Live forensics method for acquisition on the Solid State Drive (SSD) NVMe TRIM function

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Abstract

SSD currently has a new storage media technology namely Solid State Drive Non-volatile Memory Express (SSD NVMe). In addition, SSD has a feature called TRIM. The TRIM feature allows the operating system to tell SSDs which blocks are not used. TRIM removes blocks that have been marked for removal by the operating system. However, the TRIM function has a negative effect for the digital forensics specifically related to data recovery. This study aimed to compare the TRIM disable and enable functions to determine the ability of forensics tools and recovery tools to restore digital evidence on the NVMe SSD TRIM function. The operating system used in this study was Windows 10 professional with NTFS file system. Typically, acquisition is conducted by using traditional or static techniques. Therefore, there was a need of a technique to acquire SSD by using the live forensics method without shutting down the running operating system. The live forensics method was applied to acquire SSD NVMe directly to the TRIM disable and enable functions. The tools used for live acquisition and recovery were FTK Imager Portable. The inspection and analysis phases used Sleutkit Autopsy and Belkasoft Evidence Center. This research found that in the recovery process of TRIM disabled and enabled, TRIM disabled could find evidence while maintaining the integrity of evidence. It was indicated by the same hash value of the original file and the recovery file. Conversely, when TRIM is enabled, the files were damaged and could not be recovered. The files were also not identical to the original so the integrity of evidence was not guaranteed.

1. Introduction

According to research and reports of computer crime from ID-CERT [1], occurrences of computer crime are increasing significantly from year to year. Computer crime itself is an illegal act involving technology to manipulate digital data [2].

Computer technology requires speed of accessing its operation. One of the means to achieve the speedy access is SSD storage media [3]. SSD stands for Solid State Drive. It is a media that stores all information data on flash memory chips [4]. Recently, SSD has launched a technology of storage medium namely SSD Non-volatile Memory Express (NVMe). NVMe is an interface that utilizes PCIe paths to do faster data transfers [5][6]. In addition, SSD has a feature called TRIM. The TRIM feature is a command related to the running operating system which is directed to the firmware of SSD [7]. TRIM will identify which blocks are considered obsolete and delete remaining data internally [8][9]. As the consequence, the handling of information data on SSD should be done quickly since the data will immediately lost when the system shut down [8]. Figure 1 below shows the development of SSD usage [10].

![Figure 1. SSD Users Statistic](image)

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Digital forensics is a field of science that investigate digital evidence in order to collect, restore and analyze the digital evidence. The digital evidence on computer crime can be retrieved from communication devices such as smartphones, tablets, laptops or other computer users [2][11][12]. The required digital evidence can be obtained using live forensics technique. Live forensics is a method used for handling computer crime and data recovery while the computer system is running [13]. Live forensics technique will be able to improve the results of digital evidence data recovery from the TRIM function on the NVMe SSD. This technique can also guarantee the data integrity without losing the digital evidence [14][15].

Storage media such as SSDs is a non-volatile storage type. Non-volatile means that the stored data can be written and deleted, but the data still exists even if the system is shutting off [16]. This research employed non-volatile storage media on SSD. Ramadhan et al [4] conducted a research on the process of forensic data recovery on SATA SSDs using the static method. The static method includes the traditional stages for processing digital evidence using bit-by-bit images and the forensic process was run when the system is not running [17][18][19]. The research found that SSD had TRIM disabled and enabled features. Another research employing the static method was carried out by Hadi et al [20]. It was a research on the NVMe SSD interface implementing the TRIM function using NIST framework through Collection, Examination, Analysis, and Reporting stages. The study found that Autopsy tool could not recover the entire file that had been deleted with TRIM disabled function, while not all files which had been deleted using TRIM enabled function can be recovered by SluethKit Autopsy and Belkasoft tools.

In addition to static method, live forensics method can be employed in file recovery process using forensics technique. The advantages of live forensics method include faster investigation process, secure data integrity, more readable encryption technique and less memory imaging capacity compared to traditional forensic techniques [21][22]. In a research conducted by Soni et al [13], live forensics method was applied to perform data recovery while the virtual server was running. The live forensics virtual server process was carried out by using a proxmox virtual machine that provided backup features. This study aimed to restore data when the virtual server was running. The tools were SluethKit Autopsy and Belkasoft. The result of the study was successful in reading the entire contents of the imaging file and was able to find the deleted file.

2. Research Method
2.1 Method

In this study, the acquisition method was carried out by applying live forensics method on non-volatile data based on the guidelines and requirements in the Indonesian National Standard (SNI) 27037: 2014 [23]. The stages of the live forensics method according to SNI 27037: 2014 [23] are shown in Figure 2.

![Figure 2. SNI Acquisition 27037:2014](https://creativemc.org/licenses/by-sa/4.0/)

A number of previous studies had used the procedure of acquisition of live forensics according to SNI 27037: 2014 [14]. In the SNI 27037: 2014 guideline, the stages of NVMe SSD acquisition process including determining the
type of acquisition to be used, determining which type of data obtained, performing the acquisition procedure, and seizing the acquisition results for the hashing process with MD5.

Figure 3 below is the stages of examination and analysis employed in this research. Stages of inspection of digital evidence that has been acquired, and later will do extraction to get clues related to the case scenario. Stages of inspection will be carried out on the perpetrator’s computer, then the investigator’s computer is used for analysis needs. Before examining the acquisition results, the original acquisition results must be published and see the hash value between the original file and the published file, because it needs to be done to maintain the authenticity of the evidence. Furthermore, to maintain the authenticity of the evidence, the examination of the evidence is a copy of the file of the acquisition.

Figure 3. Examination and Analysis Stages

1. Preparation
   The preparation was completed by providing storage space for the imaging data which was recovered. This stage was done using the Portable FTK Imaging tool to do the acquisition. FTK Imager supports live forensics to obtain the NVMe SSD imaging file with TRIM disabled and enabled function.

2. Extraction
   In this step, extraction of the imaging file was done by identifying and recovering files that had been deleted. File extraction will also reveal the characteristics of the file structure, deleted data, file name, and md5 hash value.

3. Analysis
   This stage analyzes the results of the completed extraction process, so that it can measure the effectiveness of the extraction of TRIM function files and recommend which tools were appropriate for file recovery in this study.

The tools and materials required to obtain digital evidence in this study were ASUS X455LN laptop with Windows 10 Education operating system and 64-bit architecture as well as an external USB SSD for live acquisition storage. Forensics tools used were NVMe SSD for acquisition and FTK Portable Imager for imaging. The analysis and recovery of digital evidence were completed by Sleutkit Autopsy, Belkasoft Evidence tools.

2.2 Scenario
In the present study, the researchers conducted the research by using the SSD interface storage media NVMe TRIM function on Windows 10 with the implementation of live forensics method for file recovery of TRIM functions. This research required a scenario to obtain the digital evidence. The scenario was made to cover all activities that run on the NVMe SSD TRIM function. The scenario on the NVMe SSD was intended as a guideline for permanent deletion (shift + delete) of several files to be recovered and analyzed. In order to simplify the deletion of files, the files were distinguished by odd-even naming system. TRIM disabled was applied to odd name files and TRIM enabled was applied to even file name. The hash values of several odd-even files can be seen in Table 1 below. The performed scenario is illustrated in Figure 4.

Steps for the Perpetrator:
1. The Perpetrator used SSD NVMe with the Windows 10 Professional operating system and NTFS file system.
2. The Perpetrator divided the storage into two partitions, Drive C:\ and Drive D:\. The manipulated files were stored in partition Drive D:\.
3. The perpetrator applied the TRIM disabled and enabled functions.
4. The perpetrator permanently deleted (shift+delete) the odd-even label file on the NVMe SSD in the Drive D:\ partition.

Steps for the Investigator:
1. The investigator connects an external USB SSD SATA to the Perpetrator’s computer to store the results of file acquisition and recovery.
2. The Investigator conduct acquisition on NVMe SSDs directly on the perpetrator’s computer with an external USB SSD SATA and the Portable Imager FTK tool.
3. The Investigator’s computer was used to conduct examination and analysis of imaging results by using Sleut Kit Autopsy and Belkasoft Evidence.
### Table 1. List of Several File Samples for Odd–Even Labels and Hash Values

| File Type | File Real Name          | MD5 Value         |
|-----------|-------------------------|-------------------|
| **Document**  | D:\DOCX 1.docx           | 6db984ae2628503104cb46fab8b9ef8c |
|            | D:\DOCX 2.docx           | 6db984ae2628503104cb46fab8b9ef8c |
|            | D:\XLSX 1.xlsx           | 56c424725531715f142e77ccc5cee774 |
|            | D:\XLSX 2.xlsx           | 56c424725531715f142e77ccc5cee774 |
|            | D:\TXT 1.txt             | 6bb11f42a5b591be9ec1a0e95a5cd00c |
|            | D:\TXT 2.txt             | 6bb11f42a5b591be9ec1a0e95a5cd00c |
| **Video**   | D:\3GP 1.3gp             | cd5f422a723609bf58c69970491d88 |
|            | D:\3GP 2.3gp             | cd5f422a723609bf58c69970491d88 |
|            | D:\AVI 1.avi             | 72562d25302f0698c19040a6d50ce40c |
|            | D:\AVI 2.avi             | 72562d25302f0698c19040a6d50ce40c |
| **Image**   | D:\GIF 1.gif             | ed28cc871584230543b5a2d8a386a2cb |
|            | D:\GIF 2.gif             | ed28cc871584230543b5a2d8a386a2cb |
| **Music**   | D:\MP3 1.mp3             | d004ad9c716fb7262d09fcd812b7dbb |
|            | D:\MP3 2.mp3             | d004ad9c716fb7262d09fcd812b7dbb |
| **Application** | D:\MASTER 1.exe        | 56212ea4e41020f7bdf426bd77cd59c |
|            | D:\MASTER 2.exe          | 56212ea4e41020f7bdf426bd77cd59c |
| **Zip**     | D:\ZIP 1.zip             | 47cf035aa29599823c3ce99be426f73 |
|            | D:\ZIP 2.zip             | 47cf035aa29599823c3ce99be426f73 |
| **7z**      | D:\7Z 1.7z               | e2d9c0b0a82113ce52d5334ff24a876 |
|            | D:\7Z 2.7z               | e2d9c0b0a82113ce52d5334ff24a876 |

### Figure 4. SSD NVMe Live Forensics Recovery Scenario

#### 3. Results and Discussion

##### 3.1 Result

This research was conducted with the live forensics method using an external USB SSD to perform live acquisition of the NVMe SSD TRIM function. This was done to avoid damage and loss of digital evidence on the NVMe SSD TRIM function. Based on the predetermined scenario, the investigator performed extraction from the result of the NVMe SSD TRIM disabled and enabled function using Autopsy and Belkasoft tools.

##### 3.1.1 Preparation

At this stage, the acquisition of digital evidence contained in the NVMe SSD was performed using tools which support live forensics techniques such as Portable FTK Imager. Stage of live forensic techniques was carried out to obtain files that had been permanently deleted in the SSD NVMe using TRIM disabled and enabled function. The live forensics tools used in this study was Portable FTK Imager. Since Portable FTK Imager could retrieve data and...
information files that had been deleted, it could support live forensics techniques. Figure 5(a) and Figure 5(b) below is the documentation result of the live forensics imaging process TRIM disabled and TRIM enabled using Portable FTK Imager. Table 2 shows the results of the imaging process and MD5 hash value. The purpose of the imaging process was to avoid damage to the original digital evidence contained in the NVMe SSD when the analysis process was performed.

| Drive/Image Verify Results | Drive/Image Verify Results |
|---------------------------|---------------------------|
| Name                      | Name                      |
| Imaging TRIM Disable.001  | Imaging TRIM Enable.001   |
| Sector count              | Sector count              |
| 250067790                 | 250067790                 |
| MD5 Hash                  | MD5 Hash                  |
| 5e7d9c116485b5ae0c630b   | 4cd76a8ba35e3ad940de2104 |
| 987267d122                | 11c6ca30                  |
| Report Hash               | Report Hash               |
| 5e7d9c116485b5ae0c630b   | 4cd76a8ba35e3ad940de2104 |
| 987267d122                | 11c6ca30                  |
| Verify result             | Verify result             |
| Match                     | Match                     |
| SHA1 Hash                 | SHA1 Hash                 |
| 859d71959360a8ee192f6b   | d2198208ae4b6bf001e53a1  |
| 6f2e572202                | 4124d8a32                 |
| Report Hash               | Report Hash               |
| 859d71959360a8ee192f6b   | d2198208ae4b6bf001e53a1  |
| 6f2e572202                | 4124d8a32                 |
| Verify result             | Verify result             |
| Match                     | Match                     |
| Bad Sector List           | Bad Sector List           |
| No bad sectors found      | No bad sectors found      |

Figure 5. Imaging Results Portable FTK Imager (a) TRIM Disabled, (b) TRIM Enabled

Table 2. Acquisition Results of NVMe SSD TRIM function using Portable FTK Imager

| No | Name Drive Imaging | MD5 Value | Acquisition Proses (Time) |
|----|--------------------|-----------|---------------------------|
| a  | Imaging TRIM Disable | 5e7d9c116485b5ae0c630b987267d122 | 50 minute 46 seconds |
| b  | Imaging TRIM Enable  | 4cd76a8ba35e3ad940de210411c6ca30 | 50 minute 44 seconds |

3.1.2 Extraction

At this stage, the researchers extracted the imaging file. This process aimed to extract the imaging result. In order to maintain the integrity and authenticity of the evidence, the extraction was performed on the duplicates of the imaging result. The tools that helped the process of examination extraction and imaging analysis were Autopsy and Belkasoft. Figure 6 is a check using the Sleuthkit Autopsy tool which shows erased digital evidence, Figure 6(a) TRIM Disabled and Figure 6(b) TRIM Enabled.

Figure 6. Examination of File List of Using Sleuthkit Autopsy Tool (a) TRIM Disabled, (b) TRIM Enabled
Figure 7 is an examination using the Belkasoft Tool which shows erased digital evidence, Figure 7(a) TRIM Disabled and Figure 7(b) TRIM Enabled.

Based on the results of examination using the Sleutkit Autopsy tool on the TRIM disable function, odd labels could be recovered perfectly while none of the TRIM enabled even labels files could be recovered. Meanwhile, according to the results of examination using Belkasoft tools, none of the odd label TRIM disabled files could be recovered perfectly because these files were separated while only two TRIM enabled even label files could be recovered, but the file name and MD5 hash value were not the same as the original.

3.1.3 Analysis

At this stage, the analysis of the acquisition result was performed by Portable FTK imager. In this stage the value of the signature file that had been deleted by the TRIM disabled and enabled function was found. Signature file was a data information value used to identify content of the data [24][25]. Figure 8(a) is TRIM disabled shows that the signature of the odd label file was not damaged. Therefore, it could be concluded that the odd label file could be read and recovered. Meanwhile, Figure 8(b) is TRIM enabled shows that the signature of the even label file was damaged or modified, so the file could not be recovered.

Figure 8. Analysis Stage (a) Odd Label TRIM Disabled, (b) Even Label TRIM Enabled
The results of file recovery analysis summarized in Table 3 and Table 4 show the analysis result of the TRIM disabled and enabled file recovery processes that has been performed using the Sleutkit Autopsy tool.

### Table 3. List of Analysis and Recovery of Odd Label TRIM Disabled Files with Sleutkit Autopsy Tool

| File Name   | Recovery Results | MD5 Value     | Information          |
|-------------|------------------|---------------|----------------------|
| DOCX 1.docx | Successful recovery | 6db984ae2628503104cb46fab8b9ef8c |                      |
| XLSX 1.xlsx | Successful recovery | 56c42472531715f142e77ccc5ce9774 |                      |
| TXT 1.txt  | Successful recovery | 6bb11142a5b591be9c1a0e95a5cd00c |                      |
| 3GP 1.3gp  | Successful recovery | cd5f422a723609bf58c69970491d88 |                      |
| AVI 1.avi  | Successful recovery | 72562d253020698c19040a6d50ce0b0c |                      |
| GIF 1.gif  | Successful recovery | ed28cc871584230543ba28a386a2cb |                      |
| MP3 1.mp3 | Successful recovery | d004ad9c716fbb7262d09cd812b7b6 |                      |
| MASTER 1.exe| Successful recovery | 56f292a6a41020df7bf5426bd77cd59c |                      |
| ZIP 1.zip  | Successful recovery | 47cf035aa29599823cc99be1f2467330 |                      |
| 7Z 1.7z    | Successful recovery | 42f90c60b0a82113ce52d5334f7d2a876 |                      |

The result of the odd label TRIM disabled files analysis indicates that based on the authenticity of the evidence by analyzing the file using Autopsy, it could be assumed that all of the odd label files had an MD5 hash value that was identical or in other words, the integrity of the evidence was maintained.

### Table 4. List of Analysis and Recovery of Even Label TRIM Enabled Files with Sleutkit Autopsy Tool

| File Name   | Recovery Results | MD5 Value     | Information          |
|-------------|------------------|---------------|----------------------|
| DOCX 1.docx | Successful recovery | 6db984ae2628503104cb46fab8b9ef8c |                      |
| DOCX 2.docx | Corrupted file   | 821d1ae6d95435f795a82c26fcbcb6 |                      |
| XLSX 1.xlsx | Successful recovery | 6bb11142a5b591be9c1a0e95a5cd00c |                      |
| XLSX 2.xlsx | Corrupted file   | c4e4f486732d5873e050500e18bb414 |                      |
| TXT 1.txt  | Corrupted file   | 6bb11142a5b591be9c1a0e95a5cd00c |                      |
| TXT 2.txt  | Corrupted file   | 6bb11142a5b591be9c1a0e95a5cd00c |                      |
| 3GP 1.3gp  | Successful recovery | cd5f422a723609bf58c69970491d88 |                      |
| 3GP 2.3gp  | Corrupted file   | 299e23f97392eae859b7117db91634 |                      |
| AVI 1.avi  | Successful recovery | 72562d253020698c19040a6d50ce0b0c |                      |
| AVI 2.avi  | Corrupted file   | a13a97acca90ccce38174772e79ed152 |                      |
| GIF 1.gif  | Corrupted file   | ed28cc871584230543ba28a386a2cb |                      |
| GIF 2.gif  | Corrupted file   | -              |                      |
| MP3 1.mp3 | Successful recovery | d004ad9c716fbb7262d09cd812b7b6 |                      |
| MP3 2.mp3 | Corrupted file   | 255f0e8c535c187b3e13adbca4ae315 |                      |
| MASTER 1.exe| Successful recovery | 56f292a6a41020df7bf5426bd77cd59c |                      |
| MASTER 2.exe| Corrupted file   | a6e196d466a7e6d0498522db4c157335 |                      |
| ZIP 1.zip  | Corrupted file   | 47df035aa29599823cc99be1f2467330 |                      |
| ZIP 2.zip  | Corrupted file   | 9ba7bb2a2b3acedebdb3920751d2c0 |                      |
| 7Z 1.7z    | Corrupted file   | e2d90c60b0a82113ce52d5334f7d2a876 |                      |
| 7Z 2.7z    | Corrupted file   | d184ed7759220cb686f5eb5cb6965174 |                      |

All files with odd labels had been successfully recovered without any damage while all the even labels could not be recovered. The odd label file that had been deleted on the TRIM disabled function could be recovered perfectly. Thus, it can be concluded that when deletion of odd label files is done in a disabled state, recovery can be performed perfectly. Meanwhile, because the even label file was deleted when TRIM was enabled, the even label file could not be fully recovered.

Table 5 and Table 6 show the results of analysis and recovery of the TRIM disabled and enabled files using Belkasoft tool.

### Table 5. List of Analysis and Recovery of Odd Label TRIM Disabled Files with Belkasoft Tool

| File Name   | Recovery Results | MD5 Value     | Information          |
|-------------|------------------|---------------|----------------------|
| DOCX 1.docx | Corrupted file   | -              |                      |
| XLSX 1.xlsx | Corrupted file   | -              |                      |
| TXT 1.txt  | Corrupted file   | -              |                      |
At the examination and recovery analysis stage with the Belkasoft tools, recovery on the files that had been permanently deleted by TRIM disabled function could be performed on files with .jpg, .png, and .bmp extension type. However, the name labels changed into picture_00000414A000.jpg, picture_000003F52000.gif, picture_000014A33000.png, and picture_00001F640000.bmp. It was found that only image files could be recovered. Meanwhile, among the TRIM enabled function files, there were only two files that could be recovered and the file names were not the same as the original, namely document_000001F02000.docx and picture_00001F640000.bmp.

### 3.2 Discussion
SSD has several features including TRIM disabled and enabled features. The TRIM feature works to identify blocks considered to be obsolete and delete remaining data internally. The TRIM feature poses challenges for investigators in obtaining digital evidence. There are several studies examining TRIM features including acquisition of the TRIM function on SSD using the static method. The purpose of the research is to obtain digital evidence that has been permanently deleted when the TRIM feature is disabled or enabled. The research found that the implementation of the TRIM disabled function could not recover the entire file that had been permanently deleted with the Sluetkit Autopsy tool and that it took 12 hours 24 minutes to check, while TRIM enabled could not recover all files with the Sluetkit Autopsy tool and the process required 13 hours 25 minutes to complete. Therefore, live forensics method is able to improve data recovery results from the TRIM function. Data handling on the SSD must be performed quickly because the data will be lost if the system shut off. The result obtained regarding the TRIM disable function in this study indicates that overall the file could be recovered using the Sluetkit Autopsy tool perfectly and the hash value of the file did not change. The live acquisition of TRIM disabled using FTK Portable Imager tool took 50 minutes 46 seconds. As for the TRIM enabled, the file could be recovered entirely with the Sluetkit Autopsy tool, but the files were corrupted and the hash values were not identical. The live acquisition of TRIM enabled using the FTK Portable Imager tool took 50 minutes 44 seconds.
Based on information collected and described according to the methods and scenarios implemented in this study, it is evident that the TRIM function poses problems and challenges for digital forensics investigators. This is because the TRIM function has a negative influence, that is, TRIM can affect data recovery when TRIM is enabled on the operating system. As a result, the TRIM function will delete data considered to be obsolete and delete the remaining data internally. Technology on SSD storage media has a negative impact, especially in forensic analysis to find information and understand data stored on SSD storage media. It supports the fact that SSD is a challenge for forensic analysis [26].

4. Conclusion

Based on the results of the study, live forensic technique can be applied to the acquisition on the NVMe SSD TRIM function on a professional Windows 10 operating system. The process of examination and analysis on SSD were performed with both TRIM disabled and enabled. The percentage of recovery TRIM disabled uses 100% Autopsy tools, Belkasoft 3%. While the TRIM recovery percentage is enabled using the 99% odd label Autopsy tools and even 0% labels, Belkasoft odd labels 2% and even 0% labels. This research found that in the process of recovery, TRIM disabled could maintain the integrity of the evidence. This is indicated by the identical hash value on the original file and the recovery file. On the contrary, the files with TRIM enabled were damaged and could not be recovered. Moreover, the files are not identical to the original file, so the integrity of evidence was not guaranteed.

For further research, it is recommended to test the implementation of TRIM functions in other operating systems such as iOS and Linux, using different file systems such as ExFat, ReFS and so on, as well as exploring deletion methods, SSD handling methods, and tools used to perform file recovery in digital forensics field.

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