

# Research Issues in Flash Memory-based Mobile Storage

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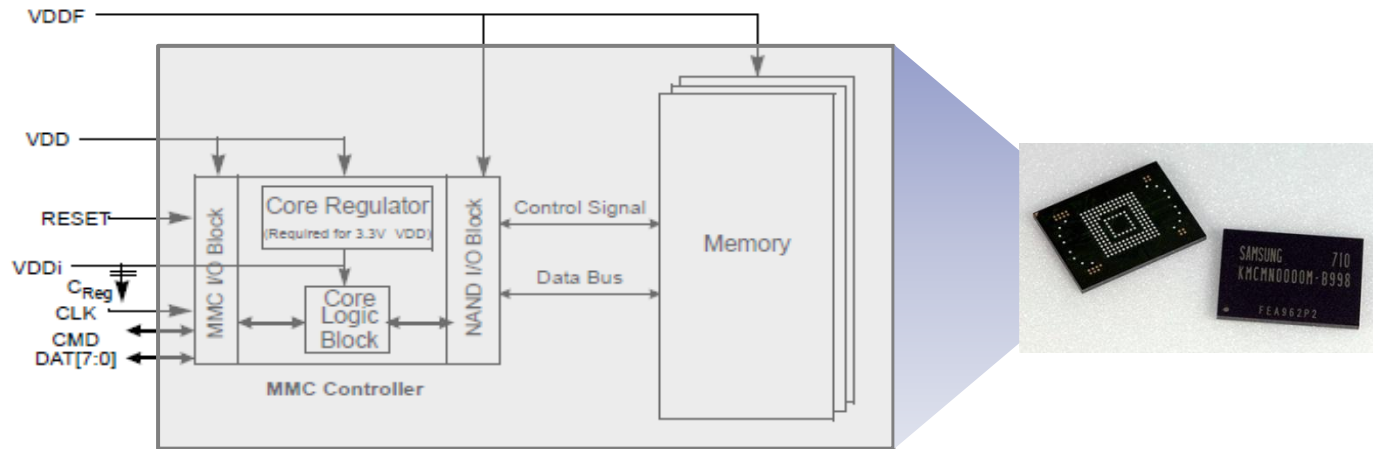
- **Introducing e.MMC**
- **eMMC Features**
- **Issues in Mobile Storage**
  - **Performance, lifetime, low power, reliability**
- **Conclusion**

# What is e.MMC?

- JEDEC standard embedded flash storage

- <http://www.jedec.org/standards-documents/focus/flash/e-mmc>

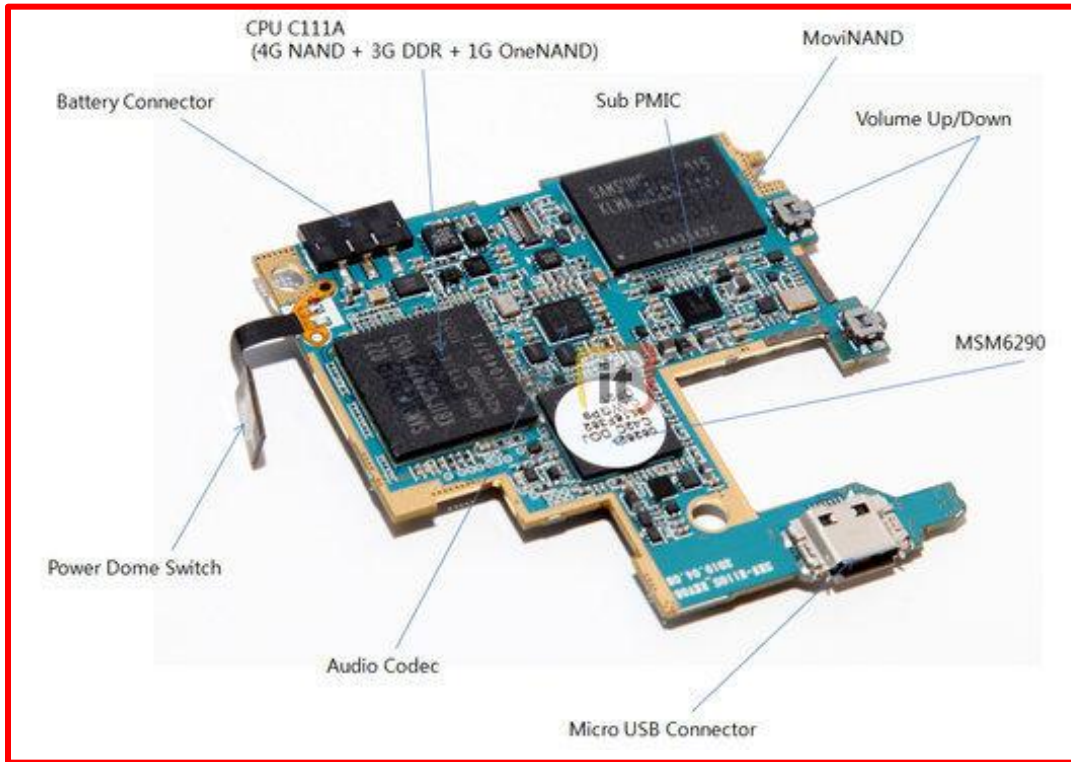
- Evolved from MMC (MultiMediaCard)



- Used in many smart phone & tablet



# eMMC in Smart Phone



(Source: [www.it.co.kr](http://www.it.co.kr))

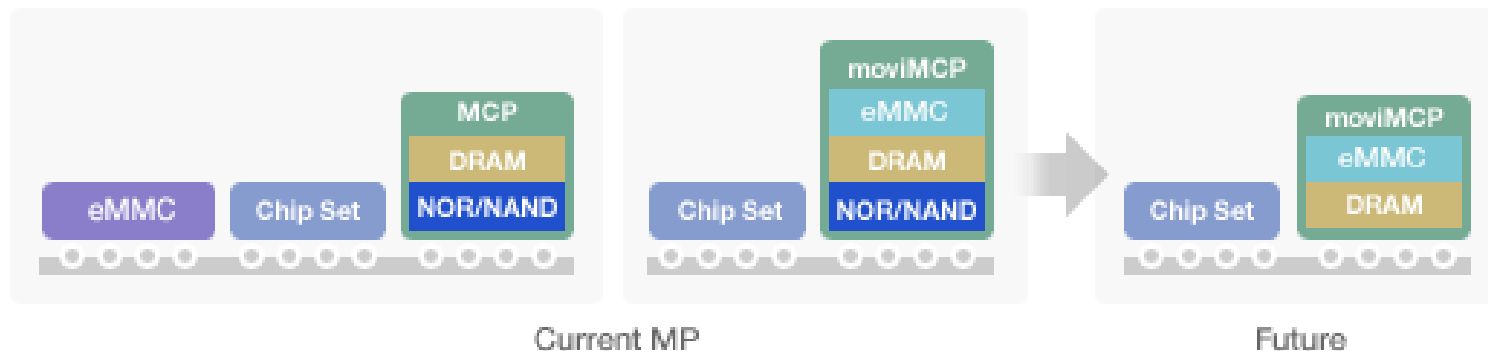
# Changes in Mobile Storage Architecture

## ■ Current generation

Flash	Type	Purpose
NOR, NAND	SLC	Boot, code
eMMC	MLC	Data

## ■ Future generation

Flash	Type	Purpose
eMMC	SLC (boot)	Boot
	SLC (partition)	Code
	MLC (partition)	Data



(Source: [www.samsungsemi.com](http://www.samsungsemi.com))

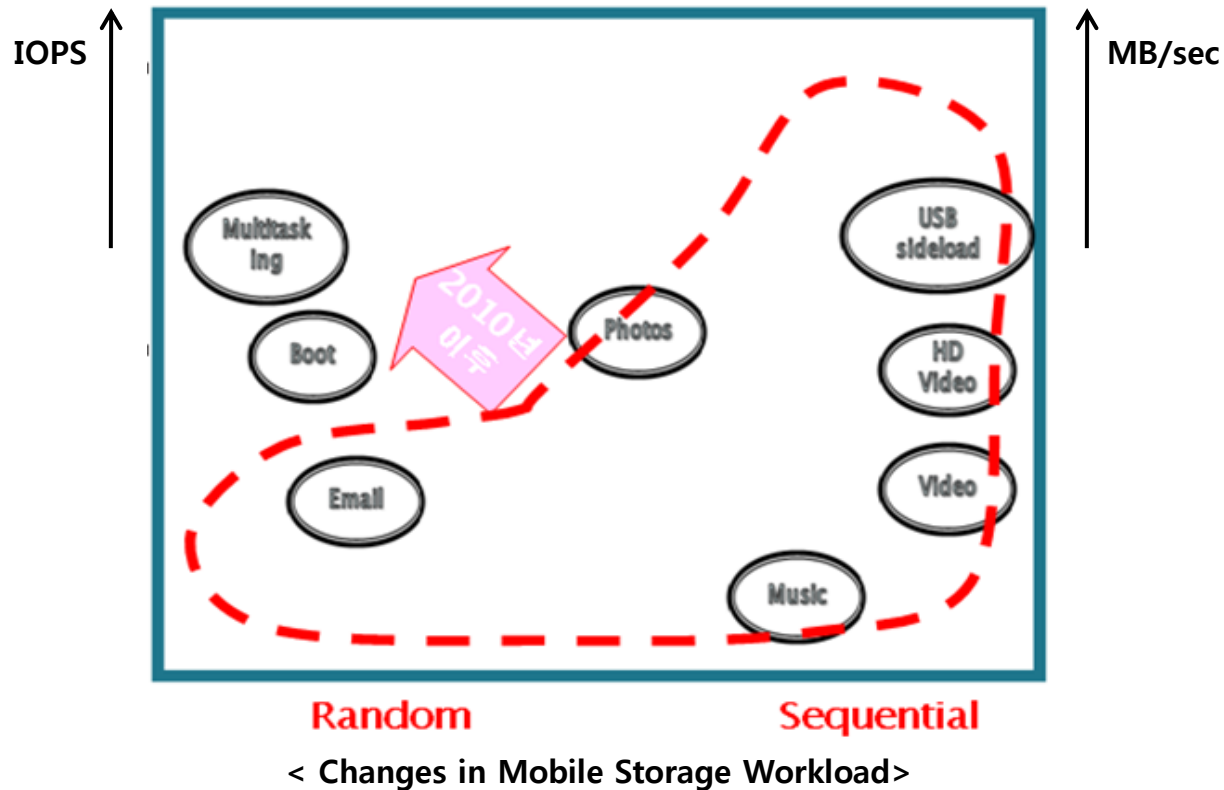
# eMMC Features

- **Basic features for card application + custom features for mobile environment**
  - **High performance – DDR, packed command, cache**
  - **Low latency – HPI, background op**
  - **Low cost – boot, partition (unified storage)**
  - **Hint – trim/discard, data tag, partition attribute, power-off notify**

Version	Features
4.3	Introduction of e.MMC, boot operation, sleep, reliable write
4.4	DDR mode, partition, trim, security enhancement
4.41	Background operation, HPI (High Priority Interrupt)
4.5	Higher data rate, data tag, partition attribute, discard, power-off notification, packed command, cache

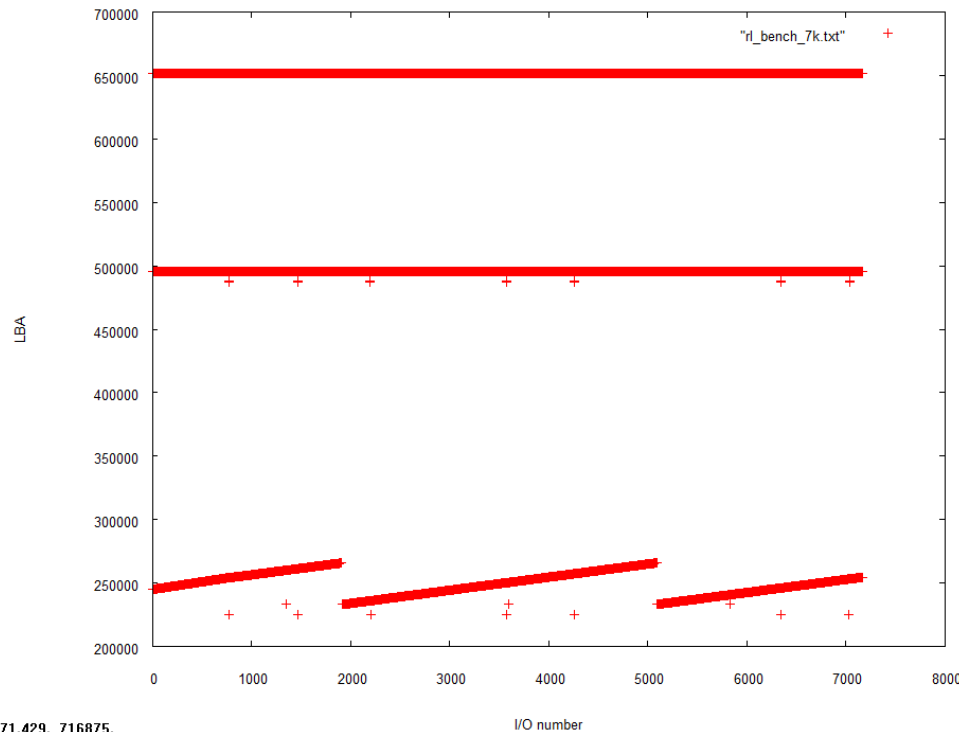
# Issues – Performance

- Performance requirements are changing
  - ~ 2009: smart phone and camcorder are main application of e.MMC → focus on **sequential performance**
  - 2010~: high-end smart phone and tablet are main → focus on **small random performance**



# Issues – Performance

- The use of database is common in smart phone
- I/O trace of database (Android, SQLite)
  - >7 write I/Os for single INSERT query
  - Small and sequential write pattern
- Ex. I/O trace of RL Benchmark → need flash-friendly SQLite!



-371.429, 716875.

I/O number



# Issues – Performance

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- **Latency does matter!**
  - Timeout spec – read 100ms, write 450ms
  - Periodic read while write (ex. Listen to mp3 while app download & install)
- **Background op & HPI could be helpful, but...**
  - How to co-optimize host and device to avoid worst case delay?
  - How to implement HPI in Android?

# Issues – Performance

## ■ Performance features of eMMC 4.5

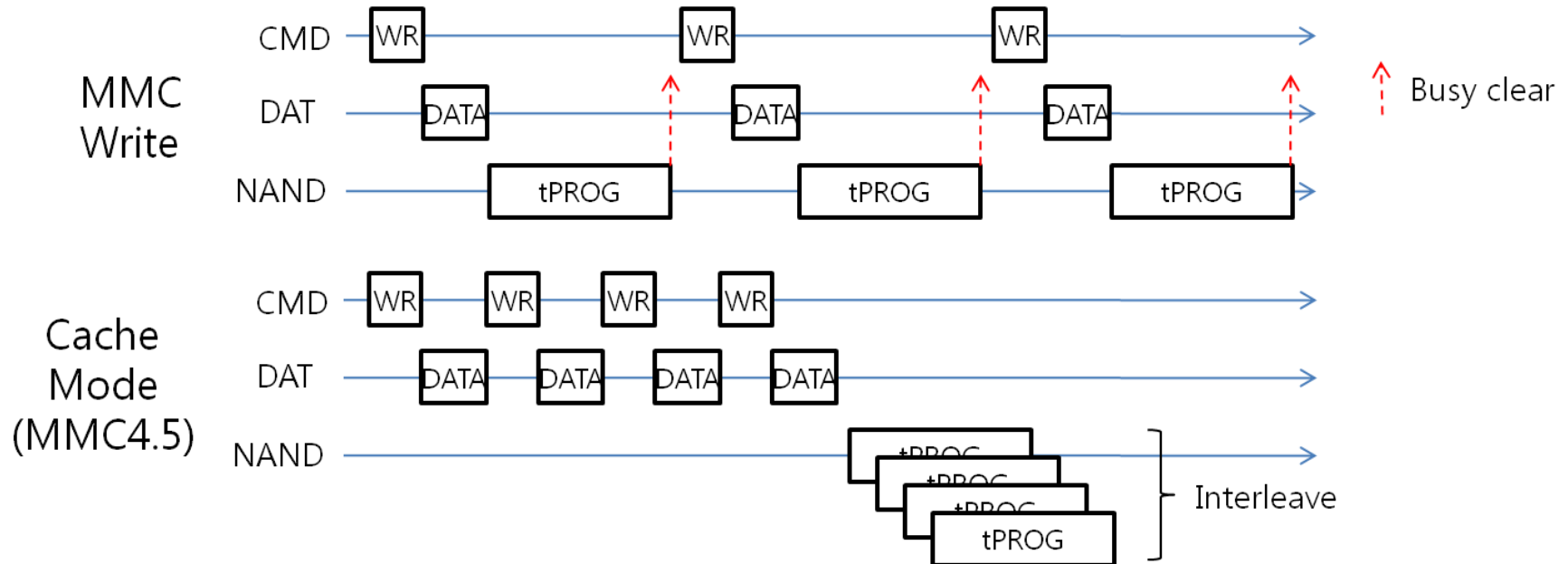
### ■ Cache management

- Similar to internal DRAM buffer of HDD/SSD
- Improve write IOPS

### ■ Packed command

- Similar to readv(), writev()
- Improve both read and write IOPS

## ■ How to utilize parallelism with limited resource?



# Issues – Lifetime

- How to maximize device lifetime under mixed workload?
  - Using partition
  - Using hint from host (ex. Data tag)
  - Using smart firmware algorithm (ex. FTL)
- Example) lifetime estimation of 8GB eMMC
  - Lifetime = capacity \* endurance / (sum of WAI \* workload)

Usage	WAI	Weekly Workload	Partition Config-1	Partition Config-2
Scenario A	40	100MB	MLC	SLC
Scenario B	20	200MB	MLC	MLC
Scenario C	10	3000MB	MLC	MLC
Scenario D	80	50MB	MLC	SLC
Lifetime(year)			11.2	13.5

- Is it possible to make 3bit eMMC to have 5 years of effective lifetime?

# Issues – Low Power

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- **Standby power of mobile storage**
  - eMMC – under 1mA, eSSD – 00mA
- **What makes the difference?**
  - Host interface – MMC vs. SATA
  - SRAM, DRAM
- **How to overcome trade-off between performance and power consumption?**
  - Higher performance target
  - Limited power budget (ex. Peak current)

# Issues – Reliability

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- **Reliability can't be compromised!**
  - Ex. SPO (Sudden Power Off)
  - How to make 2/3bit MLC reliable?
- **How to prove that eMMC is reliable against SPO?**
  - Is it possible to have a theoretical modeling?
  - HW or SW simulator?
- **Reliability vs. Performance**
  - Android vs. iPhone

# Conclusion

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- eMMC is the most popular standard mobile storage in smart phone and tablets
- There are lots of challenges to meet the ever-changing requirements with limited HW resources
  - Performance, lifetime, low power, reliability