

Forensic Data Recovery from Flash Memory

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Abstract—Current forensic tools for examination of embedded systems like mobile phones and PDA's mostly perform data extraction on a logical level and do not consider the type of storage media during data analysis. This paper suggests a low level approach for the forensic examination of flash memories and describes three low-level data acquisition methods for making full memory copies of flash memory devices. Results are presented of a file system study in which USB memory sticks from 45 different make and models were used. For different mobile phones is shown how full memory copies of their flash memories can be made and which steps are needed to translate the extracted data into a format that can be understood by common forensic media analysis tools. Artifacts, caused by flash specific operations like block erasing and wear leveling, are discussed and directions are given for enhanced data recovery and analysis on data originating from flash memory.

Index Terms—embedded systems, flash memory, physical analysis, hex analysis, forensic, mobile phones, USB sticks.

I. INTRODUCTION

THE evolution in consumer electronics has caused an exponential growth in the amount of mobile digital data. The majority of mobile phones nowadays has a build in camera and is able to record, store, play and forward picture, audio, and video data. Some countries probably have more memory sticks than inhabitants. A lot of this data is related to human behavior and might become subject of a forensic investigation.

Flash memory is currently the most dominant non-volatile solid-state storage technology in consumer electronic products. An increasing number of embedded systems use high level file systems comparable to the file systems used on personal computers. Current forensic tools for examination of embedded systems like mobile phones or PDAs mostly perform logical data acquisition. With logical data acquisition it's often not possible to recover all data from a storage medium. Deleted data for example, but sometimes also other data which is not directly relevant from a user standpoint, can not be acquired and potentially interesting information might be missed. For this reason data acquisition is wanted at the lowest layer where evidence can be expected. For hard disk based storage media it's common to copy all bytes from the original storage device to a destination storage device and then do the analysis on this copy. The same procedure is desired for embedded systems with solid-state storage media.

This paper suggests a low level approach for the forensic examination of flash memory. In chapter II the most important technology basics of flash memories are explained. Chapter III describes three low-level data acquisition methods for flash memories, first with so called *flasher tools*, then by usage of an access port commonly used for testing and debugging and finally with a semi-invasive method where the flash memory chips are physically removed from the printed circuit board. Chapter IV explains methods to translate the extracted data

to file system level where common forensic media analysis tools can be used for further analysis. Experimental results are given on data originating from USB sticks and mobile phones. Chapter V explains some artifacts characteristic to data originating from flash file systems.

II. FLASH TECHNOLOGY

Flash memory is a type of non-volatile memory that can be electrically erased and reprogrammed. Flash memory comes in two flavors, NOR¹ flash and NAND² flash, named after the basic logical structures of these chips. Contrary to NAND flash, NOR flash can be read byte by byte in constant time which is the reason why it is often used when the primary goal of the flash memory is to hold and execute firmware³, while parts of NOR flash that are not occupied by firmware can be used for user data storage. Most mobile media, like USB flash disks, or multimedia centred devices like digital camera's and camera phones, use NAND flash memory to create compact mobile data storage. This chapter explains the basics of flash technology first on the physical level and then from a logical perspective. An introduction to NAND flash memory can be found in [5], more in depth information can be found in [9].

A. Physical Characteristics

The physical mechanism to store data in flash memory is based on storing electrical charge into a floating gate of a transistor. This charge can be stored for extended periods of time without using an external power supply but gradually it will leak away caused by physical effects. Data retention specifications for current flash memory are between 10 and 100 years.

Flash memory can be written byte for byte, like EEPROM⁴, but it has to be erased in blocks at a time before it can be re-written. Erasing results in a memory block that is filled completely with 1's. In NAND flash, erase blocks are divided further into pages, for example 32 or 64 per erase block. A page is usually a multiple of 512 bytes in size, to emulate 512 byte sector size commonly found in file systems on magnetic media. Additionally, a page has a number of so called 'spare area' bytes, generally used for storing meta data. Some flash disk drivers use the concept of 'zones'⁵. A zone is a group of blocks, usually 256 to 1024. Contrary to blocks and pages, a zone is just a logical concept, there is no physical representation. See figure 1 for a dissection of NAND flash memory.

¹NOR flash memory was introduced in 1988 by Intel.

²NAND flash memory was introduced in 1989 by Toshiba.

³Firmware is software that is embedded in a hardware device (like a mobile phone or a PDA).

⁴Electrically Erasable Programmable Read Only Memory.

⁵The term partition is sometimes also used to indicate sections of flash memory.

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