Memory Centric 시대

- SK Hynix Solution 방향 (Storage 중심)

2024.10
SKHY / Solution AT
Junghyun Joh

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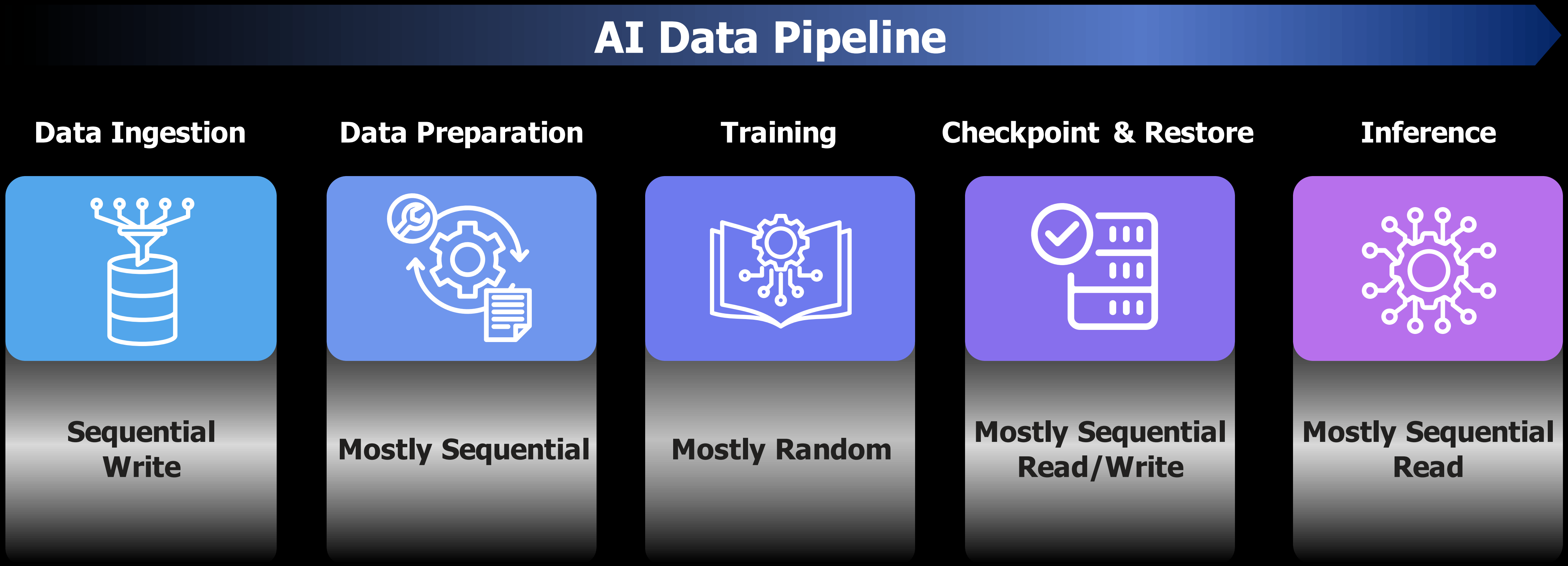
AI Pipeline and Storage Workload



AI Data Pipeline

Data Ingestion	Data Preparation	Training	Checkpoint & Restore	Inference
Sequential Write	Mostly Sequential	Mostly Random	Mostly Sequential Read/Write	Mostly Sequential Read

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Challenges to AI Deployment

AI Datacenter

Ingest | Prep | Training | Checkpoint | Inference

STORAGE

Limited rack power & space, growing dataset

COMPUTE

Power optimized SSD as cache device

On-device AI

Inference

USER EXPERIENCE

AI model loading time and user experience

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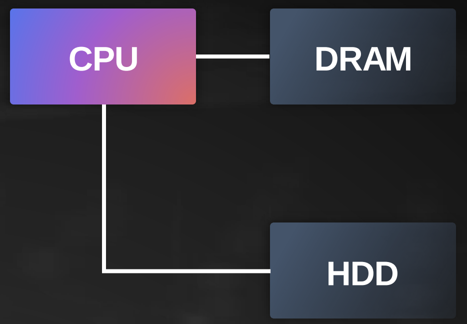
Memory Centric

Memory is system competitive

Past System

Calculator : Data Simple Calculation



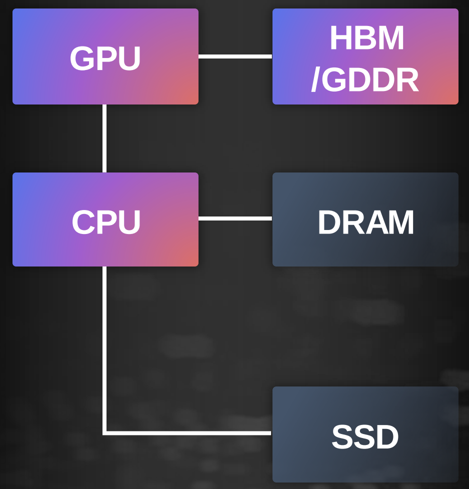
CPU

DRAM

HDD

Present System

Workable : Data/information Reading



GPU

HBM /GDDR

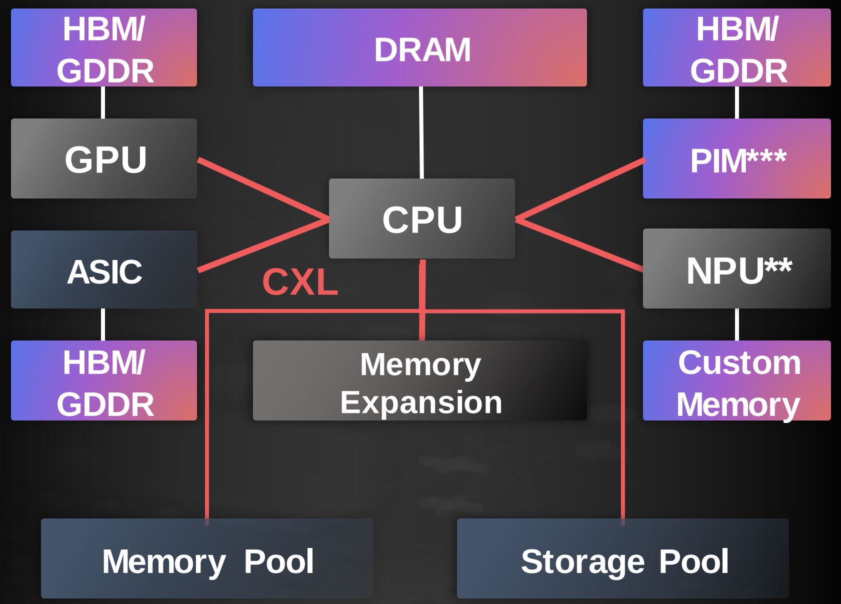
CPU

DRAM

SSD

Future System

Thinkable AI : Data/information Creation



HBM/ GDDR

DRAM

HBM/ GDDR

GPU

CPU

PIM***

ASIC

CXL

NPU**

HBM/ GDDR

Memory Expansion

Custom Memory

Memory Pool

Storage Pool

* CXL: Compute eXpress Link
** NPU: Neural Processing Unit
***PIM: Processing in Memory

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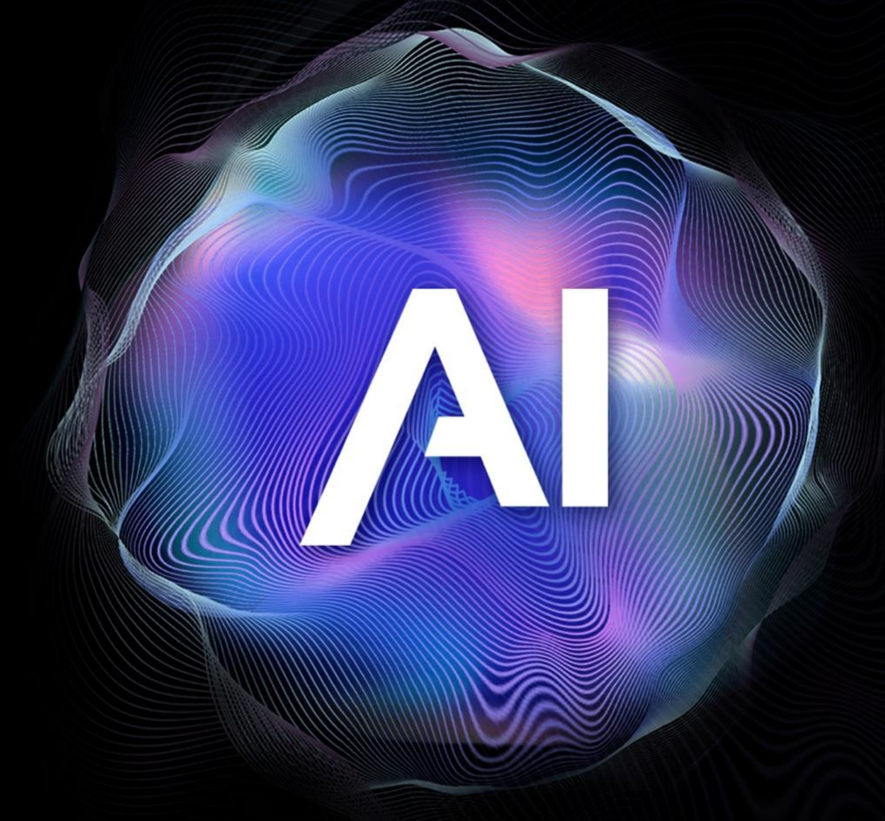
SK hynix Solution for the AI Era



Junghyun Joh

SK Hynix / Solution AT

FMS 2024
SK하이닉스 미래포럼
AI HW Summit

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1. Industry's AI Challenges

- Facing Problems

2. SK Hynix's Solutions

- Current Efforts

3. AI Memory Centric

- SK Hynix's Preparations

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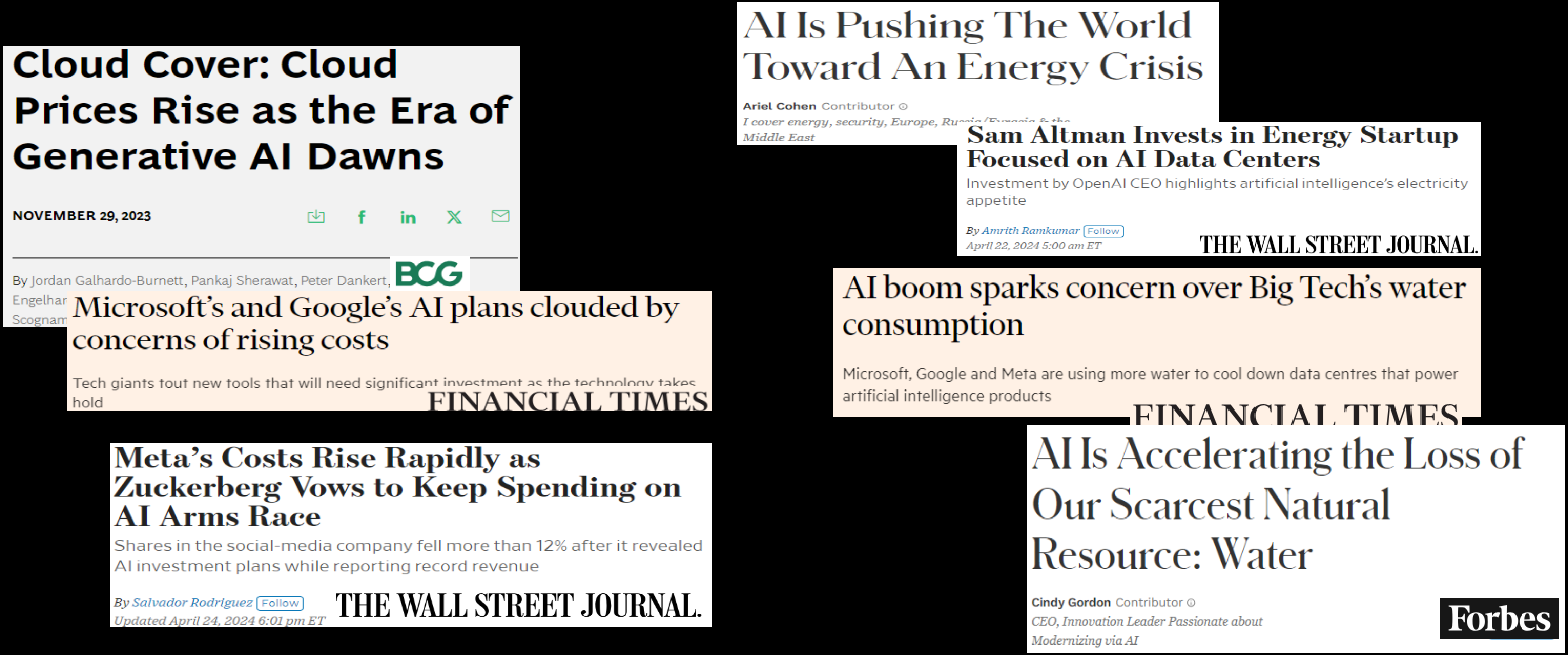
Facing Problems

Risk increasing due to Energy, Cost, Environmental issue and etc.



Cloud Cover: Cloud Prices Rise as the Era of Generative AI Dawns

NOVEMBER 29, 2023

By Jordan Galhardo-Burnett, Pankaj Sherawat, Peter Dankert, Engelhar Scognam

BCG

Microsoft's and Google's AI plans clouded by concerns of rising costs

Tech giants tout new tools that will need significant investment as the technology takes hold

FINANCIAL TIMES

Meta's Costs Rise Rapidly as Zuckerberg Vows to Keep Spending on AI Arms Race

Shares in the social-media company fell more than 12% after it revealed AI investment plans while reporting record revenue

By *Salvador Rodriguez* Follow
Updated April 24, 2024 6:01 pm ET

THE WALL STREET JOURNAL.

AI Is Pushing The World Toward An Energy Crisis

Ariel Cohen Contributor
I cover energy, security, Europe, Ru
Middle East

Sam Altman Invests in Energy Startup Focused on AI Data Centers

Investment by OpenAI CEO highlights artificial intelligence's electricity appetite

By *Amrith Ramkumar* Follow
April 22, 2024 5:00 am ET

THE WALL STREET JOURNAL.

AI boom sparks concern over Big Tech's water consumption

Microsoft, Google and Meta are using more water to cool down data centres that power artificial intelligence products

FINANCIAL TIMES

AI Is Accelerating the Loss of Our Scarcest Natural Resource: Water

Cindy Gordon Contributor
CEO, Innovation Leader Passionate about Modernizing via AI

Forbes

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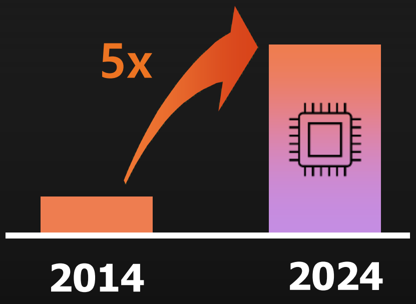
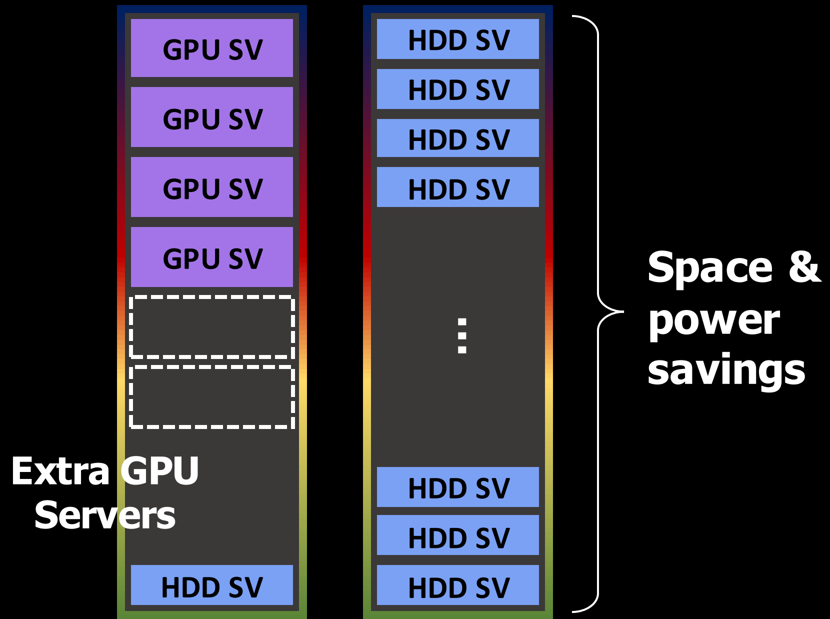
AI Datacenter Challenges: Storage

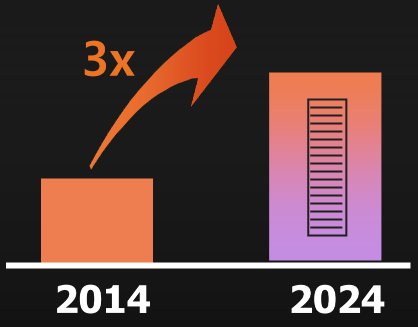
In the AI datacenter:

Avg. processor active power[1]





Avg. rack power[1]



Limited Datacenter Power and Space

[1] Source: SDxCentral

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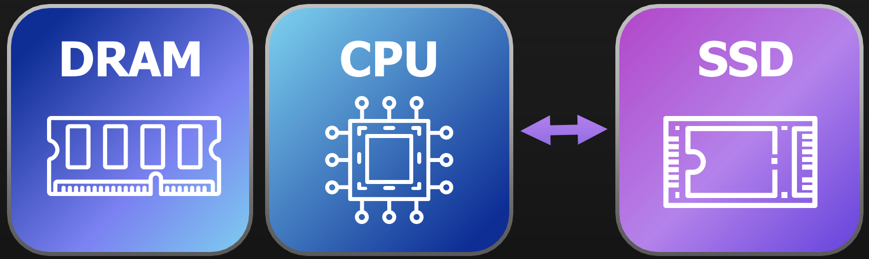
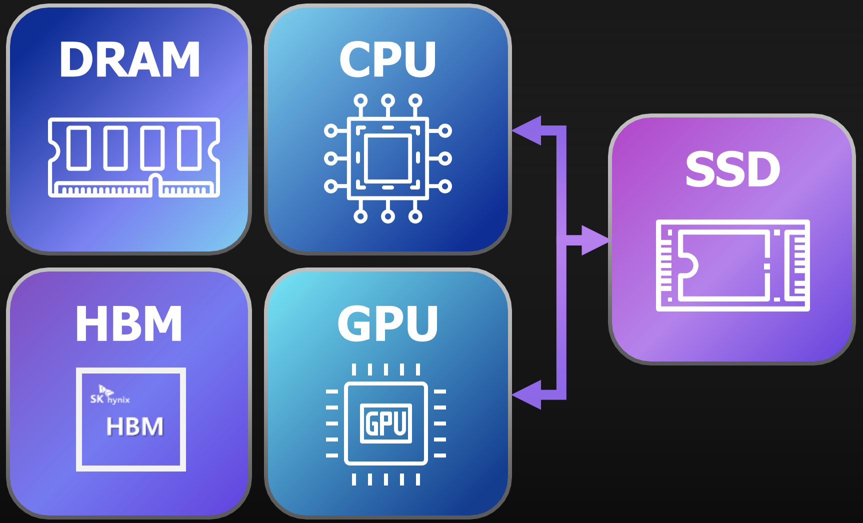
AI Datacenter Challenges: Compute

General-purpose server for Data Prep (ETL)



GPU Server for Training/ Inference



Need Something with optimized power & high performance

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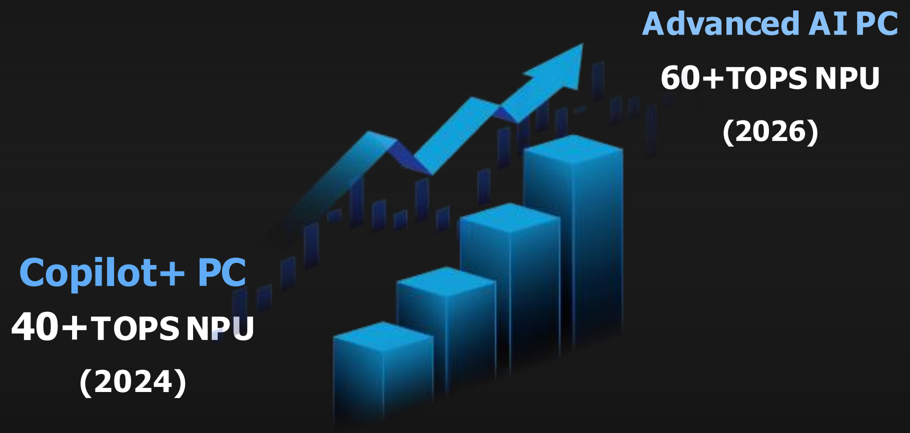
On-device AI Challenges: PC/Mobile

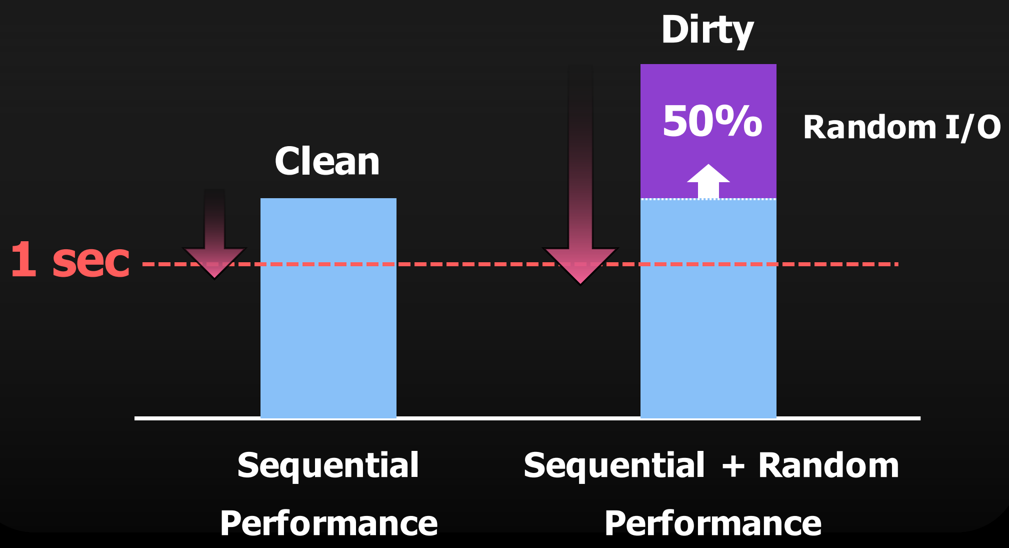
Computing Power



High-performance SSD required

User Needs

Minimal AI Model load time (<1s) from Storage to all memory states



(based on SK hynix mainstream Gen4 SSD)

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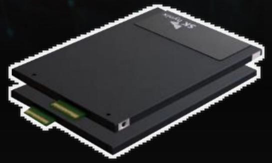
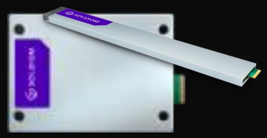
GenAI-ready Solutions

For AI Datacenter:



PCIe Gen5 Enterprise SSD
Best-in-class Performance, IOPS/W



61TB QLC Enterprise SSD
World’s highest-capacity PCIe SSD

For On-device AI:

PCIe Gen5 Client SSD
World-first for mainstream client

Zoned UFS
World-first, vertical optimized mobile storage

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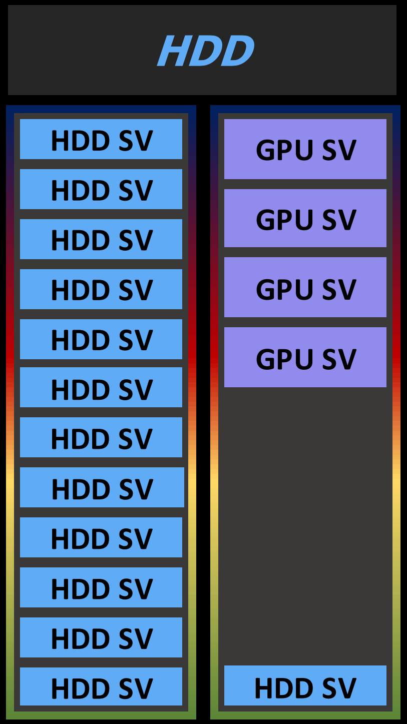
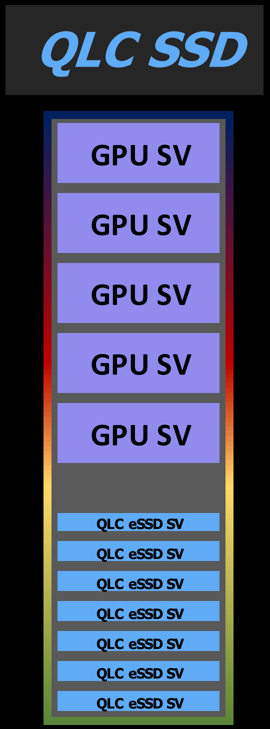
High-density QLC eSSD: vs. HDD



30TB HDD		122TB QLC SSD
4	# GPU servers configurable	5 (+1 vs. HDD rack)
4U x 13ea	# Storage servers configurable	2U x 7ea
39.78kW Compute 65% Storage 35%	Power Consumed	36.7kW Compute 89% Storage 11%
2 Racks	# Racks required	1 Rack



QLC SSD = +1 GPU server (more compute) per rack;
reduced power consumption & rack footprint

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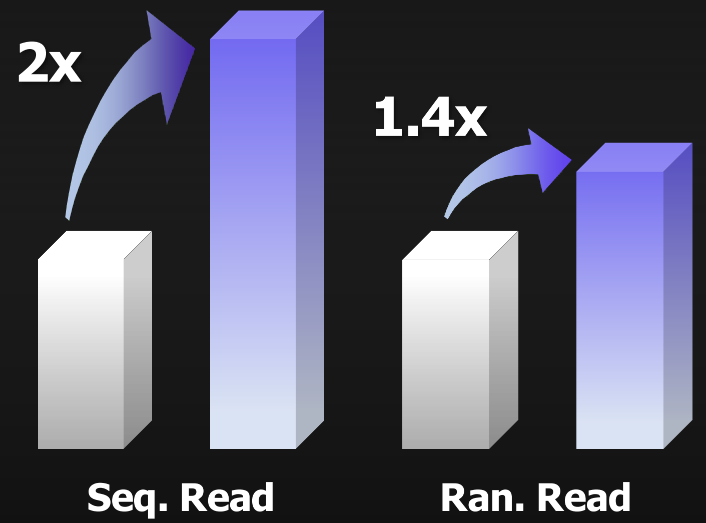
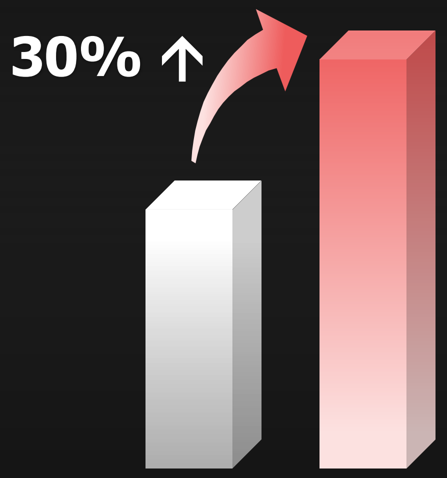
PCIe Gen5 cSSD: Gen-on-Gen Advanced

Performance



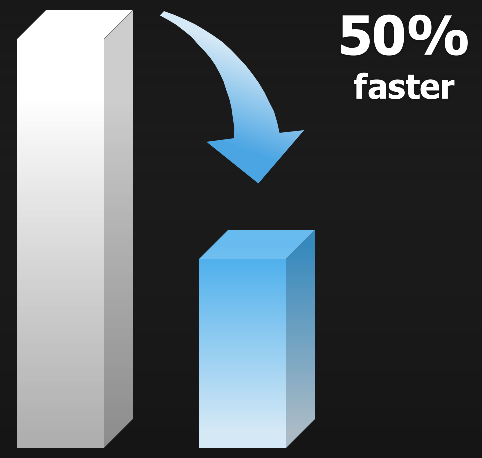
Gen4 vs. Gen5

Power Efficiency



Gen4 vs. Gen5

AI Model[1] Launch



LOADING 100% @ Clean

Gen4 vs. Gen5

[1] AI Model: Llama2 7BQ8

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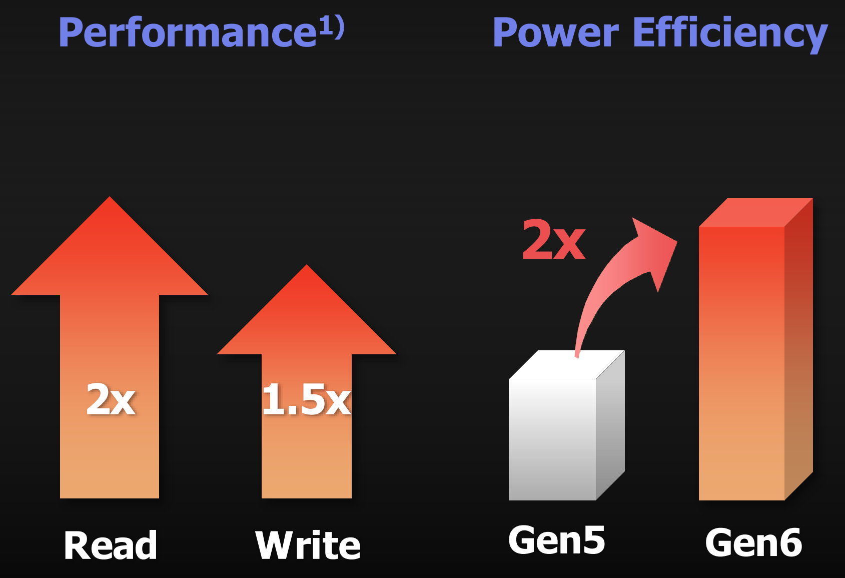
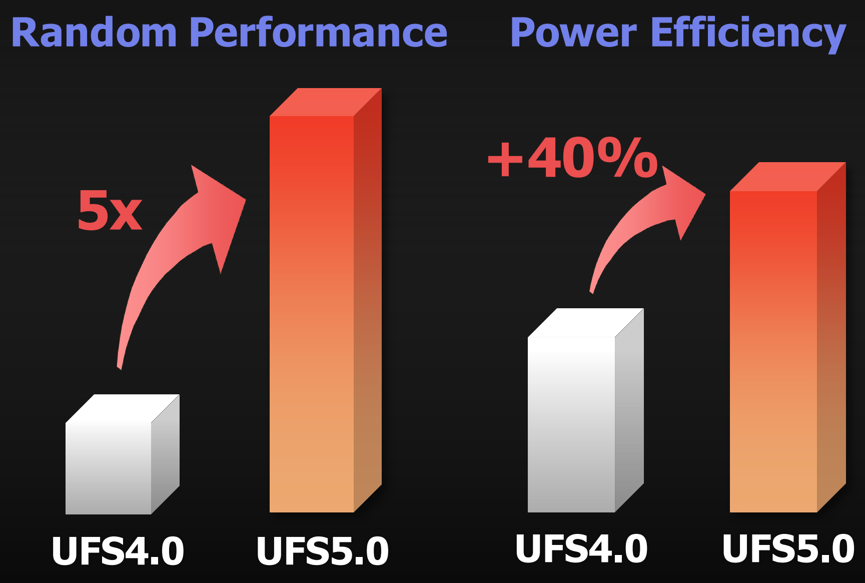
PCIe Gen6 & UFS 5.0 Solutions

PCIe Gen6 SSD



UFS 5.0[2]



Using SK hynix-proprietary, H-TPU™ architecture

1) Performance bound by max. power: 25W on Gen5 and Gen6 (estimate)

2) Estimates

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Appendix] High-density QLC eSSD: Leading Capacities

Specification

- PCIe 4.0, NVMe 1.4c, OCP 2.0

Capacity

- 7.68TB, ~ 61.44TB
- 122TB upcoming, early '25

Performance

- 7GB/s, 1M IOPs

"D5-P5336" QLC eSSD

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Appendix] PCIe Gen5 eSSD: BIC Performance

Specification

- PCIe 5.0, NVMe 2.0, OCP 2.0

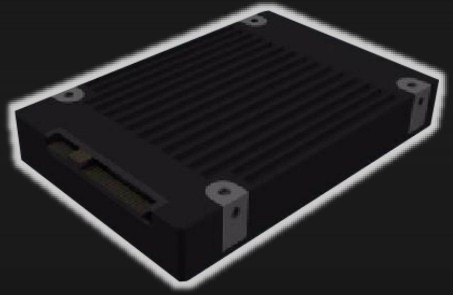
Capacity

- 1.92TB ~ 15.36TB (Read-Intensive)
- 1.6TB ~ 12.8TB (Mixed-Use)

Performance (Max.)

- Seq. R 14.5GB/s , Seq. W 9.3GB/s
- Ran. R 3,200K IOPS , Ran. W 400K IOPS
- Up to 12% better sequential write of vSAN HCI bench vs. competition

"PS10x0" Compute eSSD



U.2/U.3

E3.S

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Appendix] PCIe Gen5 cSSD: World’s First Mainstream

Specification

- PCIe 5.0, NVMe 2.0c
- HYPERWRITE^{TM} Cache Technology

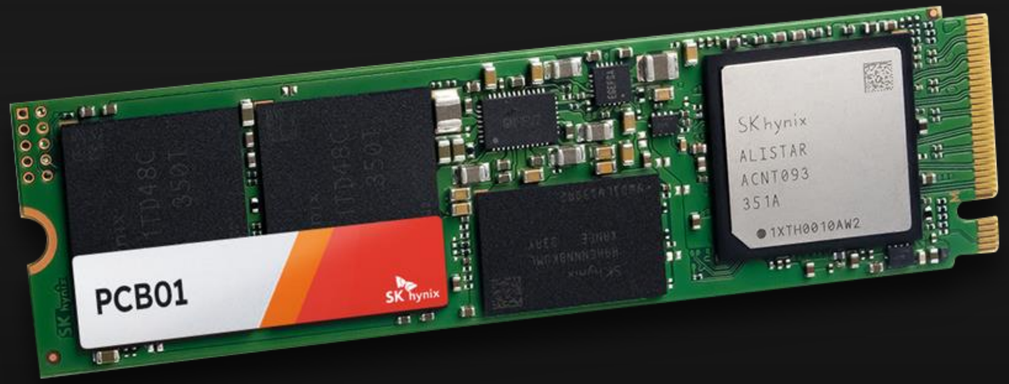
Capacity

- 512GB, 1TB, 2TB

Performance

- Seq. R 14GB/s (@10W)
- Seq. W 12GB/s (@10W)

“PCB01” mainstream cSSD



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Appendix] Zoned UFS: World’s First for Advanced Mobile

Specification

- UFS 4.0

Capacity

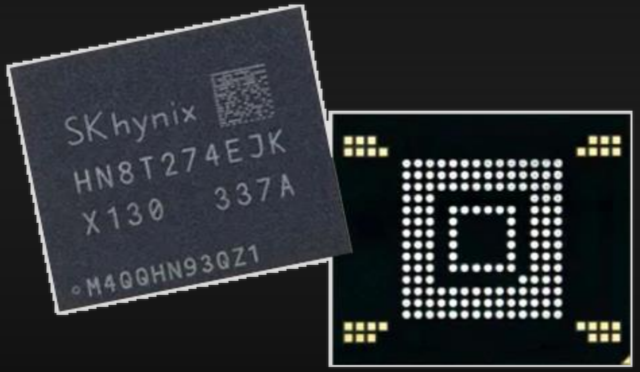
- 512GB, 1TB

ZUFS Spec

- Zone type SWR[1)]
- # Max Open Zones: 6

Vertical Optimized Mobile Storage

Zoned UFS 4.0



1) SWR : Sequential write required zone type

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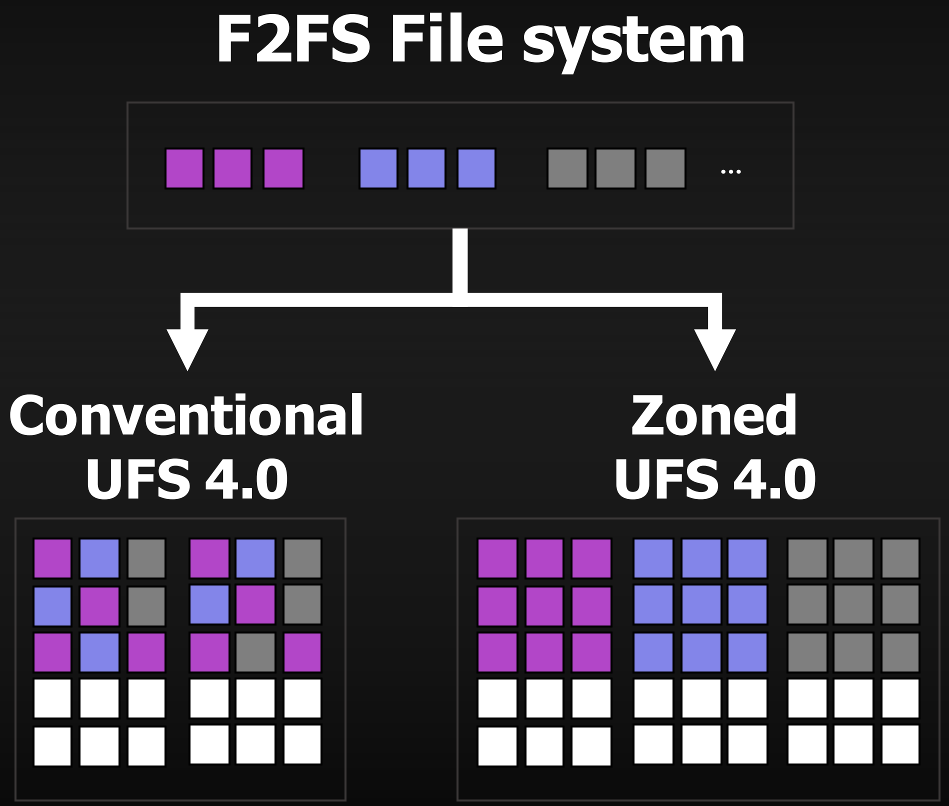
Appendix] Zoned UFS: Optimized for Advanced Mobile



F2FS File system

Conventional UFS 4.0

Zoned UFS 4.0

Application Launch Time[1)]

0.45 x

Memory Allocation Time[2)]

0.67 x

Product Lifetime

40% longer

1) Condition: long-hours use

2) Avg. of memory & storage backup/restore time

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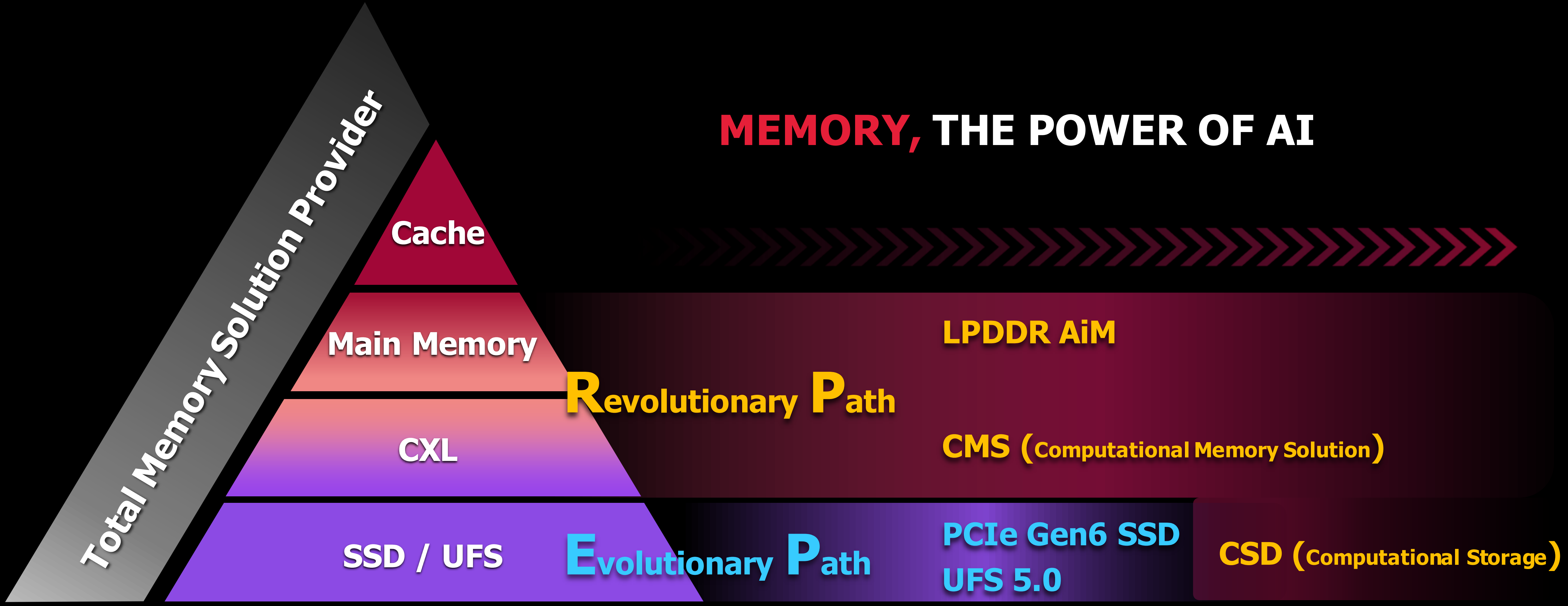
Complete AI Memory Solutions Provider

MEMORY, THE POWER OF AI


Total Memory Solution Provider
Cache
Main Memory
CXL
SSD / UFS
Revolutionary Path
LPDDR AiM
CMS (Computational Memory Solution)
Evolutionary Path
PCIe Gen6 SSD
UFS 5.0
CSD (Computational Storage)

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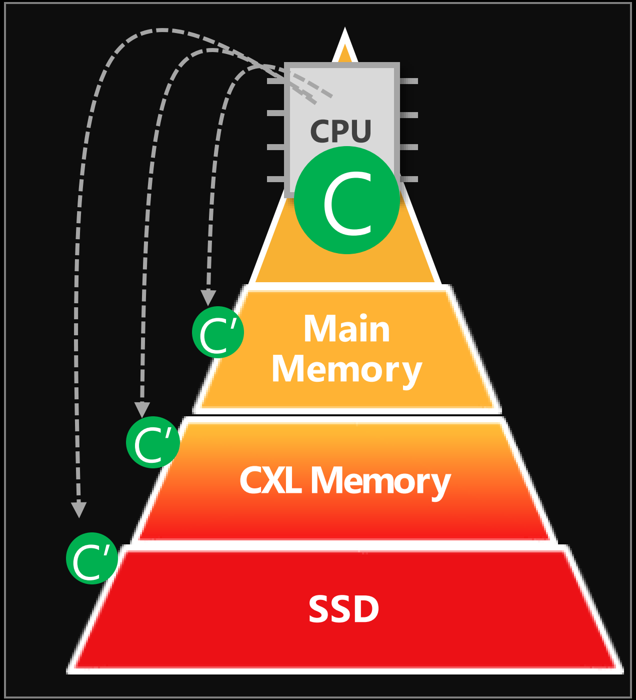
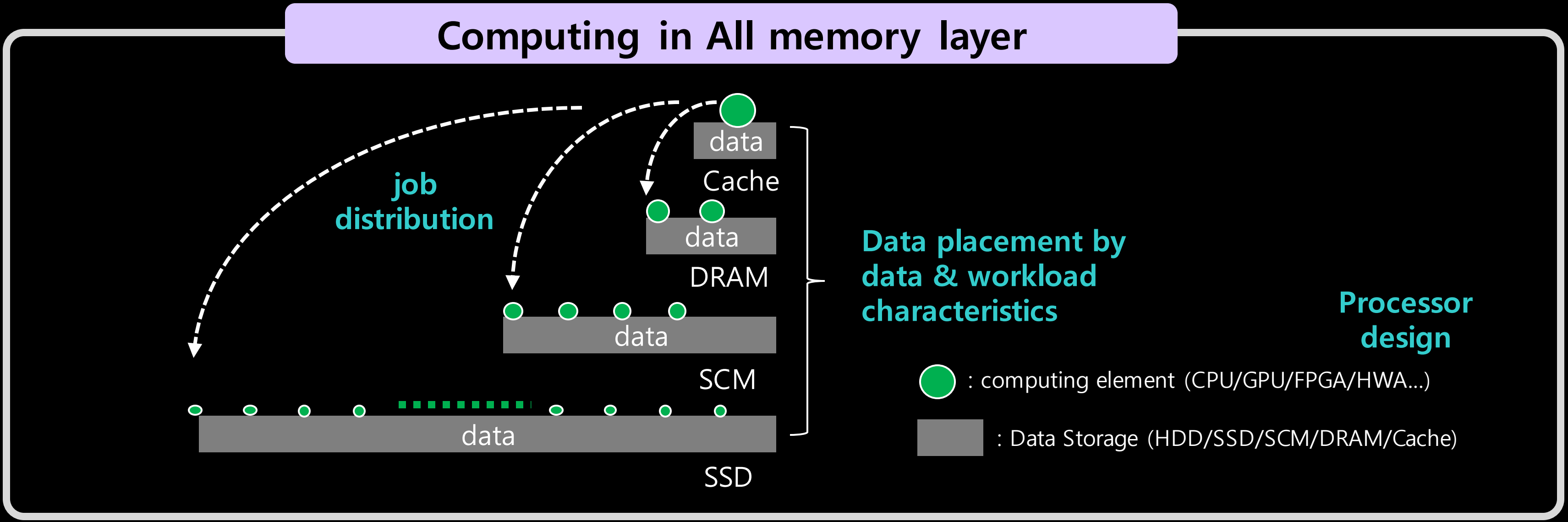
Memory Centric

Fusion in All Memory Layers



C' : computing unit


Computing in All memory layer
job distribution
data
Cache
data
DRAM
data
SCM
data
SSD
Data placement by data & workload characteristics
Processor design

● : computing element (CPU/GPU/FPGA/HWA...)

▨ : Data Storage (HDD/SSD/SCM/DRAM/Cache)

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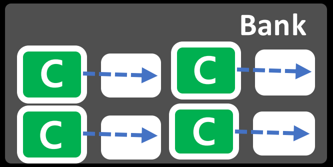
Memory & Computing Fusion

Various Memory + Computing Solution from AiM to CSD

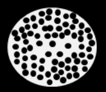
Workload density

Workload

Memory Die level (AiM)

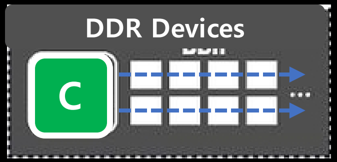


- Computing in memory die
- High density workload

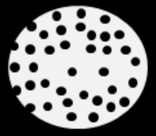


Transformer

Memory Card level (CMS)



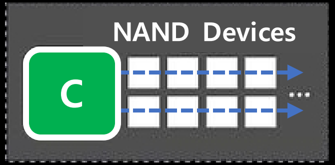
- Computing in memory card
- Low density workload



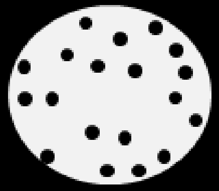
Embedding

Data Analytics

Storage level (CSD)



- Computing in SSD
- Low density & high capacity workload



Data Analytics

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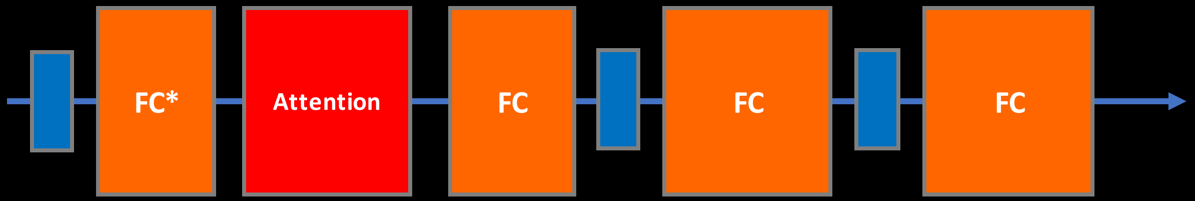
Appendix] Processing in Memory

- Even with multi batch processing, due to the attention processing for long context, there is huge portion of memory intensive function

LLM block architecture



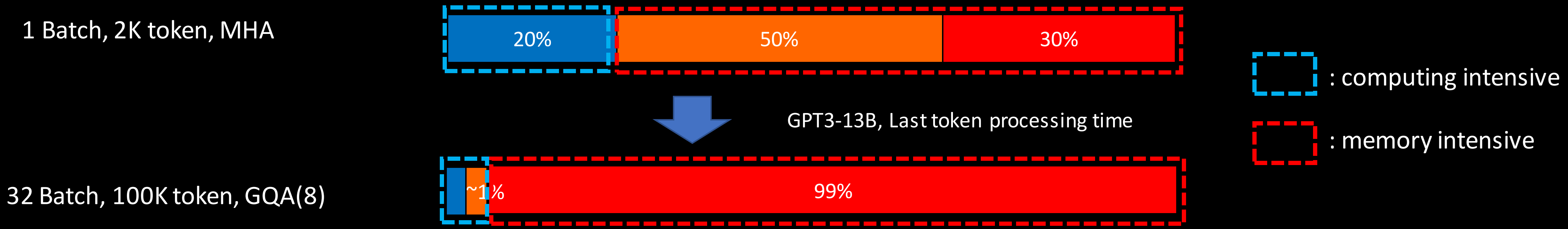
* FC : Fully connected layer

🟧 : FC weight GEMV
- In Multi batch, weight data can be reused
→ computing intensive & high GPU utilization

🟥 : Attention token GEMV
- Even in Multi batch, token data cannot be reused
→ still memory intensive & low GPU utilization

🟦 : Misc. functions
- Regardless batch
→ computing intensive & high GPU utilization

Processing time portion



LLM service trend : longer context

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Appendix] AiMX system from DC to Edge device LLM

- To provide different level of customer experience and save your operating cost

Datacenter LLM

Larger LLM size
Multi-batch
Longer context

99%

Edge device LLM

75%

Smaller LLM size
Single-batch
Long context

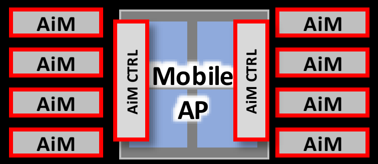
Both system has memory intensive portion as a majority

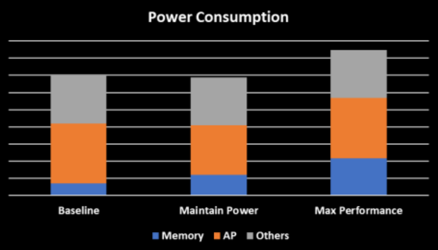
Boosting your Datacenter LLM
by adding AiMX as an attention accelerator

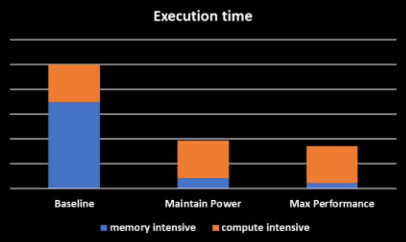
Performance

Energy consumption

Boosting your Edge device LLM
by replacing memory with AiM







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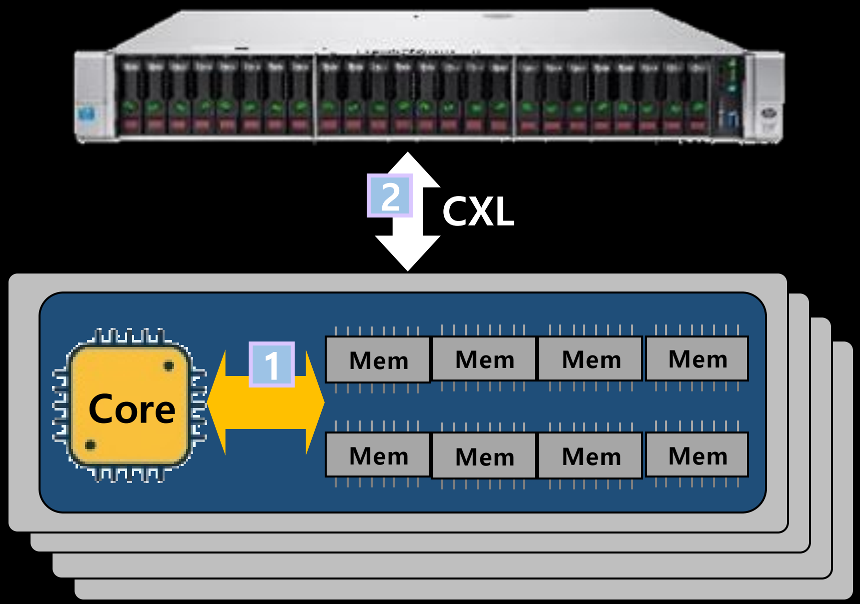
Appendix] Computational Memory Solution

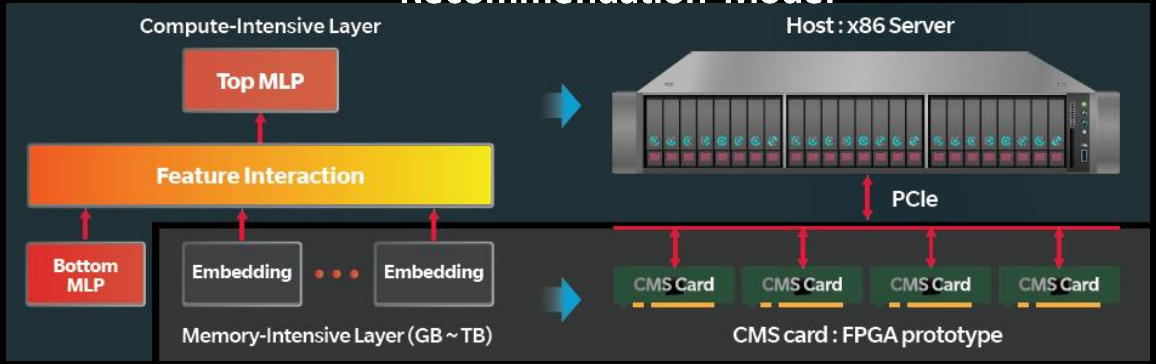
CMS



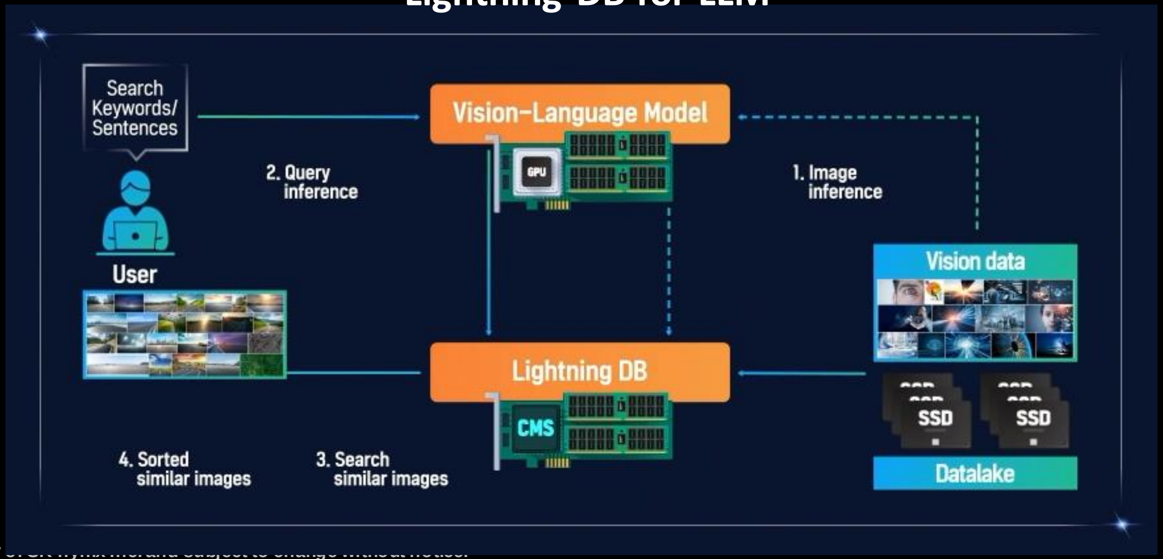
1	**Performance Improvement** By utilizing the higher Bandwidth inside the CXL module
2	**Energy Efficiency Improvement** By minimizing data movement between host and CXL module

Use case

Recommendation Model



Lightning DB for LLM



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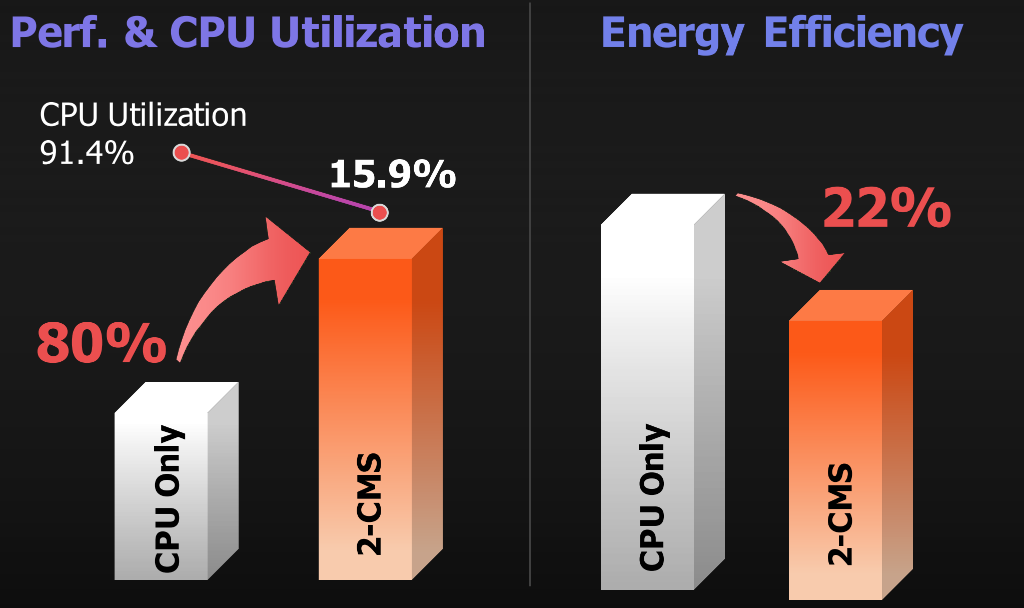
Appendix] CXL^{TM} Computational Memory Solution (CMS)

CMS 2.0

- CXL Memory Expansion
- Near-memory Processing
- Reduce data movement between CPU & CXL
- Free up CPUs to do other useful work

Data Analytics Performance



Benchmark : TPC-DS Q28 (Dataset : 38.67GB)

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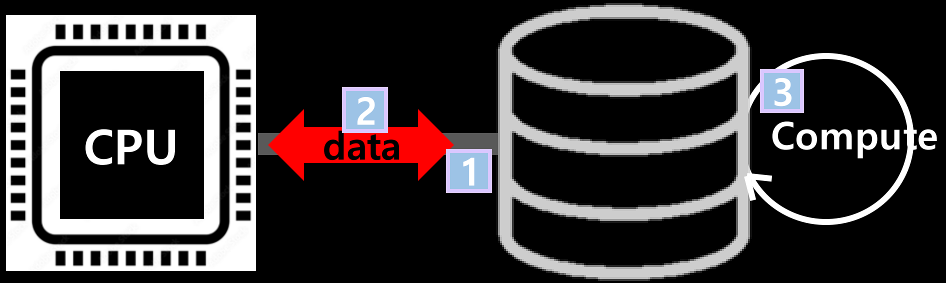
Appendix] Computational Storage Device

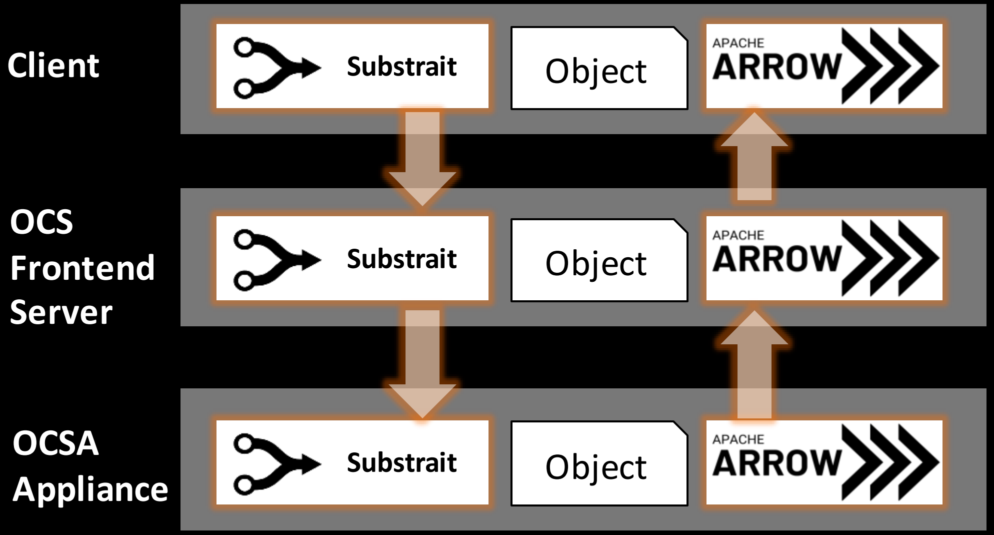
CSD



1	**Performance Improvement** By avoiding interface bottleneck
2	**Energy Efficiency Improvement** By minimizing data movement
3	**Reduce CPU overhead** By offloading tasks from Host CPU

Use case

Object based Computational Storage for Big Data Analysis



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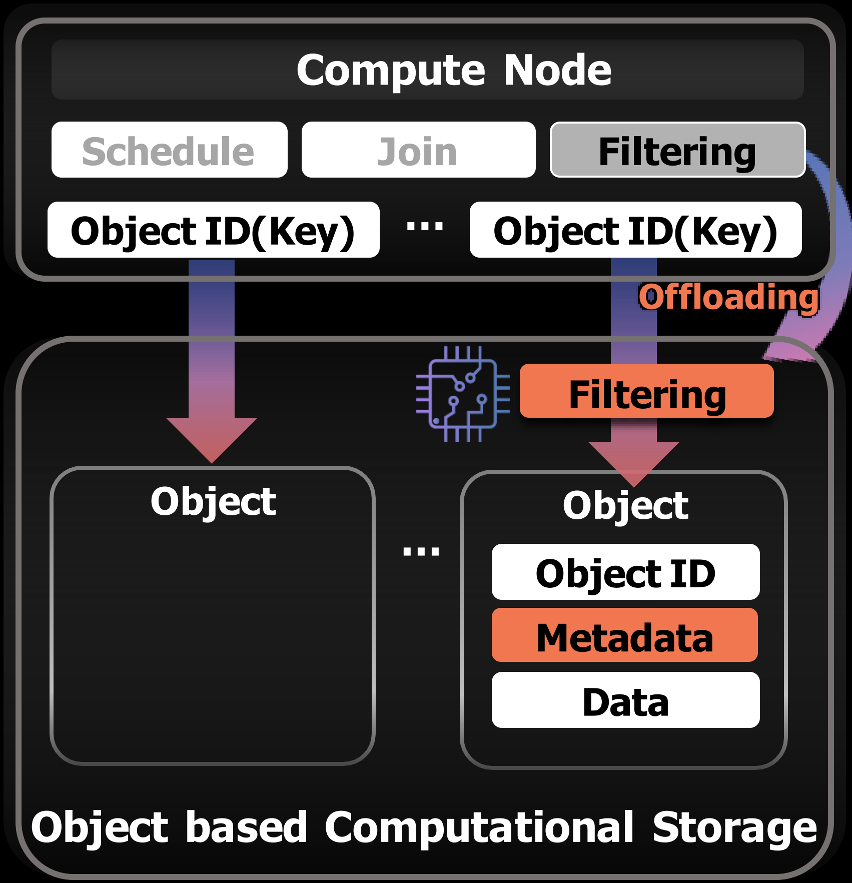
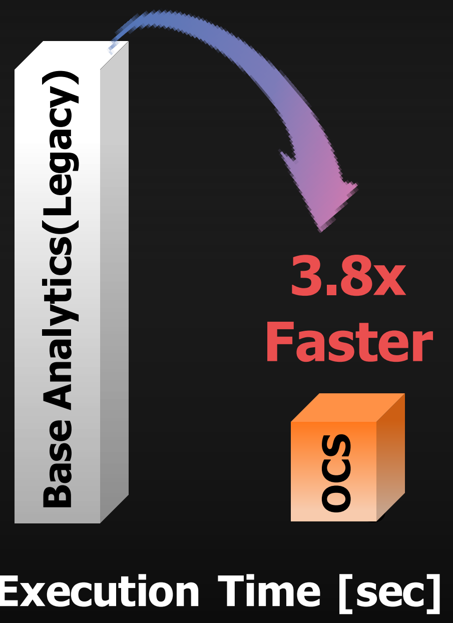
Appendix] Object-based Computational Storage (OCS)

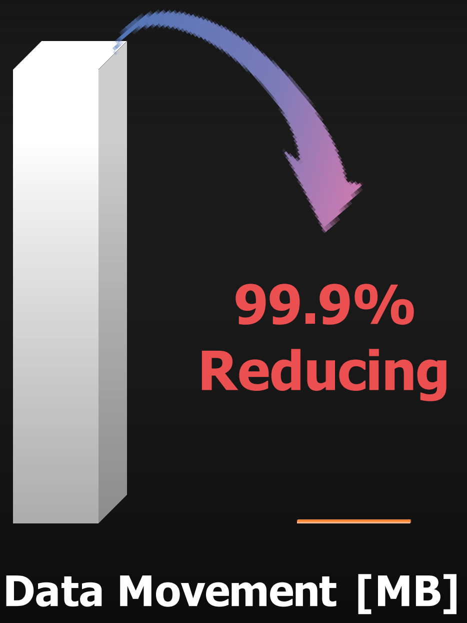
Speed and efficiency from data-awareness



Enhanced Data Analytics



Saving Host Resource



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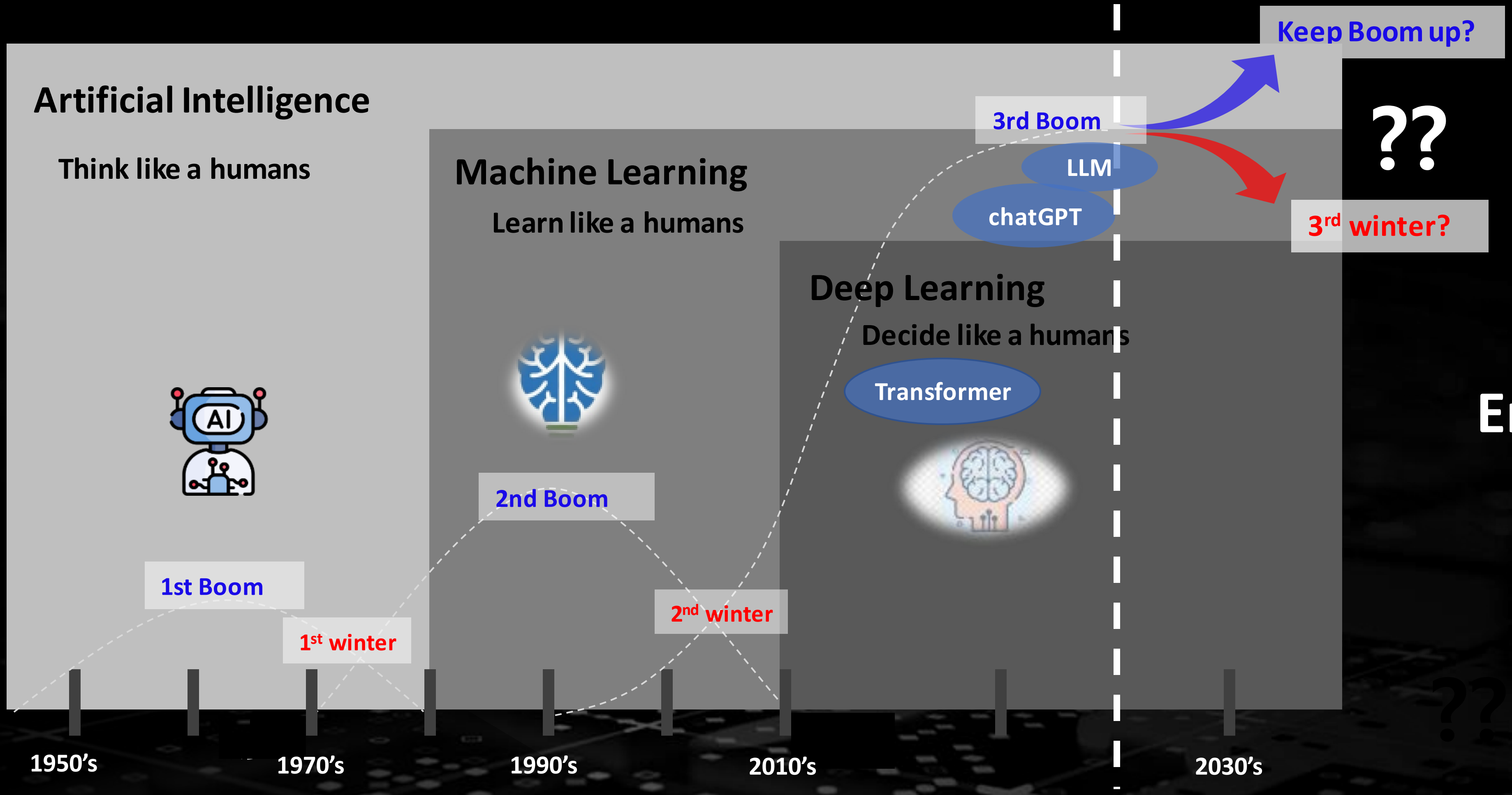
Memory Centric



Artificial Intelligence

Think like a humans

Machine Learning

Learn like a humans

Deep Learning

Decide like a humans

Transformer

chatGPT

LLM

AI Service Cost
Energy Problem
Environment Issue
…

Energy Efficiency

(SK hynix Solution)

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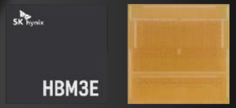
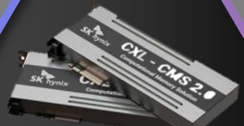
Total Memory & Storage Portfolio



HBM3E

CMM DDR5
CMM MDS

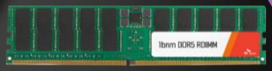


CXL CMS

AiM

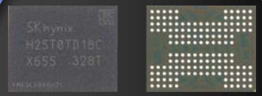
AiMx

LPDDR5T



DDR5
RDIMM

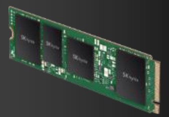
MCRDIMM



NAND

UFS / ZUFS
/ uMCP

Mainstream
cSSD



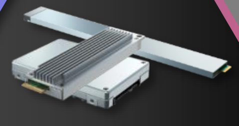
Value
TLC cSSD

Value
QLC cSSD

PCIe Gen5
16ch eSSD

High Capacity
QLC eSSD

Boot eSSD



Value
PCIe eSSD

SATA eSSD

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End of Document

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