Digital Forensics

By Viral Parmar

The Hackers Meetup™
Let's Talk About Hacking

Who Am I

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ComExpo Cyber Security Foundation
Cyber Security Researcher
Mozilla Reps, Mozilla Foundation
Given 700+ session all over the world
Solved 500+case of cyber crime and aware more then 10 lakh people about privacy and security
Motto: Know hAckiNG, but no HaCKing.

COMEXPO CYBER SECURITY FOUNDATION

History

- **1970s-1980s**: First Computer Crime
- In **1978** the first computer crime was recognized in Florida Computer Crime Act
- included legislation against unauthorized modification or deletion of data on a computer system
- over the time, due to the advancement of technology, the range of computer crimes being committed also increased
- To deal with crimes related to copyright, privacy and child pornography, various other laws were passed
- **1980s-1990s**: known as the Development Decade
- the first ever investigation (1986) in which Cliff Stoll tracked the hacker named Markus Hess happened
- two kind of digital forensics disciplines:
- ad-hoc tools and techniques developed by practitioners as a hobby
- developed by scientific community

- **2000s-2010s**: Decade of Standardization
- The need for making some specific standards that can be followed while performing investigations arose
- Scientific agencies and bodies started publishing guidelines for digital forensics
- **2002**: Scientific Working Group on Digital Evidence (SWGDE) published a paper named “Best practices for Computer Forensics”

Forensics Organizations

Scientific Working Group on Digital Evidence (SWGDE)
http://www.swgde.org/

- Made up of federal government agency, state or local law enforcement agency involved in the digital and multimedia forensic profession

American Academy of Forensic Sciences (AAFS)
http://www.aafs.org/

- Considered the premier forensic organization in the world
- Members of the Academy work for the National Institute of Standards and Technology (NIST) and National Academy of Sciences (NAS)

American Society of Crime Laboratory Directors/Laboratory Accreditation Board (ASCLD/LAB)
http://www.ascld-lab.org/index.htm
Oldest and most well known crime/forensic laboratory accrediting body in the world

American Society for Testing and Materials (ASTM)
http://www.astm.org/Standards/E2763.htm
Global organization that has developed approximately twelve thousand standards
Improve product quality, enhance safety, facilitate market access and trade, and build consumer confidence.

National Institute of Standards and Technology (NIST)
http://www.nist.gov/itl/ssd/computerforensics.cfm

- Founded in 1901
- Part of the U.S. Department of Commerce
- The first federal physical science research laboratory

1.National Initiative Cyber Security Education (NICE)
cybersecurity education program

2.National Software References Library
collection of known software file signatures
can be used by forensic examiners to quickly exclude files that have no investigative value

3.Computer Forensic Tool Testing
develop testing methodologies and standards for forensic hardware and software

Classification of Cyber Forensics

Disk forensics

- deals with extracting data/information from storage media
- searching active, deleted files and also from unallocated, slack spaces.

Network forensics

- sub-branch of digital forensics relating to the monitoring and analysis of computer network traffic
- for the purposes of information gathering, legal evidence or intrusion detection.
- Unlike other areas of digital forensics, network investigations deal with volatile and dynamic information.
- Network traffic is transmitted and then lost, so network forensics is often a pro-active investigation.

Wireless forensics

- sub-discipline of network forensics.
- main goal is to provide the methodology and tools required to collect and analyze wireless network traffic data.
- data collected can correspond to plain data or, with the broad usage of Voice-over-IP (VoIP) technologies, especially over wireless, can include voice conversations.

Database Forensics
Branch of digital forensic science relating to the forensic study of databases and their related metadata. forensic examination of a database may relate to the timestamps that apply to the row (update time) in a relational table being inspected and tested for validity in order to verify the actions of a database user.

Malware Forensics
deals with Investigating and analyzing Malicious Code for identification of Malware like viruses, Trojans, worms, keylogger’s etc and to study their payload.

Mobile device forensics
deals with examining and analysing mobile devices like mobile phones, pagers to retrieve addresses book, call logs (Missed, Dialed, Received), Paired Device History, Incoming/Out Going SMS/MMS, Videos, Photos, Audio.etc.

GPS forensics
also known as SatNav Forensics, relatively new discipline within the fast paced world of Mobile Device Forensics
used for examining and analysing GPS devices to retrieve Track Logs, Track points, Waypoints, Routes, Stored Location; Home, Office, etc,.

E-mail Forensics
Deals with recovery and analysis of e-mails including deleted e-mails, calendars and contacts.

Memory Forensics
deals with collecting data from system memory (e.g., system registers, cache, RAM) in raw form and carving the data from the raw dump.

Forensic Duplication

Forensic duplication: bit stream imaging of data from the digital media

Storage: computers, smart phones, GPS devices, USB drives etc.
We need to retrieve the information without changing the information on the devices

Two techniques for copying:
Logical backup:

- Copies the directories and files of a logical volume
- Does not capture other data that may be present on the media
- Deleted files or residual data not captured

Bit stream imaging:

- Also known as disk imaging or cloning
- Generates a bit-for-bit copy of the original media
- Require more storage space and take longer to perform than logical backups

Network Drives Imaging and Logical File Collection

There are scenarios in which it is not possible to take the evidence machine offline,

- like the machine may be a file server or a database server
- services business-critical applications
- In the course of the interview, we need to determine if the machine has any relevant data and if so, where it is stored.

Data is copied to external drives using forensic tools

- Another method of acquiring hard drive's data is via a network cable between
- a machine containing the target media, booted to forensic tool for DOS
- a second machine running forensic tool in the Windows environment
- Sometimes removing a hard drive from a laptop is problematic due to physical access or other concerns, such as proprietary security schemes attaching the hard drive to the mother-board.

A network cable acquisition is also very handy when the owner or user of the target hard drive is not physically present

- connect the examination laptop to the target machine via a network cable
- boot to forensic tool for DOS
- preview or acquire if needed
- quickly acquire data from the target hard drive

Network cable to be used:

- A “yellow” crossover cable
- Often a crossover cable has a tag or label to denote it
- A crossover cable is a network cable used for special purposes
- One purpose is to enable two computers to have network connectivity by connecting directly to each other via a single network cable

PF - PreFetch

PF number:

- In windows, there are prefetch artifacts
- In order to improve customer experience, Microsoft introduced a memory management technology called Prefetch

This mechanism

- analyses the applications that are most frequently used
- preloads them in advance
- done in order speed the operating system booting and application launching
- The Prefetch files are stored in %SYSTEMROOT%\Prefetch directory and have a .pf extension

Why is prefetch important in forensic analysis?

- Prefetch files keep track of programs that have been executed in the system even if the original file is no longer present
- Prefetch files can tell us
- when the program was executed,
- how many times and from which path

Time zone conversion

A time zone is a region of the earth that has uniform standard time, usually referred to as the local time
By convention, time zones compute their local time as an offset from UTC (Greenwich Mean Time)

For each computer system/server, time zone is set to its current location/local time.
It is very important to know the time zone of that system to establish the exact time of offence subsequent actions of the crime as supportive evidence

Since the time zone/difference may vary more than 12 hours for few locations for example United States of America vs India, date of the occurrence of the crime may also change
This is very critical and important especially in crimes involved in sending e-mails from servers out of India.

Used for converting all the acts and incidents to one common time (usually the local time), so that the offences and the offender can be clearly linked
A useful link is http://www.timeanddate.com/worldclock/meeting.html

E-mail Headers

Each e-mail whether it is a company e-mail or Web-based e-mail like hotmail, yahoo, etc., carries lot of information about that e-mail.
Information like sender IP address, e-mail address, time and date when the e-mail sent, through which server it passed, etc.

E-mail message headers are digital histories that are attached to every e-mail message that are sent and received.
Headers include servers that the e-mail has travelled through, and the date and time that the message was received or forwarded

E-mail Header components collection
Message headers are easiest to view if you copy and paste them in a text program, such as Notepad
Get them printed with along with the subject line in the presence of the IO and witnesses, to avoid allegations of tampering at a later date
For header analysis, it is best if you delete out the message description from the header as it is not necessary for investigation

Limitations of E-mail Headers as Investigative Tools

It may not be always possible to trace the originating IP address of the email message under investigation due to various reasons:

- Mail Service Providers like Google mask the originating IP address of the email
- simple header analysis cannot give the IO any clue regarding the origin of the email
- IO has to rely upon the information furnished by the mail service provider to trace the origin of the mail
- I.P spoofing and proxy servers can mislead the Investigating Officer
- by directing them to a wrong origin of the mail location
- in some cases no useful conclusion can be drawn from the header analysis
- IO should seek expert help to further proceed with the investigations

Gathering information from external agencies/companies

Information can be gathered from several external sources to help with the investigation:

- Information from ISPs
- Information from e-mail service
- Information from Mobile service providers
- Information from Social networking sites like facebook etc.
- Information from Financial institutions/Internet banking institutions
- Information from Web site domain/hosting providers
- Information from VoIP service providers

From: Name of the Investigating Officer or Supervisory Officer (Police Inspector or above) Provide Full address, phone number and Official Mail ID.		Place Date

NOTICE UNDER SECTION 91 CrPC

To,

The Manager
ABC Company
ISP Division, Mumbai.

Sub: Request to furnish the details about the IP address.

Ref: Crime Number: xxxxxxxxxx u/s xxxxxxxxx of ITAA2008 of xxxxxxxx Police Station, xxxxxxxx City / District

With reference to the above cited subject, the undersigned is investigating officer of the criminal case mentioned above. For the purposes of investigation, details of the subscriber and his/her physical address details are required as per below mentioned IP addresses.

203.94.218.220 on 07 Feb 2008 at 05:01:24 pm GMT (22:31:24 in IST)

Please treat the matter as most urgent.

Official Seal	(Signature of the Investigating Officer or Supervisory Officer Demanding Information)

What Information Can you get from a Service Provider? Overview.

Subscriber Information

- Subscriber information supplied by the user at the time of registration, including name, location, date account created, and services used.
- IP addresses associated with log-ins to a user account.
- Registration IP address data available for IDs.

Mail

- IP address of computer used to send email
- Contents of the email
- Can not search for or produce deleted emails

Information from e-mail service

- User name
- Details of all incoming and outgoing e-mails along with mails stored in Draft folder
- The IP address from where the e-mail ID is accessed.
- Registration details like IP address, date and time, other services availed, secondary e-mail ID etc.
- User activity, i.e., date and time of logged in and time it is active, etc.

Instant Messaging System

- Friends List
- Time, date, and IP address logs for Chat and Messenger use for limited period.
- Archives of Messenger communications may be available on the user's computer if the user has chosen to archive communications.
- Archives of Messenger communications may be stored in service providers servers if at least one party to the communication chose to archive communications
- Message Archive may not contain attachments to messages

Groups

- Member list, email addresses of members, and date when members joined the Group.
- Information about Group moderators.
- Contents of the Files, Photos, and Messages sections.
- Group activity log describing when members subscribe and unsubscribe, post or delete files, and similar events.

Information from ISPs:

- All the service providers enable queries by e-mail from pre-registered e-mail ids of the IOs and, such e-mail have to be from their official e-mail id
- ISP will typically provide the following information
- User name
- Telephone number
- Personal details like name, e-mail ID, address, etc., mentioned in the CAF
- Day-wise activity i.e., when and how long used, etc.
- Physical address of the IP address
- Sample letter to third party, companies, and service providers

Information from Mobile service providers

- Customer Acquisition Forms (CAF) Forms — Personal details like name, address. etc.
- Calling number, called number, time, type of call (ISD/STD/Local/SMS, etc.)
- Roaming to other cities, etc.
- Tower locations — Latitude and Longitude of the tower

Information from Social networking sites like facebook etc.

- User name
- Personal details updated in the profile
- The IP address from where the profile is accessed
- User activity, i.e., date and time of logged in and duration of the active sessions, etc.
- Friends and groups with which the user is associated, etc.
- E-mail IDs updated in the personal information

Information from Financial institutions/Internet banking institutions

- Personal details updated in the profile of the account holder
- Transactional details
- CAF and other supporting documents submitted by the customer along with the introducer details
- IP address from where the transaction happened in case of Internet banking

Information from Web site domain/hosting providers

- Registration details
- Access details
- FTP logs
- Payment details
- Technical/administrative/owner of the domain
- Details of Web site developer

Information from VoIP service providers

- Registration details
- Access details
- IP addresses
- Payment details
- Called/Calling numbers

Correlating the external data with lab findings

- A two-way correlation is required after collecting external data
- need to support the third-party information collected with the lab findings
- support the lab findings with the additional evidence collected from the third party, as well as our own investigation findings
- Build the integrity of the case as well as fully reconstruct the crime
- The Investigating Officer is required to follow the procedure in collecting the external data under proper notice/request letter as per the Law to make the evidence admissible in the court of law

Tasks we want to achieve

- Acquisition
- Validation and verification
- Extraction
- Reconstruction
- Reporting

There is a critical need in the law enforcement community to ensure the reliability of computer forensic tools
The goal of the Computer Forensic Tool Testing (CFTT) project at the National Institute of Standards and Technology (NIST) is to establish a methodology for testing computer forensic software tools by

- development of general tool specifications,
- test procedures,
- test criteria,
- test sets,
- test hardware

Requirement: forensic software tools consistently produce accurate and objective test results

The results are 3-fold:

- provide necessary information for toolmakers to improve tools,
- for users to make informed choices about acquiring and using computer forensics tools,
- for interested parties to understand the tools capabilities

International Organization on Computer Evidence

The International Organization on Computer Evidence (IOCE) was established in 1995
Provides international law enforcement agencies a forum for the exchange of information concerning computer crime investigation and other computer-related forensic issues
IOCE identifies and discusses issues of interest to its constituents, facilitates the international dissemination of information, and develops recommendations for consideration by its member agencies

IOCE International Principles
The international principles developed by IOCE for the standardized recovery of computer-based evidence are governed by the following attributes

- Consistency with all legal systems
- Allowance for the use of a common language
- Durability
- Ability to cross international boundaries
- Ability to instil confidence in the integrity of evidence
- Applicability to all forensic evidence
- Applicability at every level, including that of individual, agency, and country

These principles were presented and approved at the International Hi-Tech Crime and Forensics Conference in October 1999. They are as follow:

- Upon seizing digital evidence, actions taken should not change that evidence.
- When it is necessary for a person to access original digital evidence, that person must be forensically competent.
- All activity relating to the seizure, access, storage, or transfer of digital evidence must be fully documented, preserved, and available for review.
- An individual is responsible for all actions taken with respect to digital evidence while the digital evidence is in their possession.
- Any agency that is responsible for seizing, accessing, storing, or transferring digital evidence is responsible for compliance with these principles.

Acquisition

Acquisition:

- first task in digital forensics investigations
- making a copy of the original drive
- This procedure preserves the original drive to make sure it doesn't become corrupt and damage the digital evidence

Sub-functions:

- Physical data copy
- Logical data copy
- Data acquisition format
- Command-line acquisition
- GUI acquisition
- Remote, live, and memory acquisitions

ISO standard 27037 states the most important factors in data acquisition are

- the DEFR's (Digital Evidence First Responders) competency
- use of validated tools
- includes guidelines on how to approach acquisition in different situations
- document what was done and why

Examples:

- if you're acquiring data at a scene with hazardous materials, speed is critical
- might decide to forgo acquiring RAM
- focus on collecting devices
- acquiring volatile memory
- encrypted devices or mission-critical systems that can't be turned off

Two types of data-copying methods

- physical copying of the entire drive
- logical copying of a disk partition

Disk acquisition formats vary from raw data to vendor-specific proprietary

A raw-format imaging tool can copy data from one drive to another disk or to segmented files

- In the past, examiners performed a bit-by-bit copy from one disk to another disk the same size or larger
- As a practical way to preserve digital evidence, vendors (and some OS utilities, such as the Linux/UNIX dd command) made it possible to write bit-stream data to files
- This copy technique creates simple sequential flat files of a suspect drive or data set
- The output of these flat files is referred to as a raw format.

Validation & Verification

Verification: proves that two sets of data are identical by calculating hash values or using another similar method

- FTK validates MD5 and SHA-1 hash sets during data acquisition
- EnCase prompts you to calculate the MD5 hash value of acquired data
- Make sure that the tool used has a hashing function for verification purposes

Filtering

- Related process
- Involves sorting and searching through investigation findings
- Separate good data and suspicious data

When performing filtering:

- Good data consists of
- known files, such as OS files, common applications (Microsoft Word, for example),
- standard files used in a company's day-to-day business
- Can also use hash values to create a known good hash value list
- An investigator could ignore all files on this known good list and focus on other files that aren't on this list.
- The National Software Reference Library (NSRL) has compiled a list of known file hashes for a variety of OSs, applications, and images that you can download

- NSRL collects software from various sources and incorporates file profiles computed from this software into a Reference Data Set (RDS) of information
- The Reference Data Set (RDS) can be used by law enforcement, government, and industry organizations to review files on a computer by matching file profiles in the RDS
- Helps in determining which files are important as evidence on computers or file systems that have been seized as part of criminal investigations
- The RDS is a collection of digital signatures of known, traceable software applications.
- There are no hash values of illicit data

Validation: a way to confirm that a tool is functioning as intended

- Use forensic images that have been created for desktop and mobile devices
- These files are posted on Web sites such as NIST's CFTT or the Scientific Working Group on Digital Evidence (SWGDE)
- The sites tell what the tool should find as evidence on the drives
- Also give ranges of results
- We can determine that a tool works well for acquiring Linux images but has problems with older Windows versions
- The sites also publish the results of testing hardware acquisition tools
- After validating a tool, we must also make sure all forensic copies of a particular device have the same hash value.

Forensic Toolkit, or FTK, is a computer forensics software made by AccessData.

- It scans a hard drive looking for various information.
- It can, for example,
- potentially locate deleted emails
- scan a disk for text strings to use them as a password dictionary to crack encryption
- FTK is also associated with a standalone disk imaging program called FTK Imager

The Sleuth Kit Autopsy

Autopsy is open source

- Timeline Analysis - Advanced graphical event viewing interface (video tutorial included).
- Hash Database Filtering - Flag known bad files and ignore known good.
- Keyword Search - Indexed keyword search to find files that mention relevant terms.
- Web Artifacts - Extract history, bookmarks, and cookies from Firefox, Chrome, and IE.
- Data Carving - Recover deleted files from unallocated space using PhotoRec
- Multimedia - Extract EXIF from pictures and watch videos.
- Indicators of Compromise - Scan a computer using STIX
- Tagging and reporting features.

Extraction

- Recovery task in a digital investigation
- most challenging of all tasks to master
- Recovering data is the first step in analysing an investigation’s data

Sub-functions of extraction:

- Data viewing
- Keyword searching
- Decompressing
- Carving: technique of reassembling files from raw data fragments when no filesystem metadata is available
- Decrypting
- Bookmarking or tagging

Many digital forensics tools include a data-viewing mechanism for digital evidence

- Offer several ways to view data
- logical drive structures, such as folders and files
- display allocated file data and unallocated disk areas
- Forensics tools have functions for searching for keywords of interest to the investigation
- With some tools, you can set filters to select file types to search, such as searching only PDF files

Analyzing, recovering, and decrypting data from encrypted files

- Encryption can be used on a drive, disk partition, or file
- Many e-mail services, such as Microsoft Outlook, provide encryption protection for .pst folders and messages
- Encryption can be platform specific

Password decryption

- Passwords are typically stored as hash values, not in plaintext
- One-way hashes: we cannot apply an algorithm to break them
- Many password recovery tools have a feature for generating potential password lists for a password dictionary attack
- OSForensics is a forensics tool, and has a built-in password cracker

Reconstruction

Purpose:

- Re-create a suspect drive to show what happened during a crime or an incident
- Create a copy for other digital investigators if a drive has been compromised by malware or a suspect's actions

Methods of reconstruction:

- Disk-to-disk copy
- Partition-to-partition copy
- Image-to-disk copy
- Image-to-partition copy
- Disk-to-image copy
- Rebuilding files from carving
- One free tool is the Linux dd command

Disadvantage: it produces a flat, uncompressed file that is the same size as the source drive

Reporting

To perform a forensics disk analysis and examination, we need to create a report

The following are sub-functions of the reporting function:

- Bookmarking or tagging
- Log reports
- Timelines
- Report generator

As part of the validation process, we need to document the steps we took to acquire data from a suspect drive
Sometimes we use a single tool, sometimes multiple tools are used to acquire data

Many forensics tools can

- produce a log report that records an investigator's activities
- incorporates evidence that was bookmarked or tagged during extraction
- A built-in report generator is then used to create a report in a variety of formats

Can add a log report to the final report as documentation of the steps we took during the examination

- useful if repeating the examination is necessary
- confirm during peer review what activities were performed and what results were found in the original analysis and examination

Investigator’s report:

- Written by the investigator in detail
- Report shall contain the sequence of steps, and decisions taken
- Reports generated by tools are not sufficient

Forensic Workstations

Forensic workstations can be tailored to meet the investigation needs
Forensic workstations can be divided into the following categories:
Stationary workstation—A tower with several bays and many peripheral devices
Portable workstation—Alaptop computer with almost as many bays and peripherals as a stationary workstation
Lightweight workstation—Usually a laptop computer built into a carrying case with a small selection of peripheral options

FRED Workstation

Using a Write-Blocker

- Write-blockers protect evidence disks by preventing data from being written to them
- Forensic investigators need to absolutely assure of the fact that the data they obtain as digital evidence is not altered during the capture, analysis, and control
- Attorneys, judges, jurors need to feel confident that digital evidence has not been tampered and is legitimate

According to theNIST:

- Use an operating system and other software that is trusted to not to write anything to the disk without any explicit instruction
- Use hard disk write block tools to prevent any hard disk writes
- Software and hardware write-blockers perform the same function but in a different fashion
- Both guarantee the protection of the chain of custody (if used correctly)

Software write-blockers

- A software write blocker tool operates by monitoring and filtering drive I/O commands sent from an application or OS through a given access interface
- They provide the ability to
- simultaneously write-block as many disk devices as are connected to a computer
- no need for multiple expensive hardware write blocking devices

Example:

- Software write-blockers, such as PDBlockfrom Digital Intelligence, typically run in a shell mode
- PDBlockchanges interrupt-13 of a workstation's BIOS to prevent writing to the specified drive.
- If anyone attempts to write data to the blocked drive, an alarm sounds, advising that no writes have occurred

Features:

- The user can control automatic write blocking policies for fixed and/or removable disks.
- The user can have write blocking tool remember each fixed device's blocked or un-blocked status for ease of use on media repeatedly used on a workstation/laptop.
- Some of the write blocking tools provide a GUI interface that allows the user the ability to block and unblock any disk or flash storage device.

Hardware write-blockers

- Hardware write-blockers are used to intercept and block any modifying command from ever reaching the storage device
- With hardware write-blockers, we can connect the evidence drive to the workstation and start the OS as usual
- They prevent the OS from writing data to the blocked drive

Features:

- They offer monitoring and filtering any activity that is transmitted or received between its interface connections to the computer and the storage device
- Hardware write blockers can connect to different types of storage with adapters
- Hardware devices that write-block also provide a visual indication of function through LEDs and switches. easy to use, clear functionality to users.

Disadvantages:

- Hardware write blocking devices are very expensive
- Awkward to use since they require a physical connection
- different connector for each type of interface

Write Block Device Tubule

A forensic disk controller or hardware write-block device is a specialized type of computer hard disk controller made for the purpose of gaining read-only access to computer hard drives without the risk of damaging the drive's contents. The device is named forensic because its most common application is for use in investigations where a computer hard drive may contain evidence.

Hard Disk Cloner (Imaging)

Disk cloning is the process of copying the contents of one computer hard disk to another disk or to an "image" file. This may be done straight from one disk to another, but more often, the contents of the first disk are written to an image file as an intermediate step, then the second disk is loaded with the contents of the image

Forensic Toolkit (FTK)

Is a computer forensics software made by AccessData. It scans a hard drive looking for various information. It can for example locate deleted emails and scan a disk for text strings to use them as a password dictionary to crack encryption.

Encase Tools

EnCase is a suite of digital forensics products by Guidance Software. The software comes in several forms designed for forensic, cyber security and e-discovery use.

EnCase contains tools for several areas of the digital forensic process; acquisition, analysis and reporting. The software also includes a scripting facility called EnScript with various API's for interacting with evidence.

Encase Tableau

XRY Mobile Forensic

XRY is a digital forensics product by Micro Systemation used to analyze and recover information from mobile devices such as mobile phones, smartphones, GPS navigation tools and tablet computers. It consists of a hardware device with which to connect phones to a PC and software to extract the data.

UFED Mobile forensic

UFED Ultimate provides access to deleted data inaccessible by logical methods


cellebrite
cellebrite | TOUCH
cellebrite | UFED TOUCH


UFED SIM ID Access Card
UFED SIM ID Access Card
UFED MicroSIM ID Access Card
UFED MicroSIM ID Access Card
UFED MicroSIM ID Access Card


cellebrite
GetData

Paraben Forensics Tools

Falcon Neo Forensics Tool

Table 6-1 Comparison of forensics tool functions

Function	Magnet Forensics AXIOM, demo version	OSForensics, demo version	AccessData FTK	Guidance Software EnCase
Acquisition				
Physical data copy	✓	✓	✓	✓
Logical data copy	✓	✓	✓	
Data acquisition formats	✓	✓	✓	✓
Command-line processes				✓
GUI processes	✓	✓	✓	✓
Remote acquisition		✓	✓	✓

Table 6-1 Comparison of forensics tool functions

Function	Magnet Forensics AXIOM, demo version	OSForensics, demo version	AccessData FTK	Guidance Software EnCase
Validation and verification				
Hashing	✓	✓	✓	✓
Verification	✓	✓	✓	✓
Filtering	✓	✓	✓	✓
Analyzing file headers	✓	✓	✓	✓
Extraction				
Data viewing	✓	✓	✓	✓
Keyword searching	✓	✓	✓	✓
Decompressing	✓		✓	✓
Carving	✓	✓	✓	✓
Decrypting	✓	✓	✓	
Bookmarking	✓	✓	✓	✓

Table 6-1 Comparison of forensics tool functions

Function	Magnet Forensics AXIOM, demo version	OSForensics, demo version	AccessData FTK	Guidance Software EnCase
Reconstruction				
Disk-to-disk copy	✓	✓	✓	✓
Partition-to-partition copy	✓	✓	✓	✓
Image-to-disk copy	✓	✓	✓	✓
Image-to-partition copy	✓	✓	✓	✓
Disk-to-image copy	✓	✓	✓	✓
Rebuilding files	✓	✓	✓	✓
Reporting				
Bookmarking/tagging	✓	✓	✓	✓
Log reports	✓	✓	✓	✓
Timeline	✓	✓	✓	✓
Report generator	✓	✓	✓	✓

Validating and Testing Forensics Software

Using National Institute of Standards and Technology Tools
Using Validation Protocols
Need to make sure the evidence we recover and analyze can be admitted in court

Using National Institute of Standards and Technology Tools
The National Institute of Standards and Technology (NIST)

- publishes articles,
- provides tools,
- creates procedures for testing and validating computer forensics software
- Software should be verified to improve evidence admissibility in judicial proceedings

A lab must meet the following criteria and keep accurate records:

- Establish categories for digital forensics tools—Group digital forensics software according to categories, such as forensics tools designed to retrieve and trace e-mail
- Identify forensics category requirements—For each category, describe the technicalfeatures or functions a forensics tool must have

Develop test assertions—Based on the requirements, create tests that prove or disprove the tool's capability to meet the requirements

- Identify test cases—
- Find or create types of cases to investigate with the forensics tool
- Identify information to retrieve from a sample drive or other media.

For example, use the image of a closed case file created with a trusted forensics tool to test a new tool in the same category and see whether it produces the same results.

- Establish a test method—Considering the tool's purpose and design, specify how to test it
- Report test results—Describe the test results in a report that complies with ISO17025, which requires accurate, clear, unambiguous, and objective test reports

- **Repeatable results**: if you work in the same lab on the same machine, you generate the same results
- **Reproducible results**: if you're in a different lab working on a different machine, the tool still retrieves the same information

Using Validation Protocols

- After retrieving and examining evidence data with one tool, we should verify our results by performing the same tasks with other similar forensics tools

Example: after we use one forensics tool to retrieve disk data, we use another to see whether we retrieve the same information

- Question in court: How did you verify your results?
- need at least two tools to validate
- tool we use to validate the results should be well tested and documented

Digital Forensics Examination Protocol

- First, conduct your investigation of the digital evidence with one GUI tool
- Then perform the same investigation with a disk editor to verify that the GUI tool is seeing the same digital evidence in the same places on the test or suspect drive's image.
- If a file is recovered, obtain the hash value with the GUI tool and the disk editor, and then compare the results to verify whether the file has the same value in both tools
- Many investigators in both the public and private sectors use FTK and EnCaseas their choice of forensics software suites
- They do not rely on them solely: investigators' software libraries often include other forensics utilities to supplement these tools' capabilities

Digital Forensics Tool Upgrade Protocol

- After verification with two different tools, should test all new releases and OS patches and upgrades
- Make sure the upgrades are reliable and do not corrupt evidence data
- If you determine that a patch or upgrade isn’t reliable, do not use it on your forensic workstation until the problem has been fixed
- Can file an error report with the vendor
- not being able to read old image files with the new release
- disk editor generating errors after you apply the latest service pack etc.
- In most cases, the vendor addresses the problem and provides a new patch

Digital Device Forensics

Desktops:

- Specially built for personal use at home or work
- Equipped with two primary hardware solutions —the monitor and a casing
- In the casing, CPU is housed, the motherboard, the graphic card, storage devices, buses, power supply etc.

Laptop:

- Also known as notebook computer, is a smaller computer
- It has all the components like monitor, keyboard, mouse, and speakers, etc., in a single unit.
- It is powered through an AC adapter and can store the energy in a rechargeable battery.

Server:

- A computer which can provide services to a group of computers either inside an organization or to public users across Internet.
- Many servers have dedicated functionality, such as Web servers, file servers, print servers, database servers, mail servers, etc.
- Sometimes, they have different kinds of hardware and operating systems that makes them efficient in providing services

Digital Storage Device

Hard drives:

- Hard drives or hard disks are the main storage devices that are used in the computer to store the data
- The data stored in hard drive is non-volatile
- Come in different varieties based on their speed, size, and connecting types
- The common types of hard drives that are usually encountered are 1) IDE, 2) SATA, 3) SCSI, and 4) ZIF/SSD

IDE hard drive:

- IDE (Integrated Drive Electronics)hard drives, also known as Parallel ATA (PATA) were the most commonly used hard drives
- First developed byWestern DigitalandCompaqin 1986
- An IDE hard drive uses 40 or 80 pin flat ribbon cables to transfer data.
- Normally appears as an internal computer storage interface

ATA: ATAttachment

AT: Advanced technology

SATA hard drive:

- Serial ATA
- Similar in mechanism to that of IDE drive
- The connecting interface is different.
- Seven conductors instead of 40 or 80
- The data transfer is done serially and is faster than IDE drives.

SCSI hard drives:

- SCSI stands for Small Computer System Interface
- A set of American National Standards Institute (ANSI) standard electronic interfaces
- Allow personal computers to communicate with peripheral hardware such as disk drives, tape drives, CD-ROM drives, printers and scanners faster and more flexibly than previous parallel data transfer interfaces used in servers and RAID systems
- Can be connected as arrays both internally and externally

ZIF Drives:
ZIF stands for zero insertion force.
Connectors to these drives do not need any force to insert and extract from the sockets or other connections.
This kind of storage devices are now being used in several laptop computers.

CDS ,DvDS:

- CDs and DVDs are optical storage devices that are used to store data like audio, video, and several other types of files
- CDs can be written once (CD-R-Recordable) or data can be erased and re-written (CD-RW-Rewritable)
- The maximum size of a CD is 800 Megabytes and that of a DVD is 9.0 Gigabytes

Blu-ray:

- Name of a new optical disc format developed to enable recording, rewriting and playback of high-definition video (HD)
- Can store large amounts of data
- Can hold up to 25GB on a single-layer disc and 50GB on a dual-layer disc

Floppy disks:

- Floppy disks are magnetic storage media that are encased in a rectangular plastic case.
- They usually come in three different sizes 8 inches, 5 1/2 inches, and 3 1/2 inches. 8 and 5 1/2 inches have become obsolete now.
- Floppy disks have a write-protection option or read-only option
- Floppy disks are read from and written to by a floppy disk drive (FDD)

Flash drives:

- Flash drives are generally flash memory data storage devices that are integrated with a USB interface
- Flash memory:
- non-volatile memory chip used for storage and for transferring data
- electronically reprogrammed and erased
- Removable and portable media
- Rewritable and are much smaller in size than the typical floppy disk drive

NAS:

- Network attached storage (NAS)
- storage system that allows computers on network to share large amounts of data across high-speed Local Area Network (LAN) networks
- can store data in the files such as e-mail boxes, Web content, and remote system backups
- usually composed of an array of hard drives that are connected to a computer system

Printers and Scanners:

- Usually have cache memory which temporarily lines up (spools) the files or pages that are currently being printed
- Once switched off, that memory is usually lost
- Some large printers and scanners have inbuilt hard drives

Hand Held Device

Pagers:

- A Pager is a device that is used for short messages.
- Pagers can be one way, which can send or receive messages
- Contain limited digits or they can be alphanumeric,
- Two-waypagers which can even send and receive messages etc.

Personal Digital Assistant (PDA):

- PDAs are Palm top computers that functions as personal information manager or organizer
- Can store several types of personal data, browse Internet, etc.
- PDAs also have expandable memory and wireless Internet connectivity

Ipads/tablets:

- Ipadsare tablet computers manufactured by apple computers.
- It has same operating system as iphoneand ipod(iOS).
- This can be used as a typical computer to store data, browse Internet, make phone calls, play games, read e-books, etc.

Electronic readers/e-readers:

- Electronic readers are devices that are used to store, download, and read e-books and play games.
- These devices are wireless Internet enabled and come in different storage capacities.

Network Device

Hub:

- In computer networking, a Hub is a small device that joins multiple computers together.
- Ethernet hubs vary in the speed they support

Switch:

- A network switch is a hardware device that joins multiple computers within one LAN.
- Network switches allows network packets from them
- Also examines or inspects them to determine their source and destination

Router:

- In Network environment, a Router is a physical device that joins multiple wired or wireless networks together.
- Routers are usually located at gateways.
- It intercepts the data packets and decides where the signals have to go
- A Router can have different interface connections for different types of physical networks.

RAID(Redundant Array of Inexpensive Disks) is method of storing the same data in different places (thus, redundantly) on several hard disks

Firewall:

- Found in a computer system or network
- device that allows only authorized traffic (data) into or out of a computer or a computer network.
- continuously inspects the data packets that are going in and out of a computer network
- blocks any unauthorized and malicious traffic and serves as a security mechanism
- can be hardware, software, or a combination of both

Intrusion Detection system/Intrusion Prevention system(IDS and IPS):

- An IDS is a security mechanism that monitors all the incoming and outgoing traffic of computer network
- identifies suspicious files, programs, and patterns in the traffic
- also detects the misuse and errors in using certain computer resources like software
- IPS detects threats and attacks in the network, also prevents or blocks them
- usually sends the alarm, resets the connections, drops the malicious data packet, or blocks the attacker’s IP address

Communication Device

Telephones:

- These communication devices are also sometimes the best source of digital evidence.
- Desk phones may contain information like last dialed numbers, frequently dialed numbers,
- voicemail messages that are left by callers
- alternative phone numbers in case of any call diversions, etc.

Answering machines:

- Devices that are used with desk telephones.
- These devices will play a message to the caller when the call cannot be answered
- The caller can leave a message which will be recorded in the answering machine.
- All the messages recorded in such a way can be played later directly from the machine itself.

Fax Machines:

- Fax is any document sent over a telephone line.
- It is received by the recipient's fax machine and gets printed.
- In many corporate environments, fax servers are installed, which can store the incoming fax messages electronically and sends them through e-mail to the users or prints them on the paper.

Mobile phones:

- Mobile phones are used to make phone calls, send text messages, voice and picture/video messages (Multimedia messages —MMS),
- Take pictures and videos, etc.
- Usually has a SIM card specific to the service provider.

Smart phones:

- Smart phones are advanced type of mobile phones
- Offers services like high-speed Internet, advanced computing, and connectivity
- They run on complete operating system software like typical computers and can be considered as a pocket computer.
- Provide services like Internet, e-mail, Wi-Fi etc.

MISC. Device

Digital cameras:

- cameras that can take pictures and videos and records them digitally on to the memory present in them.
- they also support expandable memory by using multimedia cards
- more advance cameras have hard drives that can store pictures and videos

Camcorders:

- Camcorders are the digital video recorders used to capture video footages and record them digitally on to CDs, Cassettes, Multimedia cards, hard drives, etc.

Photocopiers:

- A Photocopier is a machine that can reproduce a document and make multiple copies of it quickly.
- Advanced photocopiers have features like sending the photocopy electronically to the e-mail
- stores documents in the hard drives when large numbers of documents are to be copied.

Global positioning devices:

- Satellite-based navigation system
- Provides the exact location and time information anywhere on the earth
- GPS devices have receivers for GPS satellite and provide information, such as location, directions, traffic conditions,
- Also nearby facilities like restaurants, fuel stations, etc.,
- Receives though maps and text and voice.

Digital watches:

- Digital watches are instruments that show time in digital format
- also have other facilities like compass, temperature sensors, music players, and in some embedded cameras also.
- Some advanced digital watches also have USB data connectivity to storeand transfer data.

Digital Evidence Assessment

Assessment of potential evidence in cyber crime.
Details of the case at hand is required to effective processing of evidence

The type of crime that we want to prove or disprove determines

- What evidence we need to analyse
- How the recovered information is to be used
- Related to inculpatory and exculpatory evidences

Main components:

- Evidence acquisition
- Evidence examination
- Documenting and reporting digital evidence

Evidence Acquisition

Rigorous, detailed plan for acquiring evidence

Extensive documentation is needed prior to, during, and after the acquisition process

General methods:

- The physical removal of storage devices
- Using controlled boot discs to retrieve sensitive data without affecting existing stored data
- Ensuring functionality
- Taking appropriate steps to copy and transfer evidence to the investigator’s evidence repository
- Document and authenticate the chain of evidence

Evidence Examination

Procedures must be in place for retrieving, copying, and storing evidence within appropriate databases

Digital forensics investigators typically examine data from designated archives

- use a variety of methods and approaches to analyse information
- include utilising analysis software to search massive archives of data for specific keywords or file types
- retrieve files that have been recently deleted
- analyse data tagged with times and dates
- suspicious files or programs that have been encrypted or intentionally hidden

Documenting and Reporting Digital Evidence

Document information related to hardware and software specifications

Accurate record of all activity related to the investigation
- all methods used for testing system functionality and retrieving,
- copying, and storing data,
- all actions taken to acquire, examine and assess evidence

Purpose:
- demonstrate how the integrity of user data has been preserved
- ensures that proper policies and procedures have been adhered to by all parties involved

The purpose of the entire process is to acquire data that can be presented as evidence in a court of law
An investigator's failure to accurately document his or her process could seriously compromise the validity of that evidence and ultimately, the case itself

Mobile Forensics

The following information might be stored on a mobile phone depending upon the model used:
Incoming, outgoing, and missed calls

- Multimedia Message Service (MMS; text messages)
- Short Message Service (SMS) messages
- E-mail accounts
- Instant messaging (IM) logs
- Web pages
- Photos, videos, and music files
- Calendars and address books
- Social media account information
- GPS data
- Voice recordings and voicemail
- Bank account logins
- Access to the home

- Many people store more information on smartphones and tablets than on computers
- Mobile devices used to be seized at the time of arrest
- Police used to look through them as a routine matter
- Prohibited now

U.S. Supreme court ruling :

- A search warrant is required before an arresting officer can begin examining a phone's contents
- https://newrepublic.com/article/118396/supreme-court-cellphone-case-went-further-privacy-advocates-hoped
- Phones often contain private or sensitive information
- Any information that does not pertain to the case must be redacted from the public record
- Investigating smartphones and other mobile devices is a challenging task in digital forensics because:
- No single standard exists for how and where phones store messages (many phones use similar storage schemes)
- New phones come out about every six months, and they are rarely compatible with previous models
- The cables, software, and accessories used for forensics acquisitions can become obsolete in a short time

Windows File System

A file system gives an OS a road map to data on a disk.

- The type of file system an OS uses determines how data is stored on the disk.
- When you need to access a suspect's computer to acquire or inspect data related to your investigation, you should be familiar with both the computer's OS and file system so that you can access and modify system settings when necessary.

Understanding the Boot Sequence

- To ensure that you don't contaminate or alter data on a suspect's Windows or DOS PC, you must know how to access and modify a PC's Complementary Metal Oxide Semi- conductor (CMOS) and Basic Input/ Output System (BIOS) settings
- A computer stores system configuration and date and time information in the CMOS when power to the system is off
- When a subject's computer starts, you must make sure it boots to a forensic floppy disk or CD,
- booting to the hard disk overwrites and changes evidentiary data
- You access the CMOS setup by monitoring the subject's computer during the initial bootstrap process to identify the correct key or keys to use
- The bootstrap process is contained in ROM and tells the computer how to proceed
- CMOS depends on the computer's BIOS.
- The popular BIOS manufacturer AMI use the Delete key to access CMOS

CMOS:

- Stands for "Complementary Metal Oxide Semiconductor."
- It is a technology used to produce integrated circuits.
- CMOS circuits are found in several types of electronic components, including microprocessors, batteries, and digital camera image sensors.
- "CMOS" refers to both a particular style of digital circuitry design and the family of processes used to implement that circuitry on integrated circuits (chips).

BIOS

- BIOS is the program a computer's microprocessor uses to start the computer system after it is powered on.
- Also manages data flow between the computer's operating system (OS) and attached devices, such as the hard disk, video adapter, keyboard, mouse and printer.

Disk Drives

Understand how data is organized on a disk so that you can find data effectively

- Disk drives are made up of one or more platters coated with magnetic material
- Data is stored on platters in a particular way

Geometry

- Geometry refers to a disk's logical structure of platters, tracks, and sectors.

Head

- The head is the device that reads and writes data to a drive.
- There are two heads per platter that read and write the top and bottom sides.

Tracks

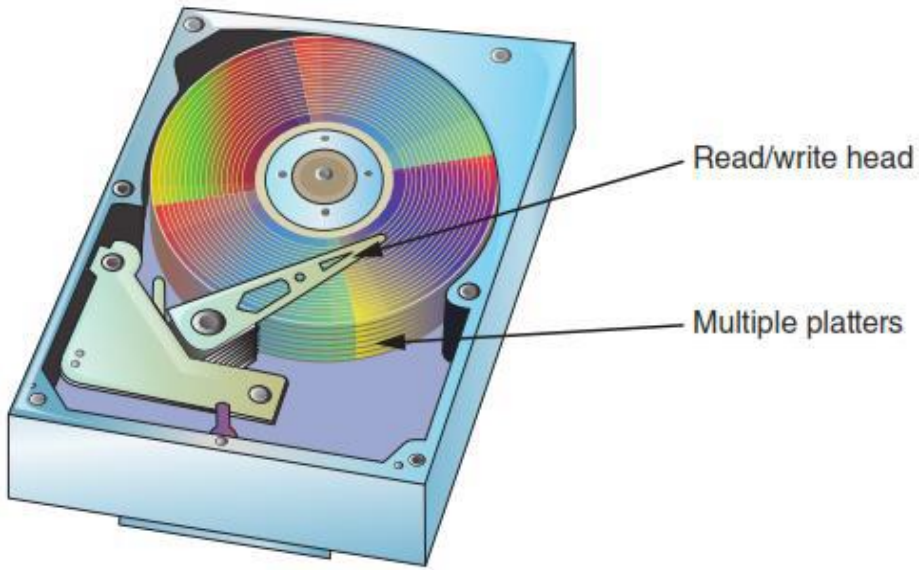
- Tracks are concentric circles on a disk platter where data is located.

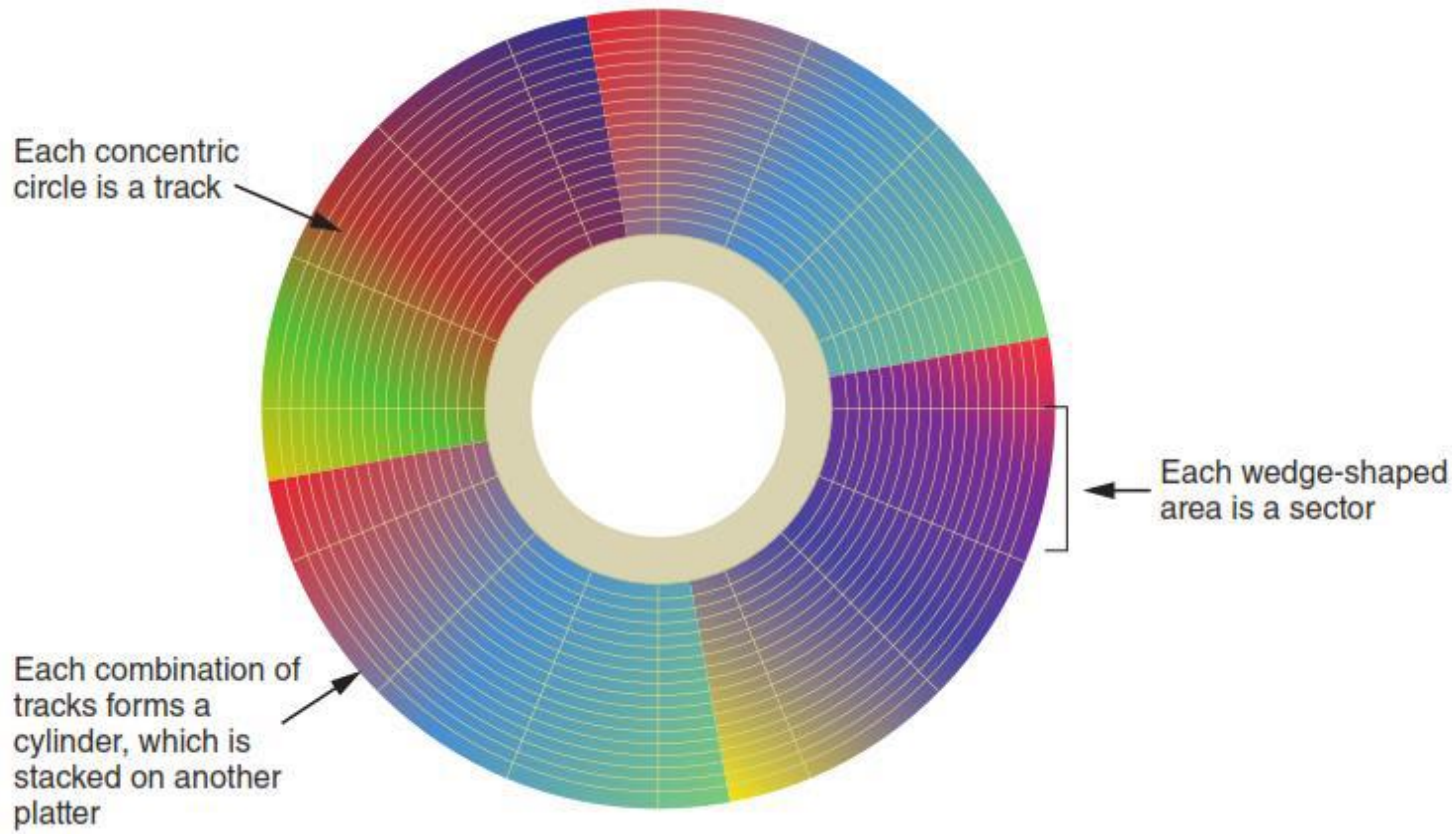
Cylinders

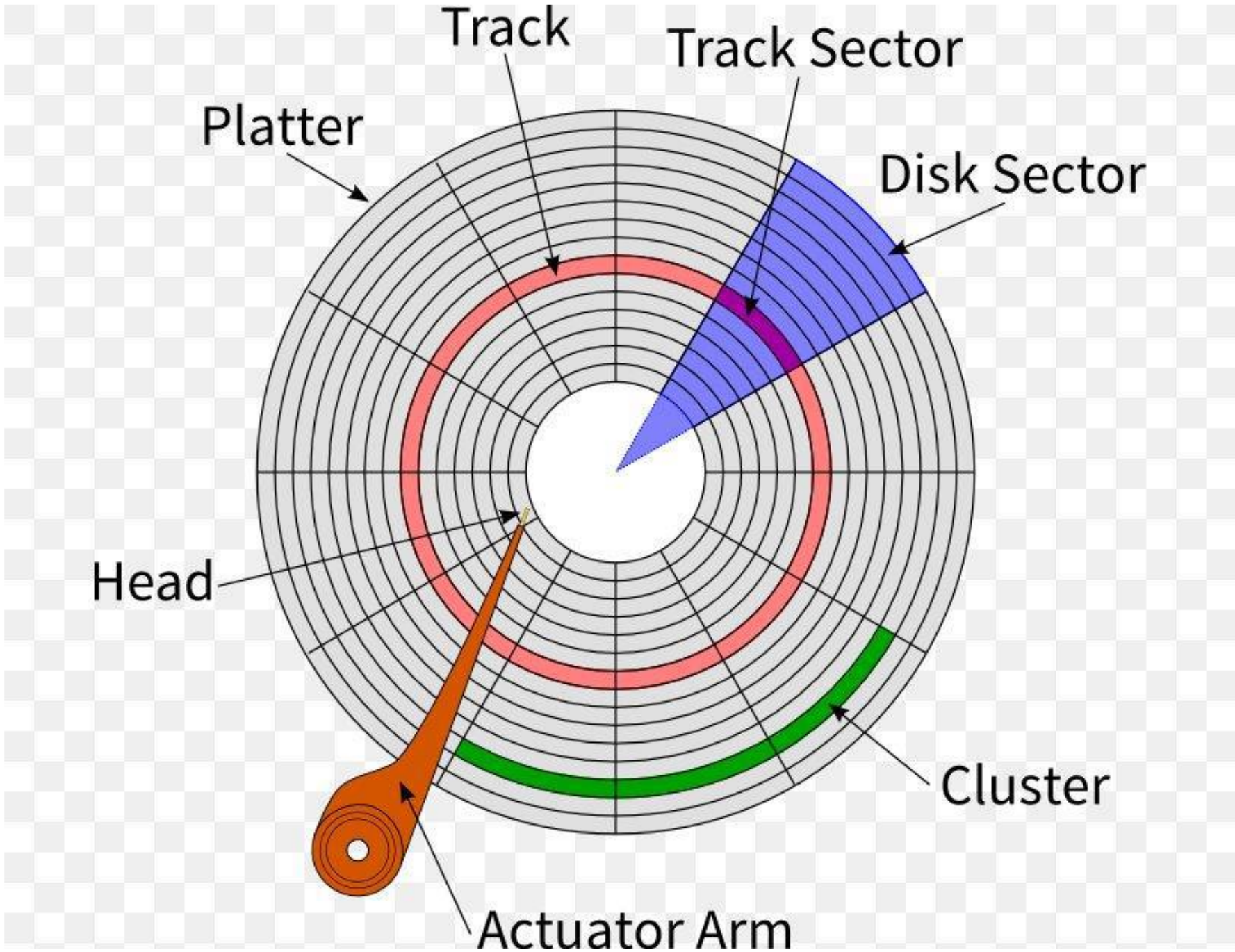
- A cylinder is a column of tracks on two or more disk platters.
- Typically, each platter has two surfaces: top and bottom.

Sectors

- A sector is a section on a track, usually made up of 512 bytes.


Read/write head
Multiple platters


Each concentric circle is a track
Each wedge-shaped area is a sector
Each combination of tracks forms a cylinder, which is stacked on another platter


Track
Track Sector
Platter
Disk Sector
Head
Cluster
Actuator Arm

Solid-State Storage Devices

- Flash memory storage devices used in USB drives, laptops, tablets, and cell phones can be a challenge for digital forensics examiners
- If deleted data isn't recovered immediately, it might be lost forever.
- The reason is a feature all flash memory devices have: wear-leveling.
- When data is deleted on a hard drive, only the references to it are removed, which leaves the original data in unallocated disk space.
- With forensics recovery tools, recovering data from magnetic media is fairly easy; you just copy the unallocated space.
- USB drives and other solid-state drive systems are different
- Memory cells shift data at the physical level to other cells that have had fewer reads and writes continuously.
- The purpose of shifting (or rotating) data from one memory cell to another is to make sure all memory cells on the flash drive wear evenly
- Memory cells are designed to perform only 10,000 to 100,000 reads/writes, depending on the manufacturer's design.
- When they reach their defined limits, they can no longer retain data.
- When you attempt to connect to the device, you get an access failure message.

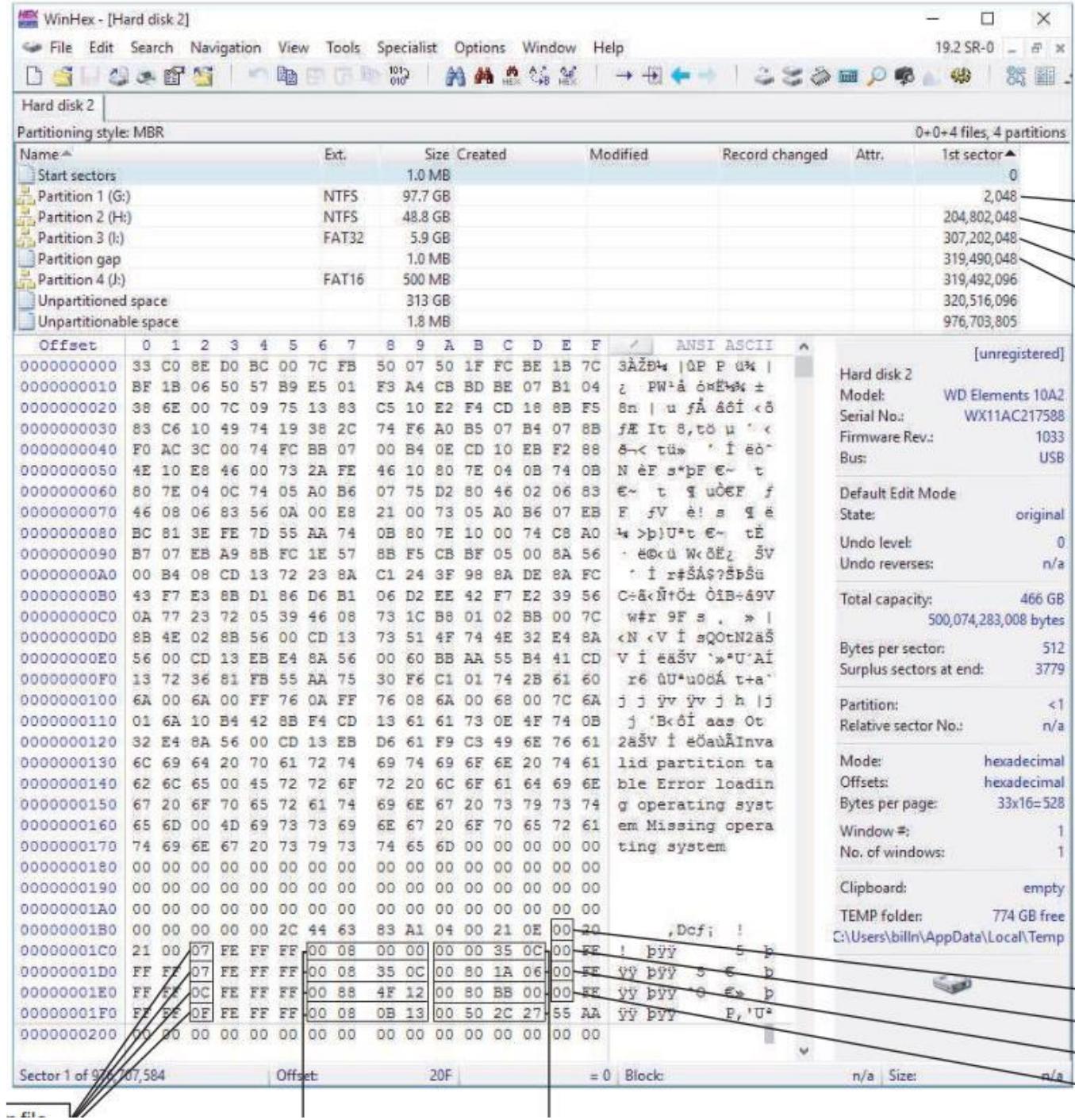
Microsoft File Structures

Two structures: File Allocation Table (FAT), and NT File System (NTFS)

- The method an OS uses to store files determines where data can be hidden.
- When you examine a computer for forensic evidence, you need to explore these hiding places to determine whether they contain files or parts of files that might be evidence of a crime or policy violation.
- In Microsoft file structures, sectors are grouped to form clusters, which are storage allocation units of one or more sectors.
- The OS groups one or more sectors into a cluster.
- Clusters are numbered sequentially, starting at 0 in NTFS and 2 in FAT.
- The OS assigns numbers to these cluster, referred to as logical addresses.
- Sector numbers, however, are referred to as physical addresses because they reside at the hardware level and go from address 0 (the first sector on the disk) to the last sector on the disk.
- The first sector of all disks contains a system area, the boot record, and a file structure database.
- Clusters and their addresses are specific to a logical disk drive, which is a disk partition.

Disk Partition

- Many hard disks are partitioned, or divided, into two or more sections.
- A partition is a logical drive.
- Windows OSs can have three primary partitions followed by an extended partition that can contain one or more logical drives.
- Someone who wants to hide data on a hard disk can create hidden partitions or voids: large unused gaps between partitions on a disk drive.
- For example, partitions containing unused space can be created between the primary partitions or logical partitions.
- This unused space between partitions is called the partition gap
- It’s possible to create a partition, add data to it, and then remove references to the partition so that it can be hidden in Windows.
- Another technique is to hide incriminating digital evidence at the end of a disk by declaring a smaller number of bytes than the actual drive size.
- With disk-editing tools, however, we can access these hidden or empty areas of the disk.
- Both tasks involve analyzing the key hexadecimal codes the OS uses to identify and maintain the file system.
- The partition table is in the Master Boot Record (MBR), located at sector 0 of the disk drive.
- In a hexadecimal editor, such as WinHex, you can find the first partition starting at offset 0x1BE (446 in decimal, 676 in Octal).



First sectors converted to decim		
0×800	=	2048
0×0C350800	=	204,802,048
0×124F8800	=	307,202,048
0×130B0800	=	319,490,048

Partition offsets
1st partition offset 0×1BE
2nd partition offset 0×1CE
3rd partition offset 0×1DE
4th partition offset 0×1EE

Examining FAT Disks

- File Allocation Table (FAT) is the file structure database that Microsoft designed for floppy disks.
- It is used to organize files on a disk so that the OS can find the files it needs.
- Since its development, other OSs, such as Linux and Macintosh, can format, read, and write to FAT storage devices such as USB drives and SD cards.
- The FAT database is typically written to a disk's outermost track and contains filenames, directory names, date and time stamps, the starting cluster number, and file attributes (archive, hidden, system, and read-only).
- There are three current versions of FAT—FAT16, FAT32, and exFAT (used for mobile personal storage devices)
- Three older FAT formats, which are FATX, Virtual FAT (VFAT), and FAT12

FAT12: This version is used specifically for floppy disks, so it has a limited amount of storage space.

FAT16: To handle larger disks, Microsoft developed FAT16, which is still used on older Microsoft Oss

FAT32: When disk technology improved and disks larger than 2 GB were developed, Microsoft released FAT32, which can access larger drives.

exFAT:

- Developed for mobile personal storage devices, such as flash memory devices, and memory sticks.
- The exFAT file system can store very large files, such as digital images, video, and audio files.

VFAT:

- Developed to handle files with more than eight-character filenames and three-character extensions; introduced with Windows 95.
- VFAT is an extension of other FAT file systems.

FATX:

- Modified version of the FAT32 file system format.
- The FATX file system format is used on the Xbox video game console hard disk.
- Unrecognizable by the Windows operating system.

Cluster Sizes

Cluster sizes vary according to the hard disk size and file system.
Minimum size allocated for any file

Table 5-2 Sectors and bytes per cluster

Drive size	Sectors per cluster	FAT16
8–32 MB	1	512 bytes
32–64 MB	2	1 KB
64–128 MB	4	2 KB
128–256 MB	8	4 KB
256–512 MB	16	8 KB
512–1024 MB	32	16 KB
1024–2048 MB	64	32 KB
2048–4096 MB	128	64 KB

- Microsoft OSs allocate disk space for files by clusters.
- This practice results in drive slack
- unused space in a cluster between the end of an active file’s content and the end of the cluster.
- leads to file slack space
- When the OS stores data in a FAT file system, it assigns a starting cluster position to a file.
- Data for the file is written to the first sector of the first assigned cluster.
- When this first assigned cluster is filled and runs out of room, FAT assigns the next available cluster to the file.
- If the next available cluster isn’t contiguous to the current cluster, the file becomes fragmented.
- In the FAT for each cluster on the volume, the OS writes the address of the next assigned cluster: linked list of (occupied, next)

Deleting FAT Files

- When a file is deleted in Windows Explorer or with the MS-DOS delete command, the OS inserts a HEX E5 (0xE5) in the filename's first letter position in the associated directory entry.
- This value tells the OS that the file is no longer available and a new file can be written to the same cluster location
- The data in the file remains on the disk drive.
- The area of the disk where the deleted file resides becomes unallocated/free disk space
- Forensics tools can recover data still residing in this area.

Examining NTFS Disks

- New Technology File System (NTFS) was introduced when Microsoft created Windows NT
- Still the main file system in Windows 10.
- NTFS offers substantial improvements over FAT file systems.
- provides more information about a file,
- includes security features, file ownership, and other file attributes.
- The system keeps track of transactions such as file deleting or saving.
- This journaling feature is helpful because
- records a transaction before the system carries it out
- in a power failure or other interruption, the system can complete the transaction or go back to the last good setting

- In NTFS, everything written to the disk is considered a file.
- On an NTFS disk, the first data set is the Partition Boot Sector, which starts at sector [0] of the disk
- Immediately after the Partition Boot Sector is the Master File Table (MFT)
- the first file on the disk
- An MFT file is created at the same time a disk partition is formatted as an NTFS volume
- NTFS results in much less file slack space.
- Clusters are smaller for smaller disk drives.

Table 5-3 Cluster sizes in an NTFS disk

Drive size	Sectors per cluster	Cluster size
7–512 MB	8	4 KB
512 MB–1 GB	8	4 KB
1–2 GB	8	4 KB
2 GB–2 TB	8	4 KB
2–16 TB	8	4 KB
16–32 TB	16	8 KB
32–64 TB	32	16 KB
64–128 TB	64	32 KB
128–256 TB	128	64 KB

FAT vs NTFS

- Fault Tolerance: NTFS automatically repairs files/folders in the case of power failures or errors. FAT32 maintains two different copies of the FAT in the case of damage.

- Security: FAT32 only offers shared permissions, while NTFS allows you to set specific permissions to local files/folders.
-
- Compression: FAT32 does not offer any compression option. NTFS does allow for individual compression of files and folders so you don’t slow down the system.

- Compatibility: NTFS is compatible with operating systems back to Windows XP. For Mac OS users, however, NTFS systems can only be read by Mac, while FAT32 drives can be both read and written to by the Mac OS.

Windows Artifacts

Deleted Data

- Hitting the delete key doesn't do anything to the data itself
- “Deleting” a file only tells the computer that the space occupied by that file is available if the computer needs it.
- Data can be extracted from these unallocated spaces

Hibernation File(Hiberfile.Sys)

- Hibernation save data to the hard drive as opposed to just holding it in RAM (like “sleep”)
- Data written to the hard-drive itself are more persistent and can be recovered.
- It is possible that files deleted by a suspect could still be found here.

Registry

- registry is a database for configuration files.
- keeps track of user and system configuration and preferences
- Items of interest include:
- search terms,
- programs that were run or installed,
- Web addresses,
- files that have been recently opened, etc.

Recycle Bin

- Normally, users count on the trash can to erase their evidence.
- Deleted files can be recovered from the recycle bin

Metadata

- Defined as data about data.
- There are two kinds of metadata: application and file system.
- The file system keeps track of our files and folders as well as some information about them.
- File system metadata include the date and time a file or folder was created, accessed, or modified.

Thumbnail Cache

- Windows creates smaller versions of the photos called thumbnails for ease of browsing
- Most users are completely unaware that these files even exist.
- These files remain even after the original images have been deleted.
- Even if we don't recover the original image, thumbnails can serve as the next best evidence.
- Their mere existence tells us that those pictures existed at one point on the system.

Most Recently Used (MRU)

- shortcuts to applications or files that have recently been used.

Restore Points

- Restore points (RPs) are snapshots of key system settings and configuration at a specific moment in time (Microsoft Corporation).
- These snapshots can be used to return the system to working order.
- Three ways by which RPs are created:
- They can be created by the system automatically before major system events, like installing software.
- They can be scheduled at regular intervals, such as weekly.
- They can be created manually by a user
- They are normally hidden from the user.
- These RPs have metadata (data about the data) associated with them.
- This information could be valuable in determining the point in time when this snapshot was taken.
- If the RP contains evidence, this can tell us exactly when that data existed on the system in question.

Prefetch

Prefetch files can show that an application was indeed installed and run on the system at one time.
Example:

- a wiping application such as “Evidence Eliminator.”
- programs like this are designed to completely destroy selected data on a hard drive.
- we may not be able to recover the original evidence as it has been wiped
- the mere presence of “Evidence Eliminator” can prove to be almost as crucial as the original files themselves

Link Files

- Link files are shortcuts in microsoft
- They point to other files
- The computer itself creates them in several different places
- Recent option in the file menu tab
- Link files have their own date and time stamps showing when they were created and last used.
- Link means that someone actually opened the file in question.

Attribution

- A windows PC will set up two accounts by default, the administrator and a guest account.
- The administrator has all rights and privileges on the machine.
- The guest generally has less authority.
- Each account on the machine is assigned a unique number called a security identifier or SID.
- Many actions on the computer are associated with, and tracked by, a specific SID.
- It's through the SID that we can tie an account to some particular action or event.
- Run the command 'whoami /user' from command line to get the SID for the logged in user.

External Drives

- Theft of intellectual property is a huge concern
- One way that would-be thieves could easily smuggle data out of an organization is by way of one of these external storage devices, such as a pen-drive.
- Additionally, these devices can also be used to inject a virus or store child pornography.
- Examiners are often asked to determine whether any such device has been attached to a computer
- Whether or not such a device was attached can be determined by data contained in the registry.

Print Spooling

- In some investigations a suspect's printing activities may be relevant.
- The delay observed after clicking the ‘print’ button is an indication of a process called spooling.
- Spooling temporarily stores the print job
- Windows creates a pair of complementary files
- Enhanced Meta File (EMF) which is an image of document to be printed
- Spool file which contains information about the print job itself.
- Spool file (.spl): printer name, computer name as well as the user account
- Normally deleted automatically after the print job is finished

Exception:

- some kind of problem and the document didn't print.
- computer that is initiating the print job may be set up to retain a copy
- Copies of extortion letters, forged contracts, stolen client lists, and maps to body dump sites are few pieces of evidences

Examining Linux File Structures

- The most widely used distributions include Ubuntu, CentOS, Mint, Fedora, and Gentoo.
- UNIX was created in the early 1970s to be a multiuser, multithreaded, secure OS.
- The Linux kernel is usually packaged with other software components, such as a GUI and applications, so that users don't have to combine several open-source elements to create a working environment.
- The term "kernel" is often used when discussing Linux because technically, Linux is only the core of the OS.
- Linus Torvalds, the inventor of Linux, maintains the official kernel.
- All other tools, graphical interfaces, and so forth are maintained and developed by others

Table 7-2 Core top-level directories of a Linux system

Directory	Contents
`/usr`	Most applications and commands are in this directory or its subdirectories `bin` (stands for "binary" and contains binary files required at boot time) and `sbin` (which requires superuser permission to run the binaries in it).
`/etc`	Most system configuration files are stored in this directory.
`/home`	The home directories for all users, usually named after their usernames.
`/root`	The home directory for the root user (superuser), which is kept separate from other user home directories.
`/dev`	Device files that act as stand-ins for the devices they represent, as
`/var`	Subdirectories such as `log` (often useful for investigations), `mail` (storing e-mail accounts), and `spool` (where print jobs are spooled).

Table 7-1 Linux system files

System file	Contents
`/etc/exports`	File systems exported to remote hosts; might include remote drive mappings
`/etc/fstab`	File system table of devices and mount points
`/var/log/lastlog`	User's last logon
`/var/log/wtmp`	Logon and logoff history information
`/var/run/utmp`	Current user's logon information
`/var/log/dmesg`	System messages log
`/var/log/syslog`	System log, occasionally called `system.log` or `kernel.log`
`/etc/shadow`	Master password file, containing hashed passwords for the local system
`/etc/group`	Group memberships for the local system
`/etc/passwd`	Account information for the local system

File Structures in Ext4

Linux supports a wide range of file systems.

- The early standard was Second Extended File System (Ext2)
- Then Third Extended File System (Ext3) replaced Ext2 in most Linux distributions.
- Its major difference from Ext2 was being a journaling file system, which has a built-in file recovery mechanism used after a crash.
- Fourth Extended File System (Ext4)
- added support for partitions larger than 16 TB,
- improved management of large files,
- offered a more flexible approach to adding file system features
- In UNIX and Linux, everything is considered a file, including disk drives, monitors, tape drives, network interface cards, system memory, and directories.
- Linux has four components defining the file system: boot block, superblock, inodeblock, and data block.
- A block is the smallest disk allocation unit in the UNIX/Linux file system and can be 512 bytes and up
- Block size depends on how the disk volume is initiated.

Boot block:

- contains the bootstrap code—instructions for startup
- A UNIX/Linux computer has only one boot block, on the main hard disk

Superblock

- contains vital information about the system and is considered part of the metadata
- specifies the disk geometry and available space
- keeps track of all inodes
- also manages the file system
- configuration information, such as block size
- file system names,
- blocks reserved for inodes,
- volume name
- Multiple copies of the superblock are kept in different locations on the disk to prevent losing such important information

Inode blocks

- contain the first data after the superblock
- an inode is assigned to every file allocation unit.
- as files or directories are created or deleted, inodes are also created or deleted.
- the link between inodes associated with files and directories controls access to those files or directories.

Data block

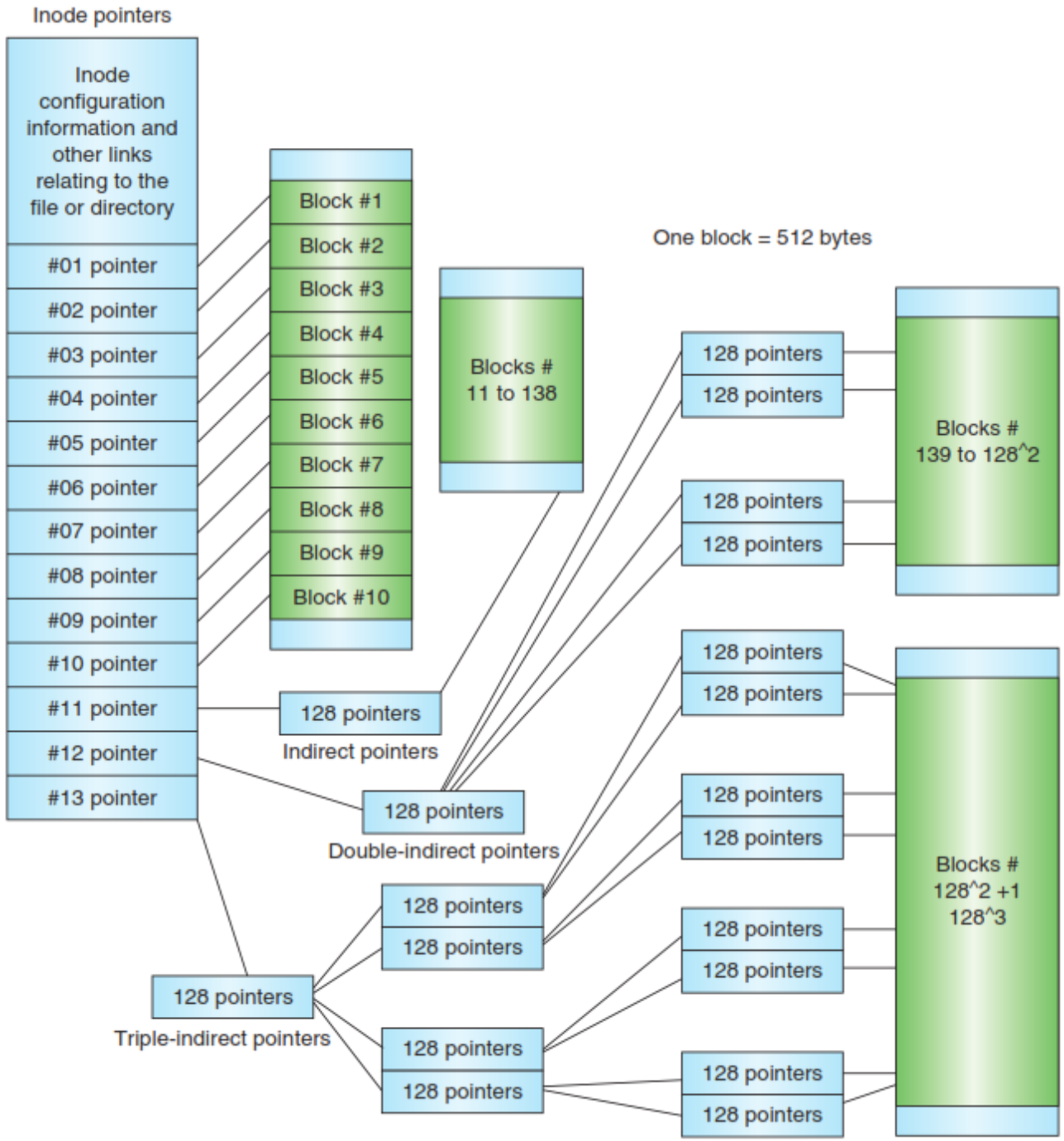
- directories and files are stored on a disk drive in this block
- this location is linked directly to inodes.
- the Linux file system on a PC has 512-byte sectors.
- a data block is equivalent to a cluster of disk sectors on a FAT or NTFS volume.
- blocks range from 1024 to 4096 bytes each on a Linux volume.

Linux file system

Inodes

- Inodes contain file and directory metadata
- When a file or directory is created on a Linux file system, an inode is assigned
- Contains the following information:
- The mode and type of the file or directory
- The number of links to a file or directory
- The number of bytes in the file or directory
- The file’s or directory’s last access time and last modified time
- The inode’s last file status change time
- The block address for the file data
- The indirect, double-indirect, and triple-indirect block addresses for the file data
- Current usage status of the inode
- The number of actual blocks assigned to a file

- The only pieces of metadata not in an inode are the filename and path.
- Inodes contain modification, access, and creation times, not filenames.
- An assigned inode has 13 pointers that link to data blocks and other pointers where files are stored.
- Pointers 1 through 10 link directly to data storage blocks in the disk's data block and contain block addresses indicating where data is stored on the disk.
- These pointers are direct pointers because each one is associated with one block of data storage.
- As a file grows, the OS provides up to three layers of additional inode pointers.
- In a file's inode, the first layer of pointers are called indirect pointers.
- The pointers in the second layer are called double-indirect pointers, and the pointers in the last or third layer are called triple-indirect pointers.


Inode pointers
Inode configuration information and other links relating to the file or directory
#01 pointer
#02 pointer
#03 pointer
#04 pointer
#05 pointer
#06 pointer
#07 pointer
#08 pointer
#09 pointer
#10 pointer
#11 pointer
#12 pointer
#13 pointer
Block #1
Block #2
Block #3
Block #4
Block #5
Block #6
Block #7
Block #8
Block #9
Block #10
Blocks # 11 to 138
One block = 512 bytes
128 pointers
Indirect pointers
128 pointers
Double-indirect pointers
128 pointers
Triple-indirect pointers
128 pointers
128 pointers
128 pointers
128 pointers
128 pointers
128 pointers
128 pointers
128 pointers
128 pointers
128 pointers
128 pointers
128 pointers
Blocks # 139 to 128^2
Blocks # 128^2 +1 128^3

Indirect Pointers

- To expand storage allocation, the OS initiates the original inode's 11th pointer, which links to 128 pointer inodes.
- Each pointer links directly to 128 blocks located in the drive's data block.
- If all 10 pointers in the original inode are consumed with file data, the 11th pointer links to another 128 pointers.
- The first pointer in this indirect group of inodes points to the 11th block.
- The last block of these 128 inodes is block 138.

Double-indirect Pointer

- If more storage is needed, the 12th pointer of the original inode is used to link to another 128 inode pointers.
- From each of these pointers, another 128 pointers are created.
- This second layer of inode pointers is then linked directly to blocks in the drive's data block.
- The first block these double-indirect pointers point to is block 139.

Triple-indirect pointer

- If more storage is needed, the 13th pointer links to 128 pointer inodes
- each pointing to another 128 pointers
- and each pointer in this second layer points to a third layer of 128 pointers
- then we encounter data blocks

Bad block inode

- All disks have more storage capacity than the manufacturer states.
- For example, a 240 GB disk might actually have 240.5 GB free space because disks always have bad sectors.
- Windows does not keep track of bad sectors, but Linux does in an inode called the bad block inode.
- The root inode is inode 2, and the bad block inode is inode 1.
- Some forensics tools ignore inode 1 and fail to recover valuable data for cases.
- Someone trying to mislead an investigator can access the bad block inode, list good sectors in it, and then hide information in these supposedly “bad” sectors.

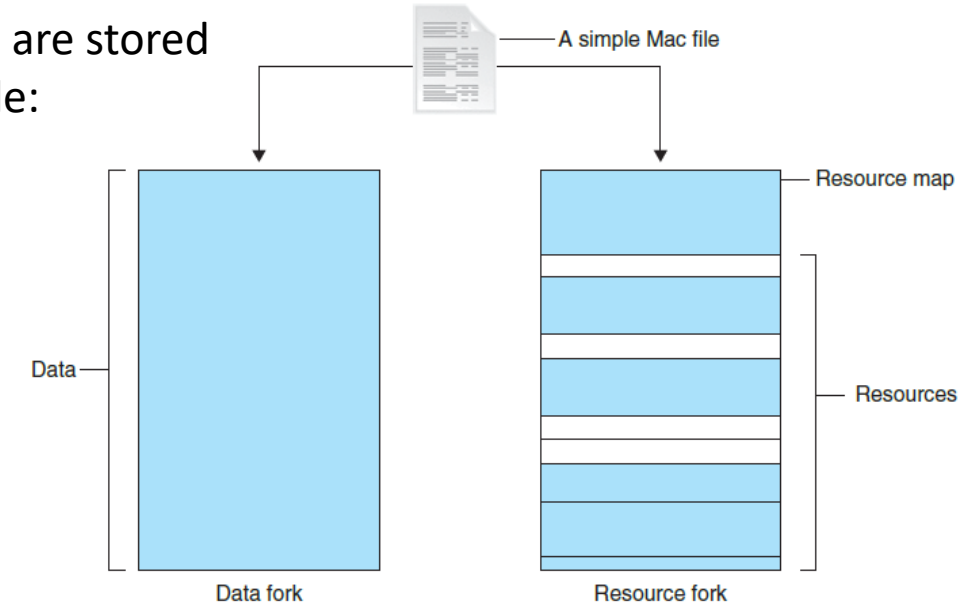
Understanding Macintosh File Structures

- The current Macintosh OS is macOS, version 10.13, code-named High Sierra.
- Other versions still in use include 10.12.5 (Sierra), 10.11 (El Capitan), 10.9 (Yosemite), 10.6 (Snow Leopard), 10.7 (Lion), and 10.8 (Mountain Lion).
- macOS is built with the new Apple File System (APFS).
- Apple's OSs have been developing since 1984 with the introduction of Apple System 1.
- In 1997, Apple introduced Mac OS 8, followed by Mac OS 9 and then OS X.
- With OS X, Macintosh moved to the Intel processor and became UNIX based.
- Before OS X, the Hierarchical File System (HFS) was used, in which files are stored in directories (folders) that can be nested in other directories.
- With Mac OS 8.1, Apple introduced Extended Format File System (HFS+).
- The main difference between HFS and HFS+ is that HFS was limited to 65,536 blocks (512 bytes per block) per volume, and HFS+ raised the number of blocks to more than 4 billion.
- Consequently, HFS+ supports smaller file sizes on larger volumes, resulting in more efficient disk use.

An Overview of Mac File Structures

In older versions of macOS, a file consists of two parts:

- a data fork, where data is stored,
- a resource fork, where file metadata and application information are stored
- Both forks contain the following essential information for each file:
- Resource map
- Resource header information for each file
- Window locations
- Icons



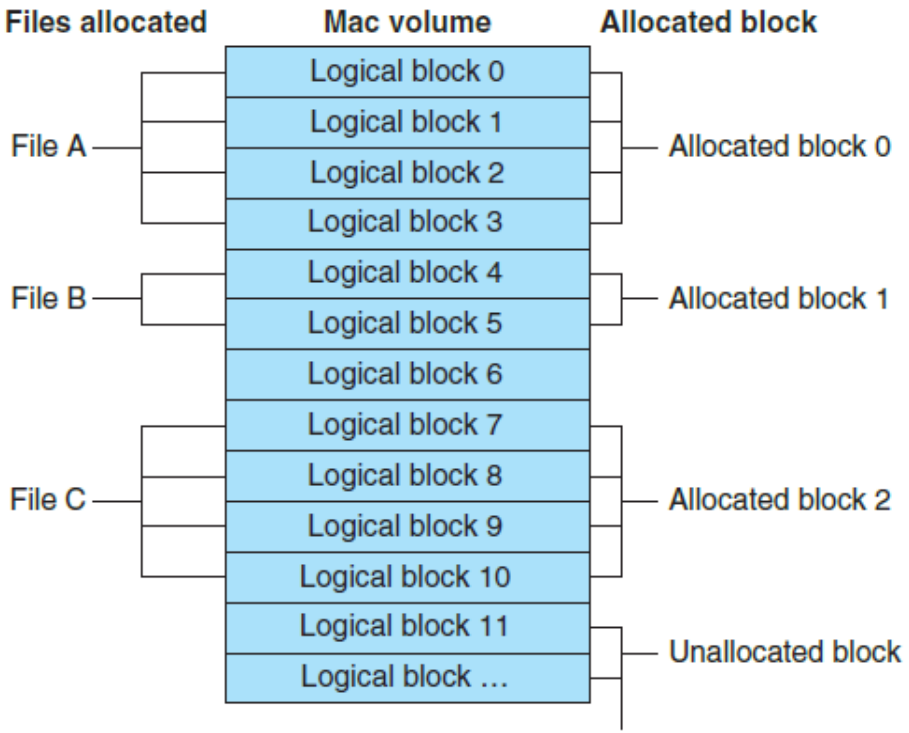
- The data fork typically contains data the user creates, such as text or spreadsheets.
- Applications, such as Microsoft Word or Excel, also read and write to the data fork.
- When you're working with an application file, the resource fork contains additional information, such as menus, dialog boxes, icons, executable code, and controls.
- In macOS, the resource or data fork can be empty.

Volume

- A volume is any storage medium used to store files.
- It can be allor partof the storage media for hard disks
- In Mac OS 9 and earlier, a volume on a floppy disk was always the entire floppy.
- With larger disks, the user or administrator now defines a volume.
- Volumes have allocation blocks and logical blocks.
- A logical block is a collection of data that cannot exceed 512 bytes.
- When you save a file, it is assigned to an allocation block, which is a group of consecutive logical blocks.

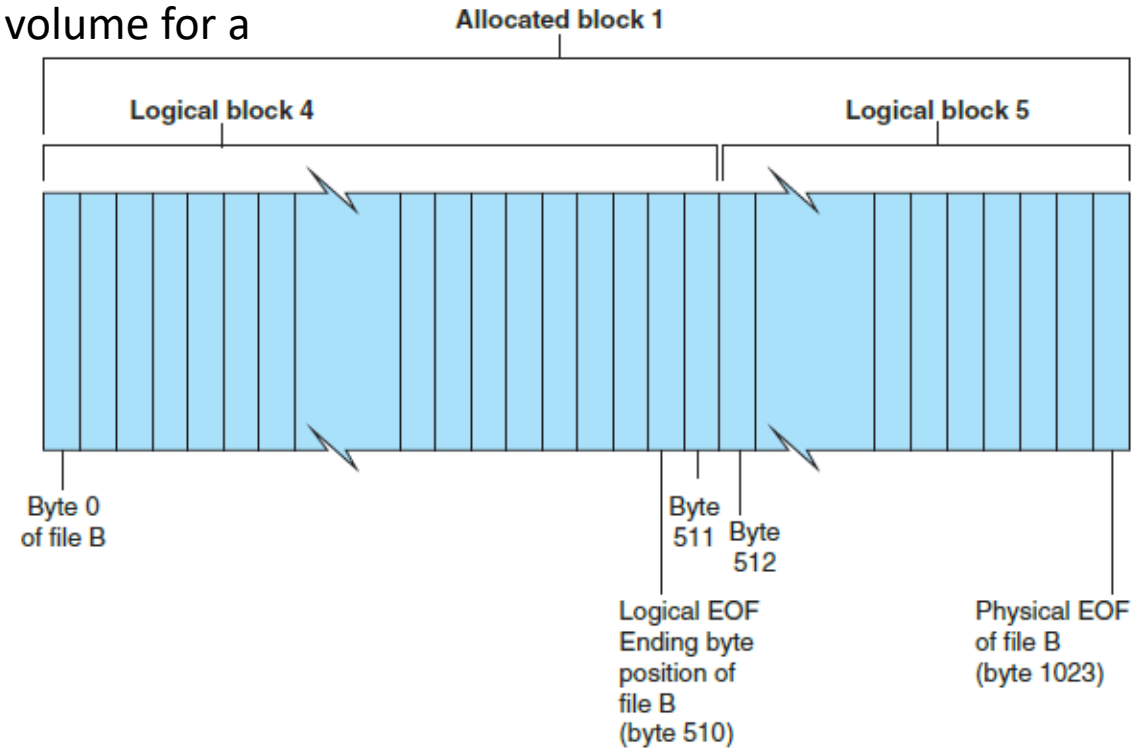
As volumes increase in size, one allocation block might be composed of three or more logical blocks

- If a file contains information, it always occupies one allocation block.
- For example, if a data fork contains only 11 bytes of data, it occupies one allocation block (512 bytes) on a disk, which leaves more than 500 bytes empty in the data fork.



End of file

- The HFS and HFS+ file systems have two descriptors for the end of a file (EOF)—
- the logical EOF
- the physical EOF.
- The logical EOF is the actual ending of a file's data,
- if file B has 510 bytes of data, byte 510 is the logical EOF
- The physical EOF is the number of bytes allotted on the volume for a file,
- for file B, it's byte 1023



- For older HFS-formatted drives, the first two logical blocks, 0 and 1, on the volume are the boot blocks containing system startup instructions.
- Optional executable code for system files can also be placed in boot blocks.
- Older Mac OSs use the Master Directory Block (MDB) for HFS, which is the Volume Information Block (VIB) in HFS+.
- All information about a volume is stored in the MDB and written to it when the volume is initialized.
- A copy of the MDB is also written to the next-to-last block on the volume to support disk utility functions.
- Utility software is software designed to help to analyze, configure, optimize or maintain a computer.
- Perform disk and disk-volume-related tasks on the macOS operating system
- When the OS mounts a volume, some information from the MDB is written to a Volume Control Block (VCB), stored in system memory
- When a user no longer needs the volume and unmounts it, the VCB is removed.

Acquisition of Digital evidence

Introduction

- Data acquisition is the process of copying data
- For digital forensics, it is the task of collecting digital evidence from electronic media
- There are two types of data acquisition: static acquisitions and live acquisitions.

Static acquisitions:

- capture data that is not accessed by other processes that can change it
- if you have preserved the original media, making a second static acquisition should produce the same results.
- the data on the original disk is not altered, no matter how many times an acquisition is done

Live acquisitions:

- file metadata, such as date and time values, changes when read by an acquisition tool
- making a second live acquisition while a computer is running collects new data because of dynamic changes in the OS.

Understanding Storage Formats for Digital Evidence

- The data a forensics acquisition tool collects is stored as an image file, typically in an open-source or proprietary format
- Each vendor has unique features, so several different proprietary formats are available
- Depending on the proprietary format, many forensics analysis tools can read other vendors' formatted acquisitions.
- Many acquisition tools create a disk-to-image file in an older open-source format, known as raw, as well as their own proprietary formats.
- The new open-source format, Advanced Forensic Format (AFF), is gaining recognition from some forensics examiners.

Raw Format

In the past, examiners performed a bit-by-bit copy from one disk to another disk the same size or larger

- As a practical way to preserve digital evidence, vendors made it possible to write bit-stream data to files
- This copy technique creates simple sequential flat files of a suspect drive or data set.

The output of these flat files is referred to as a raw format.

Advantages

- fast data transfers
- capability to ignore minor data read errors on the source drive
- most forensics tools can read the raw format, making it a universal acquisition format for most tools

Disadvantage

- requires as much storage space as the original disk or data set
- some raw format tools, typically freeware versions, might not collect marginal (bad) sectors on the source drive
- Several commercial acquisition tools can produce raw format acquisitions
- Typically perform a validation check by using Cyclic Redundancy Check (CRC32), Message Digest 5 (MD5), and Secure Hash Algorithm (SHA-1 or later) hashing functions

Proprietary Formats

Most commercial forensics tools have their own formats for collecting digital evidence.
Proprietary formats typically offer several features that complement the vendor's analysis tool

Some features include:

- The option to compress or not compress image files of a suspect drive, thus saving space on the target drive
- The capability to split an image into smaller segmented files for archiving purposes, such as to CDs or DVDs, with data integrity checks integrated into each segment
- The capability to integrate metadata into the image file, such as date and time of the acquisition, hash value (for self-authentication) of the original disk or medium, investigator or examiner name, and comments or case details

Disadvantage

- Inability to share an image between different vendors' computer forensics analysis tools.

Advanced Forensic Format

Dr. Simson L. Garfinkel developed an open-source acquisition format called Advanced Forensic Format (AFF).
This format has the following design goals:

- Capable of producing compressed or uncompressed image files
- No size restriction for disk-to-image files
- Space in the image file or segmented files for metadata
- Simple design with extensibility
- Open source for multiple computing platforms and OSs
- Internal consistency checks for self-authentication
- File extensions include .afdfor segmented image files and .afmfor AFF metadata.
- Because AFF is open source, digital forensics vendors have no implementation restrictions on this format.

Determining the Best Acquisition Method

There are two types of acquisitions: static acquisitions and live acquisitions.

- Typically, a static acquisition is done on a computer seized during a police raid, for example.
- If the computer has an encrypted drive, a live acquisition is done if the password or passphrase is available
- the computer is powered on and has been logged on to by the suspect.
- Static acquisitions are always the preferred way to collect digital evidence.
- Limitations in some situations
- encrypted drive that is readable only when the computer is powered on
- computer that is accessible only over a network

Data can be collected with four methods:

1. creating a disk-to-image file,
2. creating a disk-to-disk copy,
3. creating a logical disk-to-disk or disk-to-data file,
4. creating a sparse copy of a folder or file

Disk-to-image file

- Most common method and offers the most flexibility for investigation
- Can make one or many copies of a suspect drive
- These copies are bit-for-bit replications of the original drive
- Can use many commercial forensics tools to read the most common types of disk-to-image files you create
- These programs read the disk-to-image file as though it were the original disk.

Disk-to-disk copy

- Sometimes you cannot make a disk-to-image file because of hardware or software errors or incompatibilities
- This problem is more common when you have to acquire older drives.
- We create a disk-to-disk copy of the suspect drive.
- Several imaging tools can copy data exactly from an older disk to a newer disk.
- These programs can adjust the target disk's geometry (its cylinder, head, and track configuration) so that the copied data matches the original suspect drive.

Logical disk-to-disk

- Collecting evidence from a large drive can take several hours
- A logical acquisition captures only specific files of interest to the case or specific types of files.

Example:
an e-mail investigation that requires collecting only Outlook .pstor .ostfiles.

Sparse copy of a folder or file

- A sparse acquisition is similar to logical acquisition but also collects fragments of unallocated (deleted) data3
- Used only when we do not need to examine the entire drive.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