Using Machine Learning to Enhance Flash Endurance & Latency

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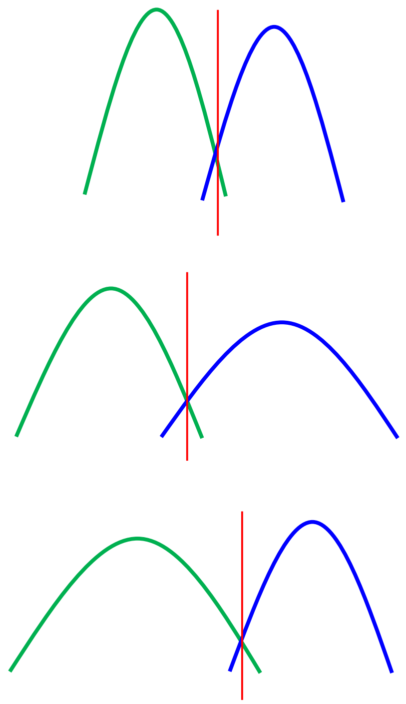
LiteOn/Storage/NVM Lab

Challenges in Error Recovery

- **During SSD Service Time:**
  - P/E Cycle, Data Retention, Read Disturb
  - Critical R/W Condition(Temperature)
- **Decoding Strategy:**
  - Read Retry
  - Soft Decoding
  - …
- **Challenges:**
  - Keep High Reliability & Low Latency under Variant Operation Condition

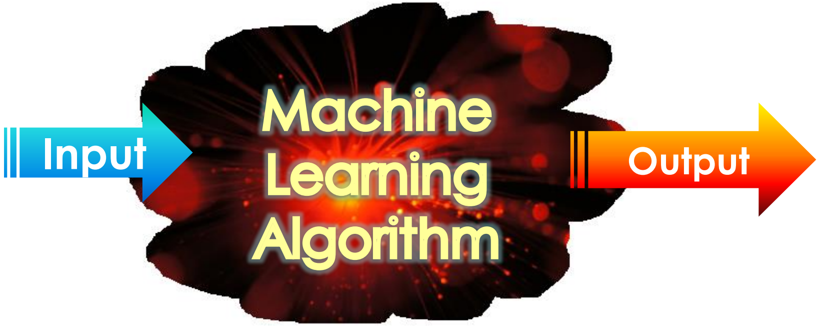


Flash Memory SUMMIT

Status Prediction

- **Input Parameters:**
  - Some factors will affect NAND Flash Status. (P/E Cycle, Retention Time, Read Count, Temperature…)
  - Some information from NAND Flash are also collected as Input Parameters (Program/Erase Time, …)
- **Status Prediction:**
  - Our target is to predict NAND Flash Status (Ex: Optimal Read Level, Error Recovery Flow …..) by Input Parameters.

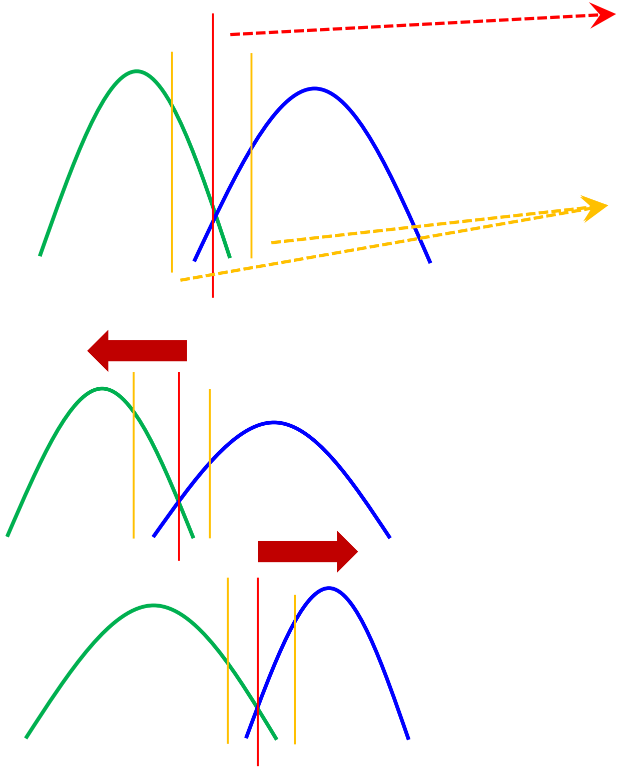
- **P/E Cycle**
- **Read Count**
- **Retention Time**
- …



- **Optimal Read Level**
- **Error Recovery Flow**
- …

Optimal Decoding Parameters

Example : Binary LDPC - MSA

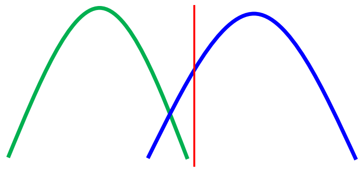


1. Read Level for Hard Bit
→ Minimize Error Bits

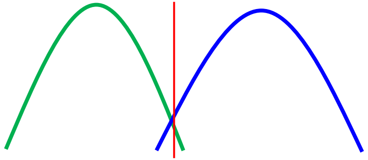
2. Read Level for Soft Bit & LLR Value
→ Maximize the Decoding Capability

- **Optimal Read Level & LLR Prediction**
  - Maximize Decoding Capability. Extend the Endurance
  - Vary with Operation Condition (P/E Cycle, Retention Time, Read Count, Temperature…)

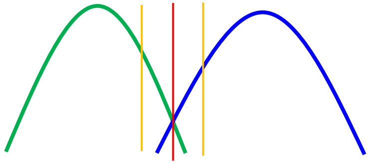
Error Recovery Flow - Prediction



1. **Default Read Level with Hard Decoding**



2. **Optimal HD Read Level with Hard Decoding**



3. **Optimal HD/SD Read Level with Soft Decoding**

Latency | **Correction Power**

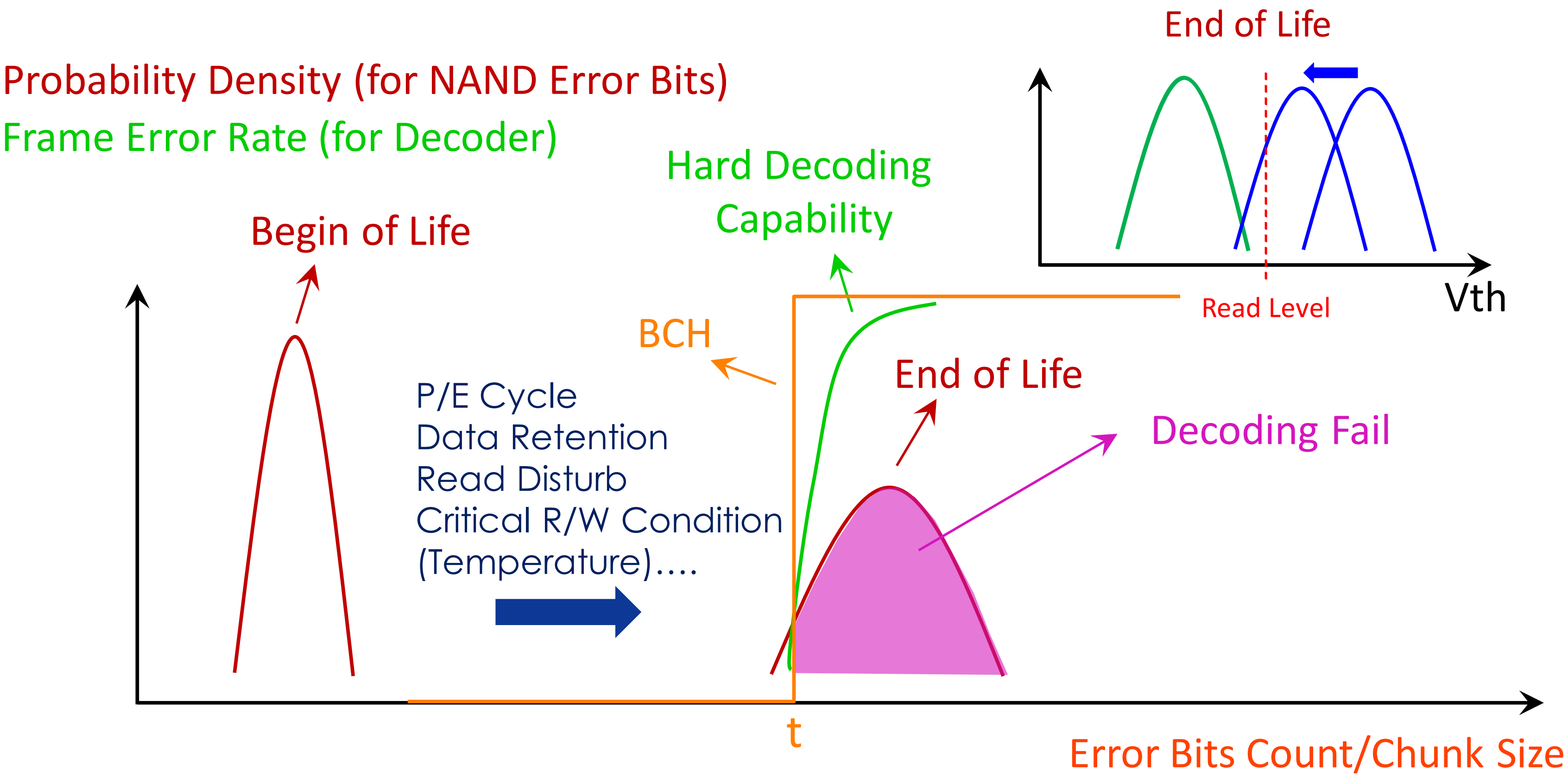
Low

High

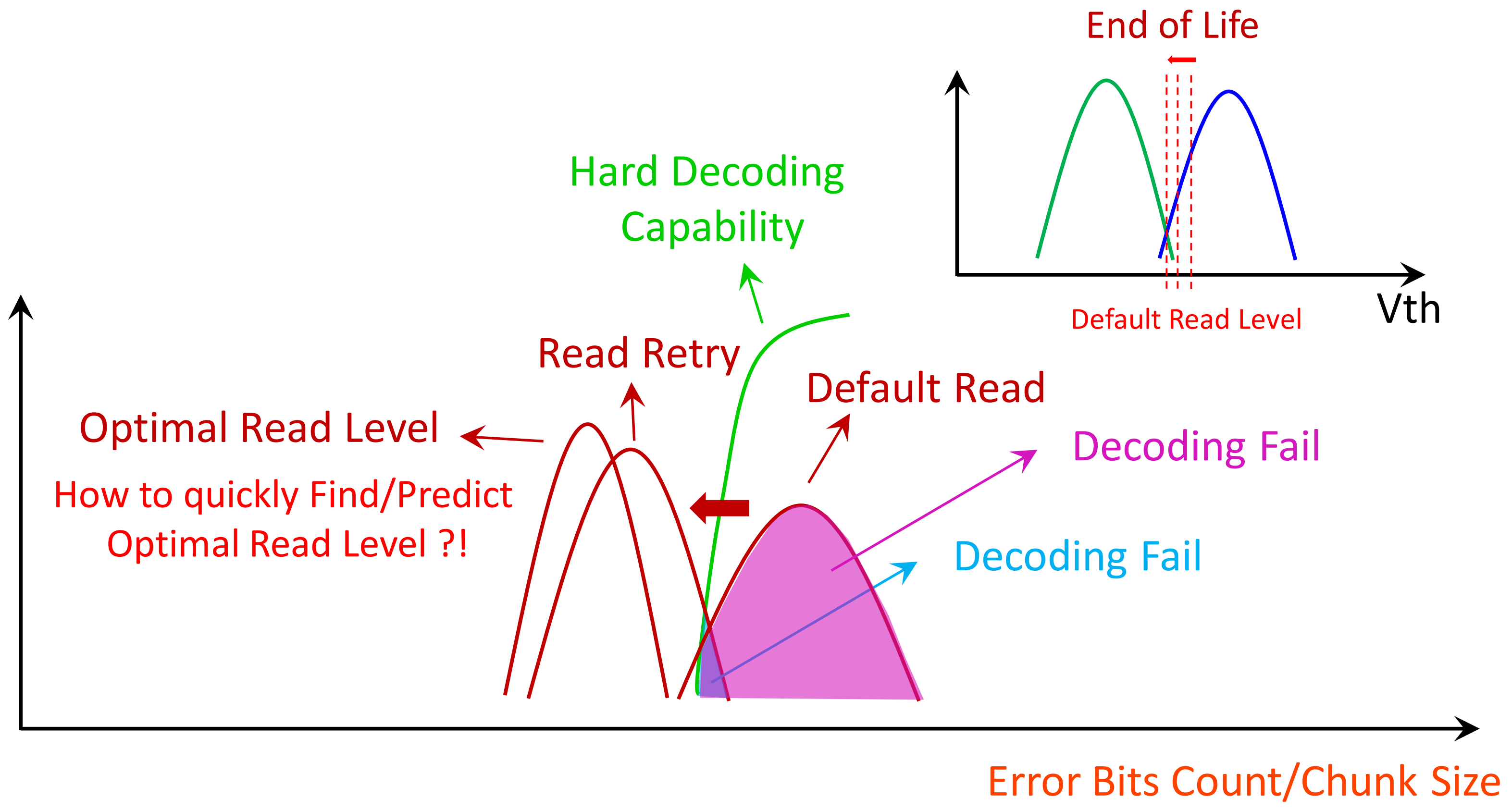
- **Error Recovery Flow Prediction**
  - Throughput/Latency Control, End of Life Prediction

Ref : NAND Flash Status Prediction, FMS 2016

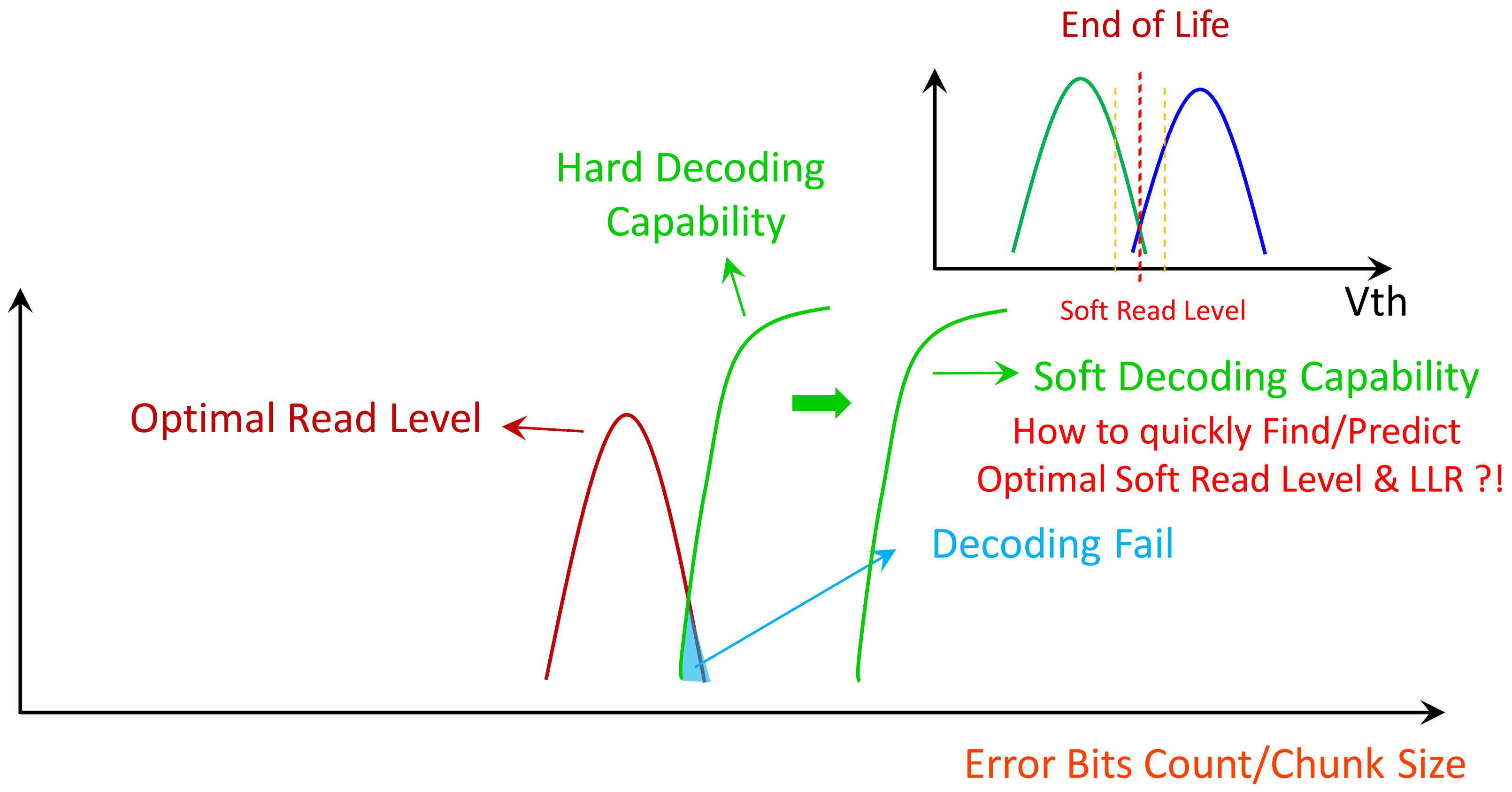
Visual Illustration - Error Recovery Flow



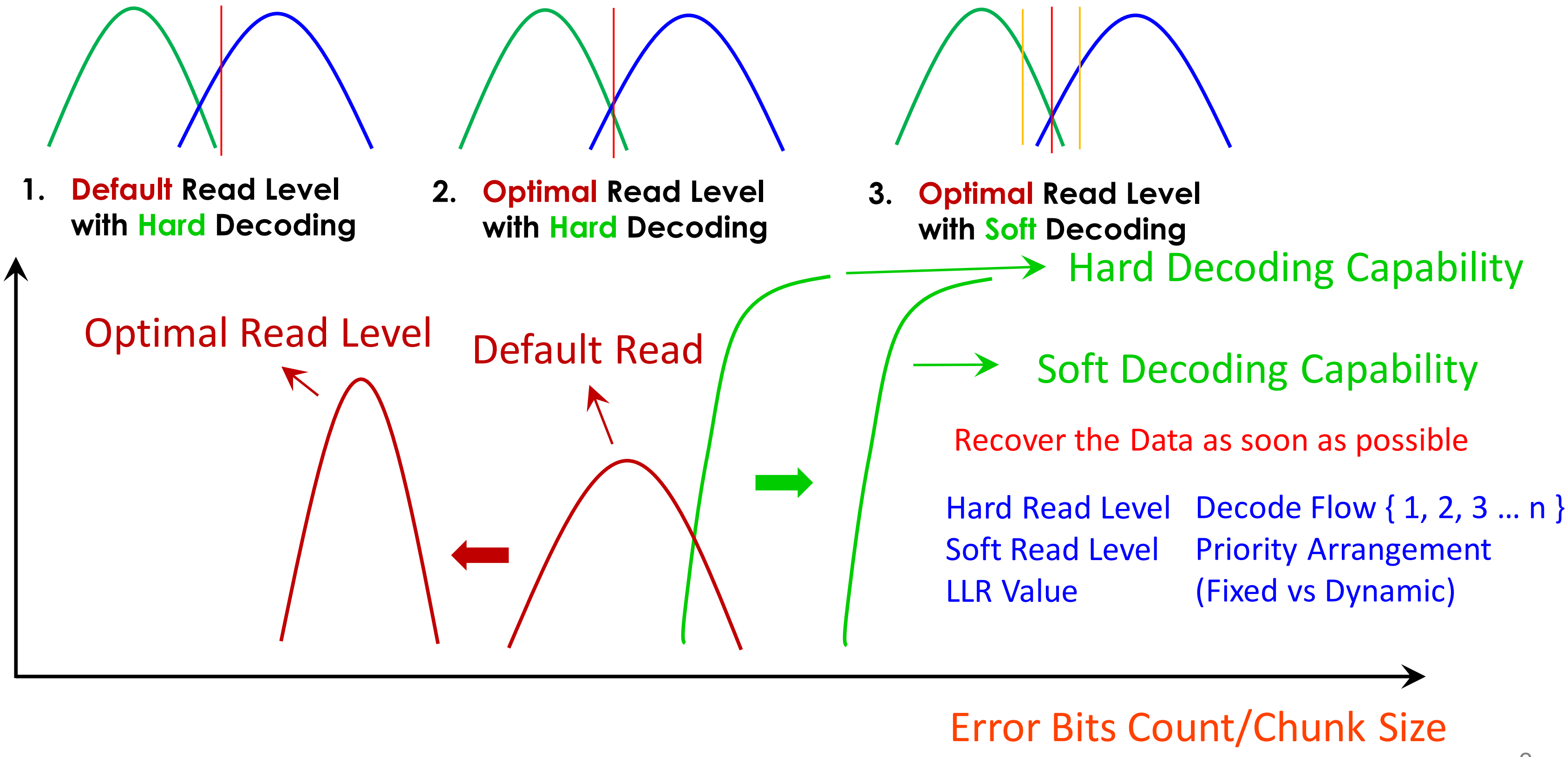
Visual Illustration – Read Retry



Visual Illustration – Soft Decode



Visual Illustration – Error Recovery Flow

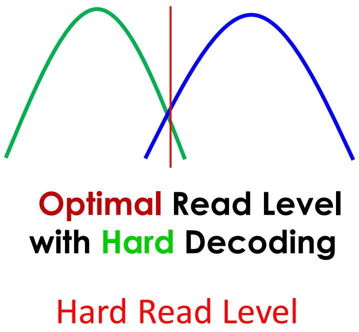


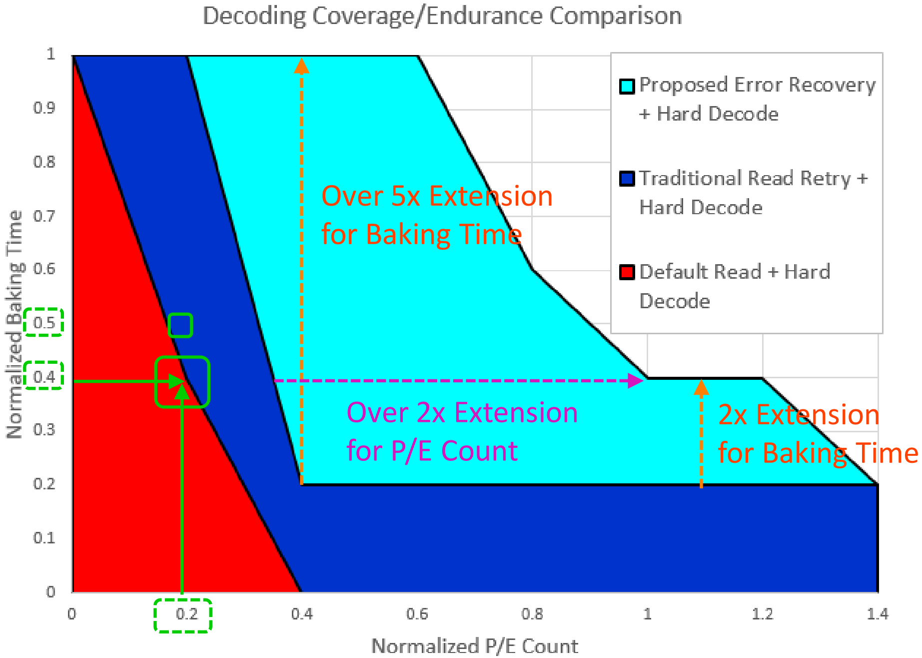
Parameter Optimization with ML

Category	Item	Description	Remark
P/E	Cycle	0, 1000, …~	
	Temperature	(Random)	
	Dwell	(Random)	
Test Item	Data Retention	0, 1, … ~ (Days)	Room Temperature
	Data Retention	0, 1, … ~ (Days)	High Temperature
	Read Disturb	0, 1000, … ~	

- A Smart Error Recovery Scheme is developed by Machine Learning
- This Scheme can be applied to variant operation condition (**combination of {PE, DR, RD, Temperature}**)
- This Scheme can extend the endurance and reduce the latency

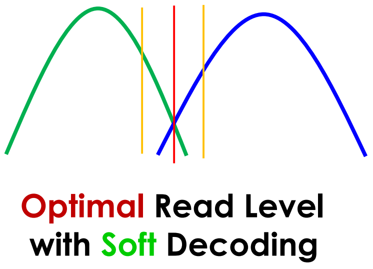
Endurance with Hard Decoding

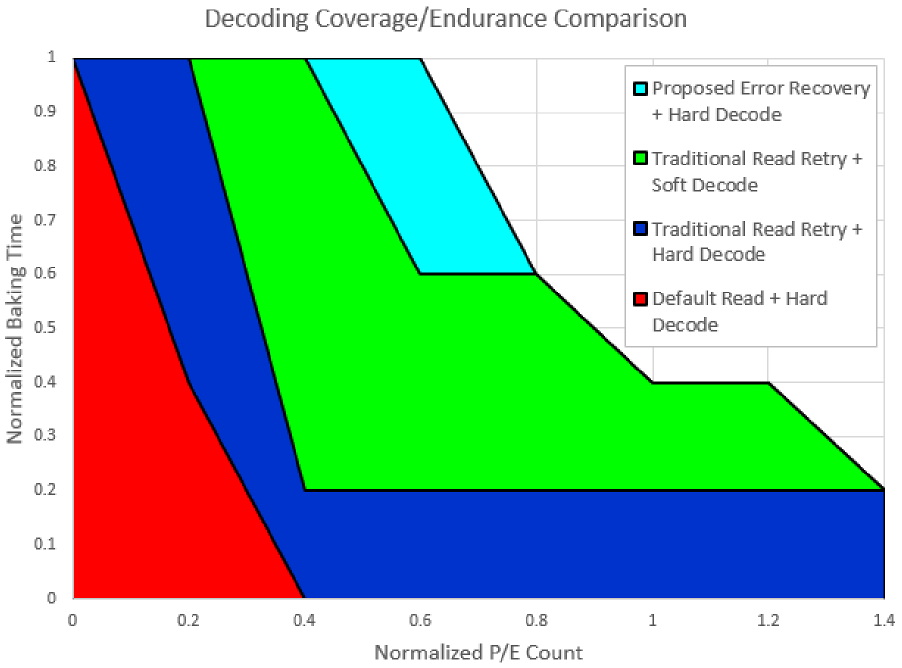




- Our Error Recovery Scheme use ML to find Optimal Read Level for variant operation conditions (**combination of {PE, DR, RD, Temperature}**)
- 5x Extension for Baking Time & 2x Extension for P/E Count

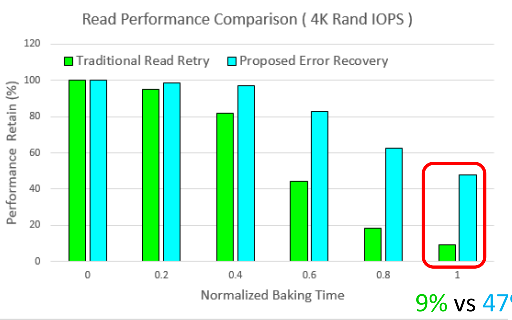
Endurance with Hard/Soft Decoding



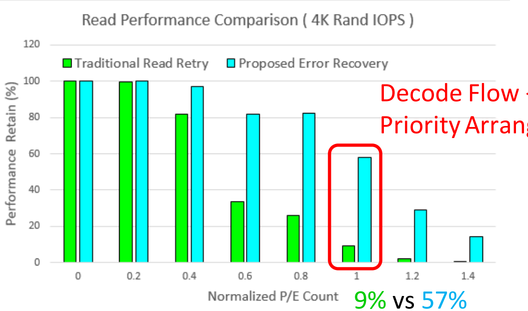


- Proposed Error Recovery Scheme with only Hard Decode is still better than Traditional Read Retry + Soft Decode in Decoding Coverage

Throughput/IOPS Comparison

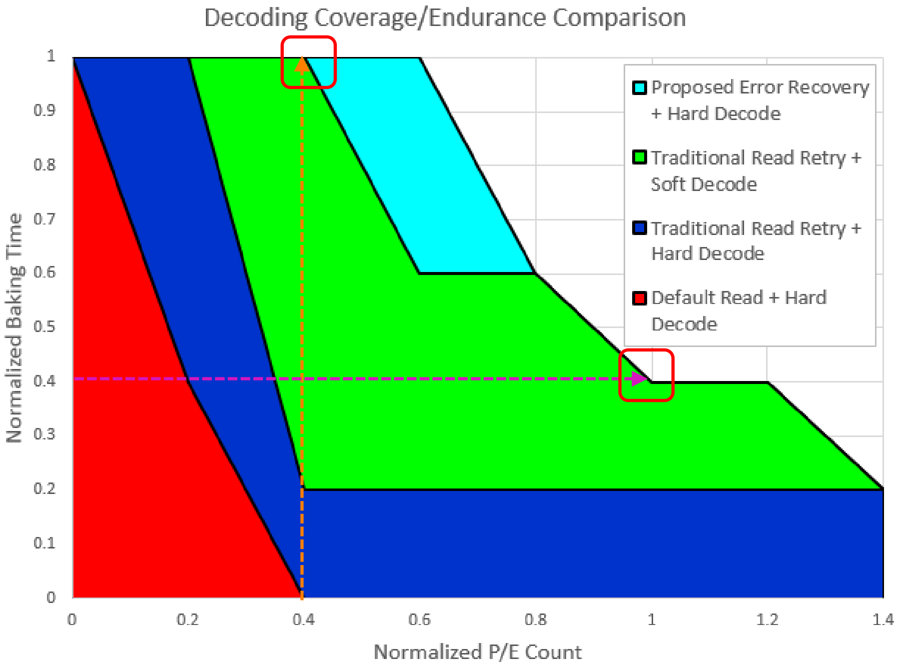


9% vs 47%



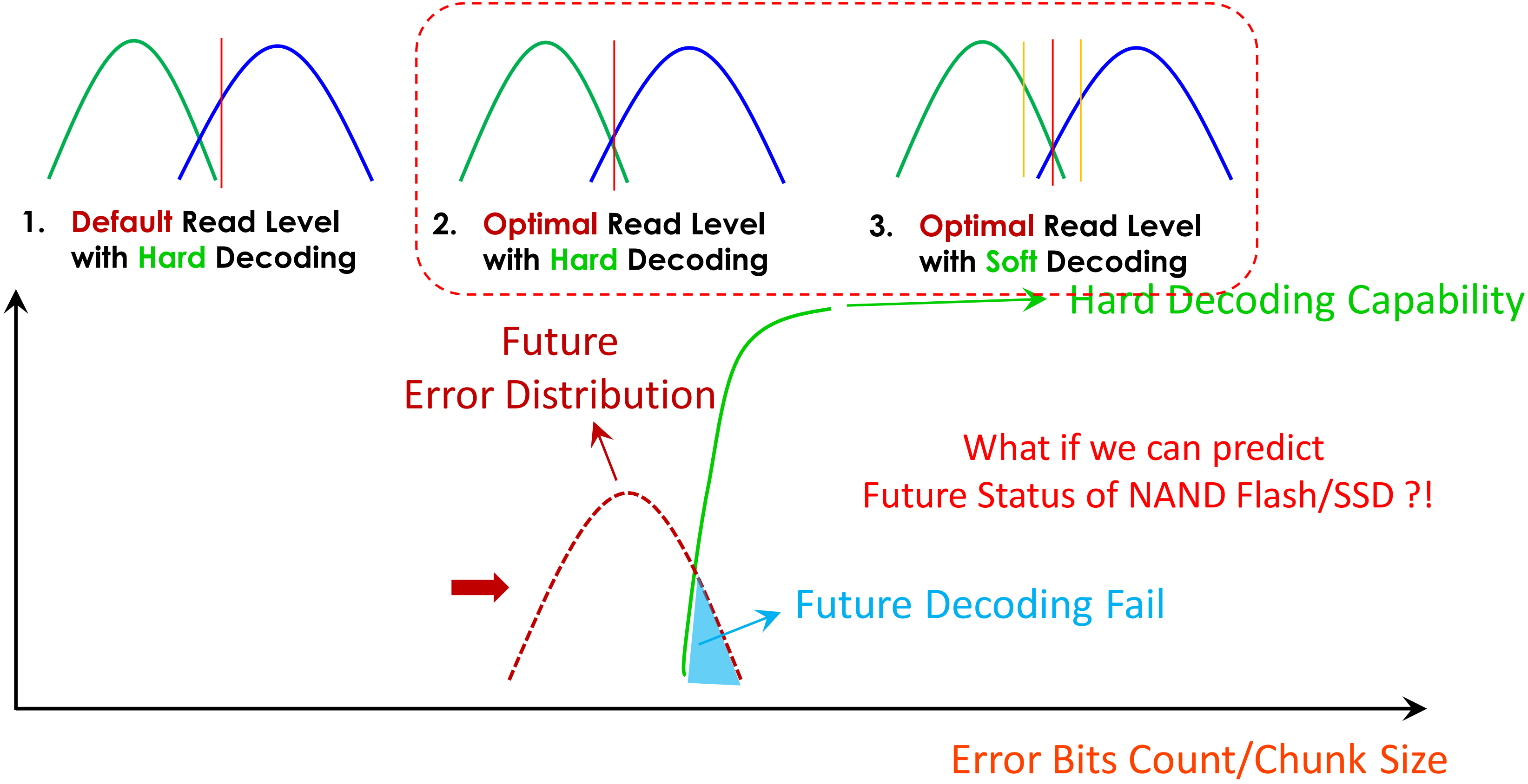
9% vs 57%

Decode Flow { 2, 3 … n }
Priority Arrangement

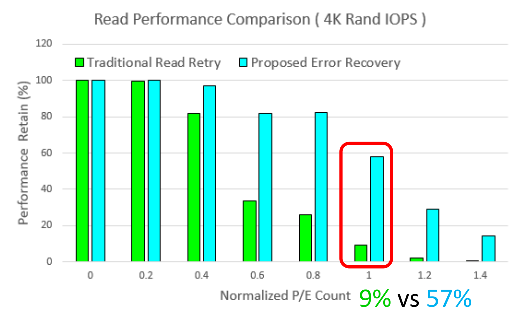


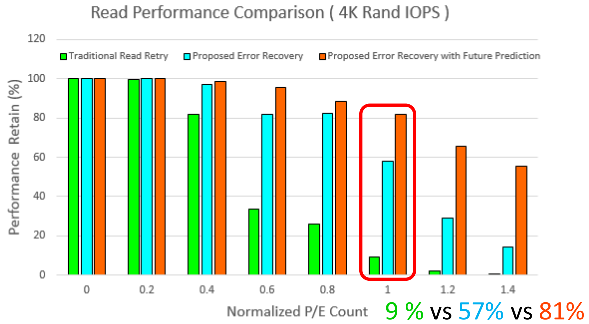
- Proposed Error Recovery Scheme always has less read latency compared with Traditional Error Recovery Scheme

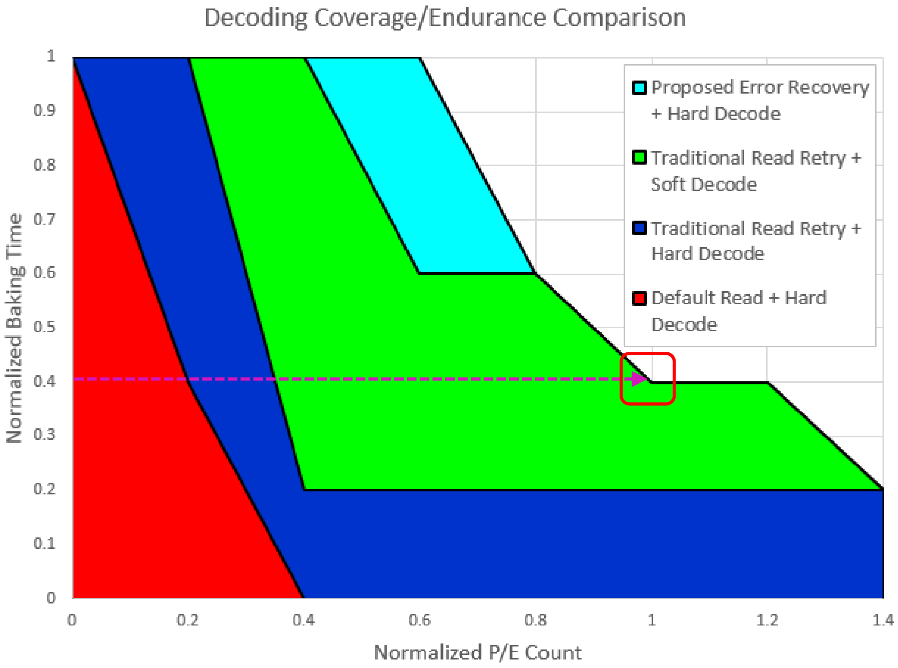
Error Recovery Flow - Prediction



Throughput with Future Status Prediction







- Read Performance Drop can be further reduced with Future Status Prediction

THANK YOU!

Any questions?

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