MRAM based NVME SSD Architecture

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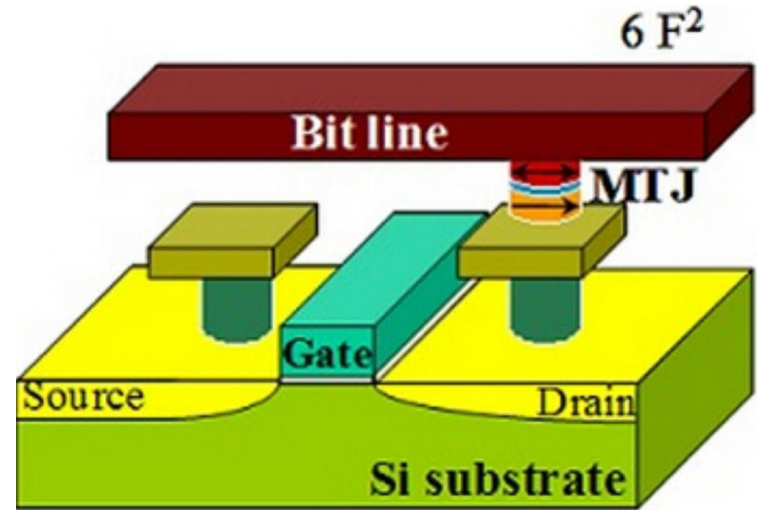Hangzhou Dianzi university (HDU), PHD candidate

1, Why MRAM for SSD?

2, How MRAM implement on NVME SSD
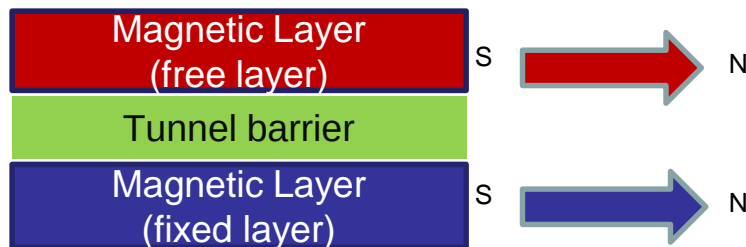
What's MRAM ?

Magnetoresistive random-access memory (MRAM) is a type of non-volatile random-access memory which stores data in magnetic domains.
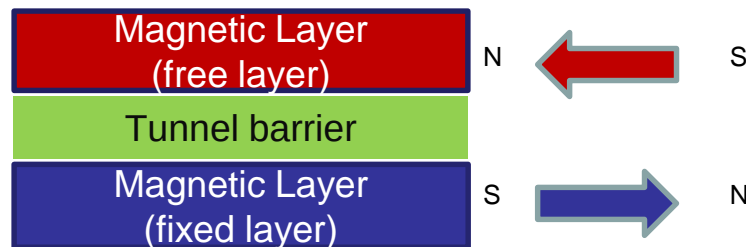
How MRAM works?

The state of the bit is detected as a change in resistance.
Low resistance as logic 0 while high resistance as logic 1

Magnetic Layer (free layer)	S → N
Tunnel barrier	
Magnetic Layer (fixed layer)	S → N

Magnetic vectors are parallel

low resistance. "0"

Magnetic Layer (free layer)	N ← S
Tunnel barrier	
Magnetic Layer (fixed layer)	S → N

Magnetic vectors are anti-parallel

high resistance. "1"

The feature of MRAM

- Non-volatile medium;

- Ultra high read/write speed;

- infinitely accessed times.

Memory compare

|	SRAM	eDRAM	DRAM	eFLASH (NOR)	FlASH (NAND)	FRAM	PRAM	MRAM	RRAM
Endurance (cycles)	Unlimited	Unlimited	Unlimited	105	105	1014	109	Unlimited	109
Read/write access time (ns)	<1	1–2	30	10/10³	100/10⁶	30	10/100	2–30	1–100
Density	Low (six transistors)	Medium	Medium	Medium	High (multiple bits per cell)	Low (limited scalability)	High (multiple bits per cell)	Medium	High (multiple bits per cell)
Write power	Medium	Medium	Medium	High	High	Medium	Medium	Medium	Medium
Standby power	High	Medium	Medium	Low	Low	Low	Low	Low	Low
Other	Volatile	Volatile. Refresh power and time needed	Volatile. Refresh power and time needed	High voltage required	High voltage required	Destructive readout	Operating T < 125 °C	Low read signal	Complex mechanism

Disadvantage

1, Expensive

2, temperature endurance
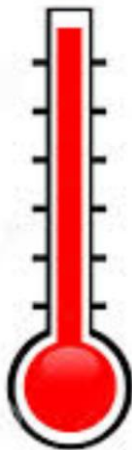
3, not standardization

MRAM Vendors

MRAM memory

- ✔ Everspin Technologies
- ✔ Avalanche Technology
- ✔ Crocus Nanoelectronics

Embedded MRAM Technologies
- ✔ Intel
- ✔ Samsung

Everspin has completed development activity and entered the pilot production phase of its 28 nm 1-Gigabit (Gb) Spin Torque Transfer Magnetoresistive Random Access Memory (STT-MRAM) product.

Everspin MRAM features

1. 1Gb density

2. JEDEC-like DDRx interface with specific modifications

3. High bandwidth (1333 MT/s per pin) with true byte addressability and extremely low latency

4. x8, x16 data width Configuration

5. high endurance

The SSD challenging?

NVMe SSD with feature of:

    1. faster to access data

    2. Low latency

    3. higher Input/Output Operations (IOPS)

But with the increase of capacity and speed:

    Power failure problems become challenging

1, Why MRAM for SSD?

2, How MRAM work on NVME SSD

MRAM Application option (1/3)

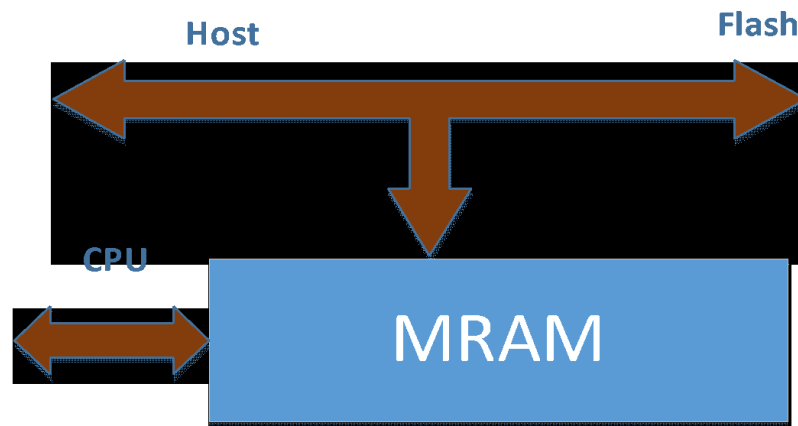1, MRAM Store mapping table only

Bandwidth required is low

MRAM Application option (2/3)

2, Table & Data backup

Store mapping table and backup data only.
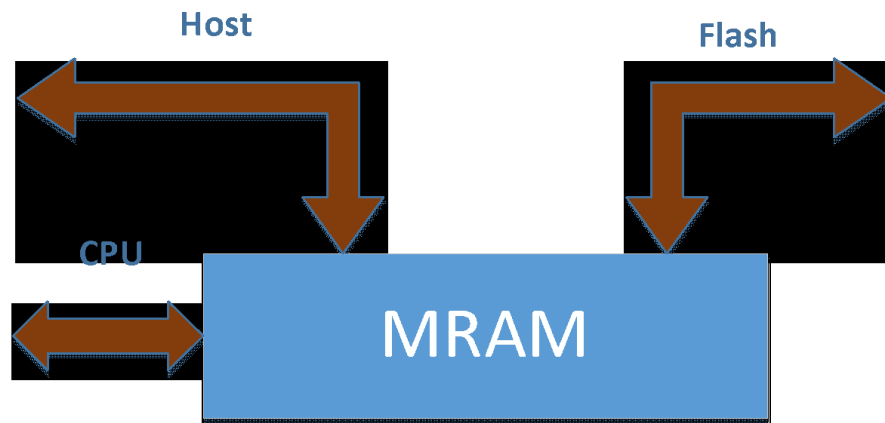
Bandwidth required is medium

MRAM Application option (3/3)

3, Table & Data cache

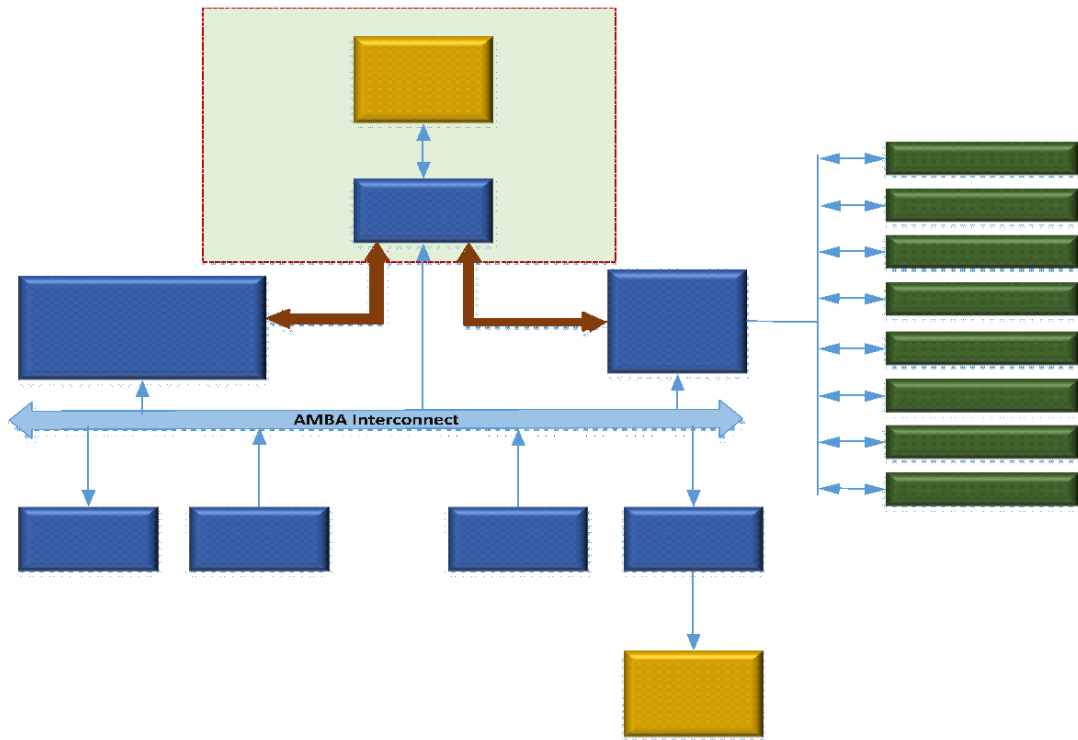Store mapping table, and MRAM work as cache

Bandwidth required is high

A New SSD Architecture with the everspin MRAM chip

1. NVME CONTROLLER

2. FLASH CONTROLLER(16)

3. NVME CPU

4. FTL CPU

5. DRAM CONTROLLER

6. MRAM CONTROLLER

7. Peripher

MRAM distribution

Three usage of MRAM

1. Permanent FTL table

2. Nvme Data Cache

3. Hot data mirror buffer

① Permanent Mappping Table

② Data Cache

③ Hot User Data

PCIE Gen3x4 bandwidth

PCIE GEN3 8Gb (130~128) *4 ≈ 4GB.

DRAM with 80% Utilization to Support R/W,

required 10GB

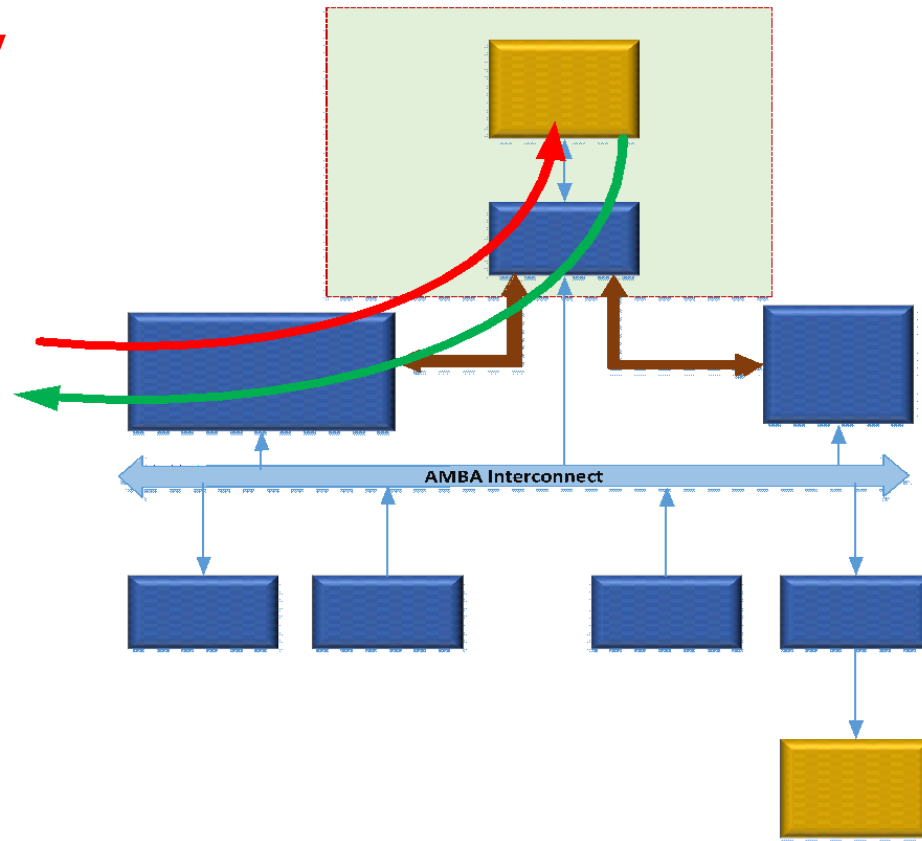DDR1333 * 64 bit Required ≈1.3G*8 (10.4GB)

How about Gen4*4 ？

DDR2666*64

Feature of SSD with MRAM

◆ Power loss data integrity, No super-cap

◆ FTL concise and robust, few data need protect

  when power loss.

◆ ultra low write latency

◆ ultra low read latency when user data cache hit

Write Latency

Response immediately
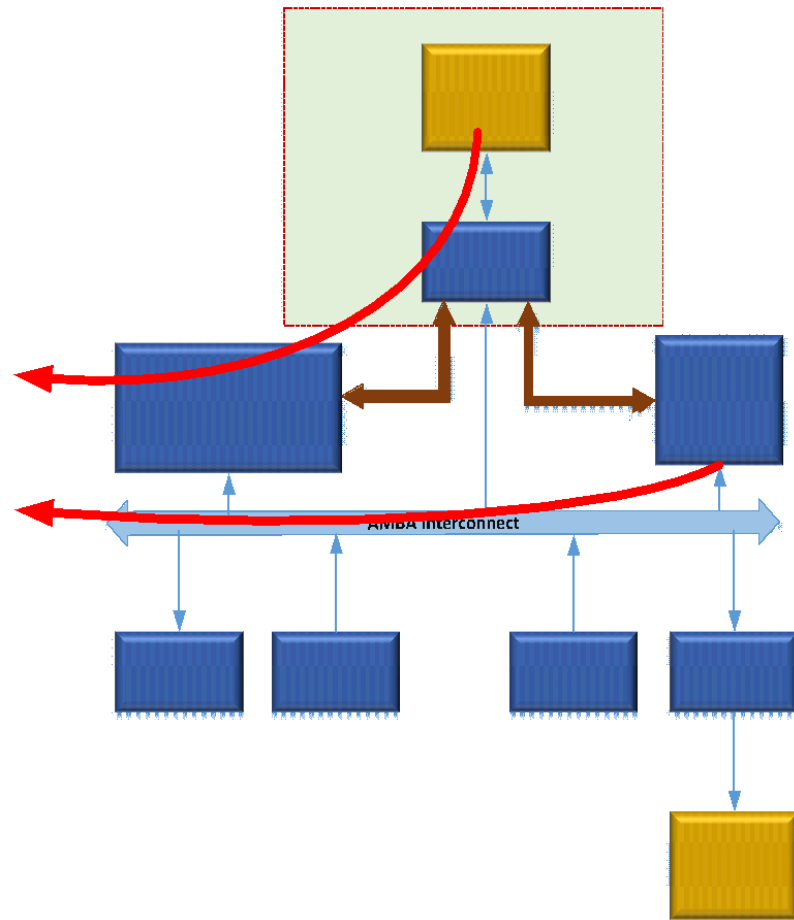
when data push to MRAM

Read Latency

Read Data0, Cache hit include nvme data or hot mirror data.

Ultra low read latency

Summary

1, MRAM is infinitely accessed and Non-volatile memory.

2, The NVME SSD With MRAM improved performance of power failure, and read/write latency.

Thank you!