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, NOR[1] flash and NAND[2] 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 firmware[3], 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 EEPROM[4], 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.

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[1] NOR flash memory was introduced in 1988 by Intel.
[2] NAND flash memory was introduced in 1989 by Toshiba.
[3] Firmware is software that is embedded in a hardware device (like a mobile phone or a PDA).
[4] Electrically Erasable Programmable Read Only Memory.
[5] The term partition is sometimes also used to indicate sections of flash memory.

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Lauren Gardner

Forensic Data Recovery From Flash Memory:

Digital Forensics and Cyber Crime Sanjay Goel,2010-01-13 The First International Conference on Digital Forensics and Cyber Crime ICDF2C was held in Albany from September 30 to October 2 2009 The field of digital for sics is growing rapidly with implications for several fields including law enforcement network security disaster recovery and accounting This is a multidisciplinary area that requires expertise in several areas including law computer science finance networking data mining and criminal justice This conference brought together pr titioners and researchers from diverse fields providing opportunities for business and intellectual engagement among attendees All the conference sessions were very well attended with vigorous discussions and strong audience interest The conference featured an excellent program comprising high quality paper pr entations and invited speakers from all around the world The first day featured a plenary session including George Philip President of University at Albany Harry Corbit Suprintendent of New York State Police and William Pelgrin Director of New York State Office of Cyber Security and Critical Infrastructure Coordination An outstanding keynote was provided by Miklos Vasarhelyi on continuous auditing This was followed by two parallel sessions on accounting fraud financial crime and m timedia and handheld forensics The second day of the conference featured a mesm izing keynote talk by Nitesh Dhanjani from Ernst and Young that focused on psyc logical profiling based on open source intelligence from social network analysis The third day of the conference featured both basic and advanced tutorials on open source forensics

Forensics in Telecommunications, Information and Multimedia Matthew Sorell,2009-05-26 The Second International Conference on Forensic Applications and Techniques in Telecommunications Information and Multimedia e Forensics 2009 took place in Adelaide South Australia during January 19 21 2009 at the Australian National Wine Centre University of Adelaide In addition to the peer reviewed academic papers presented in this volume the c ference featured a significant number of plenary contributions from recognized tional and international leaders in digital forensic investigation Keynote speaker Andy Jones head of security research at British Telecom outlined the emerging challenges of investigation as new devices enter the market These clude the impact of solid state memory ultra portable devices and distributed storage also known as cloud computing The plenary session on Digital Forensics Practice included Troy O Malley Que sland Police Service who outlined the paperless case file system now in use in Que sland noting that efficiency and efficacy gains in using the system have now meant that police can arrive at a suspect s home before the suspect Joseph Razik represe ing Patrick Perrot of the Institut de Recherche Criminelle de la Gendarmerie Nati ale France summarized research activities in speech image video and multimedia at the IRCGN The plenary session on The Interaction Between Technology and Law brought a legal perspective to the technological challenges of digital forensic investigation Advancements in Cybercrime Investigation and Digital Forensics A. Harisha,Amarnath Mishra,Chandra Singh,2023-10-06 Vast manpower and resources are needed to investigate cybercrimes The use of new advanced technologies such as machine learning combined with automation are

effective in providing significant additional support in prevention of cyber attacks in the speedy recovery of data and in reducing human error This new volume offers a comprehensive study of the advances that have been made in cybercrime investigations and digital forensics highlighting the most up to date tools that help to mitigate cyber attacks and to extract digital evidence for forensic investigations to recover lost purposefully deleted or damaged files The chapters look at technological cybersecurity tools such as artificial intelligence machine learning data mining and others for mitigation and investigation **Applied Informatics** Hector Florez,Hernán Astudillo,2024-10-18 The two volume set CCIS 2236 and 2237 constitutes the refereed proceedings of the 7th International Conference on Applied Informatics ICAI 2024 held in Vina del Mar Chile during October 24 26 2024 The 39 full papers presented in these proceedings were carefully reviewed and selected from 123 submissions The papers were organized in the following topical sections Part I Artificial Intelligence Bioinformatics Cloud Computing Data Analysis Decision Systems and Game Development Part II Health Care Information Systems Interdisciplinary Information Studies Learning Management Systems Natural Language Processing Social and Behavioral Applications Software and Systems Modeling and Software Architectures Digital Forensics for Handheld Devices Eamon P. Doherty,2012-08-17 Approximately 80 percent of the world s population now owns a cell phone which can hold evidence or contain logs about communications concerning a crime Cameras PDAs and GPS devices can also contain information related to corporate policy infractions and crimes Aimed to prepare investigators in the public and private sectors Digital Forensics for Handheld Devices examines both the theoretical and practical aspects of investigating handheld digital devices This book touches on all areas of mobile device forensics including topics from the legal technical academic and social aspects of the discipline It provides guidance on how to seize data examine it and prepare it as evidence for court This includes the use of chain of custody forms for seized evidence and Faraday Bags for digital devices to prevent further connectivity and tampering of evidence Emphasizing the policies required in the work environment the author provides readers with a clear understanding of the differences between a corporate investigation and a criminal investigation The book also Offers best practices for establishing an incident response policy and seizing data from company or privately owned digital devices Provides guidance in establishing dedicated examinations free of viruses spyware and connections to other devices that could taint evidence Supplies guidance on determining protocols for complicated crime scenes with external media and devices that may have connected with the handheld device Considering important privacy issues and the Fourth Amendment this book facilitates an understanding of how to use digital forensic tools to investigate the complete range of available digital devices including flash drives cell phones PDAs digital cameras and netbooks It includes examples of commercially available digital forensic tools and ends with a discussion of the education and certifications required for various careers in mobile device forensics **Windows Forensics** Chad Steel,2007-08-20 The evidence is in to solve Windows crime you need Windows tools An arcane pursuit a decade ago forensic science today is a household term And

while the computer forensic analyst may not lead as exciting a life as TV s CSIs do he or she relies just as heavily on scientific principles and just as surely solves crime Whether you are contemplating a career in this growing field or are already an analyst in a Unix Linux environment this book prepares you to combat computer crime in the Windows world Here are the tools to help you recover sabotaged files track down the source of threatening e mails investigate industrial espionage and expose computer criminals Identify evidence of fraud electronic theft and employee Internet abuse Investigate crime related to instant messaging Lotus Notes r and increasingly popular browsers such as Firefox r Learn what it takes to become a computer forensics analyst Take advantage of sample forms and layouts as well as case studies Protect the integrity of evidence Compile a forensic response toolkit Assess and analyze damage from computer crime and process the crime scene Develop a structure for effectively conducting investigations Discover how to locate evidence in the Windows Registry

Computer Forensics Linda Volonino,Reynaldo Anzaldua,Jana Godwin,2007 For introductory and intermediate courses in computer forensics digital investigations or computer crime investigation By applying information systems computer security and criminal justice principles and practices to crime investigations and other legal actions this text teaches students how to use forensically sound methodologies and software to acquire admissible electronic evidence e evidence with coverage of computer and email forensics cell phone and IM forensics and PDA and Blackberry forensics *The Forensic Potential of Flash Memory* ,2009 This thesis explores the forensic opportunities afforded by flash memory It starts with a discussion of flash storage starting with the physics of flash devices the development of flash translation layers which allow flash devices to be used with unmodified legacy operating systems and flash file systems which provide for better utilization of flash storage at a somewhat higher cost Then this thesis provides a comprehension survey of the relevant academic literature and evaluates the work that others have done in the field of flash data recovery It provides a theory of circumstances when residual data may exist on flash memory through the intentional deletion and overwrite of previously saved data based upon a thorough patent review and freely available documentation It clearly documents the steps of configuring a Linux kernel to use the YAFFS2 Yet Another Flash File System used in Android and the JFFS2 the Journaling Flash File System used on the One Laptop per Child Program flash file systems It then conducts experiments to confirm or deny these theories with a focus on the recovery of data and other evidence that overwritten and deleted data once existed Finally this thesis makes recommendations for further research **CompTIA Security+ Certification Boxed Set (Exam SY0-301)** Glen E. Clarke,Daniel Lachance,2013-10-11 The best fully integrated CompTIA Security self study package featuring 1200 practice exam questions Save 12% on this Boxed Set with bonus electronic content CompTIA Security Certification Boxed Set Exam SY0 301 provides you with a variety of exam focused test prep resources designed to work together as a comprehensive program for self study CompTIA Security Certification Study Guide features 100% complete coverage of all official objectives for the exam Exam Readiness Checklist you re ready for the exam when all objectives on the

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