Optimizing Performance and Reliability of Mobile Storage Memory

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Memory Trend

PC Era (1980~)
CPU centric (GHz spec.)

Smart & Mobile Era (2007~)
Mobile experience centric
(always connected)

Next Waves (2014~)
customized usages
(high performance, reliable)

Mobile Storage Requirements

- **Applications demand mobile storages of high performance and reliability**

Application	Client	Network	Server
Usages	Main storage	Boot, cache	Boot, storage
Power	Ultra Low	Low	Low
Form Factor	Ultra Small	Small	Small
Performance	High	Mid to High	Mid to High
Reliability	Mid to High	High	High

Challenges of NAND Flash

- Performance
  - Host access is basically random
  - Sequential is more natural in NAND

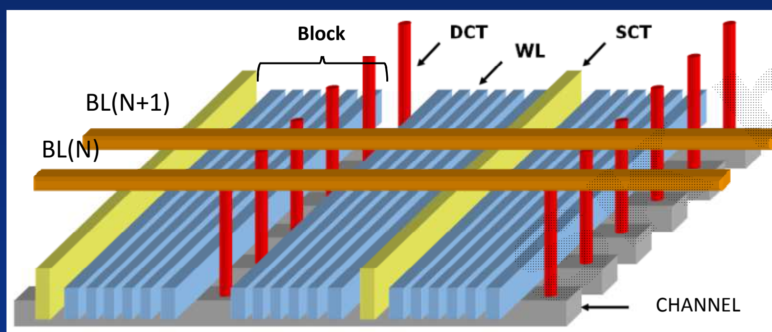
- Reliability
  - Life span restriction due to endurance
  - Data could be lost after exceeding retention spec.

How to get the most from Flash storage device ?

NAND configuration

- Sequential access is more natural than random
- Random access requires NAND page changes with performance overhead and more wear out

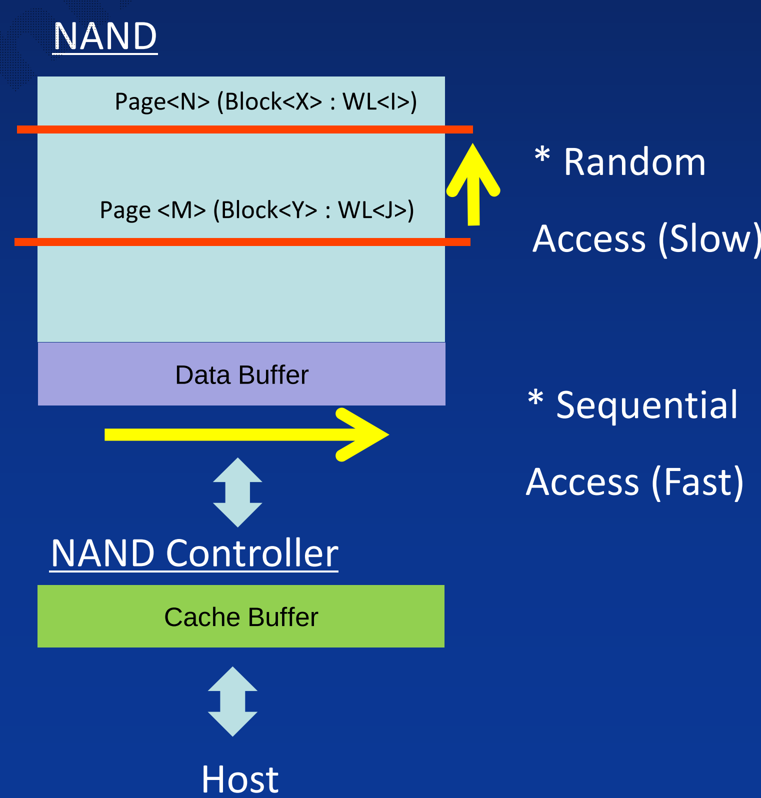
NAND structure



Read — Busy — Ready

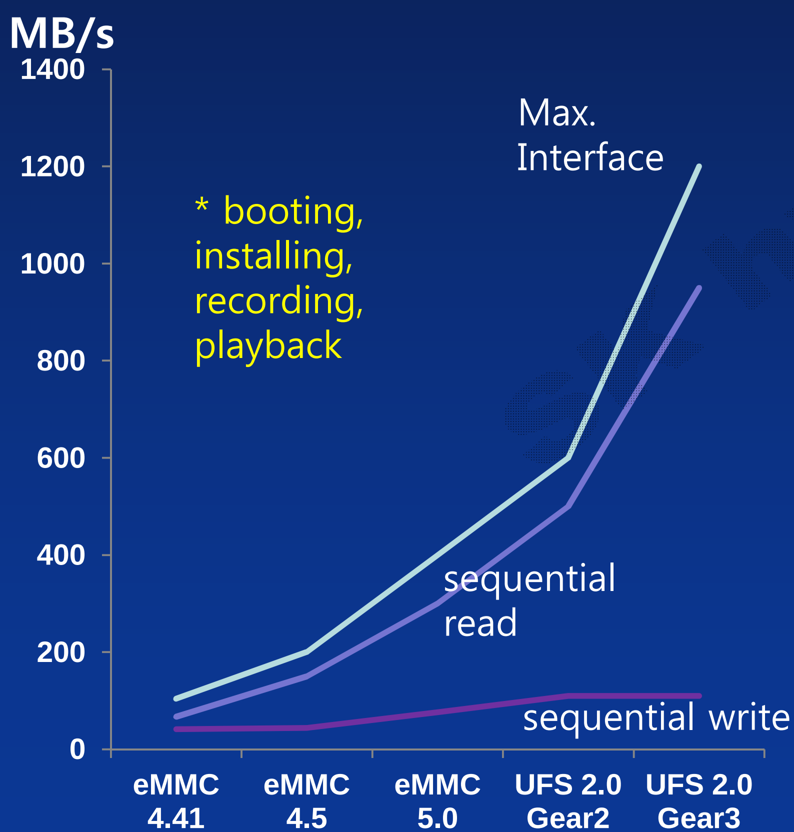
Write — Busy — Ready

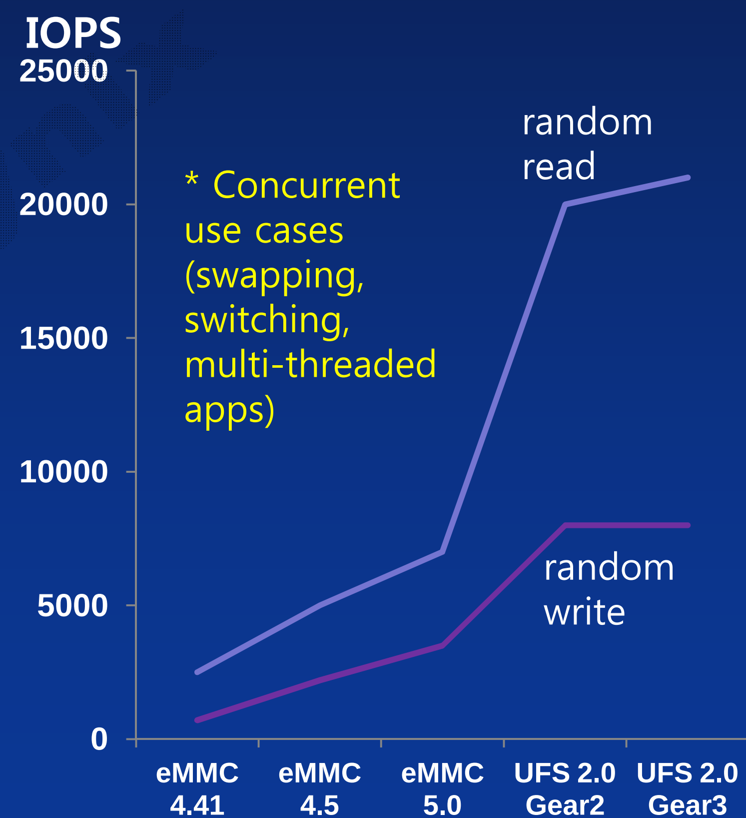
* Busy : overhead per page change



Performance Asymmetry

- Sequential vs. random asymmetry continues
- Cache buffer size restriction due to cost, power, etc.





Life Span by endurance

- **Life span depends on Max. host usage and how many writes NAND allows.**
- **Larger chunk size and address alignment can help life span longer.**

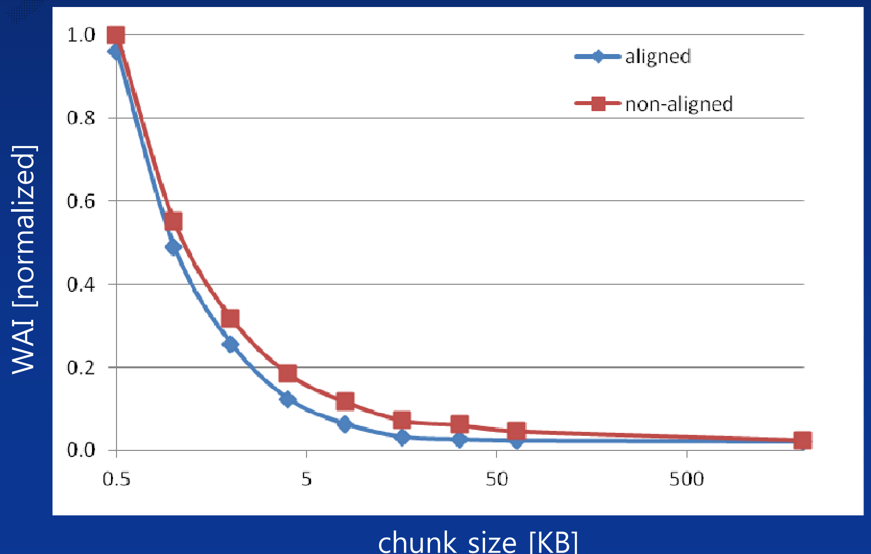
- Life Span [yrs]

$$= \frac{\text{NAND Density} * \text{NAND Cycles}}{\text{WAI} * \text{Yearly Usage (Max)}}$$

- WAI (Wear Acceleration Index)

$$= \frac{\text{Actual Size written to NAND}}{\text{Data size written by host}}$$

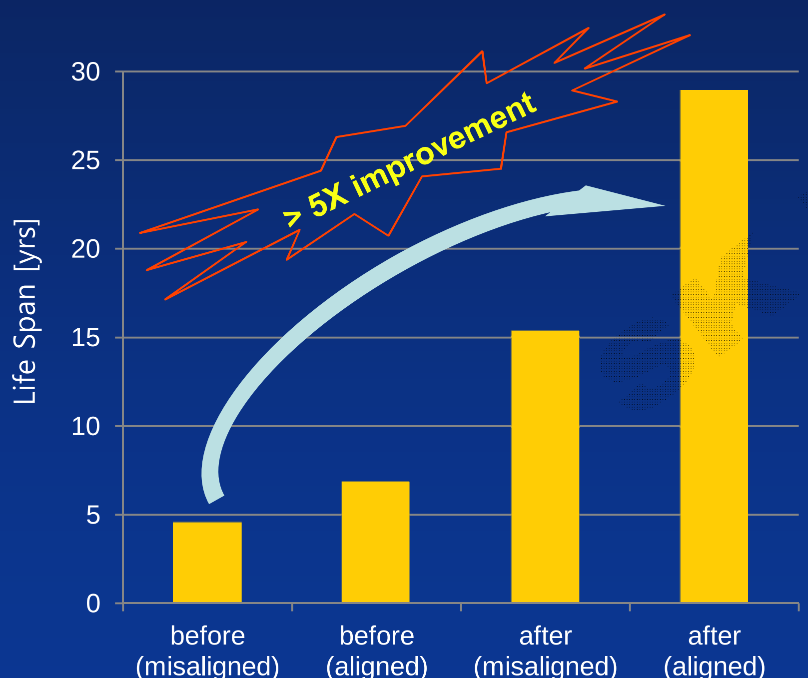
- WAI vs. chunk size *



* Random access

Life span calculator

- Input : Max. GB per year, P/E cycle, Density
- Chunk size optimization and address alignment can help



Applications	Max GB/year	% of total GB/yr	Chunk size [KB]	
			Before chunk optimization (misaligned)	After chunk optimization (Aligned)
application 1	1.0	0.12%	1	1
application 2	1.0	0.12%	4	32
application 3	0.3	0.03%	4	32
application 4	89.1	10.64%	4	32
application 5	240.0	28.66%	4	64
application 6	12.0	1.43%	4	32
application 7	178.2	21.28%	4	2048
application 8	106.9	12.77%	4	32
application 9	3.6	0.43%	4	4
application 10	0.0	0.00%	4	4
application 11	32.0	3.82%	4	32
application 12	7.1	0.85%	1	1
application 13	0.1	0.01%	1	1
application 14	0.0	0.00%	4	4
application 15	164.3	19.62%	4	32
application 16	1.8	0.21%	4	4
total	837.4			
NAND Density [GB]			32	32
NAND cycles per block			3000	3000
Life Span [yrs]			4.51	28.93

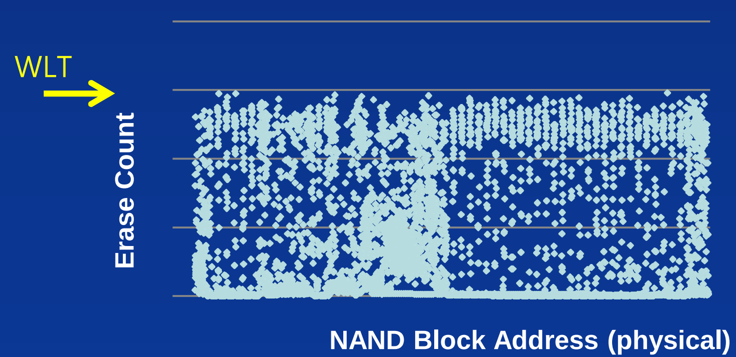
Refresh period calculator

- Refresh period depends on Min. host usage and wear leveling policy of NAND storage.
- WAI and wear leveling optimization is necessary

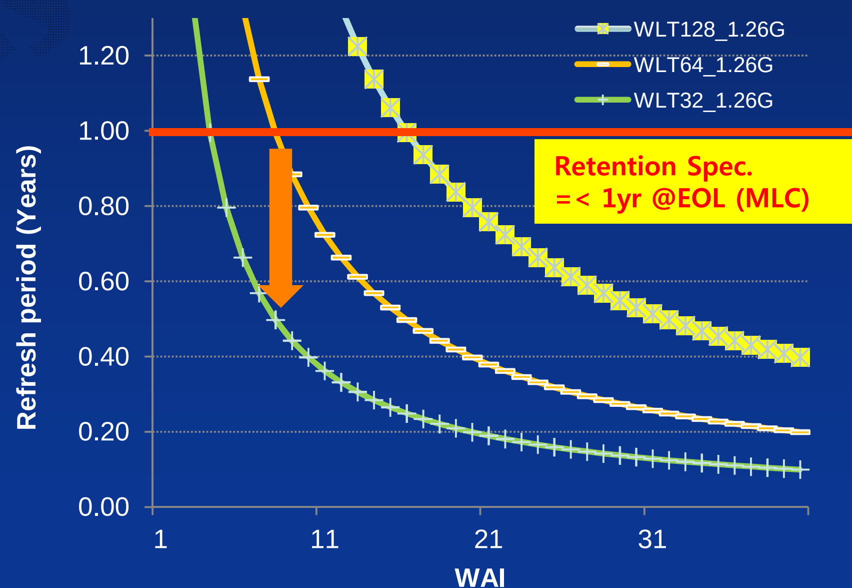
- Refresh period [yrs]

$$= \frac{\text{NAND Density} * \text{WLT}}{\text{WAI} * \text{Yearly Usage (Min)}}$$

- **WLT** (Wear Leveling Threshold)



- Refresh period vs. WLT

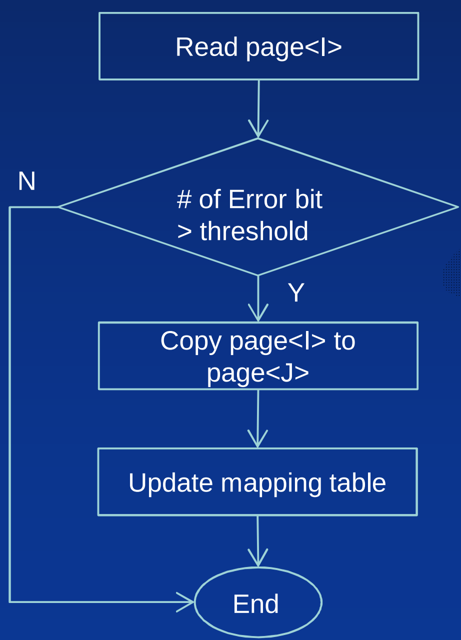


* User density = 64GB
* Min. Usage = 1.26GB/day

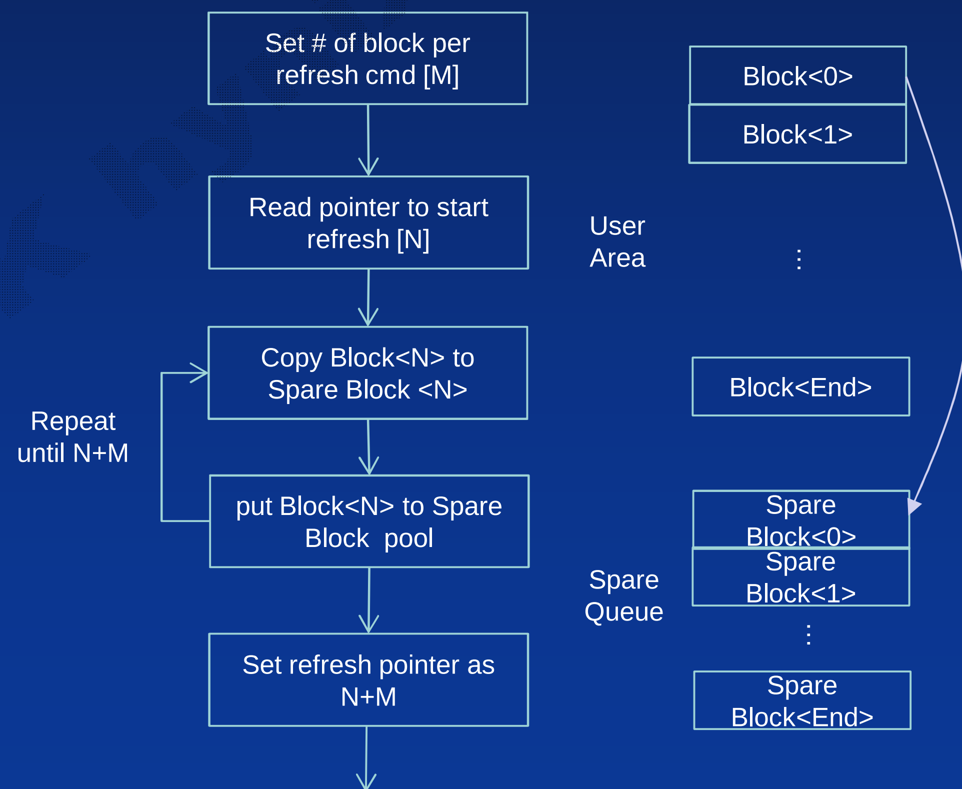
Refresh algorithms

- **Customized solutions to refresh NAND blocks before retention spec.**

1) Self Refresh



2) Refresh by host (vendor command)



Summary

- Performance
  - Larger chunk and alignment can help storage performance better
- Reliability
  - Refer to both Life span and refresh period calculators
  - Chunk optimization and alignment can help storage working longer
  - Refresh algorithms as backup solutions

Better understanding gives better result !!

For more discussions…

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