

**Thesis for the Degree of Doctor**

**Enhanced Data Recovery Schemes for  
MLC NAND Flash Memory**

**MLC 낸드 플래시 메모리에서 데이터  
복구 기법 개선**

**June 2020**

**Department of Computer Science and Engineering**

**Graduate School of Soongsil University**

**Tran Van Dai**



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A thesis supervisor : Dong-Joo Park

**Thesis submitted in partial fulfillment of the  
requirements for the Degree of Doctor**

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**Department of Computer Science and Engineering  
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Degree of Doctor by Tran Van Dai

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June 2020

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## **ACKNOWLEDGEMENT**

Firstly, I would like to thank to the Korea International Cooperation Agency (KOICA), the Ministry of Information and Communications (MIC) of the Socialist Republic of Vietnam, and Korea – Vietnam Friendship Information Technology College (VietHanIT) for this opportunity and their supports during my Ph.D. journey program in the Soongsil University (SSU). During the past three years, I have experienced a good academic also the social experience. I desire to thank all whose are part of this experience.

Secondly, I would love to show many thank for my supervisor, Professor Dong-Joo Park. His advices, instruction, and supervision of my dissertation were very important and helpful for me. He has also provided me with perceptive opinions and viewpoints for my research. And I wish great thanks to the other professors in Department of Computer Science and Engineering for come up with their useful recommendation which supported to improve my research. And I also gave many thanks to the other professors and staffs in SSU who have shared much of valuable knowledge and support me during my Ph.D. journey in Korea.

Thirdly, I especially gave to thank all the members of my Database lab who perseverance, enthusiasm, and patience to me. They supported and suggested me a lot of useful recommendations.

Finally, I am grateful to the steady love and support from my family during the Ph.D. journey. And they always believe in and encourage me of the meaning in life during past three years.

June 2020

Author: Tran Van Dai.

# TABLE OF CONTENTS

ABSTRACT IN ENGLISH .....	VII
ABSTRACT IN KOREAN .....	IX
<b>CHAPTER 1 INTRODUCTION .....</b>	<b>1</b>
1.1 Overview .....	1
1.2 Motivation.....	2
1.3 Problem Statement and Research Objectives.....	2
1.4 Organization.....	4
<b>CHAPTER 2 BACKGROUND AND RELATED WORK.....</b>	<b>7</b>
2.1 Background.....	7
2.1.1 Flash memory .....	7
2.1.2 Flash Translation Layer (FTL) .....	10
2.1.3 B-tree .....	12
2.1.4 T*-Tree Index Technique .....	14
2.1.5 Power-off failure .....	16
2.2 Related work.....	17
2.2.1 B-Tree Index Buffer Recovery Method Group .....	18
2.2.1.1 IBSF Technique .....	19
2.2.1.2 BFTL Technique .....	20



2.2.1.3 MR-Tree Technique .....	22
2.2.1.4 Comparison.....	24
2.2.2 Index Segment Log Directory Technical Group .....	25
2.2.2.1 BISLD Technique .....	25
2.2.2.2 T*-ISLD Method Recovery System Structure .....	26
2.2.2.3 NAND Flash File Crash Recovery Technique.....	28
2.2.2.4 Comparison.....	29
2.2.3 Power Loss Recovery (PLR) Group.....	30
2.2.3.1 A-PLR.....	31
2.2.3.2 HYFLUR .....	35
2.2.3.3 C-HYFLUR .....	38
2.2.3.4 Comparison.....	42
<b>CHAPTER 3 SoPM: A NOVEL DATA RECOVERY</b>	
<b>TECHNIQUE ON MLC NAND FLASH MEMORY .....</b>	<b>44</b>
3.1 Overview .....	44
3.2 ECC.....	45
3.3 In-page management of ECC.....	46
3.4 SoPM scheme .....	47
<b>CHAPTER 4 SoBM: AN EFFICIENT DATA RECOVERY</b>	
<b>SCHEME WITH BLOCK-LEVEL MAPPING APPROACH ON</b>	
<b>NAND FLASH MEMORY .....</b>	<b>53</b>

4.1 Overview.....	53
4.2 SoBM scheme.....	54
<b>CHAPTER 5 SoHM: AN ENHANCED DATA RECOVERY TECHNIQUE USING HYBRID MAPPING APPROACH FOR NAND FLASH MEMORY .....</b>	<b>60</b>
5.1 Overview.....	60
5.2 SoHM scheme.....	61
<b>CHAPTER 6 CONCLUSION AND FUTURE WORK.....</b>	<b>67</b>
6.1 Conclusion .....	67
6.2 Future work.....	69
 <b>REFERENCES.....</b>	 <b>70</b>

## LIST OF TABLES

[TABLE 2-1] COMPARISON OF NOR AND NAND FLASH [6].....	8
[TABLE 2-2] COMPARISON OF FTL ALGORITHMS [1] .....	11
[TABLE 2-3] RATIO OF SEQUENCE (RS) COMPARISON [16].....	24
[TABLE 2-4] RECOVERY PERFORMANCE (UNIT: MS) COMPARISON [11].....	30
[TABLE 2-5] A COMPARISON OF IN-PAGE, IN-BLOCK AND HYBRID.....	33
[TABLE 2-6] AVERAGE RESPONSE TIME (MS) [12] .....	43
[TABLE 3-1] ECC ALGORITHMS WITH ERROR CORRECTION LEVEL [38].....	45
[TABLE 3-2] NAND FLASH SPECIFICATION FOR SOPM [42] .....	50
[TABLE 4-1] NAND FLASH SPECIFICATION FOR SOBM [42] .....	56
[TABLE 5-1] NAND FLASH SPECIFICATION FOR SOHM [42].....	63

## LIST OF FIGURES

[FIGURE 2-1] 2GB MLC NAND FLASH ORGANIZATION.....	7
[FIGURE 2-2] STRUCTURE OF NAND FLASH MEMORY .....	9
[FIGURE 2-3] THE FLASH TRANSLATION LAYER STRUCTURE .....	12
[FIGURE 2-4] B-TREE ON FLASH MEMORY .....	14
[FIGURE 2-5] T*-TREE.....	15
[FIGURE 2-6] DATA RECOVERY TECHNIQUES ON FLASH MEMORY OVERVIEW .....	18
[FIGURE 2-7] THE ARCHITECTURE OF IBSF .....	20
[FIGURE 2-8] THE ARCHITECTURE OF BFTL.....	22
[FIGURE 2-9] STRUCTURE OF MR-TREE .....	23
[FIGURE 2-10] RECOVERY STRUCTURE IN BISLD .....	26
[FIGURE 2-11] RECOVERY STRUCTURE IN T*-ISLD.....	27
[FIGURE 2-12] FAILURE RECOVERY ALGORITHM .....	28
[FIGURE 2-13] CRASH RECOVERY TECHNIQUE.....	29
[FIGURE 2-14] A-PLR (A) BACKUP AND (B) RECOVERY PROCESS .....	34
[FIGURE 2-15] DESCRIPTION OF A FLUSH OPERATION .....	36
[FIGURE 2-16] A BRIEF DESCRIPTION OF URF OPERATION.....	36
[FIGURE 2-17] A BRIEF DESCRIPTION OF MTF OPERATION .....	37
[FIGURE 2-18] RAM CONFIGURATION .....	39
[FIGURE 2-19] URF OPERATION .....	39
[FIGURE 2-20] THE STRUCTURE OF TSB.....	40

[FIGURE 3-1] STRUCTURE OF THE SPARE AREA OF SOPM.....	48
[FIGURE 3-2] THE PROCESS OF DATA RECOVERY OF SOPM .....	49
[FIGURE 3-3] READ TIME COMPARISON.....	52
[FIGURE 3-4] TOTAL TIME COMPARISON .....	52
[FIGURE 4-1] STRUCTURE OF THE SPARE AREA OF SOB.....	54
[FIGURE 4-2] DATA RECOVERY PROCESS OF SOB.....	55
[FIGURE 4-3] COMPARISON READ TIME.....	59
[FIGURE 4-4] COMPARISON RECOVERY TIME .....	59
[FIGURE 5-1] STRUCTURE OF THE SPARE AREA OF SOHM .....	61
[FIGURE 5-2] DATA RECOVERY PROCESS OF SOHM.....	62
[FIGURE 5-3] THE READ OPERATION TIME COMPARISON.....	66
[FIGURE 5-4] THE RECOVERY OPERATION TIME COMPARISON .....	66

## **ABSTRACT**

# **Enhanced Data Recovery Schemes for MLC NAND Flash Memory**

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Nowadays, flash memory has been widely utilized in most of mobile devices due to its benefits, for example high mobility, fast data access, and low power consumption. Nevertheless, flash memory also owns the drawbacks to overcome like erase-before-write and write response time or unsymmetrical read: one of the solutions is namely Flash Translation Layer (FTL). Moreover, the data can be lost after power failure happens in the systems. Thus, recovery of data in this case is of prime significance. Error code correction (ECC) is one of the methods which are supplied with the flash device of the manufacturer and there have been techniques for example In-Page Backup, In-Block Backup, Hybrid Backup, A-PLR (Accumulation developed from Power Loss Recovery), HYFLUR (Hybrid FLUR Recovery), and C-HYFLUR (Compression technique for HYFLUR). However, these methods still have the weaknesses for instance mapping information

overhead and recovery time. So, this thesis introduces three techniques based on the page leveling mapping, block leveling mapping and hybrid mapping methods using the spare area in FTL. And the results display better mapping information management cost and recovery time than those of former schemes.

**Keywords:** MLC NAND Flash memory; Data recovery; FTL; PLR; Spare area; Mapping information;

국문초록

# MLC 낸드 플래시 메모리에서 데이터 복구 기법 개선

트란 반 다이  
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최근 플래시 메모리는 높은 이동성, 저전력 소비 및 빠른 데이터 액세스와 같은 잘 알려진 장점으로 인해 대부분의 모바일 장치에서 사용되고 있다. 그러나 플래시 메모리에는 쓰기 전 삭제 및 비대칭 읽기 또는 쓰기 응답 시간과 같은 극복해야 할 단점도 있다. 이러한 단점을 해결하기 위해 FTL (Flash Translation Layer)이라는 미들웨어를 사용한다. 다른 저장매체와 마찬가지로, 플래시 메모리 시스템에서도 시스템 고장이나 정전에 의해 데이터 손실이 발생할 경우 데이터를 복구하는 것은 중요한 문제라고 할 수 있다. 현재까지 제시된 데이터 복구 기술은 제조업체에서 플래시 장치와 함께 제공하는 ECC (오류 코드 수정)와 인페이지 백



업, 블록 내 백업, 하이브리드 백업, A-PLR (축적 기반 전원 손실 복구), HYFLUR (하이브리드 FLUsh 복구) 및 C-HYFLUR (HYFLUR의 압축 체계) 등이 있다. 그럼에도 불구하고, 이들 기술은 정보 오버헤드를 발생시킬 뿐만 아니라 복구 시간이 길다는 단점을 갖는다. 따라서 본 논문에서는 FTL의 스페어 영역을 사용하여 페이지 레벨링 매핑, 블록 레벨링 매핑 및 하이브리드 매핑 방법을 기반으로 하는 세 가지 기법을 제안한다. 실험 결과를 통해 제안하는 기법이 이전 데이터 복구 기법보다 복구 시간과 매핑 정보 관리 오버헤드 관점에서 더 우수함을 보인다.