Leading Next Storage era Through Vertical Optimization

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TheAIO Co., Ltd.

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Company Overview

Company Name	The-AIO / the-aio co., Ltd. (The Advanced IO)
Vision	Total Storage Solution Provider
Establish Day	Jun 16th 2011
CEO	Jin-Hyoung, Kwon (jh.kwon@the-aio.com)
Products	• Standard Product : eMMC/UFS/SD controller and S/W • Differentiated Product : SpikeNAND™, eMMC^{Plus} etc. controller and S/W • Storage Sub-System : Enterprise SSD + SW Package
Members	49 People (R&D proportion **84%**)
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Vision

Total Storage Solution Provider

Year 2020
KRW 1 tr.

- **Embedded Solution**
  - eMMC5.0 / uSD3.0
  - eMMC^Plus
  - eMMC4.5
  - Sample Silicon

'13.Q2

'14.Q1

- **Enterprise SSD Solution**

'15.Q3

- **Enterprise SSD + SW Package**

- **Server Solution Launching**

`12 `13 `14 `15 `16 `17 `18 `19 `20

Storage Device

- **Host SW Optimization Tech.**
  - Pattern Shaper
- **Device Firmware Tech.**
  - A-FTL(AIO's Advanced FTL)
  - RFE
- **Hardware IPs SoC Design Tech.**
  - Design - ECC(BCH & LDPC)
  - DFC, NFC
  - Analog IPs

Storage sub-System

- **Host SW Optimization Tech.**
  - Vertical Optimization
- **Device Firmware (FTL) Tech.**
  - Object Storage Device
- **Hardware IPs SoC Design Tech.**
  - Multicore processing tech.
  - In storage Processing engine
  - In-SSD RAID & RFE
  - De-duplication and Compression

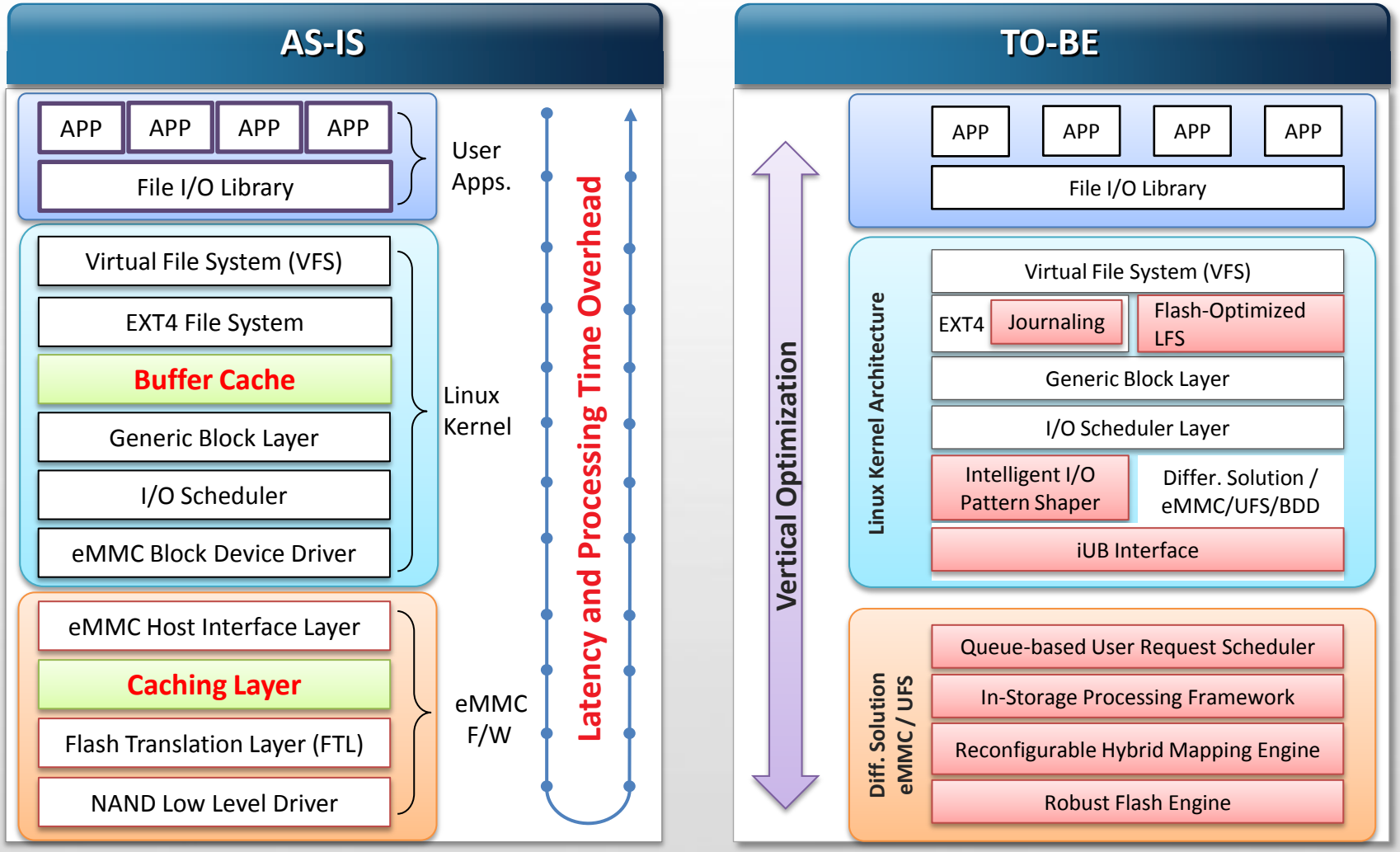
Storage System

- **Host SW Optimization Tech.**
  - Automatic tier
  - Database Accelerator
  - Storage Virtualization
  - Object Storage Server
  - Vertical Optimization
- **Device Firmware (FTL) Tech.**
  - Object Storage Device
- **Hardware IPs SoC Design Tech.**
  - Super High Perf. Computing

Vertical Optimization and Integration

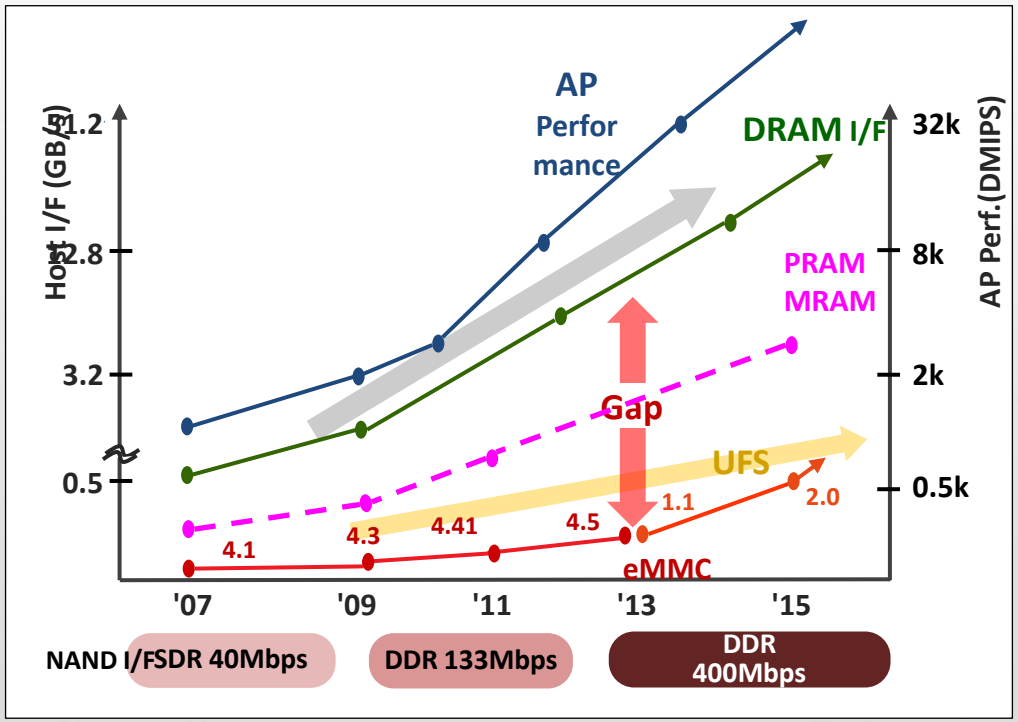
Key Technology for Next Storage Era

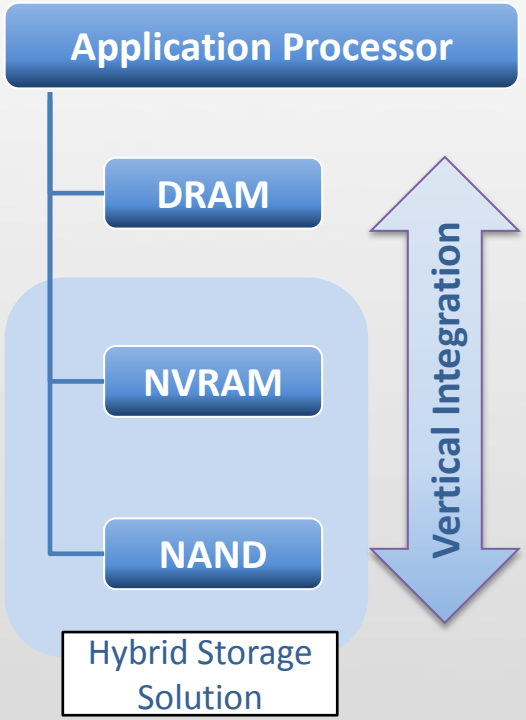
- Legacy storage stack which was developed for HDD has many limitation



Needs for better storage performance

- **NVRAM can be a new solution for better storage performance**
  - Pros.: NVRAM can compensate for the performance gap between DRAM and NAND
  - Cons.: Need to clear issues from marketability and capacity
- **AIO is proposing a NVRAM-NAND hybrid storage solution**
  - NVRAM-NAND hybrid storage solution covers NVRAM standalone issues

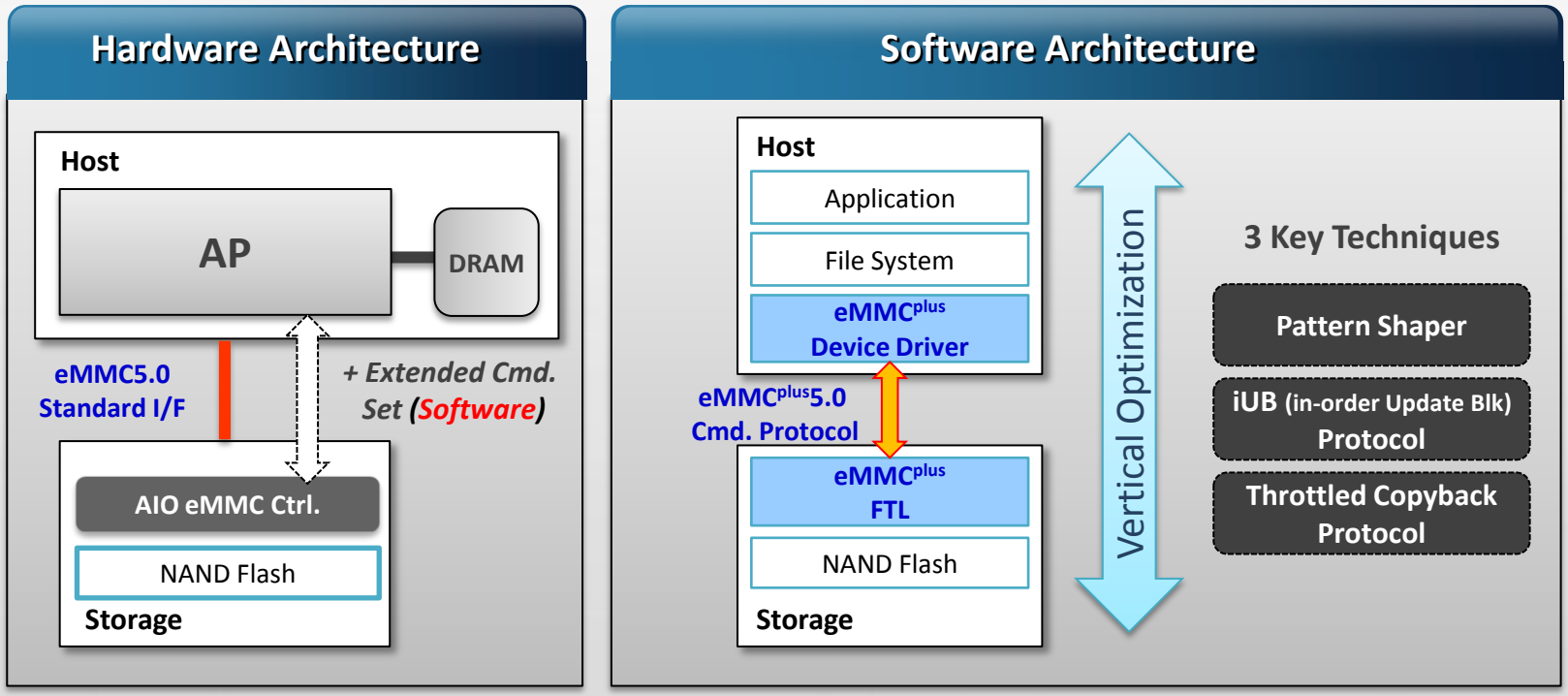




Current optimized solution

eMMC^{plus} 5.0 Solution

- **Advanced eMMC Solution with Full Compatibility with Standard eMMC5.0**
  - No Host Side HW Change needed
- **Higher Performance**
  - 10x Higher Random Write Performance : Pattern Shaper
- **Reliability with Low Cost TLC NAND**
  - 4x Longer Endurance : Pattern Shaper / iUB → Low Cost (TLC instead of MLC)



Demo: Competitor eMMC vs. eMMC^{plus}

Androbench Settings

- Write file-size : 16MB
- Read file-size : 32MB
- Sequential IO size : 256KB
- Random I/O size : 4KB
- # of SQL transaction : 1000

File system utilization: 0%

NAND : 64Gb MLC x 2 way

	Competitor		AIO eMMC^{plus}
Sequential Read	93.2 MB/s	- 5.7%	87.8 MB/s
Sequential Write	22.6 MB/s	26.4%	28.5 MB/s
Random Read	12.9 MB/s	23.0%	15.9 MB/s
Random Write	1.5 MB/s	69.5%	2.5 MB/s
SQLite Insert	112.4 TPS	25.4%	140.9 TPS
SQLite Update	113.7 TPS	8.0%	122.8 TPS
SQLite Delete	120.7 TPS	11.7%	134.8 TPS
Browser	54.3 ms	57.0%	34.6 ms
Market	128.9 ms	12.6%	114.5 ms
Camera	121.9 ms	15.1%	105.8 ms
Camcorder	266.2 ms	6.8%	249.2 ms
Total Time	72''		47''

eMMC^{plus}4.51: Performance Summary

- **MP version silicon is expected to *outperform competitors by significant amount***

[Performance in OS-less environment (over raw device)]

OS-Less (Raw Device)		1st Silicon		MP Silicon (Estimated)		eMMC 4.51 Competitor		
		1Ch. 2way 16GB@DDR200		1Ch. 2way 16GB@DDR266		1x2 16GB	1x2 16GB	1x4 16GB
		eMMC	eMMC^{plus}	eMMC	eMMC^{plus}	A	B	C
Sequential (MB/s)	Read	**140**	←	**180**	←	169	166	125
	Write	**62**	←	**80**	←	37	60	38
Random (IOPS)	S-Read	**8,774**	←	**9,000**	←†	7,501	5,450	4,553
	A-Write	3,011	**15,872**	3,100	**17,920**	2,110	2,388	2,243

[Performance in Android-Linux environment (over file system, AIOzone)]

Sequential (MB/s)	Read	111	**116**	120	**120**	102	99	83
	Write	58	**61**	70	**70**	34	47	35
Random (IOPS)	S-Read	3,316	**3,073**	3,400	**3,400**†	2,949	2,648	2,278
	A-Write	1,819	**11,666**	2,000‡	**13,200**	1,737	1,575	1,356

Note1: eMMC^{plus} performance is calculated based on eMMC performance

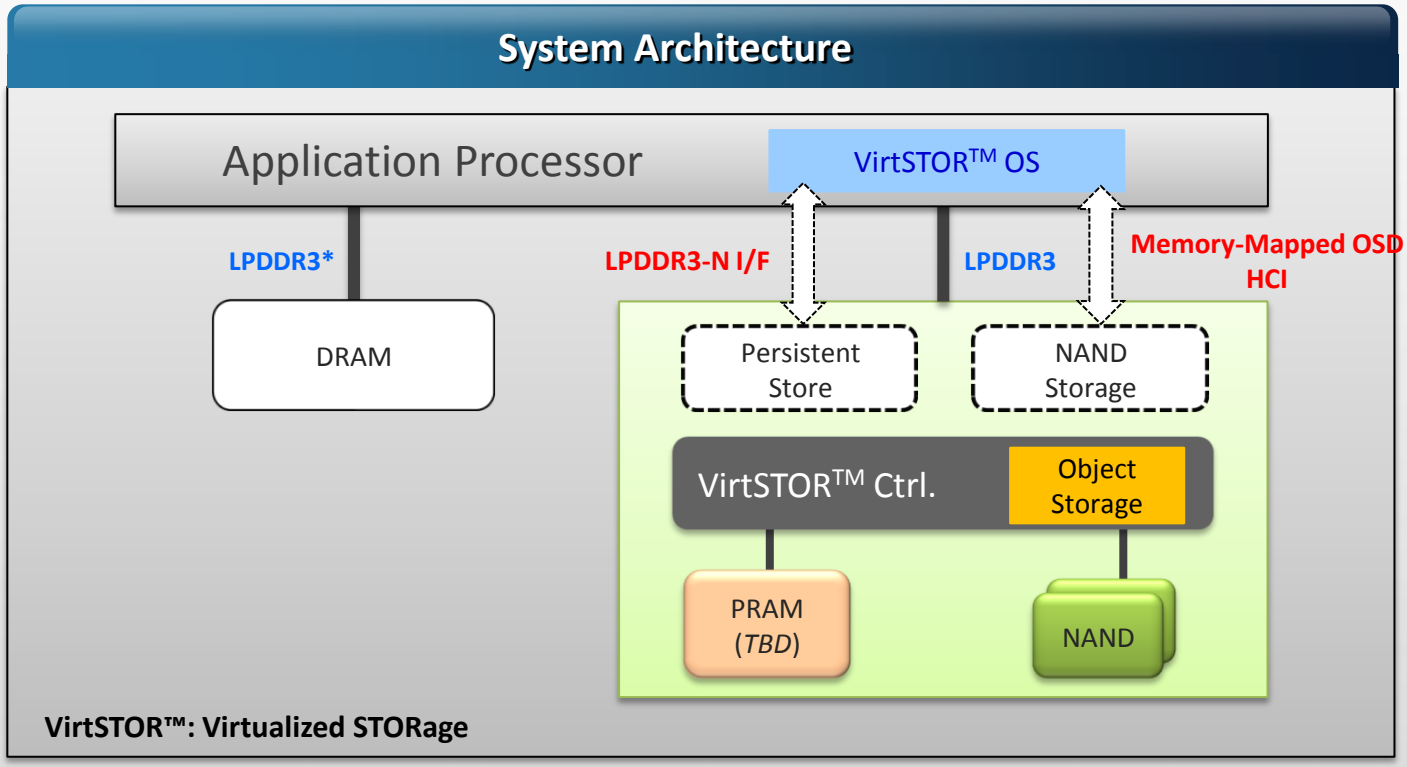
Note2: NAND for AIO eMMC – 64Gb MLC of B company (1xnm)

† Constant regardless of range (iUB mapping)

Preparing the new NVRAM era

VirtSTOR™: NVM-Powered Storage Solution

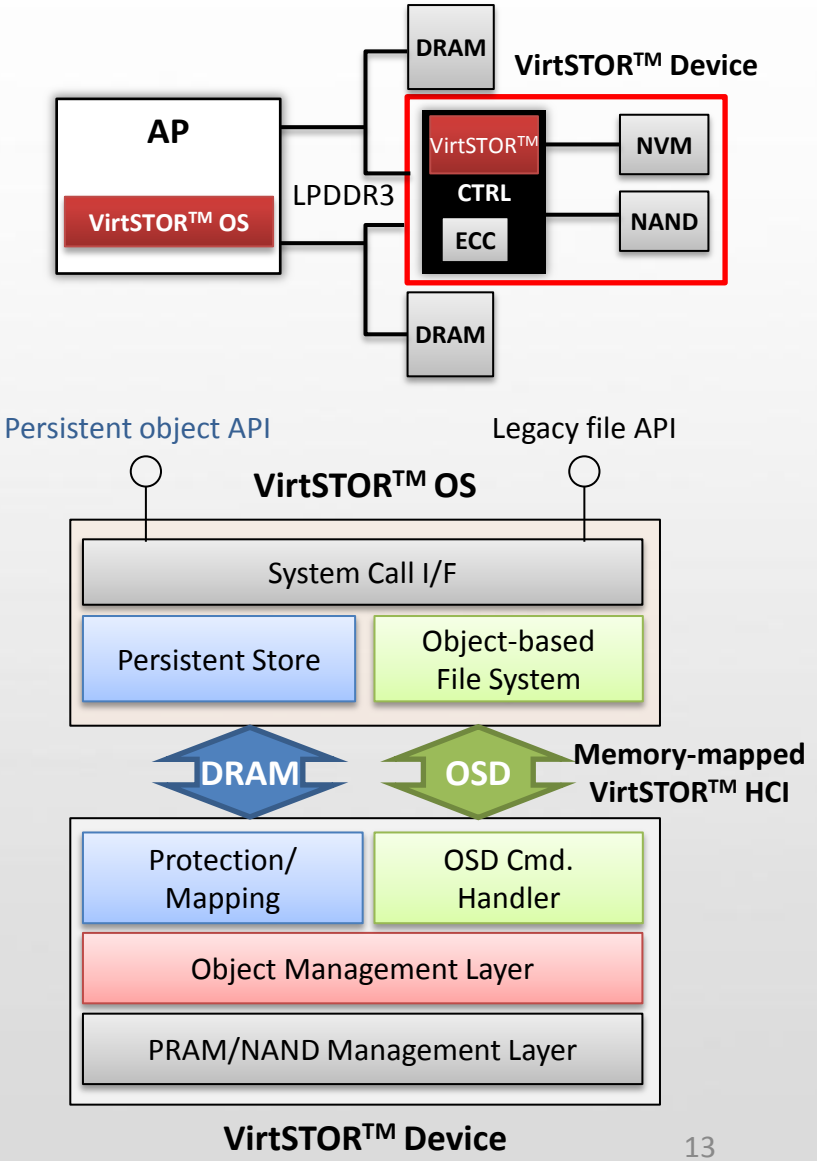
- **NVM-Unified Solution to Improve Performance and Reliability**
  - NVM-Powered : **Ultra Fast Random Performance, Reliability Enhancement**
  - Dual-Mode Access : Persistent Object Interface, Object-Storage Device (OSD) Interface
  - Object-based NAND Space Management : Common Backend Store



* Could be LPDDR3/4 or other next generation DRAM interface (TBD)

VirtSTOR™ Technology

- **Object-based NAND space management**
  - Common backend store
  - Infrastructure for intelligent storage; i.e., In-storage Processing Engine
- **Tiered storage with NVM at the first tier**
  - Un-buffered small random writes
    - E.g., Database, journal data, lock files, meta data of file system and FTL
  - Temporary data update
    - E.g., LSB/CSB backups
- **Internal use of NVM**
  - FTL meta management
  - NAND reliability information storage
- **Thin-provisioning of NVM**
  - Swapping between PRAM ↔ NAND
- **Hardware-assisted PRAM access**
  - TLB for minimum access latency
  - Protection mechanism



Effectiveness of Proposed Architecture

High Performance	• NVRAM absorbs random write traffic from applications and file systems • Application directly accesses persistent store; no OS overhead • Fast booting and application start-up; recovery but no reconstruction, XIP
High Reliability and Endurance	• Smaller WAF(write amplification Factor); random writes to NVRAM • In-storage RAID technique; NVRAM as a parity store • LSB/CSB page data backup and NAND reliability information in NVRAM
Easy integration and Maintenance	• Thin file system stack in operating system • Tiering is performed autonomously by storage • Architecture transparent to application and file system
Low Cost	• Thin provisioning of NVRAM with high capacity backup storage (i.e., NAND) • Smaller SRAM usage for NAND management

Conclusion

Confidential

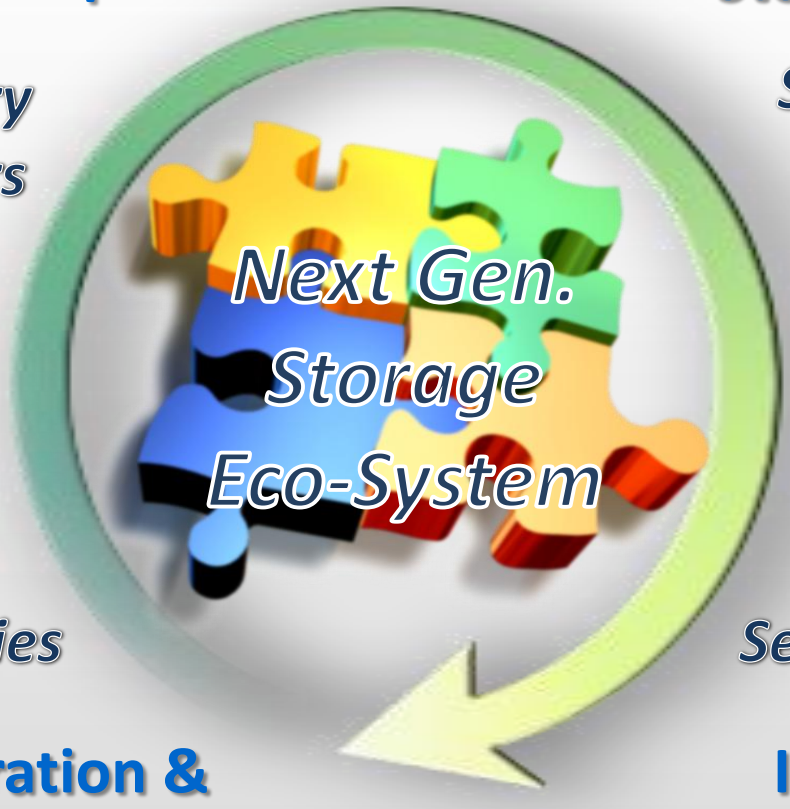
New Storage Solution Era begins with Cooperation

NVRAM Development

Memory Vendors

Storage Solution

Solution Vendor



Academies

Set Makers

Arch. Exploration & Concept Validation

Integration & Commercialization

Thank You

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