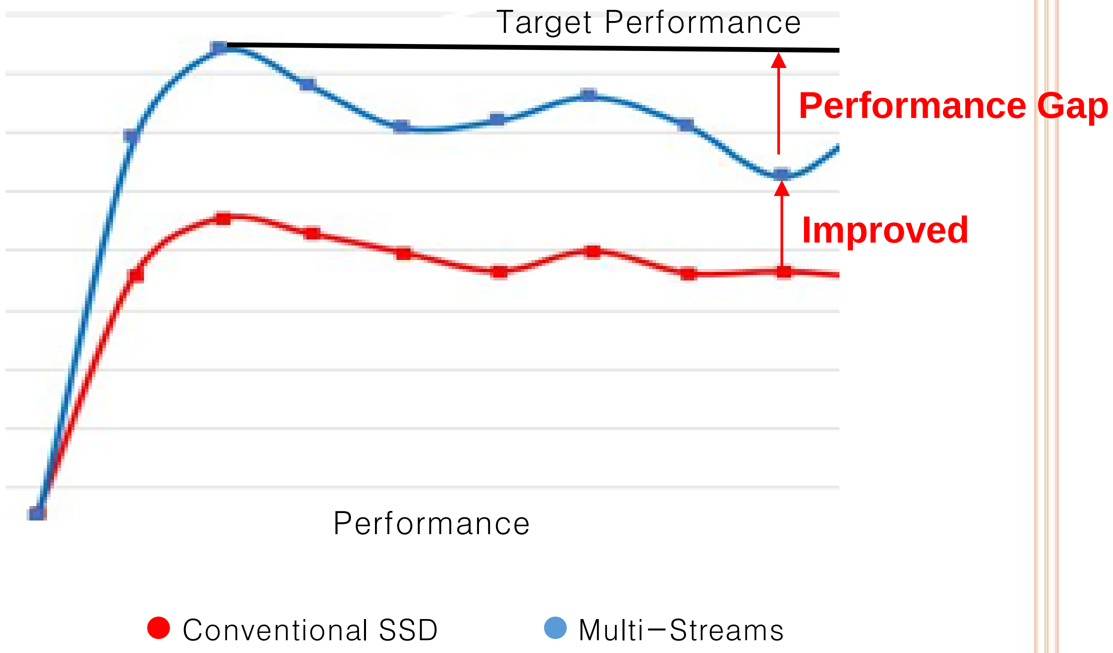
	Log Abstraction	In-Host Placement Policy	In-Drive Reliability
Multi-Streams SSD (HotStor `14)	✗	●	✓
OCSSD 1.2 (ASPLOS `16)	✓	✓	✗
IO Determinism (Fall `16)	✗	●	✓
OCSSD 2.0 (FAST `17)	✓	✓	✓
Zoned Namespaces (NVMe Spec. `19)	✓	✓	✓

Reference MSFT, `17 Storage Developer Conference

Introduction: Case of Multi-Streams

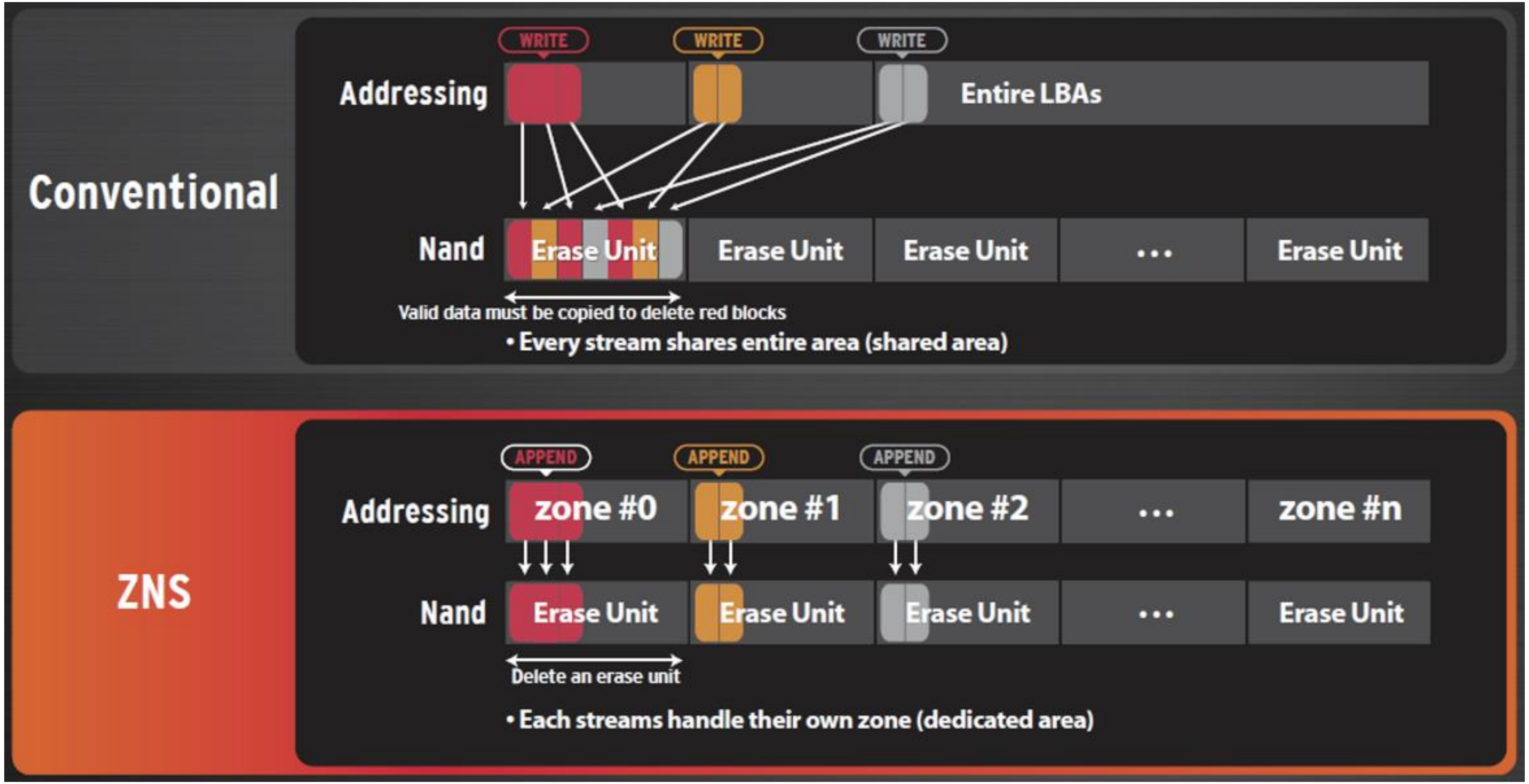
- Garbage Collection is reduced but not completely removed
- Lifespan & Performance can be enhanced but not to the optimal level





Introduction: ZNS Concept

- Only sequential write is accepted in each Zone (random write is not allowed)
- Zones are erased by the host issuing a special command, Zone Reset (no GC)



Introduction: SK hynix‘s ZNS SSD Prototype

- **Prototype available on two SK hynix SSD products**

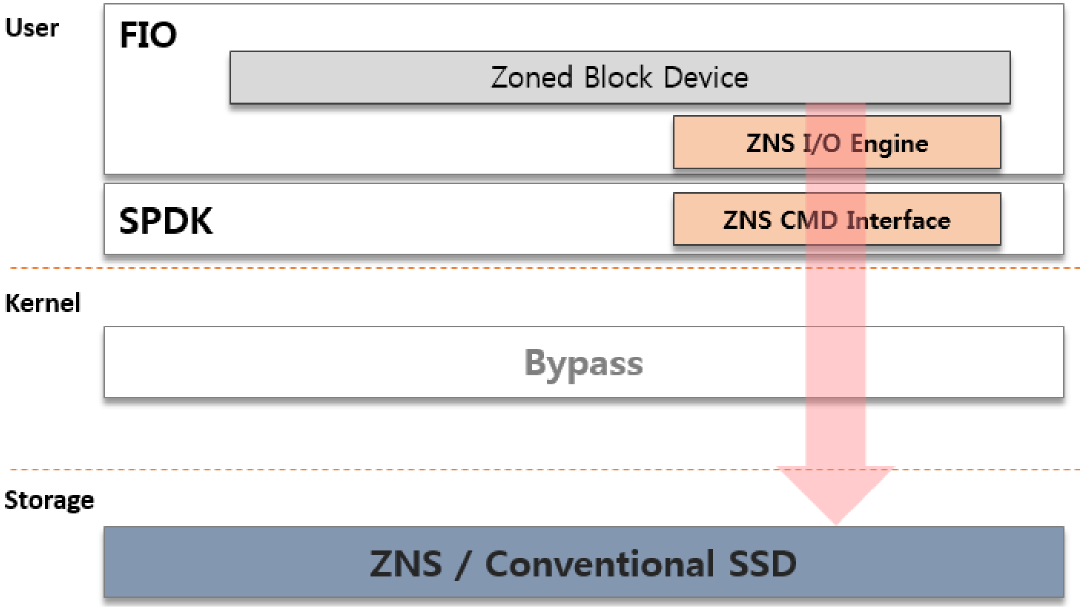
Item		PE4011
Interface		PCIe Gen3 x 4
Protocol		NVMe 1.2.1
Form Factor		M.2 22110
Capacity		1920GB
NAND	Density	512 Gb
	Type	3D **TLC**

Item		PE6011
Interface		PCIe Gen3 x 4
Protocol		NVMe 1.3
Form Factor		U.2 7mm
Capacity		3840TB
NAND	Density	512 Gb
	Type	3D **TLC**

Performance Evaluation: Configuration & Environment

- New ZNS commands added in SPDK
- Emulated workload generated and run by FIO
- Kernel S/W stack is bypassed to remove overhead

Test Framework



Environment

- Hardware:
  - CPU: Intel(R) Xeon(R) CPU E5-2667 v4 @ 3.20GHz
  - Memory: 251GB
  - SSD(ZNS/Conventional): PE4011, PE6011
- Software:
  - Ubuntu 15.04
  - Linux 4.20.0 x86_64
  - FIO-3.12, SPDK

Performance Evaluation: Expected Benefits

SK hynix

I. Extend SSD Lifespan

II. Reduce Read Tail Latency (QoS)

III. Improve I/O Performance

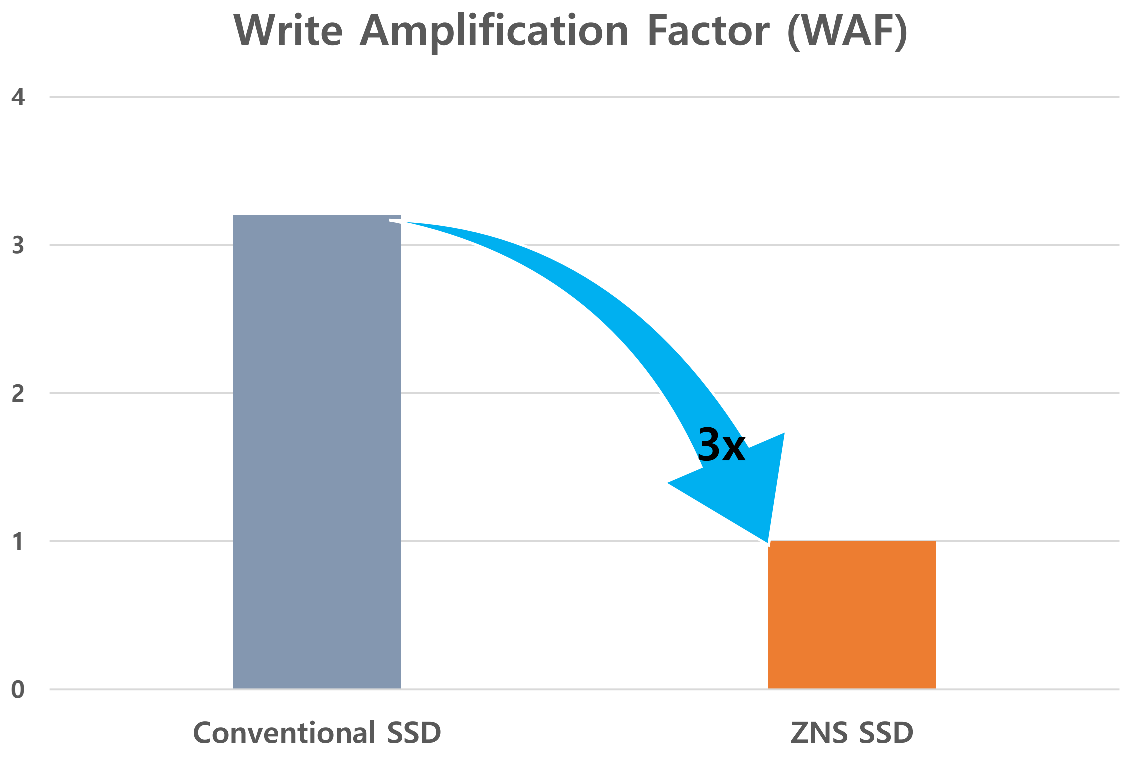
IV. Reduce Overprovisioning

V. Reduce DRAM in SSD

Performance Evaluation: Expected Benefits (1/5)

- Extend SSD Lifespan
  - Increase lifespan 3x for the case of 8-writes
  - No Garbage Collection is required

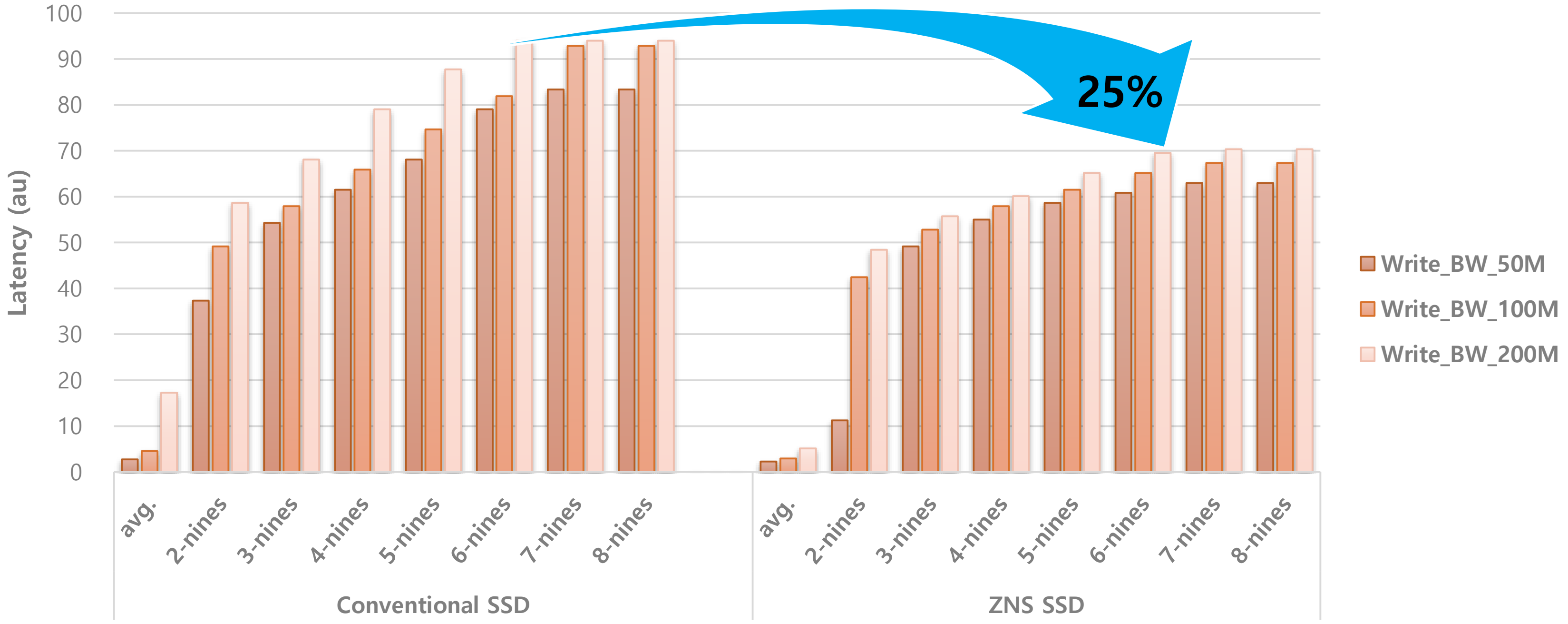
$$WAF = \frac{Bytes\ written\ to\ NAND}{Bytes\ written\ from\ Host}$$



128KB(Block Size), 8-writes

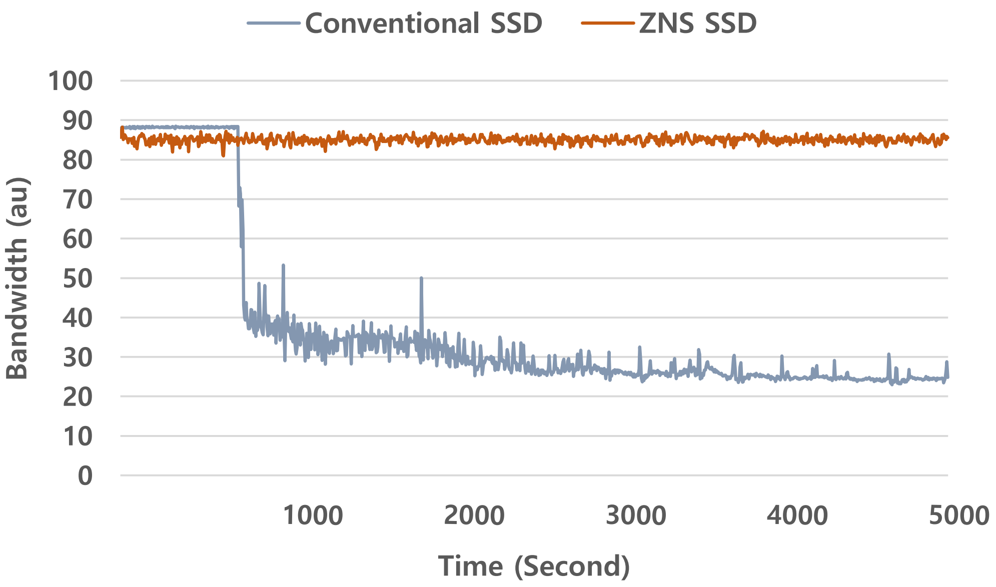
Performance Evaluation: Expected Benefits (2/5)

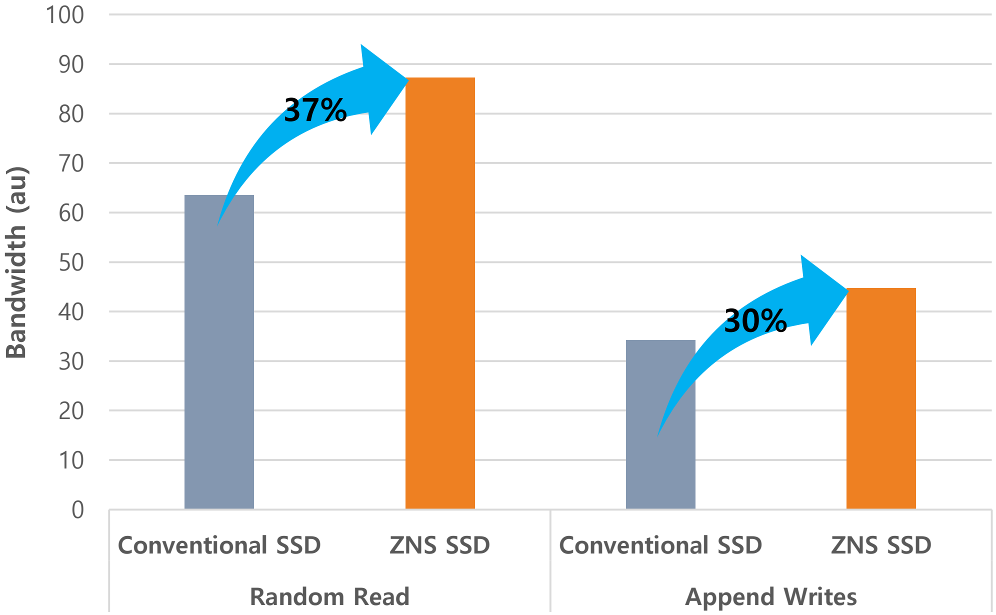
- Improve Read Tail Latency
  - Reduce IO interference by SSD’s internal background operations
  - Improve read response for mixed workloads



Performance Evaluation: Expected Benefits (3/5)

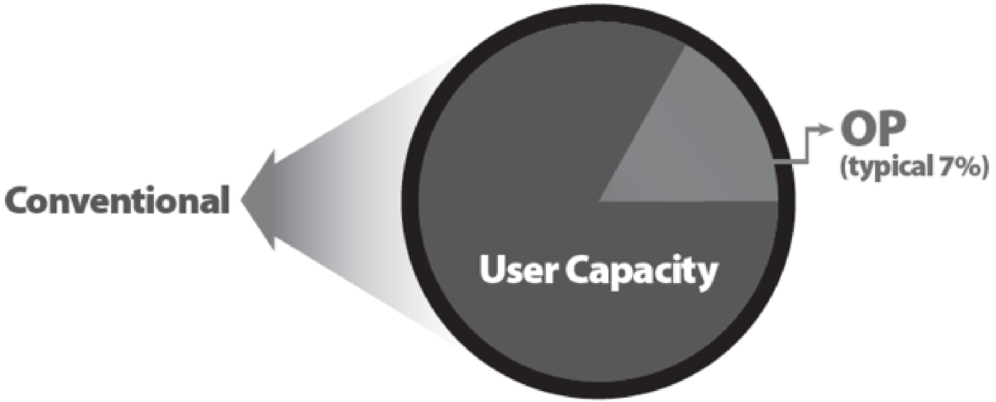
- Improve I/O Performance
  - Getting consistent throughput
  - Higher bandwidth for mixed workloads (1 Random Read and 5 Writes)

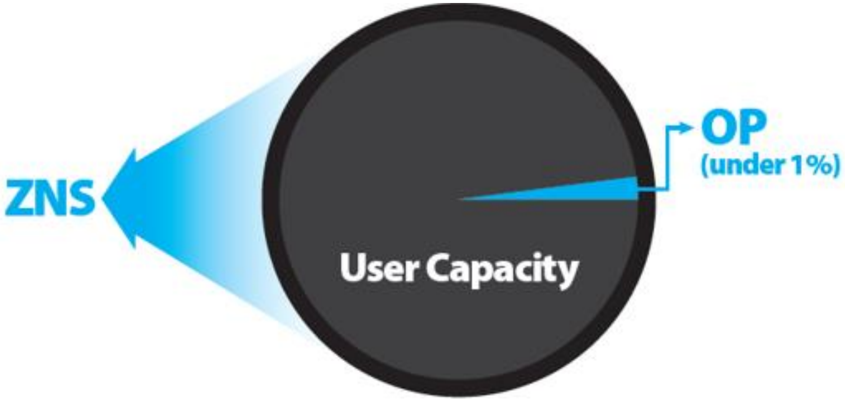




Performance Evaluation: Expected Benefits (4/5)

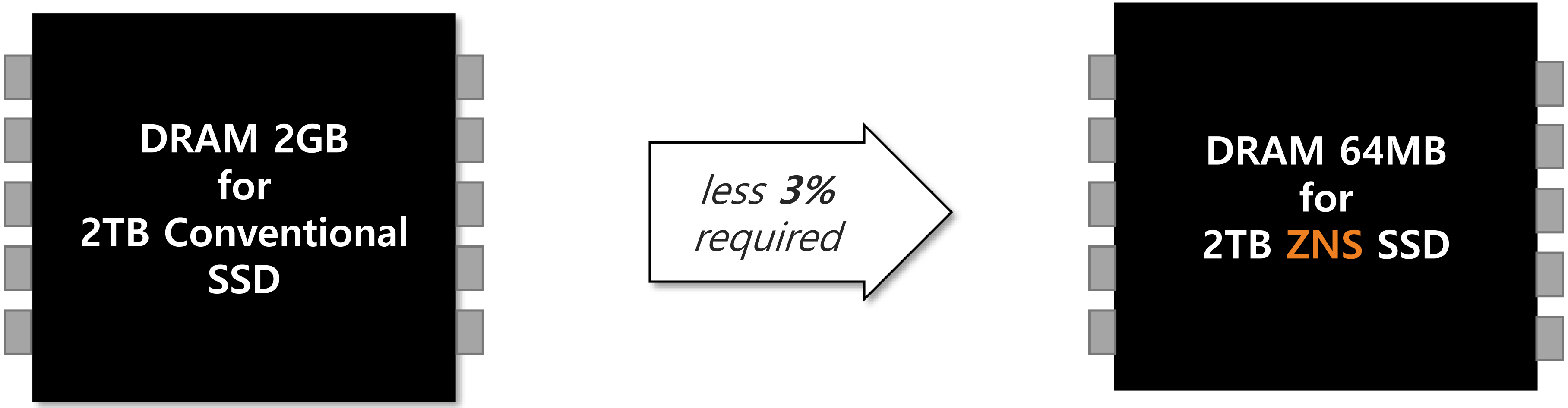
- Less Overprovisioning(OP)
  - Reduce OP area for removing Garbage Collection
  - Eventually, user capacity is increased





Performance Evaluation: Expected Benefits (5/5)

- Reduce DRAM size requirement for SSD
  - Less DRAM is required per 1TB capacity
  - Make rooms for more critical DRAM use



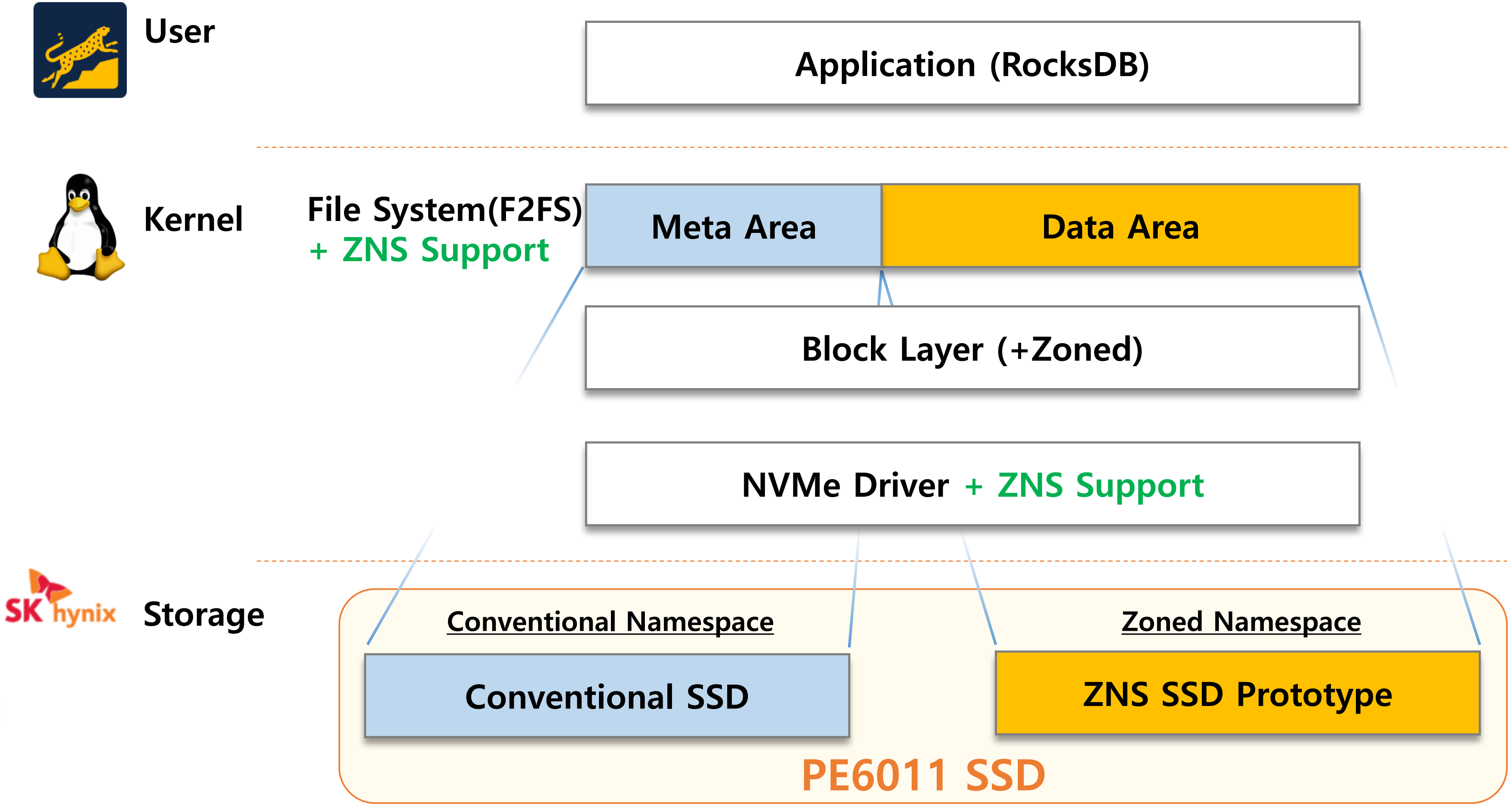
DRAM 2GB
for
2TB Conventional
SSD

less ***3%***
required

DRAM 64MB
for
2TB ZNS SSD

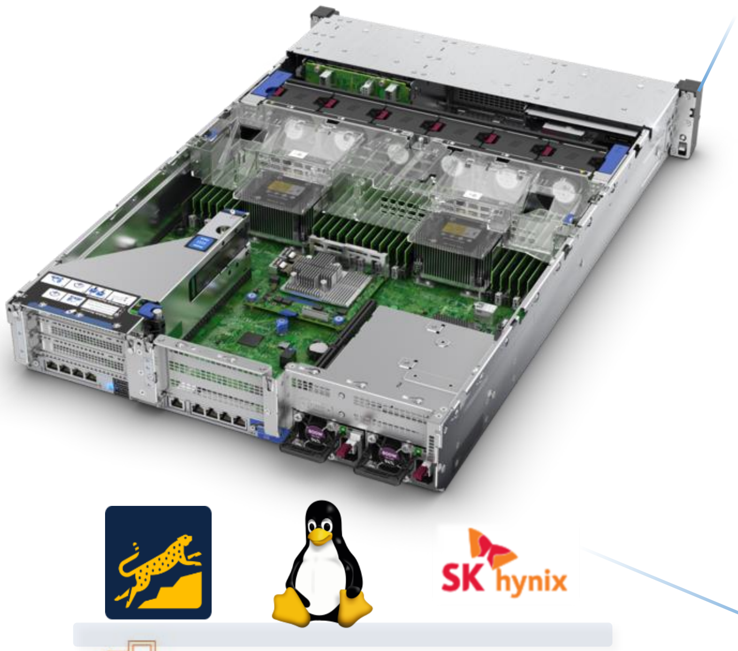
SW Enablement: RocksDB, F2FS with ZNS SSD

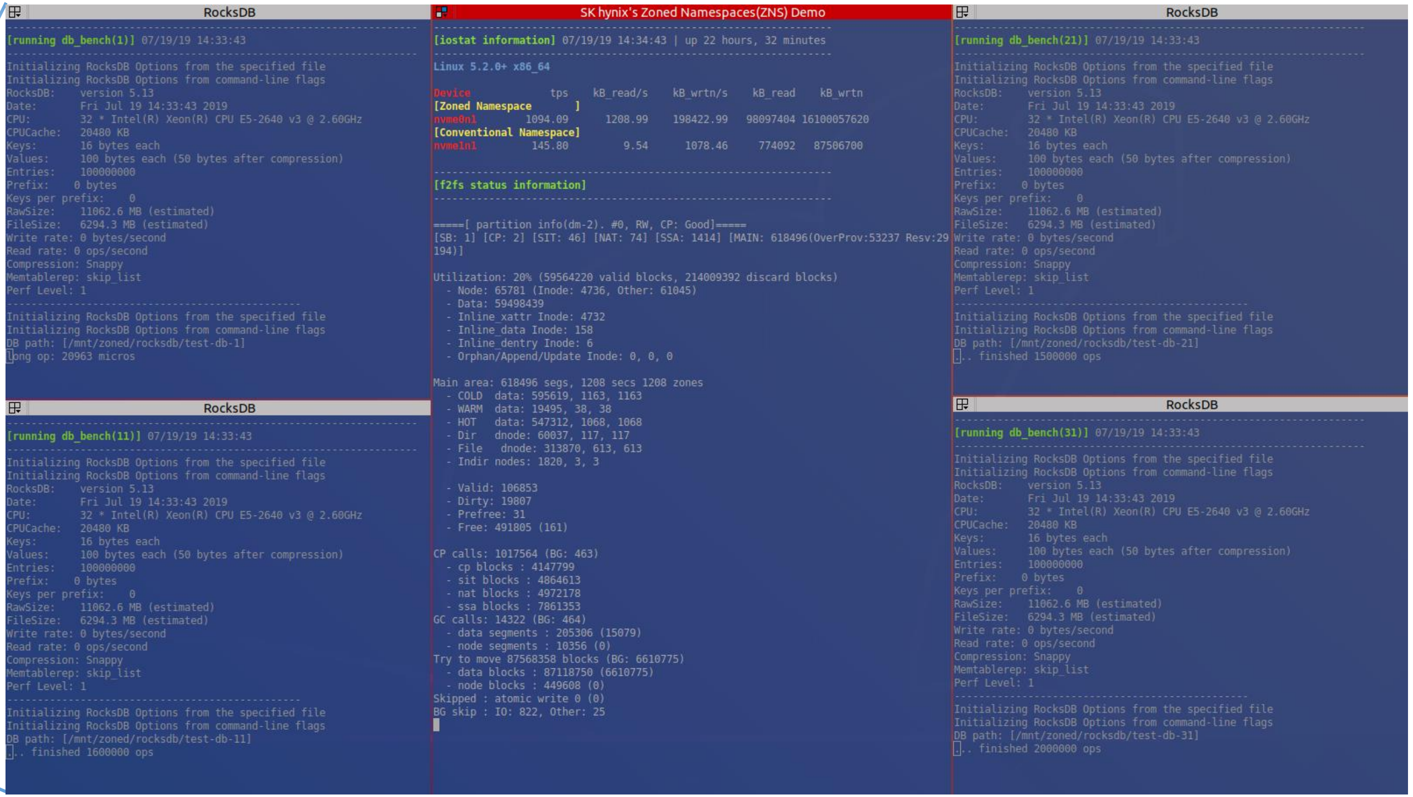
- "Linux kernel that supports Zoned Device" + "Two types of PE6011 SSD"
  - PE6011-based ZNS SSD for append-only write in F2FS
  - Conventional SSD for random-write in F2FS



SW Enablement: Live Demo

- Running RocksDB with db_bench on ZNS-configured Linux Host System
- Key-value data is stored into PE6011 ZNS SSD





```
------------------------------------------------------------------
[running db_bench(1)] 07/19/19 14:33:43
------------------------------------------------------------------
Initializing RocksDB Options from the specified file
Initializing RocksDB Options from command-line flags
RocksDB:    version 5.13
Date:       Fri Jul 19 14:33:43 2019
CPU:        32 * Intel(R) Xeon(R) CPU E5-2640 v3 @ 2.60GHz
CPUCache:   20480 KB
Keys:       16 bytes each
Values:     100 bytes each (50 bytes after compression)
Entries:    100000000
Prefix:    0 bytes
Keys per prefix:    0
RawSize:    11062.6 MB (estimated)
FileSize:   6294.3 MB (estimated)
Write rate: 0 bytes/second
Read rate: 0 ops/second
Compression: Snappy
Memtablerep: skip_list
Perf Level: 1
------------------------------------------------
Initializing RocksDB Options from the specified file
Initializing RocksDB Options from command-line flags
DB path: [/mnt/zoned/rocksdb/test-db-1]
long op: 20963 micros
```

```
------------------------------------------------------------------
[running db_bench(11)] 07/19/19 14:33:43
------------------------------------------------------------------
Initializing RocksDB Options from the specified file
Initializing RocksDB Options from command-line flags
RocksDB:    version 5.13
Date:       Fri Jul 19 14:33:43 2019
CPU:        32 * Intel(R) Xeon(R) CPU E5-2640 v3 @ 2.60GHz
CPUCache:   20480 KB
Keys:       16 bytes each
Values:     100 bytes each (50 bytes after compression)
Entries:    100000000
Prefix:    0 bytes
Keys per prefix:    0
RawSize:    11062.6 MB (estimated)
FileSize:   6294.3 MB (estimated)
Write rate: 0 bytes/second
Read rate: 0 ops/second
Compression: Snappy
Memtablerep: skip_list
Perf Level: 1
------------------------------------------------
Initializing RocksDB Options from the specified file
Initializing RocksDB Options from command-line flags
DB path: [/mnt/zoned/rocksdb/test-db-11]
... finished 1600000 ops
```

```
------------------------------------------------------------------
[iostat information] 07/19/19 14:34:43 | up 22 hours, 32 minutes
------------------------------------------------------------------
Linux 5.2.0+ x86_64

Device            tps    kB_read/s    kB_wrtn/s    kB_read    kB_wrtn
[Zoned Namespace       ]
nvme0n1        1094.09      1208.99    198422.99   98097404 16100057620
[Conventional Namespace]
nvme1n1         145.80         9.54      1078.46     774092   87506700

------------------------------------------------------------------
[f2fs status information]
------------------------------------------------------------------

=====[ partition info(dm-2). #0, RW, CP: Good]=====
[SB: 1] [CP: 2] [SIT: 46] [NAT: 74] [SSA: 1414] [MAIN: 618496(OverProv:53237 Resv:29
194)]

Utilization: 20% (59564220 valid blocks, 214009392 discard blocks)
  - Node: 65781 (Inode: 4736, Other: 61045)
  - Data: 59498439
  - Inline_xattr Inode: 4732
  - Inline_data Inode: 158
  - Inline_dentry Inode: 6
  - Orphan/Append/Update Inode: 0, 0, 0

Main area: 618496 segs, 1208 secs 1208 zones
  - COLD  data: 595619, 1163, 1163
  - WARM  data: 19495, 38, 38
  - HOT   data: 547312, 1068, 1068
  - Dir   dnode: 60037, 117, 117
  - File   dnode: 313870, 613, 613
  - Indir nodes: 1820, 3, 3

  - Valid: 106853
  - Dirty: 19807
  - Prefree: 31
  - Free: 491805 (161)

CP calls: 1017564 (BG: 463)
  - cp blocks : 4147799
  - sit blocks : 4864613
  - nat blocks : 4972178
  - ssa blocks : 7861353
GC calls: 14322 (BG: 464)
  - data segments : 205306 (15079)
  - node segments : 10356 (0)
Try to move 87568358 blocks (BG: 6610775)
  - data blocks : 87118750 (6610775)
  - node blocks : 449608 (0)
Skipped : atomic write 0 (0)
BG skip : IO: 822, Other: 25
```

```
------------------------------------------------------------------
[running db_bench(21)] 07/19/19 14:33:43
------------------------------------------------------------------
Initializing RocksDB Options from the specified file
Initializing RocksDB Options from command-line flags
RocksDB:    version 5.13
Date:       Fri Jul 19 14:33:43 2019
CPU:        32 * Intel(R) Xeon(R) CPU E5-2640 v3 @ 2.60GHz
CPUCache:   20480 KB
Keys:       16 bytes each
Values:     100 bytes each (50 bytes after compression)
Entries:    100000000
Prefix:    0 bytes
Keys per prefix:    0
RawSize:    11062.6 MB (estimated)
FileSize:   6294.3 MB (estimated)
Write rate: 0 bytes/second
Read rate: 0 ops/second
Compression: Snappy
Memtablerep: skip_list
Perf Level: 1
------------------------------------------------
Initializing RocksDB Options from the specified file
Initializing RocksDB Options from command-line flags
DB path: [/mnt/zoned/rocksdb/test-db-21]
... finished 1500000 ops
```

```
------------------------------------------------------------------
[running db_bench(31)] 07/19/19 14:33:43
------------------------------------------------------------------
Initializing RocksDB Options from the specified file
Initializing RocksDB Options from command-line flags
RocksDB:    version 5.13
Date:       Fri Jul 19 14:33:43 2019
CPU:        32 * Intel(R) Xeon(R) CPU E5-2640 v3 @ 2.60GHz
CPUCache:   20480 KB
Keys:       16 bytes each
Values:     100 bytes each (50 bytes after compression)
Entries:    100000000
Prefix:    0 bytes
Keys per prefix:    0
RawSize:    11062.6 MB (estimated)
FileSize:   6294.3 MB (estimated)
Write rate: 0 bytes/second
Read rate: 0 ops/second
Compression: Snappy
Memtablerep: skip_list
Perf Level: 1
------------------------------------------------
Initializing RocksDB Options from the specified file
Initializing RocksDB Options from command-line flags
DB path: [/mnt/zoned/rocksdb/test-db-31]
... finished 2000000 ops
```

Summary

1. **Two SK hynix's NVMe ZNS Prototypes**
   - PE4011
   - PE6011
2. **Expected Benefits with ZNS**
   - Extend SSD Lifespan
   - Improve Performance & QoS
   - Reduce SSD's memory resource requirement (OP, DRAM)
3. **Linux Host enabled with ZNS Prototype**

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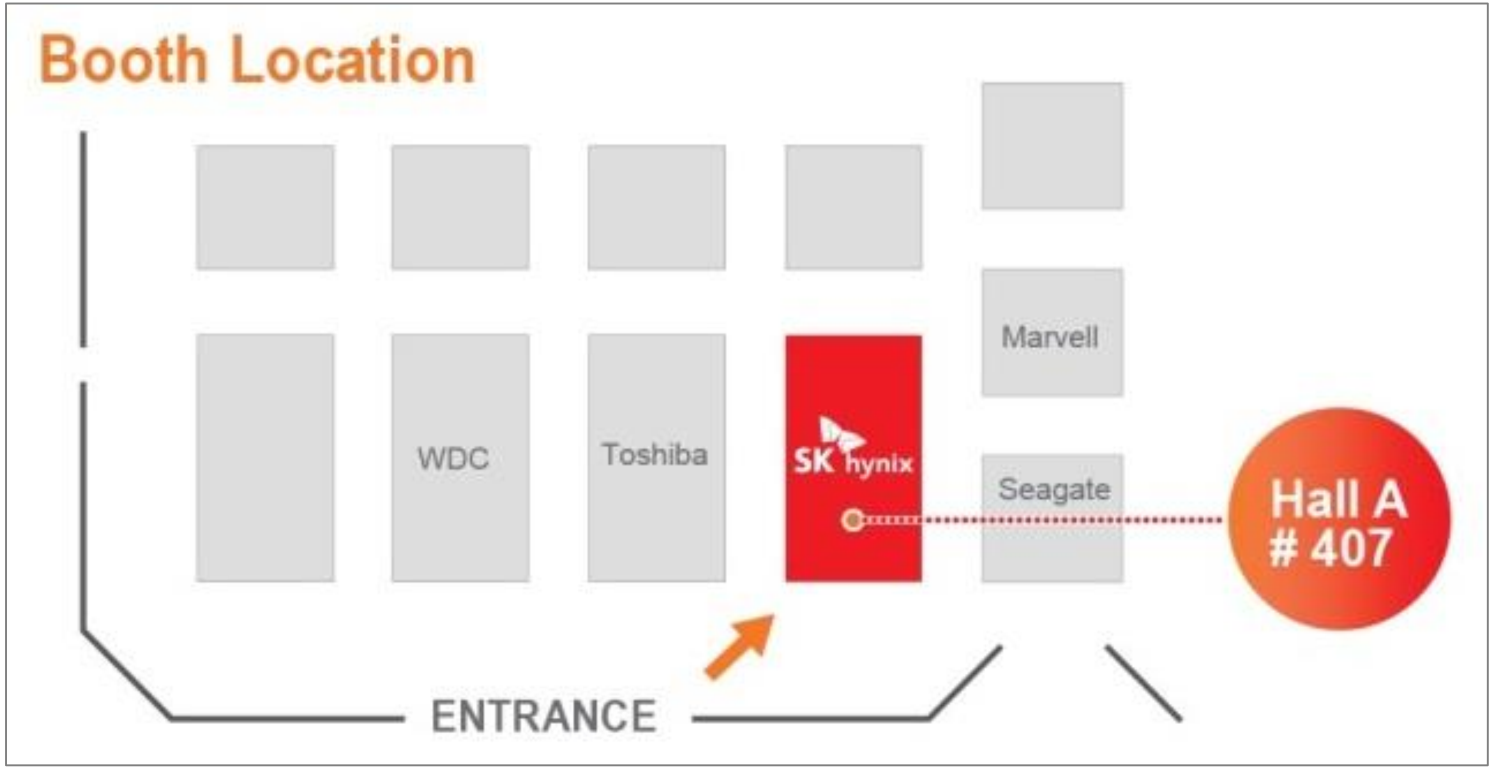

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