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 memories.

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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Albert J. Marcella

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

Data Recovery Techniques for Computer Forensics Alex Khang,2025-04-24 Data Recovery Techniques for Computer Forensics is a practical and comprehensive reference designed for professionals students and researchers in digital forensics data recovery and information security This handbook provides clear structured guidance on essential principles and practical techniques for recovering lost or compromised digital data in forensic investigations The book begins with the fundamentals of data recovery and examines the major causes of data loss including software errors and hardware failures It then explores contemporary data protection technologies and delves into the structure and organization of hard disks laying a solid foundation for understanding data storage systems Specialized chapters cover the recovery and management of various file systems including FAT16 FAT32 and NTFS along with methods for partition recovery and an introduction to dynamic disk management The final section introduces essential data security software used to protect and recover digital information Key Features Covers basic and applied data recovery concepts for forensic applications Explains causes of data loss and modern data protection technologies Detailed chapters on hard disk structure data organization and partition recovery Practical guidance on managing and recovering FAT16 FAT32 and NTFS file systems Introduces dynamic disk configurations and essential data security tools   **Handbook of Digital Forensics and Investigation** Eoghan Casey,2009-10-07 Handbook of Digital Forensics and Investigation builds on the success of the Handbook of Computer Crime Investigation bringing together renowned experts in all areas of digital forensics and investigation to provide the

consummate resource for practitioners in the field It is also designed as an accompanying text to Digital Evidence and Computer Crime This unique collection details how to conduct digital investigations in both criminal and civil contexts and how to locate and utilize digital evidence on computers networks and embedded systems Specifically the Investigative Methodology section of the Handbook provides expert guidance in the three main areas of practice Forensic Analysis Electronic Discovery and Intrusion Investigation The Technology section is extended and updated to reflect the state of the art in each area of specialization The main areas of focus in the Technology section are forensic analysis of Windows Unix Macintosh and embedded systems including cellular telephones and other mobile devices and investigations involving networks including enterprise environments and mobile telecommunications technology This handbook is an essential technical reference and on the job guide that IT professionals forensic practitioners law enforcement and attorneys will rely on when confronted with computer related crime and digital evidence of any kind Provides methodologies proven in practice for conducting digital investigations of all kinds Demonstrates how to locate and interpret a wide variety of digital evidence and how it can be useful in investigations Presents tools in the context of the investigative process including EnCase FTK ProDiscover foremost XACT Network Miner Splunk flow tools and many other specialized utilities and analysis platforms Case examples in every chapter give readers a practical understanding of the technical logistical and legal challenges that arise in real investigations *IT-Forensik* Antje Raab-Düsterhöft,2024-10-22 Die IT Forensik hat zum Ziel Cybercrime Vorf lle wie z B Hacker Angriffe Phishing Attacken oder einen Daten Diebstahl aufzukl ren Dazu werden digitale Spuren die T ter in IT Systemen hinterlassen haben erfasst und ausgewertet IT Forensik hilft die Schwachstellen von IT Systemen zu erkennen und die Sicherheit der IT Systeme zu erh hen **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 Flash Memory Evolution Sterling Blackwood,AI,2025-02-25 Flash Memory Evolution explores the captivating story of portable digital storage from early CompactFlash cards to today s ubiquitous SD cards and USB drives It highlights how relentless innovation driven by the demand for portable reliable and affordable data storage has transformed how we manage data Early flash memory cards like CompactFlash and SmartMedia though now largely obsolete paved the way for the high capacity fingernail sized storage we rely on today The book breaks down the technological advancements standardization battles and market forces that have shaped flash memory s evolution The book progresses logically starting with the fundamental concepts of flash memory technology and the rise and fall of early formats It then analyzes the emergence of SD cards and USB drives as dominant standards propelled by their versatility and ongoing advancements in storage density This evolution isn t just about increasing capacity it reflects the constant interplay between technological innovation and market forces The book adopts a professional yet accessible style making it valuable for both technical readers and anyone interested in the history of computers and technology *Fundamentals of Network Forensics* R.C. Joshi,Emmanuel S. Pilli,2016-11-25 This timely text reference presents a detailed introduction to the essential aspects of computer network forensics The book considers not only how to uncover information hidden in email messages web pages and web servers but also what this reveals about the functioning of the Internet and its core protocols This in turn enables the identification of shortcomings and highlights where improvements can be made for a more secure network Topics and features provides learning objectives in every chapter and review questions throughout the book to test understanding introduces the basic concepts of network process models network forensics frameworks and network forensics tools discusses various techniques for the acquisition of packets in a network forensics system network forensics analysis and attribution in network forensics examines a range of advanced topics including botnet smartphone and cloud forensics reviews a number of freely available tools for performing forensic activities **iOS Forensics 101** Rob Botwright,101-01-01 Dive into the world of iOS Forensics with our comprehensive book bundle iOS Forensics 101 Extracting Logical and Physical Data from iPhone iPad and Mac OS This essential collection comprises four meticulously crafted volumes that will elevate your expertise in digital investigations within Apple s ecosystem Book 1 iOS Forensics 101 Introduction to Digital Investigations Begin your journey with a solid foundation in digital forensics Explore the intricacies of iOS devices learn essential methodologies and grasp legal considerations critical to conducting effective investigations From understanding device architecture to navigating forensic challenges this volume prepares you for the complexities ahead Book 2 iOS Forensics 101 Techniques for Extracting Logical Data Unlock the secrets to extracting and analyzing logical data from iPhones iPads and Mac OS devices Discover techniques for accessing iCloud backups examining app data and recovering user generated content With practical insights and hands on guidance master the tools needed to uncover crucial evidence while maintaining forensic integrity Book 3 iOS Forensics 101 Mastering Physical Data Acquisition Take your skills to the

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validation and new application exploration in wireless networks **Advances in Digital Forensics VIII** Gilbert Peterson,Sujeet Shenoi,2012-12-09 Digital forensics deals with the acquisition preservation examination analysis and presentation of electronic evidence Networked computing wireless communications and portable electronic devices have expanded the role of digital forensics beyond traditional computer crime investigations Practically every crime now involves some aspect of digital evidence digital forensics provides the techniques and tools to articulate this evidence Digital forensics also has myriad intelligence applications Furthermore it has a vital role in information assurance investigations of security breaches yield valuable information that can be used to design more secure systems Advances in Digital Forensics VIII describes original research results and innovative applications in the discipline of digital forensics In addition it highlights some of the major technical and legal issues related to digital evidence and electronic crime investigations The areas of coverage include themes and issues forensic techniques mobile phone forensics cloud forensics network forensics and advanced forensic techniques This book is the eighth volume in the annual series produced by the International Federation for Information Processing IFIP Working Group 11 9 on Digital Forensics an international community of scientists engineers and practitioners dedicated to advancing the state of the art of research and practice in digital forensics The book contains a selection of twenty two edited papers from the Eighth Annual IFIP WG 11 9 International Conference on Digital Forensics held at the University of Pretoria Pretoria South Africa in the spring of 2012 Advances in Digital Forensics VIII is an important resource for researchers faculty members and graduate students as well as for practitioners and individuals engaged in research and development efforts for the law enforcement and intelligence communities Gilbert Peterson is an Associate Professor of Computer Engineering at the Air Force Institute of Technology Wright Patterson Air Force Base Ohio USA Sujeet Shenoi is the F P Walter Professor of Computer Science and a Professor of Chemical Engineering at the University of Tulsa Tulsa Oklahoma USA **Advances in Digital Forensics IV** Indrajit Ray,Sujeet Shenoi,2008-08-29 Practically every crime now involves some aspect of digital evidence This is the most recent volume in the Advances in Digital Forensics series It describes original research results and innovative applications in the emerging discipline of digital forensics In addition it highlights some of the major technical and legal issues related to digital evidence and electronic crime investigations This book contains a selection of twenty eight edited papers from the Fourth Annual IFIP WG 11 9 Conference on Digital Forensics held at Kyoto University Kyoto Japan in the spring of 2008 Cyber Forensics Albert J. Marcella,2021-09-12 Threat actors be they cyber criminals terrorists hacktivists or disgruntled employees are employing sophisticated attack techniques and anti forensics tools to cover their attacks and breach attempts As emerging and hybrid technologies continue to influence daily business decisions the proactive use of cyber forensics to better assess the risks that the exploitation of these technologies pose to enterprise wide operations is rapidly becoming a strategic business objective This book moves beyond the typical technical approach to discussing cyber forensics processes and procedures Instead the

authors examine how cyber forensics can be applied to identifying collecting and examining evidential data from emerging and hybrid technologies while taking steps to proactively manage the influence and impact as well as the policy and governance aspects of these technologies and their effect on business operations A world class team of cyber forensics researchers investigators practitioners and law enforcement professionals have come together to provide the reader with insights and recommendations into the proactive application of cyber forensic methodologies and procedures to both protect data and to identify digital evidence related to the misuse of these data This book is an essential guide for both the technical and non technical executive manager attorney auditor and general practitioner who is seeking an authoritative source on how cyber forensics may be applied to both evidential data collection and to proactively managing today s and tomorrow s emerging and hybrid technologies The book will also serve as a primary or supplemental text in both under and post graduate academic programs addressing information operational and emerging technologies cyber forensics networks cloud computing and cybersecurity **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 **Forensic Accounting and Fraud Examination** Mary-Jo Kranacher,Richard Riley,Joseph T Wells,2010-06-08 Forensic Accounting provides comprehensive coverage of fraud detection and deterrence and includes the broader educational material of the forensic accounting field with all the necessary accompaniments The text follows the model curriculum for education in fraud and forensic funded by the U S national Institute of Justice and developed by a Technical Working Group of experts in the field The text serves as a comprehensive and authoritative resource for teaching forensic accounting concepts and procedures that is also and appropriate and pedagogically ready for class room use This easy to read comprehensive textbook includes case study examples to clearly explain technical concepts and bring the material to life **Digital Forensics for Handheld Devices** Eamon P. Doherty,2012-08-17 Approximately 80 percent of the worlds 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 **Digital Forensics and Investigation** Mr. Rohit Manglik,2024-07-21 EduGorilla Publication is a trusted name in the education sector committed to empowering learners with high quality study materials

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