Guide to Computer Forensics and Investigations Sixth Edition

Chapter 5

Working with Windows and CLI Systems

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Objectives

- Explain the purpose and structure of file systems
- Describe Microsoft file structures
- Explain the structure of NTFS disks
- List some options for decrypting drives encrypted with whole disk encryption
- Explain how the Windows Registry works
- Describe Microsoft startup tasks
- Explain the purpose of a virtual machine

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Understanding File Systems

- **File system**
  - Gives OS a road map to data on a disk
- 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
  - You should be familiar with both the computer's OS and file systems

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Understanding the Boot Sequence (1 of 3)

- Complementary Metal Oxide Semiconductor (CMOS)
  - Computer stores system configuration and date and time information in the CMOS
    - When power to the system is off
- Basic Input/Output System (BIOS) or Extensible Firmware Interface (EFI)
  - Contains programs that perform input and output at the hardware level

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Understanding the Boot Sequence (2 of 3)

- **Bootstrap process**
  - Contained in ROM, tells the computer how to proceed
  - Displays the key or keys you press to open the CMOS setup screen
- CMOS should be modified to boot from a forensic floppy disk or CD

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Understanding the Boot Sequence (3 of 3)

Figure 5-1 A typical CMOS setup screen

Source: American Megatrends, Inc., *https://ami.com/en/*

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Understanding Disk Drives (1 of 4)

- Disk drives are made up of one or more platters coated with magnetic material
- Disk drive components
  - Geometry
  - Head
  - Tracks
  - Cylinders
  - Sectors

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Understanding Disk Drives (2 of 4)

Figure 5-2 Components of a disk drive

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Understanding Disk Drives (3 of 4)

Figure 5-3 CHS calculation

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Understanding Disk Drives (4 of 4)

- Properties handled at the drive's hardware or firmware level
  - **Zone bit recording (ZBR)**
  - **Track density**
  - **Areal density**
  - **Head and cylinder skew**

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Solid-State Storage Devices

- All flash memory devices have a feature called **wear-leveling**
  - An internal firmware feature used in solid-state drives that ensures even wear of read/writes for all memory cells
- When dealing with solid-state devices, making a full forensic copy as soon as possible is crucial
  - In case you need to recover data from unallocated disk space

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Exploring Microsoft File Structures (1 of 2)

- In Microsoft file structures, sectors are grouped to form **clusters**
  - Storage allocation units of one or more sectors
- Clusters range from 512 bytes up to 32,000 bytes each
- Combining sectors minimizes the overhead of writing or reading files to a disk

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Exploring Microsoft File Structures (2 of 2)

- Clusters are numbered sequentially starting at 0 in NTFS and 2 in FAT
  - First sector of all disks contains a system area, the boot record, and a file structure database
- OS assigns these cluster numbers, called **logical addresses**
- Sector numbers are called **physical addresses**
- Clusters and their addresses are specific to a logical disk drive, which is a disk partition

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Disk Partitions (1 of 3)

- 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
- Hidden partitions or voids
  - Large unused gaps between partitions on a disk
- **Partition gap**
  - Unused space between partitions

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Disk Partitions (2 of 3)

- 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 at offset 0x1BE
  - The file system's hexadecimal code is offset 3 bytes from 0x1BE for the first partition

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Disk Partitions (3 of 3)

Figure 5-4 The partition table in a hexadecimal editor

Source: X-Ways AG, *www.x-ways.net*

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Examining FAT Disks (1 of 7)

- **File Allocation Table (FAT)**
  - File structure database that Microsoft originally designed for floppy disks
- 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
- Three current FAT versions
  - FAT16, FAT32, and exFAT (used for mobile personal storage devices)
- Cluster sizes vary according to the hard disk size and file system

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Examining FAT Disks (2 of 7)

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

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Examining FAT Disks (3 of 7)

- Microsoft OSs allocate disk space for files by clusters
  - Results in **drive slack**
    - Unused space in a cluster between the end of an active file's content and the end of the cluster
- Drive slack includes:
  - **RAM slack** and **file slack**
- An unintentional side effect of FAT16 allowing large clusters was that it reduced fragmentation
  - As cluster size increased

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Examining FAT Disks (4 of 7)

Figure 5-8 File slack space

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Examining FAT Disks (5 of 7)

- When you run out of room for an allocated cluster
  - OS allocates another cluster for your file
- As files grow and require more disk space, assigned clusters are chained together
  - The chain can be broken or fragmented
- 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

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Examining FAT Disks (6 of 7)

Figure 5-9 Chained sectors associated with clusters as a result of increasing file size

Source: X-Ways AG, *www.x-ways.net*

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Examining FAT Disks (7 of 7)

- 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
  - File becomes fragmented

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Deleting FAT Files

- In Microsoft OSs, when a file is deleted
  - Directory entry is marked as a deleted file
    - With the HEX E5 character replacing the first letter of the filename
    - FAT chain for that file is set to 0
- Data in the file remains on the disk drive
- Area of the disk where the deleted file resides becomes **unallocated disk space**
  - Available to receive new data from newly created files or other files needing more space

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Examining NTFS Disks (1 of 3)

- **NT File System (NTFS)**
  - Introduced with Windows NT
  - Primary file system for Windows 10
- Improvements over FAT file systems
  - NTFS provides more information about a file
  - NTFS gives more control over files and folders
- NTFS was Microsoft's move toward a journaling file system
  - It records a transaction before the system carries it out

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Examining NTFS Disks (2 of 3)

- In NTFS, everything written to the disk is considered a file
- On an NTFS disk
  - First data set is the **Partition Boot Sector**
  - Next is **Master File Table (MFT)**
- NTFS results in much less file slack space
- Clusters are smaller for smaller disk drives
- NTFS also uses **Unicode**
  - An international data format

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Examining NTFS Disks (3 of 3)

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

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NTFS System Files (1 of 3)

- MFT contains information about all files on the disk
  - Including the system files the OS uses
- In the MFT, the first 15 records are reserved for system files
- Records in the MFT are called **metadata**

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NTFS File System (2 of 3)

Table 5-4 Metadata records in the MFT

Filename	System file	Record position	Description
`$Mft`	MFT	0	Base file record for each folder on the NTFS volume; other record positions in the MFT are allocated if more space is needed.
`$MftMirr`	MFT 2	1	The first four records of the MFT are saved in this position. If a single sector fails in the first MFT, the records can be restored, allowing recovery of the MFT.
`$LogFile`	Log file	2	Previous transactions are stored here to allow recovery after a system failure in the NTFS volume.
`$Volume`	Volume	3	Information specific to the volume, such as label and version, is stored here.

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NTFS File System (3 of 3)

Table 5-4 Metadata records in the MFT (*continued*)

Filename	System file	Record position	Description
`$AttrDef`	Attribute definitions	4	A table listing attribute names, numbers, and definitions.
`$`	Root filename index	5	This is the root folder on the NTFS volume.
`$Bitmap`	Boot sector	6	A map of the NTFS partition shows which clusters are in use and which are available.
`$Boot`	Boot sector	7	Used to mount the NTFS volume during the bootstrap process; additional code is listed here if it's the boot drive for the system.
`$BadClus`	Bad cluster file	8	For clusters that have unrecoverable errors, an entry of the cluster location is made in this file.
`$Secure`	Security file	9	Unique security descriptors for the volume are listed in this file. It's where the access control list (ACL) is maintained for all files and folders on the NTFS volume.
`$Upcase`	Upcase table	10	Converts all lowercase characters to uppercase Unicode characters for the NTFS volume.
`$Extend`	NTFS extension file	11	Optional extensions are listed here, such as quotas, object identifiers, and reparse point data.
		12–15	Reserved for future use.

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MFT and File Attributes (1 of 7)

- In the NTFS MFT
  - All files and folders are stored in separate records of 1024 bytes each
- Each record contains file or folder information
  - This information is divided into record fields containing metadata
- A record field is referred to as an **attribute ID**
- File or folder information is typically stored in one of two ways in an MFT record:
  - Resident and nonresident

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MFT and File Attributes (2 of 7)

- Files larger than 512 bytes are stored outside the MFT
  - MFT record provides cluster addresses where the file is stored on the drive's partition
    - Referred to as **data runs**
- Each MFT record starts with a header identifying it as a resident or nonresident attribute

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MFT and File Attributes (3 of 7)

Table 5-5 Attributes in the MFT

Attribute ID	Purpose
0x10	$Standard Information This field contains data on file creation, alterations, MFT changes, read dates and times, and DOS file permissions.
0x20	$Attribute_List Attributes that don't fit in the MFT (nonresident attributes) are listed here along with their locations.
0x30	$File_Name The long and short names for a file are contained here. Up to 255 Unicode bytes are available for long filenames. For POSIX requirements, additional names or hard links can also be listed. Files with short filenames have only one attribute ID 0x30. In older Windows OSs, long filenames have two ID 0x30s in the MFT record: one for the short name and one for the long name. In Windows 10, there's only one 0x30 that combines the short and long filenames.
0x40	$Object_ID ($Volume_Version in Windows NT) Ownership and who has access rights to the file or folder are listed here. Every MFT record is assigned a unique GUID. Depending on your NTFS setup, some file records might not contain this attribute ID.
0x50	$Security_Descriptor Contains the access control list (ACL) for the file.
0x60	$Volume_Name The volume-unique file identifier is listed here. Not all files need this unique identifier.
0x70	$Volume_Information This field indicates the version and state of the volume.
0x80	$Data File data for resident files or data runs for nonresident files.
0x90	$Index_Root Implemented for use of folders and indexes.
0xA0	$Index_Allocation Implemented for use of folders and indexes.

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MFT and File Attributes (4 of 7)

Table 5-5 Attributes in the MFT (*continued*)

Attribute ID	Purpose
0xB0	$Bitmap A bitmap indicating cluster status, such as which clusters are in use and which are available.
0xC0	$Reparse_Point This field is used for volume mount points and Installable File System (IFS) filter drivers. For the IFS, it marks specific files used by drivers.
0xD0	$EA_Information For use with OS/2 HPFS.
0xE0	For use with OS/2 HPFS.
0x100	$Logged_Utility_Stream This field is used by Encrypting File System (EFS) in Windows 2000 and later.

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MFT and File Attributes (5 of 7)

A: All MFT records start with FILE0
B: Start of attribute 0x10
C: Length of attribute 0x10 (value 60)
D: Start of attribute 0x30
E: Length of attribute 0x30 (value 70)
F: Start of attribute 0x40
G: Length of attribute 0x40 (value 28)
H: Start of attribute 0x80
I: Length of attribute 0x80 (value 70)
J: Attribute 0x80 resident flag
K: Starting position of resident data

Figure 5-10 Resident file in an MFT record

Source: X-Ways AG, *www.x-ways.net*

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MFT and File Attributes (6 of 7)

Offset	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	ANSI ASCII
035B3C00	46	49	4C	45	30	00	03	00	5F	A7	B2	00	00	00	00	00	FILE0 _§²
035B3C10	03	00	01	00	38	00	00	00	80	01	00	00	00	04	00	00	8 €
035B3C20	00	00	00	00	00	00	00	00	05	00	00	00	A5	17	00	00	¥
035B3C30	09	00	00	00	00	00	00	00	10	00	00	00	60	00	00	00	`
035B3C40	00	00	00	00	00	00	00	00	48	00	00	00	18	00	00	00	H
035B3C50	10	C0	13	88	0B	7C	C9	01	6A	22	16	88	0B	7C	C9	01	À ˆ |É j" ˆ |É
035B3C60	A8	D4	5D	7D	8B	7E	C9	01	6A	22	16	88	0B	7C	C9	01	¨Ô]}‹~É j" ˆ |É
035B3C70	20	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
035B3C80	00	00	00	00	09	01	00	00	00	00	00	00	00	00	00	00	
035B3C90	00	00	00	00	00	00	00	00	30	00	00	00	70	00	00	00	0 p
035B3CA0	00	00	00	00	00	00	02	00	52	00	00	00	18	00	01	00	R
035B3CB0	8A	00	00	00	00	00	01	00	10	C0	13	88	0B	7C	C9	01	Š À ˆ |É
035B3CC0	6A	22	16	88	0B	7C	C9	01	6A	22	16	88	0B	7C	C9	01	j" ˆ |É j" ˆ |É
035B3CD0	6A	22	16	88	0B	7C	C9	01	00	00	00	00	00	00	00	00	j" ˆ |É
035B3CE0	00	00	00	00	00	00	00	00	20	00	00	00	00	00	00	00	
035B3CF0	08	03	42	00	65	00	6E	00	32	00	2E	00	72	00	74	00	B e n 2 . r t
035B3D00	66	00	00	00	00	00	00	00	40	00	00	00	28	00	00	00	f @ (
035B3D10	00	00	00	00	00	00	04	00	10	00	00	00	18	00	00	00	
035B3D20	F7	7C	F1	27	DF	E7	DD	11	A8	3F	00	22	15	D5	88	06	÷|ñ'ßçÝ ¨? " Õˆ
035B3D30	80	00	00	00	48	00	00	00	01	00	00	00	00	00	03	00	€ H
035B3D40	00	00	00	00	00	00	00	00	02	00	00	00	00	00	00	00	
035B3D50	40	00	00	00	00	00	00	00	00	06	00	00	00	00	00	00	@
035B3D60	78	05	00	00	00	00	00	00	78	05	00	00	00	00	00	00	x x
035B3D70	31	03	15	55	01	00	01	00	FF	FF	FF	FF	82	79	47	11	1 U ÿÿÿÿ,yG

A: Start of nonresident attribute 0x80
B: Length of nonresident attribute 0x80
C: Attribute 0x80 nonresident flag
D: Starting point of data run
E: End-of-record marker (FF FF FF FF) for the MFT record

Figure 5-12 **Nonresident file in an MFT record**

Source: X-Ways AG, *www.x-ways.net*

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MFT and File Attributes (7 of 7)

- When a disk is created as an NTFS file structure
  - OS assigns logical clusters to the entire disk partition
- These assigned clusters are called **logical cluster numbers (LCNs)**
  - Become the addresses that allow the MFT to link to nonresident files on the disk's partition
- When data is first written to nonresident files, an LCN address is assigned to the file
  - This LCN becomes the file's **virtual cluster number (VCN)**

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MFT Structures for File Data (1 of 7)

- For the header of all MFT records, the record fields of interest are as follows:
  - *At offset 0x00* - the MFT record identifier FILE
  - *At offset 0x1C to 0x1F* - size of the MFT record
  - *At offset 0x14* - length of the header (indicates where the next attribute starts)
  - *At offset 0x32 and 0x33* - the update sequence array, which stores the last 2 bytes of the first sector of the MFT record

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MFT Structures for File Data (2 of 7)

MFT record identifier

Length of the MFT record header

Size of the entire MFT record

Offset	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	ANSI ASCII
000002000	46	49	4C	45	30	00	03	00	11	8F	42	0C	00	00	00	00	FILE0 B
000002010	01	00	01	00	38	00	01	00	D0	01	00	00	00	04	00	00	8 Ð
000002020	00	00	00	00	00	00	00	00	06	00	00	00	00	00	00	00	
000002030	05	02	77	69	00	00	00	00	10	00	00	00	60	00	00	00	wi `

Update sequence array: This data goes into position/offset IE and IF

Note: This data is swapped with data in position IE and IF of the MFT record

Figure 5-13 An MFT header

Source: X-Ways AG, *www.x-ways.net*

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MFT Structures for File Data (3 of 7)

Figure 5-14 **Attribute 0x10: Standard Information**

Source: X-Ways AG, *www.x-ways.net*

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MFT Structures for File Data (4 of 7)

A: Attribute 0x30 short filename
B: Size of attribute 0x30 short filename
C: Short create date and time
D: Short last modified date and time
E: Short last access date and time
F: Short record update date and time
G: Starting position of short filename
H: Attribute 0x30 long filename
I: Size of attribute 0x30 long filename
J: Long create date and time
K: Long last modified date and time
L: Long last access date and time
M: Long record update date and time
N: Starting position of long filename

Figure 5-15 Attribute 0x30: short and long filenames

Source: X-Ways AG, *www.x-ways.net*

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MFT Structures for File Data (5 of 7)

Figure 5-16 **Attribute 0x40: Object_ID**

Source: X-Ways AG, *www.x-ways.net*

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MFT Structures for File Data (6 of 7)

Figure 5-17 **Attribute 0x80: Data for a resident file**

Source: X-Ways AG, *www.x-ways.net*

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MFT Structures for File Data (7 of 7)

Figure 5-18 Attribute 0x80: Data for a nonresident file

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NTFS Alternate Data Streams (1 of 2)

- **Alternate data streams**
  - Ways data can be appended to existing files
  - Can obscure valuable evidentiary data, intentionally or by coincidence
- In NTFS, an alternate data stream becomes an additional file attribute
  - Allows the file to be associated with different applications
- You can only tell whether a file has a data stream attached by examining that file's MFT entry

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NTFS Alternate Data Streams (2 of 2)

Offset	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	ANSI ASCII
024C0E00	46	49	4C	45	30	00	03	00	5C	AC	B2	00	00	00	00	00	FILE0 \¬²
024C0E10	04	00	01	00	38	00	00	00	B8	01	00	00	00	04	00	00	8 ¸
024C0E20	00	00	00	00	00	00	00	00	07	00	00	00	A1	00	00	00	¡
024C0E30	09	00	00	00	00	00	00	00	10	00	00	00	60	00	00	00	`
024C0E40	00	00	00	00	00	00	00	00	48	00	00	00	18	00	00	00	H
024C0E50	B2	4C	07	BB	D3	7C	C9	01	14	4A	A3	3D	C8	7D	C9	01	²L »Ó|É J£=È}É
024C0E60	14	4A	A3	3D	C8	7D	C9	01	60	69	A5	EC	F8	D0	C9	01	J£=È}É `i¥ìøÐÉ
024C0E70	20	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
024C0E80	00	00	00	00	09	01	00	00	00	00	00	00	00	00	00	00	
024C0E90	00	00	00	00	00	00	00	00	30	00	00	00	70	00	00	00	0 p
024C0EA0	00	00	00	00	00	00	02	00	54	00	00	00	18	00	01	00	T
024C0EB0	8A	00	00	00	00	00	01	00	B2	4C	07	BB	D3	7C	C9	01	Š ²L »Ó|É
024C0EC0	B2	4C	07	BB	D3	7C	C9	01	B2	4C	07	BB	D3	7C	C9	01	²L »Ó|É ²L »Ó|É
024C0ED0	B2	4C	07	BB	D3	7C	C9	01	00	00	00	00	00	00	00	00	²L »Ó|É
024C0EE0	00	00	00	00	00	00	00	00	20	00	00	00	00	00	00	00	
024C0EF0	09	03	42	00	46	00	31	00	5F	00	34	00	2E	00	74	00	B F 1 _ 4 . t
024C0F00	78	00	74	00	00	00	00	00	80	00	00	00	50	00	00	00	x t € P
024C0F10	00	00	18	00	00	00	05	00	38	00	00	00	18	00	00	00	8
024C0F20	57	65	6C	6C	20	64	6F	6E	65	20	69	73	20	62	65	74	Well done is bet
024C0F30	74	65	72	20	74	68	61	6E	20	77	65	6C	6C	20	73	61	ter than well sa
024C0F40	69	64	2E	0D	0A	20	20	42	65	6E	6A	61	6D	69	6E	20	id. Benjamin
024C0F50	46	72	61	6E	6B	6C	69	6E	80	00	00	00	58	00	00	00	Franklin€ X
024C0F60	01	06	40	00	00	00	06	00	00	00	00	00	00	00	00	00	@
024C0F70	00	00	00	00	00	00	00	00	50	00	00	00	00	00	00	00	P
024C0F80	00	02	00	00	00	00	00	00	3B	00	00	00	00	00	00	00	;
024C0F90	3B	00	00	00	00	00	00	00	68	00	69	00	64	00	64	00	; h i d d
024C0FA0	65	00	6E	00	00	00	00	00	31	01	31	A2	00	00	21	E4	e n 1 1¢ !ä
024C0FB0	FF	FF	FF	FF	82	79	47	11	00	00	00	00	00	00	00	00	ÿÿÿÿ‚yG

Second attribute 0x80

Start of data run for second attribute 0x80 (location of hidden alternate data stream)

Size of second attribute 0x80

Figure 5-24 A text alternate data stream

Source: X-Ways AG, *www.x-ways.net*

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NTFS Compressed Files

- NTFS provides compression similar to FAT DriveSpace 3 (a Windows 98 compression utility)
- With NTFS, files, folders, or entire volumes can be compressed
- Most computer forensics tools can uncompress and analyze compressed Windows data

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NTFS Encrypting File System (EFS)

- **Encrypting File System (EFS)**
  - Introduced with Windows 2000
  - Implements a **public key** and **private key** method of encrypting files, folders, or disk volumes
- When EFS is used in Windows 2000 and later
  - A **recovery certificate** is generated and sent to the local Windows administrator account
- Users can apply EFS to files stored on their local workstations or a remote server

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EFS Recovery Key Agent

- Recovery Key Agent implements the recovery certificate
  - Which is in the Windows administrator account
- Windows administrators can recover a key in two ways: through Windows or from a command prompt
- Commands:
  - cipher
  - copy

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Deleting NTFS Files

- When a file is deleted in Windows NT and later
  - The OS renames it and moves it to the Recycle Bin
- Can use the `del` (delete) MS-DOS command
  - Eliminates the file from the MFT listing in the same way FAT does

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Resilient File System

- **Resilient File System** (**ReFS**) - designed to address very large data storage needs
  - Such as the cloud
- Features incorporated into ReFS's design:
  - Maximized data availability
  - Improved data integrity
  - Designed for scalability
- ReFS uses disk structures similar to the MFT in NTFS

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Understanding Whole Disk Encryption (1 of 3)

- In recent years, there has been more concern about loss of
  - **Personal identity information (PII)** and trade secrets caused by computer theft
- Of particular concern is the theft of laptop computers and handheld devices
- To help prevent loss of information, software vendors now provide whole disk encryption

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Understanding Whole Disk Encryption (2 of 3)

- Current whole disk encryption tools offer the following features:
  - Preboot authentication
  - Full or partial disk encryption with secure hibernation
  - Advanced encryption algorithms
  - Key management function

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Understanding Whole Disk Encryption (3 of 3)

- Whole disk encryption tools encrypt each sector of a drive separately
- Many of these tools encrypt the drive's boot sector
  - To prevent any efforts to bypass the secured drive's partition
- To examine an encrypted drive, decrypt it first
  - Run a vendor-specific program to decrypt the drive
  - Many vendors use a bootable CD or USB drive that prompts for a **one-time passphrase**

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Examining Microsoft BitLocker

- Available Vista Enterprise/Ultimate, Windows 7, 8, and 10 Professional/Enterprise, and Server 2008 and later
- Hardware and software requirements
  - A computer capable of running Windows Vista or later
  - The TPM microchip, version 1.2 or newer
  - A computer BIOS compliant with Trusted Computing Group (TCG)
  - Two NTFS partitions
  - The BIOS configured so that the hard drive boots first before checking other bootable peripherals

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Examining Third-Party Disk Encryption Tools

- Some available third-party WDE utilities:
  - Endpoint Encryption
  - Voltage SecureFile
  - Jetico BestCrypt Volume Encryption

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Understanding the Windows Registry

- **Registry**
  - A database that stores hardware and software configuration information, network connections, user preferences, and setup information
- To view the Registry, you can use:
  - Regedit (Registry Editor) program for Windows 9x systems
  - Regedt32 for Windows 2000, XP, and Vista
  - Both utilities can be used for Windows 7 and 8

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Exploring the Organization of the Windows Registry (1 of 5)

- Registry terminology:
  - Registry
  - Registry Editor
  - HKEY
  - Key
  - Subkey
  - Branch
  - Value
  - Default value
  - Hives

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Exploring the Organization of the Windows Registry (2 of 5)

Table 5-6 Registry file locations and purposes

Filename and location	Purpose of file
Users*user-account*\`Ntuser.dat`	User-protected storage area; contains the list of most recently used files and desktop configuration settings
Windows\system32\config\`Default.dat`	Contains the computer's system settings
Windows\system32\config\`SAM.dat`	Contains user account management and security settings
Windows\system32\config\`Security.dat`	Contains the computer's security settings
Windows\system32\config\`Software.dat`	Contains installed programs' settings and associated usernames and passwords
Windows\system32\config\`System.dat`	Contains additional computer system settings
Windows\system32\config\systemprofile	Contains additional NTUSER information

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Exploring the Organization of the Windows Registry (3 of 5)

Figure 5-26 Viewing HKEYs in Registry Editor

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Exploring the Organization of the Windows Registry (4 of 5)

Table 5-7 Registry HKEYs and their functions

HKEY	Function
HKEY_CLASSES_ROOT	A symbolic link to HKEY_LOCAL_MACHINE\SOFTWARE\Classes; provides file type and file extension information, URL protocol prefixes, and so forth
HKEY_CURRENT_USER	A symbolic link to HKEY_USERS; stores settings for the currently logged-on user
HKEY_LOCAL_MACHINE	Contains information about installed hardware and software
HKEY_USERS	Stores information for the currently logged-on user; only one key in this HKEY is linked to HKEY_CURRENT_USER

(*continues*)

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Exploring the Organization of the Windows Registry (5 of 5)

Table 5-7 **Registry HKEYs and their functions** (*continued*)

HKEY	Function
HKEY_CURRENT_CONFIG	A symbolic link to HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Hardware ProfileVxxxx (with xxxx representing the current hardware profile); contains hardware configuration settings
HKEY_DYN_DATA	Used only in Windows 9x/Me systems; stores hardware configuration settings

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Examining the Windows Registry (1 of 2)

- Tools with built-in or add-on Registry viewers:
  - X-Ways Forensics
  - OSForensics
  - Forensic Explorer
  - FTK

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Examining the Windows Registry (2 of 2)

Figure 5-30 Entering a search term

Source: PassMark Software, *www.osforensics.com*

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Understanding Microsoft Startup Tasks

- Learn what files are accessed when Windows starts
- This information helps you determine when a suspect's computer was last accessed
  - Important with computers that might have been used after an incident was reported

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Startup in Windows 7, Windows 8 and Windows 10

- Windows 8 and 10 are multiplatform OSs
  - Can run on desktops, laptops, tablets, and smartphones
- The boot process uses a boot configuration data (BCD) store
- The BCD contains the boot loader that initiates the system's bootstrap process
  - Press F8 or F12 when the system starts to access the Advanced Boot Options

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Startup in Windows NT and Later (1 of 5)

- All NTFS computers perform the following steps when the computer is turned on:
  - Power-on self test (POST)
  - Initial startup
  - Boot loader
  - Hardware detection and configuration
  - Kernel loading
  - User logon

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Startup in Windows NT and Later (2 of 5)

- Startup Files for Windows Vista:
  - The Ntldr program in Windows XP used to load the OS has been replaced with these three boot utilities:
    - Bootmgr.exe
    - Winload.exe
    - Winresume.exe
  - Windows Vista includes the BCD editor for modifying boot options and updating the BCD registry file
  - The BCD store replaces the Windows XP boot.ini file

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Startup in Windows NT and Later (3 of 5)

- Startup Files for Windows XP:
  - **NT Loader (NTLDR)**
  - **Boot.ini**
  - **Ntoskrnl.exe**
  - **Bootvid.dll**
  - **Hal.dll**
  - **BootSect.dos**
  - **NTDetect.com**
  - **NTBootdd.sys**
  - **Pagefile.sys**
- **Device drivers**
  - Contain instructions for the OS for hardware devices

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Startup in Windows NT and Later (4 of 5)

Table 5-8 Windows XP system files

Filename	Description
`Ntoskrnl.exe`	The XP executable and kernel
`Ntkrnlpa.exe`	The physical address support program for accessing more than 4 GB of physical RAM
`Hal.dll`	The Hardware Abstraction Layer (described earlier)
`Win32k.sys`	The kernel-mode portion of the Win32 subsystem
`Ntdll.dll`	System service dispatch stubs to executable functions and internal support functions
`Kernel32.dll`	Core Win32 subsystem DLL file
`Advapi32.dll`	Core Win32 subsystem DLL file
`User32.dll`	Core Win32 subsystem DLL file
`Gdi32.dll`	Core Win32 subsystem DLL file

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Startup in Windows NT and Later (5 of 5)

- Contamination Concerns with Windows XP
  - When you start a Windows XP NTFS workstation, several files are accessed immediately
    - The last access date and time stamp for the files change to the current date and time
  - Destroys any potential evidence
    - That shows when a Windows XP workstation was last used

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Understanding Virtual Machines (1 of 3)

- **Virtual machines**
  - Enable you to run another OS on an existing physical computer (known as the host computer) by emulating a computer's hardware environment
- A virtual machine is just a few files on your hard drive
  - Must allocate space to it
- A virtual machine recognizes components of the physical machine it's loaded on
  - Virtual OS is limited by the physical machine's OS

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Understanding Virtual Machines (2 of 3)

Figure 5-31 A virtual machine running on the host computer's desktop

Source: Oracle VirtualBox, *www.virtualbox.org*

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Understanding Virtual Machines (3 of 3)

- In digital forensics
  - Virtual machines make it possible to restore a suspect drive on your virtual machine
    - And run nonstandard software the suspect might have loaded
- From a network forensics standpoint, you need to be aware of some potential issues, such as:
  - A virtual machine used to attack another system or network

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Creating a Virtual Machine

- Common applications for creating virtual machines
  - VMware Server, VMware Player and VMware Workstation, Oracle VM VirtualBox, Microsoft Virtual PC, and Hyper-V
- Using VirtualBox
  - An open-source program (download)
- Consult with your instructor before doing the activities using VirtualBox

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Summary (1 of 3)

- When starting a suspect's computer, using boot media, such as forensic boot CDs or USB drives, you must ensure that disk evidence isn't altered
- The Master Boot Record (MBR) stores information about partitions on a disk
- Microsoft used FAT12 and FAT16 on older operating systems
- To find a hard disk's capacity, use the cylinders, heads, and sectors (CHS) calculation

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Summary (2 of 3)

- When files are deleted in a FAT file system, the hexadecimal value 0x05 is inserted in the first character of the filename in the directory
- NTFS is more versatile because it uses the Master File Table (MFT) to track file information
- Records in the MFT contain attribute IDs that store metadata about files
- In NTFS, alternate data streams can obscure information that might be of evidentiary value

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Summary (3 of 3)

- File slack, RAM slack, and drive slack are areas in which valuable information can reside on a drive
- NTFS can encrypt data with EFS and BitLocker
- NTFS can compress files, folders, or volumes
- Windows Registry keeps a record of attached hardware, user preferences, network connections, and installed software
- Virtualization software enables you to run other OSs on a host computer

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