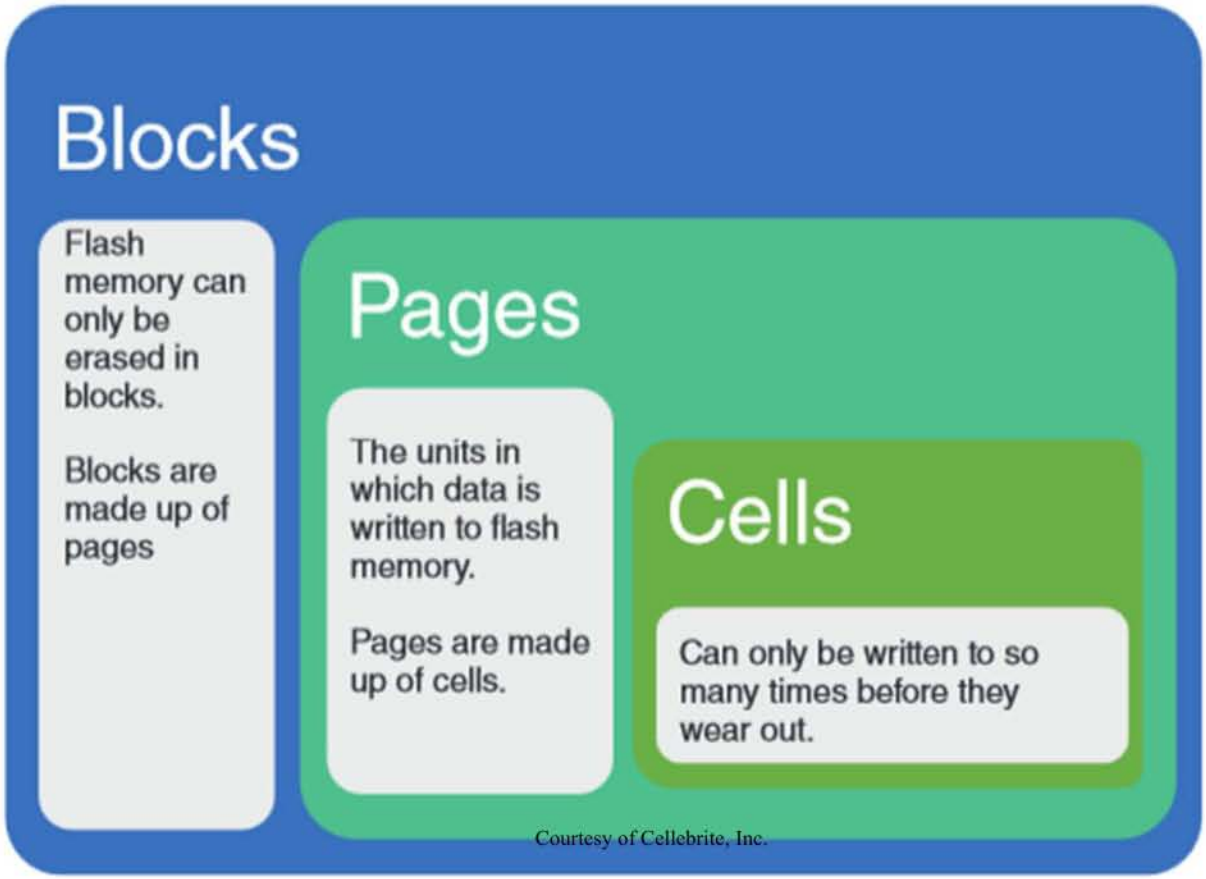
Differences of Cellular and Computer Forensics

- Memory Manager
- Write Protection
- Hash matching
- File Systems
- Seizure
- Necessity of Multiple Tools

Flash Memory Technology

- Flash memory chips used in mobile devices are different from traditional hard drives
- Flash memory cells have limited amount of read/write cycles
- Flash Memory found on mobile devices can not overwrite deleted data, the data blocks need to be prepared for the next writes

Flash Memory Technology



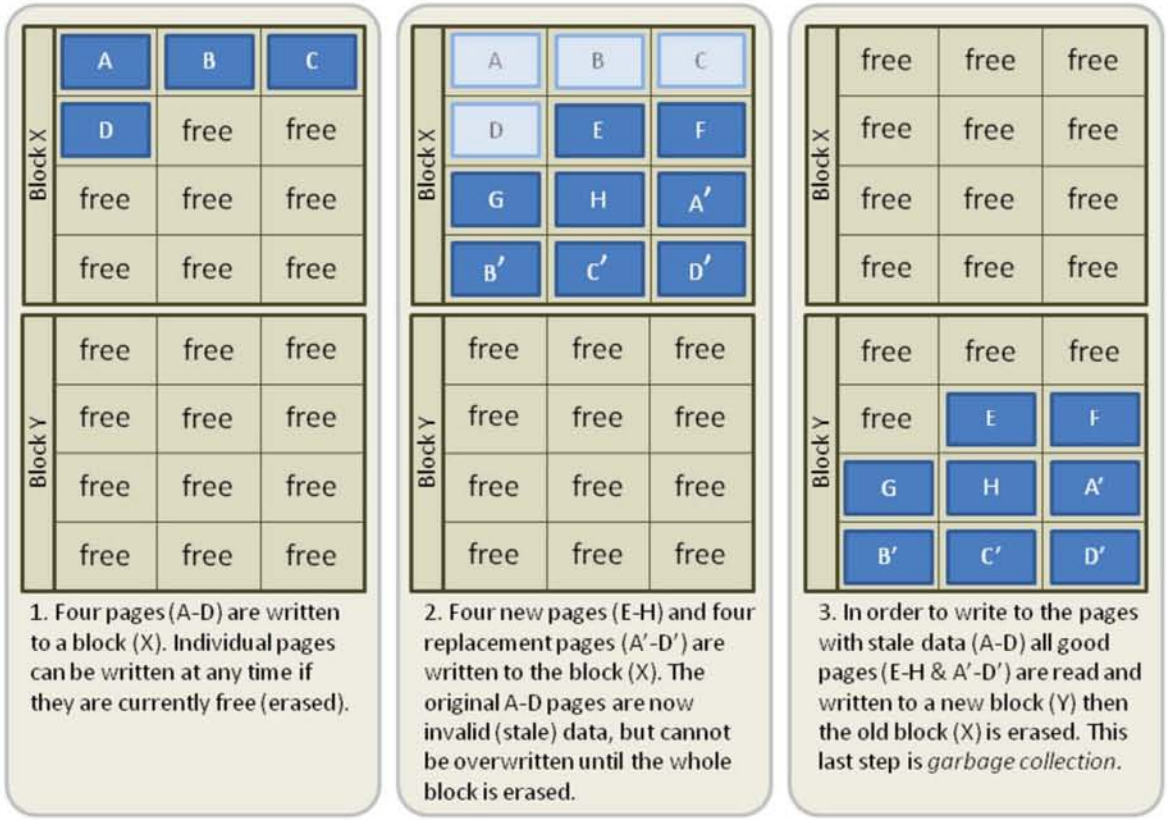
Courtesy of Cellebrite, Inc.

Flash Memory Technology

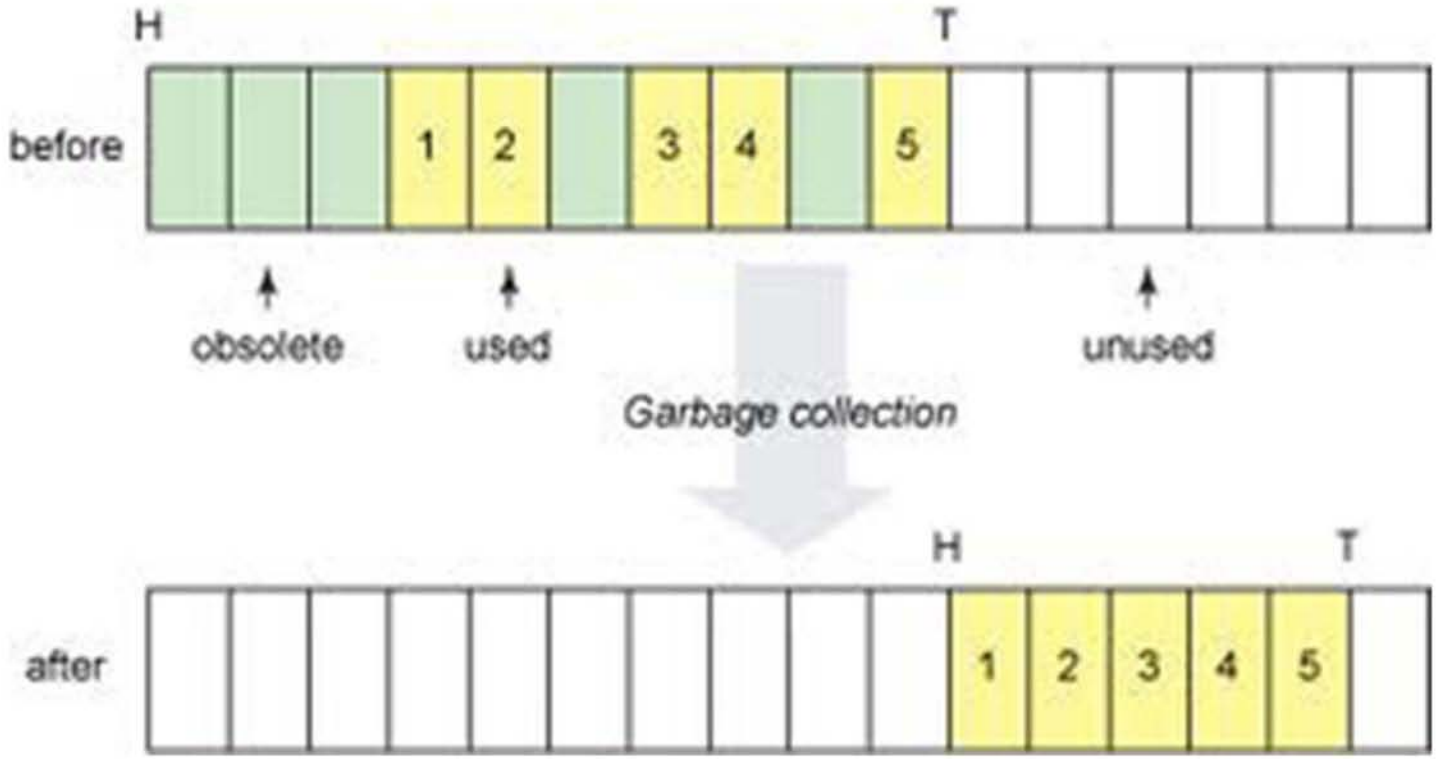
- Wear Leveling evenly distributes writes across the flash memory
- Wear leveling is necessary for the longevity of the memory
- Can be positive for forensics, greater chance for the recovery of deleted data

Flash Memory Technology

- Garbage Collection – The process of preparing blocks for writes
- Garbage collection does not necessarily occur immediately after deletion of data



Flash Memory Technology



Flash Memory Technology

- Wear leveling and garbage collection are not user generated functions
- Constant power cycles may invoke wear leveling or garbage collection, which could lead to overwriting data

Flash Memory Technology

Channels - U.S. cell providers purchase channels from the FCC, but are only provided with a limited spectrum. The providers then have to break up the channel in order for multiple users (customers) to be able to make and receive calls.

Common Handset Transmission Techniques

Several techniques exist for dividing the channel

- TDMA - Time Division Multiple Access, now GSM
- CDMA - Code Division Multiple Access
- UMTS – Updated 3g tech, aka WCDMA
- LTE – From GSM, moving everything over data

Slide 9

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, 3/1/2018

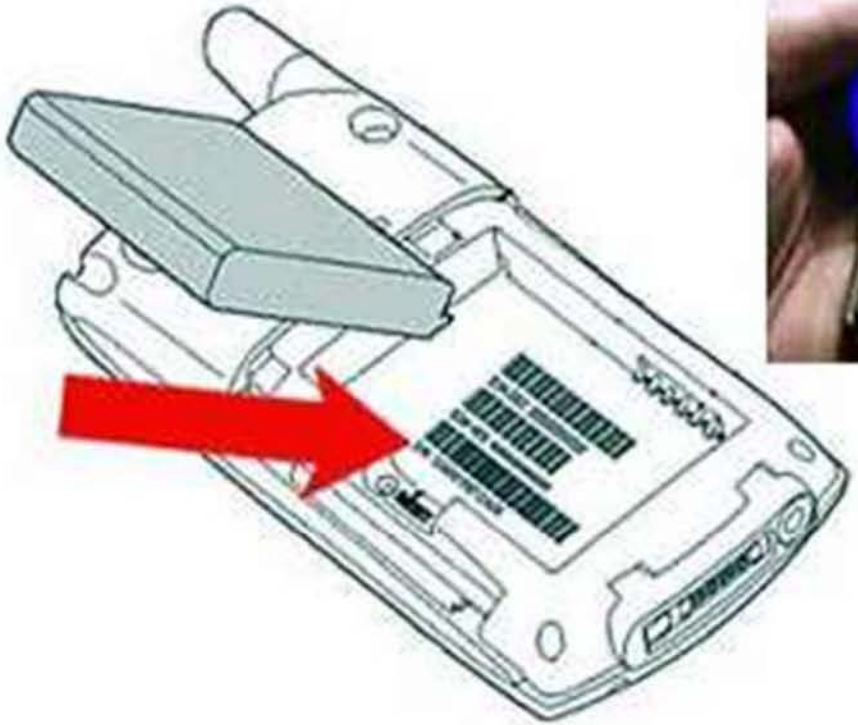
Device Identifiers - CDMA

- **Electronic Serial Number (ESN)**, ESNs are typically found written in both decimal and hexadecimal versions under a phone's battery. CDMA networks use the ESN to identify a phone and determine what subscriber account, if any, the phone is linked. ESNs are being phased out in favor of the MEID, a longer number that is compatible with the IMEI system

- **Mobile Equipment Identifier (MEID)**, the MEID is compatible with the existing IMEI number system used in GSM handsets. MEID numbers are being phased in to replace ESN numbers currently used in CDMA devices, since the pool of new ESN numbers has been virtually exhausted.

- **International Mobile Equipment Identity (IMEI)** is a number, usually unique, to identify GSM, WCDMA, and iDEN mobile phones, as well as some satellite phones. It is usually found printed inside the battery compartment of the phone

Device Identifiers - GSM



Universal Integrated Circuit Cards

- Subscriber Identity Module (SIM), a small card, contains a GSM network subscriber's account information which allows the device to authenticate to a the network
- Moving a SIM card from one phone to another allows a subscriber to switch cell phones without having to contact their mobile network carrier
- SIM cards may store limited amounts of recoverable data, such as phone numbers, SMS messages, location information (last connected tower), phone book, and subscriber information

Universal Integrated Circuit Cards

SIM – Subscriber Identity Module
CSIM – CDMA Subscriber Identity Module
USIM – Universal Subscriber Identity Module

A UICC can contain up to three applications: SIM, USIM and CSIM

SIM Cards

- Universal Subscriber Identity Module (USIM) (3GPP). The USIM brought, among other things, security improvements like the mutual authentication and longer encryption keys and an improved address book
  - USIM is found in LTE devices to allow them to connect to GSM networks
- Removable User Identity Module (R-UIM) is a card developed for devices to allow GSM devices to connect to a CDMA network
- CDMA Subscriber Identity Module (CSIM) is a card which allows CDMA devices to connect to GSM networks

SIM Cards

Authentication Key or Ki

- A 128 bit key is used to authenticate on the mobile network
- Each SIM has a unique authentication key assigned by the operator

Device Identifiers – SIM Cards

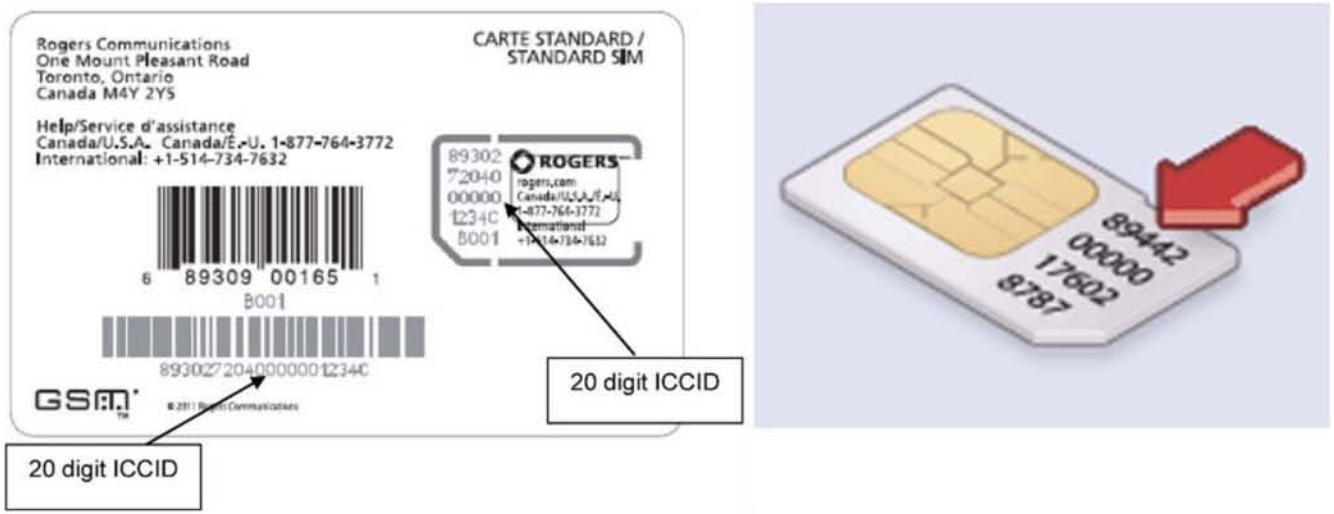
- **International Mobile Subscriber Identity (IMSI)** is a unique number associated with all GSM and UMTS network mobile phone users. It is stored in the SIM inside the phone and is sent by the phone to the network

- **ICC-ID** - Each SIM is internationally identified by its ICC-ID. ICC-IDs are stored in the SIM cards. Part of this number is usually engraved or printed on the SIM card body. Additionally, the number reveals the carrier and country of the carrier (e.g. 8901410 is AT&T in the United States)

ICC-ID

GSM - ISO Standard:

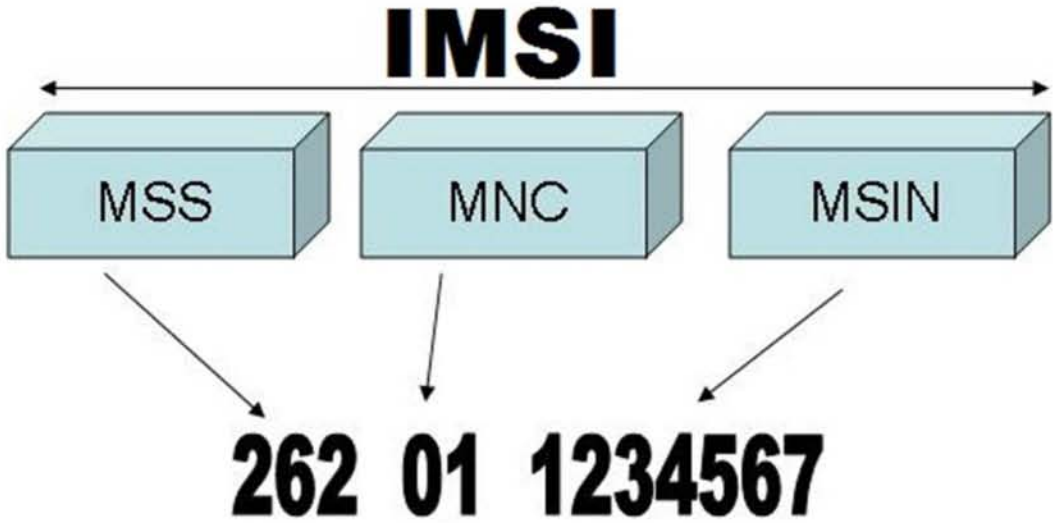
- First two digits are 89
- Next two to three digits represent the county code, e.g. 310 represents the U.S.
- Next two to three digits represent the service provider, see international numbering plans website
- Next digits (up to four-teen) is the card serial number



IMSI

GSM SIM cards:

- First two to three digits represent the mobile country code
- Next two to three is the mobile network code
- The remainder (up to ten digits) is the mobile subscriber identity number (MSIDN)



SIM Cards

Numberingplans.com - Number analysis tools

Use the on-line analysis tools for finding out information about specific numbers. Analyses can be done on phone numbers, but also on IMEI, IMSI, IPSC, and SIM numbers.

SIM Cards

- The handset will store IMSI's that were used in the handset
- The amount of IMSI's number stored varies from handset to handset

SIM Cards

Pin Locks

- Access is secured with a four digit pin number
- If an incorrect pin is entered three times then it becomes PUK locked

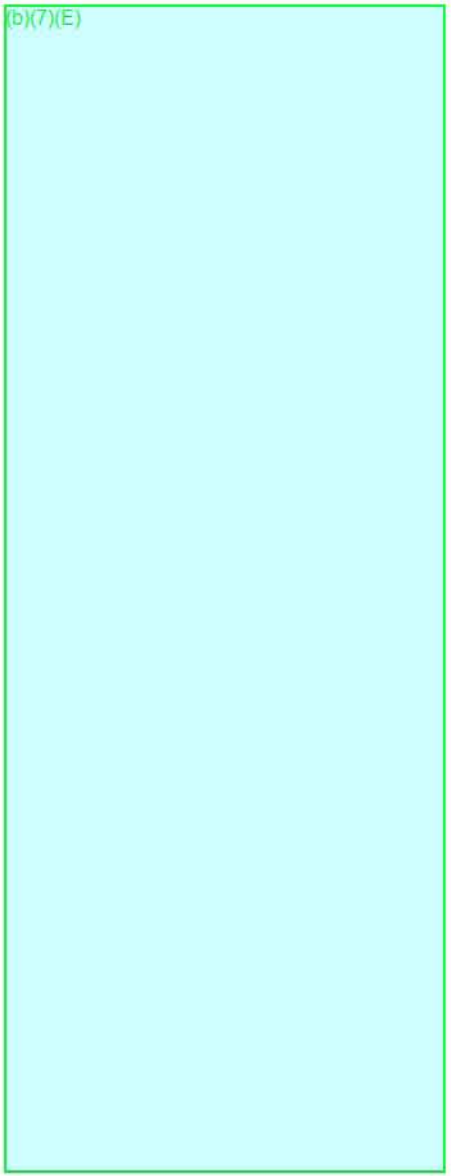
PUK Locks

- This password level security can be unlocked by a service provider (with appropriate legal process). However, if the PUK code is entered incorrectly ten times, the card is permanently locked from access
- There is no current technology available to bypass a PUK lock

SIM Cards

File System – Hierarchial

MF = Master File
DF = Dedicated File
EF = Elementary File



TCFTP

SIM Cards

ICCID

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SIM Card Entries

TCFTP

Device Handling

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Securing the Mobile Device On Scene

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Handling of a Live Mobile Device

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Reasons to Isolate from Network

- Leaving a device connected during transport will alter location and/or cell tower information
- A remote wipe command may be sent from the enterprise, provider, or user which will delete user data on the phone
- If data is still incoming to the mobile device it increases the chances that deleted information may be overwritten
    - E.g. Incoming call logs may be modified

Off Network Issues

- Phones that have been blocked from connecting to a network will boost power output trying to obtain a radio signal
    - These phones will drain battery power much faster than normal
- If you leave a seized phone on and block its connection to the cellular network it is important to put the phone on a battery charger
- Be careful that the battery charger does not function as an antenna, and carry signal from the provider to the phone
- Please note that user data can still be modified even if the handset is isolated from the network
    - Automatic functions such as alarms or appointment announcements can occur

Issues With Turning Mobile Device Off

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TCFTP

Ask for Information

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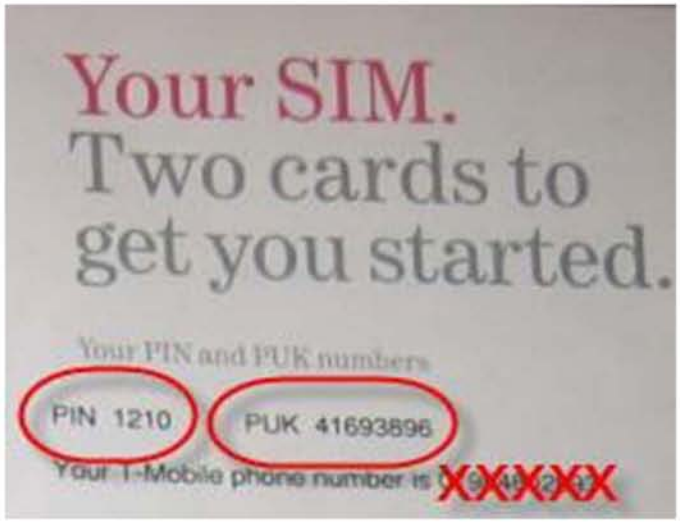
Related Hardware and Software

- Chargers, data cables, and software disks
- SIM cards, removable media, storage media adapters,
    - Some adapters will have internal storage capacity
- Do not use the card reader seized at a crime scene, to avoid compromising evidence stored in the reader's internal memory
- Cases/Packaging



Data Acquisition

Data Acquisition – Levels of Analysis

- Logical Objects
- File system
- Physical
  - Non-Invasive (i.e. bootloader, JTAG)
  - Invasive (i.e. chip-off)

Logical Objects

- A term used to describe an examination where only types of data (e.g. call logs, SMS messages) are extracted and presented to the examiner as the user would see them on the phone
- No binary data is provided to the examiner and as such there is no way to validate results
- This communication takes place based on the tool using phone based communication protocols to essentially ask the phone for each object type
- Pros: Fast acquisition, most widely supported
- Cons: No deleted data, limited content, no acquisition hashing or image file, validation only through visual inspection of the device, device needs to be unlocked

Cell Phone Objects

Examples of objects which an examiner, under the right conditions, can extract are as follows:

- Email
- Instant Messaging (IM)
- Multimedia Messaging Service (MMS)
- Short Message Service (SMS)
- Voicemail and transcribed voicemail
- App Data
- Audio and video
- Calendar entries
- Call records
- Contact or address book
- Date, time, and time zone
- Documents
- Historical location information
- Photos
- Subscriber information (through phone number)
- Web browsing activity

A Note About Messaging

SMS Traffic

Short Message Service (SMS) traffic, maximum of 160 characters, is routed from the originating phone to the tower and then on to the Short Message Service Center where the message is stored until the destination phone is found on the network. There is no guarantee from the network that the message actually made it to the recipient.

MMS

Multimedia Messaging Service (MMS) is a standard way to send messages that include multimedia content to and from mobile phones. It extends the core SMS (Short Message Service) capability that allowed exchange of text messages only up to 160 characters in length. The most popular use is to send photographs from camera-equipped handsets, although it is also popular as a method of delivering news and entertainment content including videos, pictures, text pages and ringtones.

File System

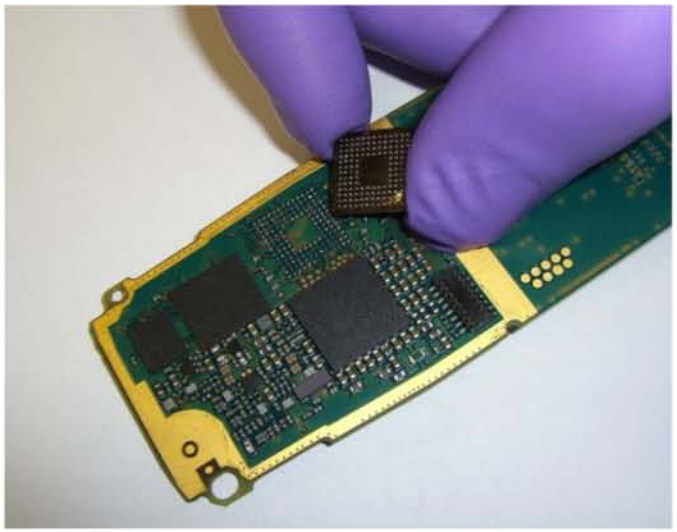
- A term used to describe an examination where an examiner can interact with the file system (viewing individual files by selected different folders, and the files with the folders) while being able to view both the tool's interpretation of the data as well as the hex code that was extracted from the phone
- Although this type of examination allows a deeper look at the data on the phone, it once again is based off of the tool "asking" the phone for its contents
- Pros: Deleted data from databases, validation of tool parsing, not dependent on tool parsing
- Cons: No deleted data from unallocated areas, longer acquisition time than logical object, no acquisition hash

Physical – Non-Invasive

- In a physical non-invasive examination, a physical read is taking place
- The tool is reading the memory directly from the phone as opposed to asking the phone to present the data to the examiner
- Reads can be accomplished through a variety of connections, protocols and bootloaders, e.g. USB, JTAG
- Pros: Acquisition hash and image file, greater opportunity to recover deleted information, ability to examine entire data area
- Cons: Long acquisition times, tool parsing support varies by phone, greater interaction with device

Physical - Invasive

- Physical - Invasive is a term used for an examination that involves the disassembling of a phone including the removal and reading of the device's memory chip
    - This forensic process is destructive and will leave the device in an inoperable state; however, the resulting image can be hashed and examined with any commercially available tool



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Data Acquisition Process

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Data Acquisition Process

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Data Acquisition Process

Extraction Process

- Logical Objects Acquisition - Application Programming Interface (API)
  - Interface which allows 3rd party apps to communicate with the device
  - Forensic tools will load an application on the device and then make calls for data objects
  - The API of the device is what determines which objects can be accessed, based on permission
  - May require user interaction to uninstall program

- Physical Acquisition - Bootloaders
  - Small piece of code is loaded into RAM at start up
  - Prevents the device from continuing into its normal boot procedure
  - Executes command to read memory
  - May require device to be in recovery or download mode
  - Does not leave remnants of its use

Extraction Process

- USB Debugging
  - Android Debug Bridge (ADB) commands are used to acquire the file system
  - USB Debugging must be enabled on Android devices
    - USB Debugging setting is found within Developer Options
    - Developer Options was viewable within Settings in earlier Android versions
    - If no Developer Options within Settings folder, navigate to 'About Device' and tap 'Device Build' seven times for Developer Options to appear in Settings

- Device Backup
  - Process in which a backup is made of a device and the data from the backup is analyzed
  - iOS uses Apple File Connection (AFC), which is the iTunes backup API
  - Limited acquisition depending on what objects are included in the backup
  - Backup files may be encrypted, which may interfere with the process

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Power While Processing

Battery Issues

- Battery is fully discharged
- Battery is missing
- Battery is not holding a charge

Tools

- Power Supply
- Cellebrite Power Up Cable

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Power While Processing

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Smart Phones

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iOS

- When an iPhone battery fully discharges, once power is restored, the clock will reset to UNIX epoch (December 31st, 1969)
- Once the iPhone is allowed to connect to a provider or wifi network, the time will update
- Artifacts modified before the phone connects to a network will display date and time stamps from 1969 or 1970

iOS Security

Secure Boot Chain

- Startup process consists of components that are cryptographically signed by Apple
- Each step of the startup process must be validated before proceeding to the next step
- If any step of the startup process fails, the device is placed into recovery mode and the connect to iTunes logo is displayed on the screen

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Data Protection

- On the fly decryption
- Device's Unique Identifier (UID) is fused into processor at manufacturing and no record is logged by Apple or any other part manufacturer
- UID allows data to be tied to a particular device – Eliminates chip off process
- iOS consists of a hierarchy of keys, based on the hardware encryption technologies built into each iOS device

iOS Security

4 Levels of Data Protection – iOS 8

- No Protection
  - App data is protected only by UID and accessible when first powering on device
  - Find My iPhone
- Protected until First User Authentication
  - App data is protected until device is unlocked
  - Default for 3rd Party Apps not assigned another classification
- Protected unless Open
  - App data is protected unless the App itself is open
- Complete Protection
  - App data is always protected
  - Apple Mail

iOS Artifact Locations

- The Applications folder holds all the user installed applications for the device, requires individual parsing
  - Chat logs from ICQ clients
  - Address books from Facebook
  - Photographs and documents stored by various applications
- Application folders are identified by a GUID and not an application name
- Processes exist to translate these GUIDs to the actual application name
- In practice, it is easier to open each folder and read the application name.app that is stored in the root of the folder

iOS Artifact Locations

- Each application folder typically contains three sub folders
  - Application
  - Documents
  - Preferences

- These folders, particularly the Documents folder, will hold the more useful database or other data files the investigator will be interested in

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- Also of note, the sql databases may hold deleted information

- If necessary, the files can be opened in a hex editor and searched by keyword, visual inspection, or third party tools

Android

- When examining an Android phone, an examiner should image any SD cards present first
  - Much of the saved media will be present on the SD card

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Blackberry

- Blackberry passwords are difficult to circumvent
  - An examiner should not attempt to guess the password as too many attempts will initiate a wipe

- Every personal Blackberry device seized with a password enabled will require JTAG or chip off work
  - Will not defeat encryption only device lock

- If a Blackberry was a unit on a Blackberry Enterprise Server (BES) network, there will be valuable information that can be gathered from the BES server
  - A BES administrator can reset the password on the device allowing the examiner access

Blackberry

- A Blackberry backup file is saved as a *.ipd file

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- Do not use Blackberry Desktop Manager to extract information from a Blackberry
  - The Blackberry will sync with the examiner's computer clock
  - This could erase data on the device

- Blackberry OS 10 is based on the QNX file system and support for parsing this file system is limited

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Considerations

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Considerations

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Legal Considerations

- Review Search Warrants:
  - Time Constraints
  - Scope of Warrant

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- U.S. v Riley - No search incident to arrest

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- Terminology
  - Report
  - Testimony
  - Extraction v Image

References

- (b)(7)(E)
- http://www.mobileforensicscentral.com/mfc/
- http://www.swgde.org/
- http://www.phonescoop.com/phones/finder.php
- http://www.fonefinder.net/
- http://www.numberingplans.com/?page=home
- http://www.appleexaminer.com
- http://www.apple.com/legal/more-resources/law-enforcement/
- Apple Law Enforcement Liaison - Law_enforcement_esc@apple.com

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Questions?

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Drones

- Seizure
- Disassembly
- Data Storage Locations
- Extraction
- Analysis

Drones
Seizure

- You may need more than just the Drone
- Cell Phone or Tablet
- Cloud Storage Account
- SD Cards
- Cameras
- Keep all items off network!

Drones
Disassembly

- Youtube
- Cellebrite Manual
- Owners Manual

Drones
Data Locations

- Chipset
- SD Card
- Camera/ Camera SD Card
- PC/Lap Top
- Cell Phone or Tablet
- Cloud

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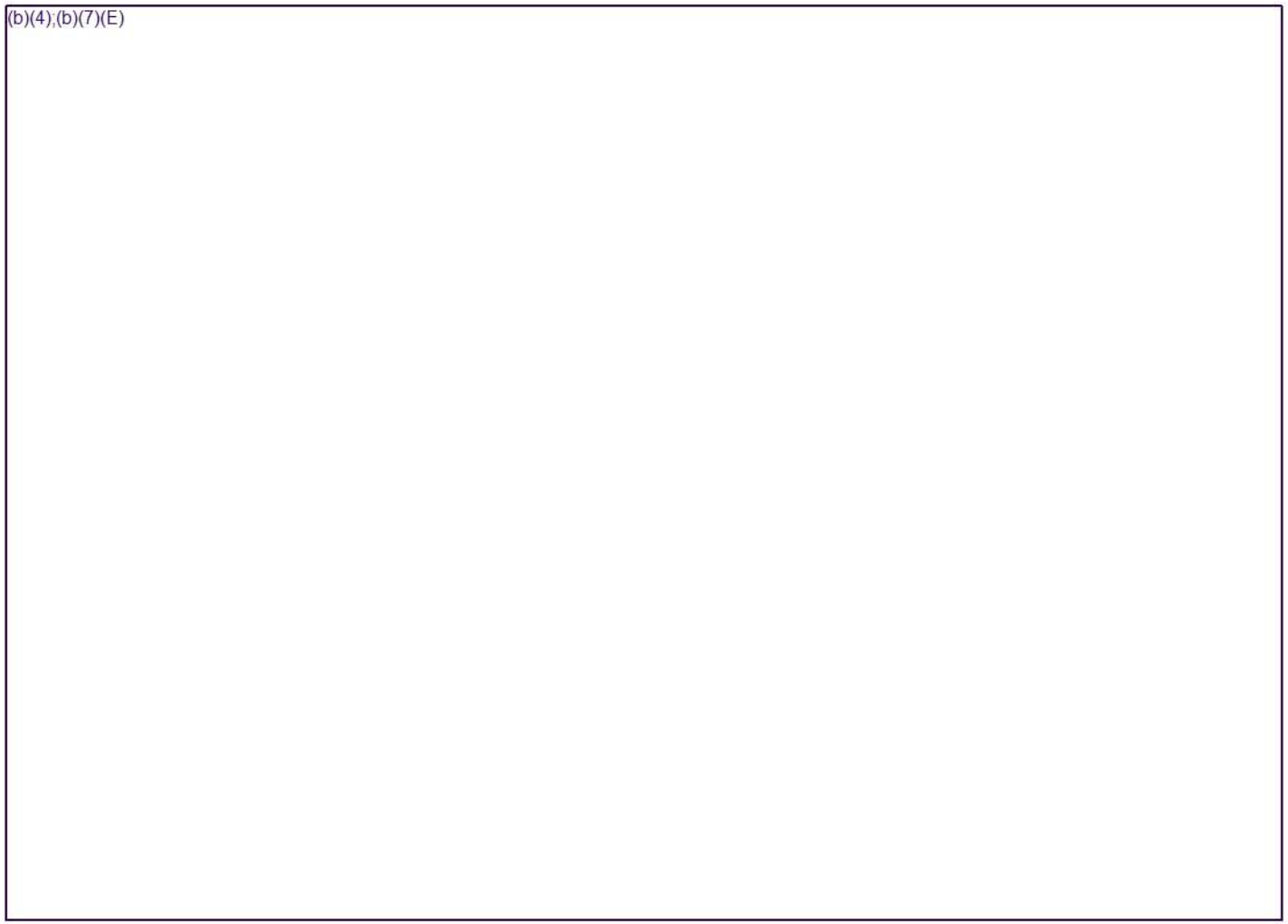

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Questions?

Contract ID	Award/IDV Type	Vendor Name	Date Signed	Contracting Office Name
HSCEMD17P00012	PURCHASE ORDER	CELLEBRITE INC.	9-Mar-17	MISSION SUPPORT DALLAS
HSCEMD16J00044	DELIVERY ORDER	CELLEBRITE USA CORP	17-Aug-16	MISSION SUPPORT DALLAS
HSCEMD16J00037	DELIVERY ORDER	CELLEBRITE USA CORP	1-Aug-16	MISSION SUPPORT DALLAS
HSCEMD16P00017	PURCHASE ORDER	GUIDANCE SOFTWARE, INC.	11-Feb-16	INVESTIGATIONS AND OPERATIONS SUPPORT DALLAS
HSCEMD16P00033	PURCHASE ORDER	CELLEBRITE USA CORP	25-Apr-16	MISSION SUPPORT DALLAS
HSCETE16F00037	DELIVERY ORDER	MSAB INCORPORATED	27-Jul-16	INFORMATION TECHNOLOGY DIVISION
HSCEMD16J00021	DELIVERY ORDER	CELLEBRITE USA CORP	29-Jun-16	MISSION SUPPORT DALLAS
HSCETE16P00035	PURCHASE ORDER	SUSTEEN INC	26-Aug-16	INFORMATION TECHNOLOGY DIVISION
HSCETE17F00004	DELIVERY ORDER	OXYGEN FORENSICS INC.	3-Mar-17	INFORMATION TECHNOLOGY DIVISION
HSCEMD16P00033	PURCHASE ORDER	CELLEBRITE USA CORP	15-Jun-16	MISSION SUPPORT DALLAS
HSCEMD16J00002	DELIVERY ORDER	CELLEBRITE USA CORP	22-Jan-16	INVESTIGATIONS AND OPERATIONS SUPPORT DALLAS
HSCETE17J00166	DELIVERY ORDER	CELLEBRITE USA CORP	25-May-17	INFORMATION TECHNOLOGY DIVISION
HSCEMD16J00036	DELIVERY ORDER	CELLEBRITE USA CORP	1-Aug-16	MISSION SUPPORT DALLAS
HSCETE16J00048	DELIVERY ORDER	CELLEBRITE USA CORP	2-Mar-16	INFORMATION TECHNOLOGY DIVISION
HSCEMD16J00034	DELIVERY ORDER	CELLEBRITE USA CORP	28-Jul-16	MISSION SUPPORT DALLAS
HSCEMD16P00092	PURCHASE ORDER	CELLEBRITE USA CORP	12-Aug-16	MISSION SUPPORT DALLAS
HSCETE16P00006	PURCHASE ORDER	MSAB INCORPORATED	2-Mar-16	INFORMATION TECHNOLOGY COMMODITIES
HSCEMD16P00057	PURCHASE ORDER	CELLEBRITE USA CORP	1-Jul-16	MISSION SUPPORT DALLAS
HSCEMD16J00049	DELIVERY ORDER	CELLEBRITE USA CORP	22-Aug-16	MISSION SUPPORT DALLAS
HSCEMD17J00025	DELIVERY ORDER	CELLEBRITE USA CORP	28-Apr-17	MISSION SUPPORT DALLAS
HSCEMD16J00026	DELIVERY ORDER	CELLEBRITE USA CORP	13-Jul-16	MISSION SUPPORT DALLAS
HSCEMD16J00047	DELIVERY ORDER	CELLEBRITE USA CORP	7-Sep-16	MISSION SUPPORT DALLAS
HSCEMD16J00005	DELIVERY ORDER	CELLEBRITE USA CORP	20-Apr-16	MISSION SUPPORT DALLAS
HSCETE17F00004	DELIVERY ORDER	OXYGEN FORENSICS INC.	29-Mar-17	INFORMATION TECHNOLOGY DIVISION

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delivering mobile expertise

What Happens When You Press that Button?

Explaining Cellebrite UFED Data Extraction Processes

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Table of Contents

UFED Basics 3

Extraction Types 4

Logical extraction 5

Logical extractions of iOS devices 5

How does the examiner know which method to choose? 6

File system extractions 7

Decoding 7

Can decoding miss some data? 8

Wear leveling and garbage collection 8

Physical extraction 9

Boot loaders 10

Why Cellebrite boot loaders are forensically sound 10

Other physical extraction methodologies 11

Authentication and reporting 12

In Conclusion 13

Glossary of Terms 14

UFED Basics

Cellebrite makes mobile device evidence extraction available on two different platforms: the UFED Touch, or the UFED 4PC. The UFED 4PC is extraction software that can be installed on any PC platform, accessible and securable in the same way as any other PC-based software.

The UFED Touch consists of standalone proprietary hardware, with the UFED software installed on the Microsoft® Windows® Embedded Standard 2009 platform. Users can only access limited functionality—shut down, log on/off—and cannot access the Windows operating system.

The UFED Touch and UFED 4PC interfaces and architecture are exactly the same. UFED software is designed to execute only read commands, and to prevent the opportunity to alter it to issue write commands to mobile devices. While the operator should document which platform, version, and extraction type were used, no other differences fundamentally exist between UFED Touch and UFED 4PC extractions.

UFED operators should also adhere to the same best practices for both Touch and 4PC platforms that they do for any forensic computer installation:

- Isolate the forensic machine from the Internet while performing forensic examinations.
- Don't store digital evidence on any computer that is or will be connected to the Internet at any time.
- If performing an over-the-air software update, the operator should not simultaneously have an evidence device or evidence storage connected to the forensic machine.
- Extract mobile device evidence to a storage medium specifically designed and prepared for that purpose: a Flash drive, external hard drive, a location on an internal forensic network, or internal drive or partition within the forensic computer.

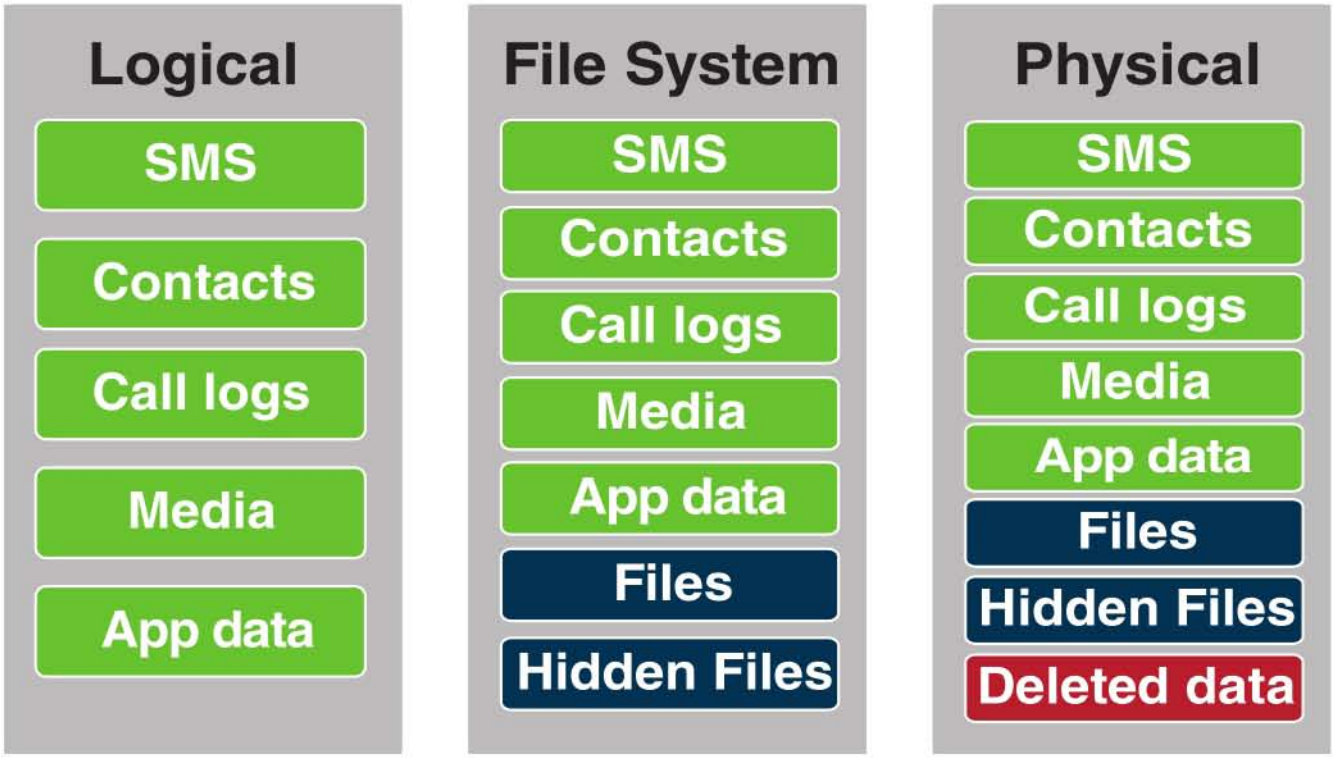
As of April 2014, a permission management feature was included in the UFED 3.0 update. UFED Permission Management is an optional feature that allows forensic lab administrators to enforce operator accountability and limit search scopes, either based on extraction type or to specific data types.

This way, administrators can control who performs extractions based on their level of training, job responsibilities, or other "right to know, need to know" criteria as specified in their organization's policies or standard operating procedures. Cellebrite encourages all customers who distribute mobile evidence collection in their organizations to use UFED Permission Management.

Extraction Types

There are two different methods of mobile device data extraction: logical and physical. (A third extraction type, the file system extraction, technically falls under the "logical" heading.) Different data types, if they are supported for the device, are available from each extraction category, as shown in the graphic below.

In the rare instances when the extraction fails, the user must simply start the extraction over. The failure does not affect the quality or integrity of evidentiary data because it only affects the transmission of data from the device, not the data on the device.



In most cases, mobile phones are connected to the UFED device via a USB cable connection, which communicates with the phone to extract its data. The use of a USB connection provides a proven reliable channel upon which to copy data from evidence device to the forensic image.

Depending on the subject phone's OS, logical extractions may instead use USB/Bluetooth protocol APIs or, with older devices, serial protocols in order to extract the data. Operators should document which connection type they used for each extraction.

Logical extraction

Logical extraction of data is performed, for the most part, through a designated API (Application Programming Interface), available from the device vendor. Just as the API allows commercial third-party apps to communicate with the device OS (operating system), it also enables forensically sound data extraction.

Upon connection, the UFED loads the relevant vendor API to the device. The UFED then makes read-only API calls to request data from the phone. The phone replies to valid API requests to extract designated content items such as text messages (SMS), phonebook entries, pictures, etc.

From a technical standpoint, API-based logical extraction is straightforward to implement and the results are provided in a readable format. However, the logical method is limited to the scope of content the specific vendor has made available through its API.

Pictures taken via third-party app, for example, are likely stored in a folder that is different from the default.

Therefore, the API will not see that they exist and will not make them available to a UFED logical extraction. To access this data, an examiner would need to access the file system and examine the data associated with the particular application in question. In addition, not all devices have a common interface to extract emails, and the API will not be applicable.

Logical extractions of iOS devices

In July 2011 Cellebrite identified the need for a faster means of extracting data from iOS devices. The pre-UFED Touch hardware, the UFED Classic or UFED 36, could take many hours to perform these extractions. Cellebrite solved the problem by implementing iOS extraction within its analysis software, UFED Physical Analyzer, as of version 2.1.

It is possible for iOS device extractions to differ between the UFED Touch/UFED 4PC interface and the UFED Physical Analyzer.

That's because the UFED Touch/UFED 4PC obtains the Apple iTunes backup interface using its API, the Apple File Connection (AFC)—the same interface used to back up the device to a computer.

File system extraction with UFED Physical Analyzer is almost identical to physical extraction in that it relies on a boot loader to access the device's memory; however, rather than obtain a bit-for-bit image including unallocated space, the software extracts only the device file system. This extraction process is proprietary rather than dependent on Apple's API.

Moreover, UFED Physical Analyzer makes three different types of iTunes backup ("Advanced Logical") extractions possible.

- **Method 1** like the UFED Touch, relies on the iTunes backup using Apple's backup infrastructure
- **Method 2** extracts backup data if the device is encrypted and the UFED operator does not know the device passcode
- **Method 3** is recommended for both encrypted and unencrypted jailbroken devices

How does the examiner know which method to choose?

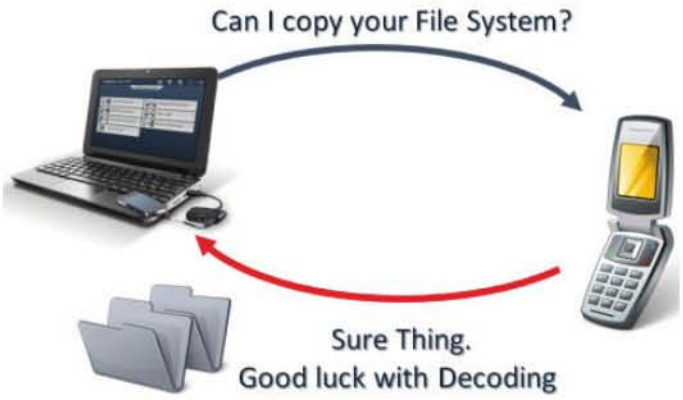
The UFED Physical Analyzer interface automatically selects the appropriate extraction method—based on the device's backup configuration, jailbreak status, model, and iOS version—but the operator has the option to use other methods as well, and to combine the data sets. The interface explains which data is available with each extraction method. Users should document which method(s) they used and why they used it, when possible.

File system extraction

Another logical method extends the examiner's reach to the phone's live partition. Available with the UFED Ultimate license, a file system extraction uses different device-specific methods to copy the file system. While these are comparable to the API used in logical methods, they use different sets of built-in protocols, depending on the OS. The mix of protocols often differs from device family to device family.

In some cases, not only with iOS devices as described above but also with Android and BlackBerry® models, it may be necessary to rely on device backup files to make available files, hidden files, and other data that is not necessarily accessible through the phone's API.

This can include some user deleted and hidden data contained within SQLite databases, including web history, email headers, EXIF data on images, and system data.



Decoding

The decoding process translates the raw data within a database file to a recognizable format. Data extracted via APIs and backups require no decoding because it is intrinsic to these methods, which present media files such as pictures and videos as they are seen on the device.

However, data within other database files, such as those that contain text messages, must be separately decoded to parse out the messages. UFED Physical Analyzer automatically performs this decoding process, presenting decoded data both in human-readable format, and as raw data as stored in the device's memory.

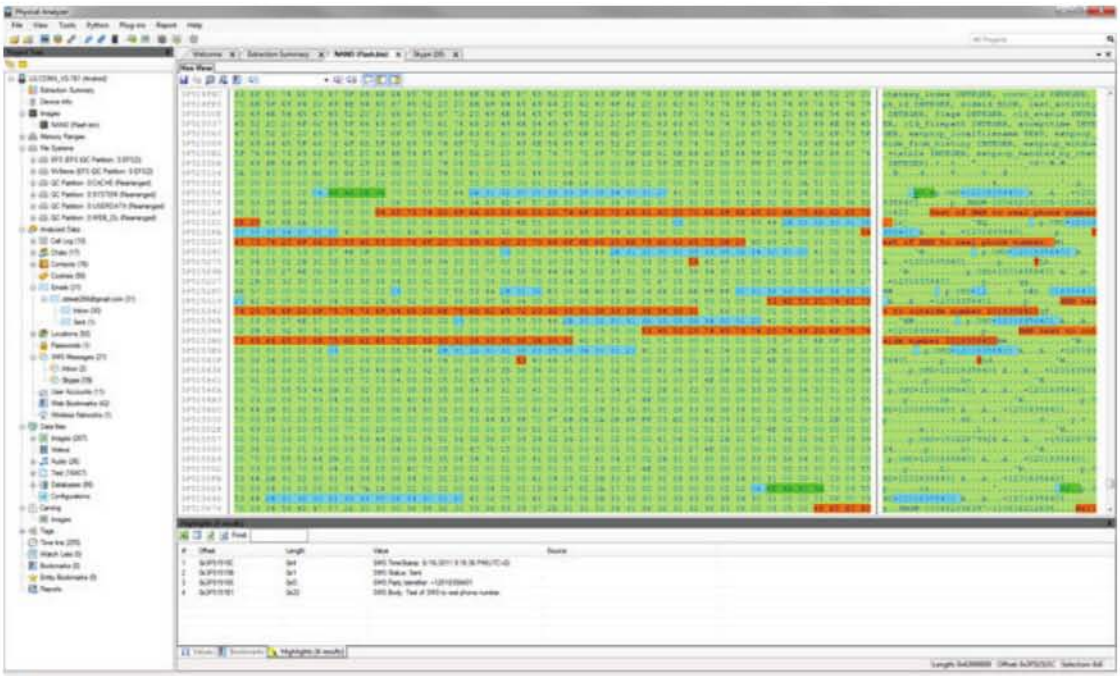


Figure 1: UFED Physical Analyzer displays data in human-readable format, as well as in its raw state as stored on the device.

Can decoding miss some data?

It is possible for automatic decoding to miss some data. Decoding relies on programming that tells the software to look for and interpret data in certain places on the device, based on patterns from previous make, model and operating system versions. Cellebrite's access to mobile device manufacturers and carriers makes this easier for the UFED to accomplish than it does for other tools, but it is not a guarantee.

This is particularly an issue when it comes to app data, which is stored within SQLite database files and plist files on iOS devices. UFED Physical Analyzer identifies that these files exist, and certain database file extractions from some Android and BlackBerry® smartphone apps — including Facebook, Skype, Twitter, Viber, Yahoo messenger, Whatsapp, TigerText and others—are even possible through UFED Logical.

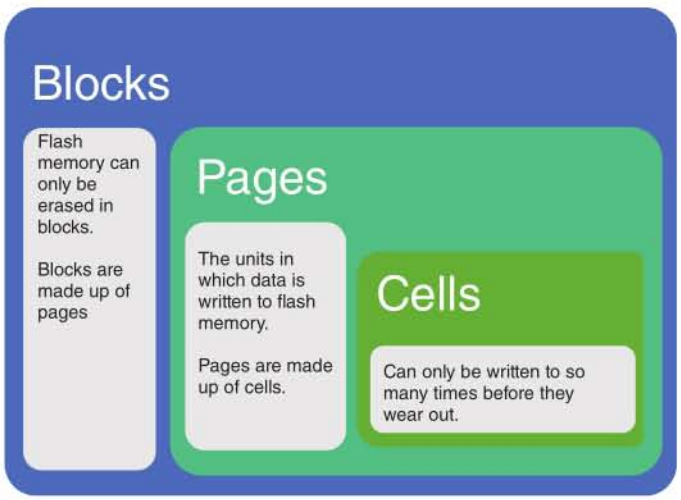
This data also requires decoding through the process described above. However, it is unfeasible, due to the large number of apps available, for UFED Physical Analyzer software to be programmed to parse every SQLite database file that is present. If a database exists that UFED Physical Analyzer knows to look for—if it supports decoding for a particular app—it will decode and present the data. However, an obscure or unsupported app will not show up in the "analyzed items" section of the Physical Analyzer software.

Wear leveling and garbage collection

Unlike traditional hard disk drives, which simply overwrite unneeded data blocks with new data, mobile devices' flash memory must erase unneeded data blocks before new data can be written.

This process extends the memory life, storing data more efficiently by distributing it (and thus, write/erase cycles) evenly across each solid state drive (SSD) chip. Known as wear leveling, this process complicates the extraction and decoding process because it is possible for data to look different from one extraction to the next.

This is because of "garbage collection," the process of erasing the unneeded data blocks. Blocks are composed of pages, where data is written, but the data can only be erased in blocks. When pages within a block become unnecessary, wear leveling rewrites the "good" pages into an empty block, and garbage collection erases the unneeded blocks.



Garbage collection happens in the background, but its speed and frequency can vary from SSD to SSD. As a result, it may be that the examiner performs an extraction before garbage collection has occurred. If this happens, deleted data may be written multiple times in multiple locations on the SSD.
(See Figure 2.)

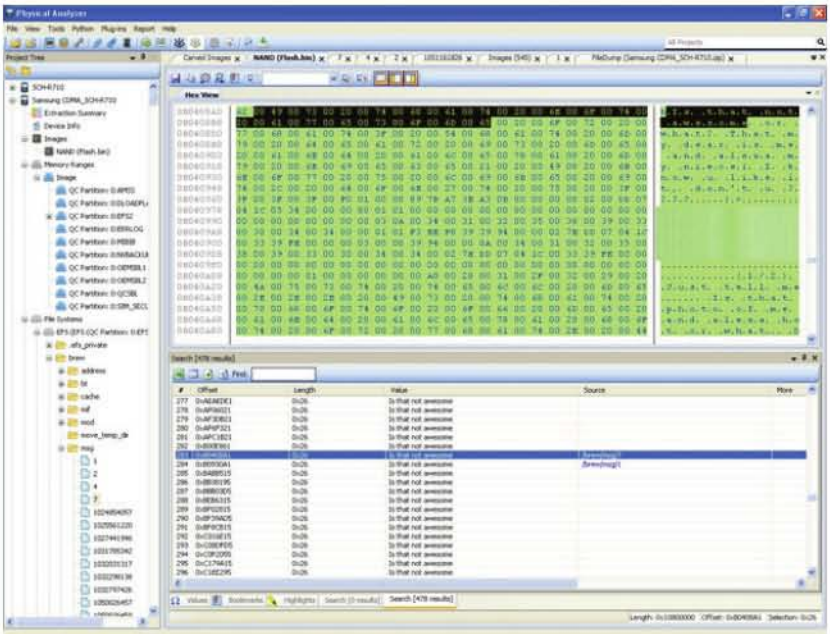


Figure 1: wear leveling in action. the same text message shows up multiple times because garbage collection has not yet happened

While this can be beneficial in terms of recovering deleted data, it can also complicate forensic exams—not only by increasing the amount of data to be parsed, but also by potentially changing the pattern on which the decoding process relies to parse data. It is possible for wear leveling to affect the offset (found in the hex code) so that it doesn't match the pattern in the decoding program.

Whether due to a lack of decoding or wear leveling, the data is likely present in the extraction, but forensic examiners should be prepared to use the hexadecimal viewer within UFED Physical Analyzer to carve for additional data if needed. Additionally, they should be prepared to explain why the tool extracted but did not decode the data, and if possible, how they validated that the carved data was stored on the device.

Physical extraction

To allow the most comprehensive and detailed analysis of the device, Cellebrite's physical extraction capability accesses the additional data layers, in both allocated and unallocated space, that construct the phone's physical memory. These layers include three different groups of content pertinent to investigators:

1. "Logical" content unavailable through API (e.g. call logs on smartphones and feature phones)

2. Deleted content

3. Content that the phone collects without any user action (and sometimes without user knowledge). For example: wi-fi networks, GPS locations, web history, email headers and EXIF data on images, and system data.

The physical extraction allows the examiner to access this data by creating a bit-for-bit copy of the mobile device's flash memory. As with the file system extraction, the data within this copy can be decoded via UFED Physical Analyzer. Seeing where the data is located within the device's memory enables the analyst to interpret the data.

Boot loaders

A common method used to physically extract binary files from mobile phones is through "rescue mode" or "download mode". Operating in this mode, mobile phones are designed to allow the insertion of a small piece of code, called boot loaders, into the RAM during start-up.

In the commercial world, this allows the operator to use a product called a "flasher box" to insert the boot loader and overwrite the device's flash memory, so as to upgrade the device or change service providers.

Although flasher boxes have been successfully used in a forensic context, they were not developed to be forensic tools. They are not "read-only" devices, and as a result they make it possible for unskilled users to make inadvertent changes to the evidence.

Some mobile forensic products incorporate these third-party boot loaders. However, this is a "black box" solution because there is no access to the device's source code.

The utilization of third-party boot loaders may involve risks of modifying the evidence and in some cases even cause phone malfunction.

Why Cellebrite boot loaders are forensically sound

While Cellebrite relies on the boot loader concept, its boot loaders are designed in-house around each individual device platform with its variety of chipsets, peripherals, memory chip interfaces, and USB/serial controllers to be efficient and deliver quick, accurate results using a repeatable, reproducible methodology. By controlling every part of the code running on the device, Cellebrite ensures that the process is non-intrusive and that nothing in the device's user partition is changed.

It also avoids data integrity concerns associated with jailbreaking an iOS device, rooting an Android, or other methods that bypass a smartphone's factory settings, including built-in security and other restrictions, to provide administrative "root" access to its operating system.

During the initial stage of the device's booting, the UFED sends the boot loader to the device's RAM memory. The device will start running the boot loader, but will not continue its regular booting procedure into the OS. The Cellebrite boot loaders then execute "read only" actions that extract evidence from mobile devices and leave no artifacts behind.

Each boot loader is specifically designed to read the contents of the device's memory, and send it back to the UFED.

In the majority of devices, Cellebrite's proprietary boot loader can bypass all security mechanisms, even if the device is locked, without jailbreaking, rooting or flashing the device. Because the boot loader contains nothing but code used to read the various memory chips on the device, and does not write to the memory chips on the device data at any stage during or after the extraction process, the data extraction and passcode bypass processes are forensically sound.

Other physical extraction methodologies

Even so, newer devices, including some Android smartphones, don't have a built-in functionality to upload boot loaders.
In some cases this may necessitate "temporary rooting" in order to gain access to the information. During this process, Cellebrite clients are uploaded to the device to enable temporary rooting and thus, extraction. Following the extraction, the client is uninstalled and the device boots as usual, non-rooted.

In other instances, UFED users have the option to use a different type of client. This can leave a footprint in the user data partition, notably the potential for writing to small, unallocated areas of the storage medium. The client is installed in the next available bit of unallocated space, which then becomes allocated for that purpose.

This type of installation is comparable to walking into a snowy crime scene to retrieve a murder weapon. The investigator may leave his or her own footprints behind, but this necessity is acceptable in court as long as it is carefully documented. As a result, the UFED prompts users by first asking if they want to install a client.

In addition, the UFED has a setting that by default uninstalls the client after it is written to the device.

While this is useful for intelligence professionals who must operate covertly, law enforcement who use the client should follow their department's protocol about whether or not to uninstall the client, or should document its use and whether or not they uninstalled it.

Some agencies, for example, may require examiners to always disable the "automatic uninstall" setting, declare and document its use and leave the client in place. Other agencies may require this action only for suspect phones, but allow the client to be uninstalled from a victim's phone as long as its use is documented.

Likewise, another family of several LG phones (a very small percentage) require, when the device is locked and there is no other way to access the data, flashing of a proprietary boot loader to the phone.

This necessitates rewriting the phone's memory, permanently changing the device boot loader to Cellebrite's own.

The UFED warns the user when this is about to happen, and still does not change any user data. The chance of damaging the device in this case is very low; there is a small chance of overwriting data in unallocated space. Examiners should document the situations in which this is necessary, and why.

Authentication and reporting

Once logical, file system, and physical extractions are complete, the UFED generates an extraction file, along with a .UFD (text) file that tells UFED Physical Analyzer what the extraction is. The .UFD file contains information about the extraction, such as which UFED was used (including its serial number); start time, finish time, and date; and hash information. With iOS physical extractions, the .UFD file also contains decryption keys. For binary images, it may contain some information to ease the decoding procedure.

For logical extractions, the .UFD file references a .ZIP or backup file; for physical extractions, the .UFD file references an .IMG (image) file or a .BIN (binary) image file, depending on how the extraction was performed and on which platform.

Any data which the UFED extracts is hashed using SHA256 and/or MD5 algorithms, which helps to maintain data authenticity. These algorithms are included within the .UFD file.

However, UFED Physical Analyzer does not create a forensic "container" comparable to an EnCase .E01 file.

As a last step, UFED Physical Analyzer creates a report. Report formats can vary, with logical, file system or physical extractions reported in the UFED report package (UFDR), Microsoft Word® or Excel®, Open Document Format (ODF), HTML, PDF, or XML files.

When necessary, some of these formats can be imported into other forensic and data management tools for additional analysis.

For attorneys and other authorized personnel, Cellebrite makes available a free application, UFED Reader, available in the installation package with each UFED license. UFED Reader allows anyone to view, search and filter results from the .UFDR report package. Interested attorneys should ask licensed users to download and send a copy of UFED Reader.

In Conclusion

The extraction processes employed by Cellebrite UFED can seem complex, and it is wise to ensure that the investigators or examiners being called as witnesses have a good enough grasp of the technology to explain it in a way that a jury can understand.

To this end, Cellebrite strongly encourages all users to attend certification training in order to best understand—and explain—how to extract, decode, analyze and document mobile device evidence using these advanced methodologies.

Certification training is available worldwide and in multiple delivery modes, including online and in-class. To learn more, visit: **http://www.cellebritelearningcenter.com.**

Glossary of Terms

ADB: Android Debugging Bridge. A command line, client/server tool that allows developers to communicate with an Android device. ADB can be used to install and uninstall apps, run shell commands, backup and restore a device, and so on. In a mobile forensics context it can be important, in some makes and models, to enabling physical and file system extractions from Android devices.

Allocated space: The area on a device's memory that stores data in an organized manner, and contains its operating system and user data. Logical extractions obtain data from allocated space only.

API: Application Programming Interface. Specifies how apps and firmware on a mobile device should interact with one another.

Boot loader: A small piece of code that is inserted into the RAM during start-up. In the commercial wireless world, this allows flashing of firmware. In the forensic world, it allows a non-intrusive means of accessing and copying user data into a forensic image.

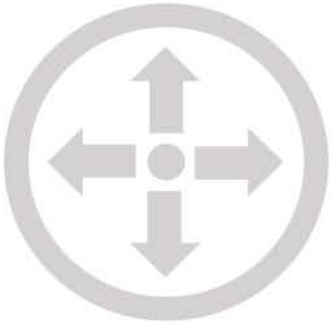
Carving: The process of finding data contained within the hexadecimal code, apart from what the forensic software has automatically offered. Carving can become necessary when the forensic tool parses data from unsupported apps, with deleted data including images, and other situations with file system and physical extractions.

Client/agent: A client is used during logical extractions. It is a very small application that is temporarily installed on a limited number of Android, older Windows Mobile, Palm OS, and Symbian models. The client is unlike a boot loader in that, rather than be installed to the device RAM, it acts like any other third-party app by installing to the device ROM. It does not overwrite any data; it will not install, for example, on a device whose memory is full. It provides enough access to the device's file system that allows UFED to index the file system and determine how many files exist, then extract the data. It is automatically removed from the device after the extraction is complete. Users are encouraged to document when the UFED prompts them to use the client, and whether they proceed with the use.

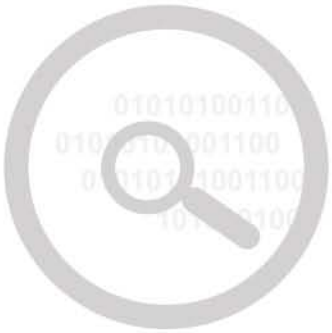
Decoding: The process of translating raw hexadecimal data into an easily readable format. An automatic process within UFED Physical Analyzer and UFED Logical Analyzer, decoding renders data easier for the examiner to find and analyze. From file system and physical extractions, the examiner always has the option to examine hexadecimal code within the raw data.

Extraction: The process of obtaining mobile device data and storing it in an approved location for processing.

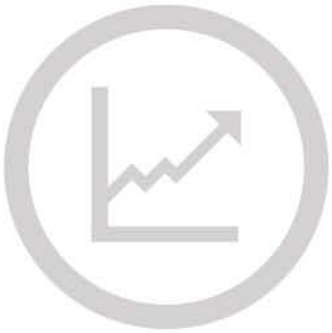
Jailbreaking/rooting: A jailbroken iOS device or a rooted Android device is one whose owner has taken steps to bypass its factory settings, including built-in security and other restrictions. Jailbreaking an iOS device allows the user to install third-party apps from sources other than the App Store, while rooting an Android device provides administrative "root" access to its operating system. UFED solutions do not rely on jailbreaking or permanent rooting to perform forensic extractions, as other mobile forensic tools do.

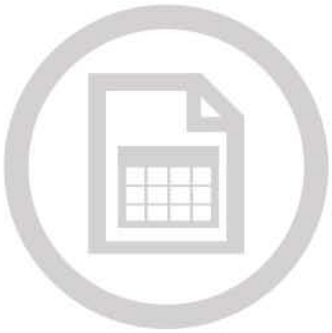


SQLite database: A database file format often used for data storage. Commonly used for storage of mobile and application data, but many smartphones may use .db files, .plists, and other file formats as well.



Unallocated space: The area on a device's memory outside the defined file system that is available to write data to. Very often, deleted data or fragments can be found and carved from unallocated space.





Department of Homeland Security

U.S. Immigration and Customs Enforcement

Homeland Security Investigations

Computer Forensics Handbook

HSI HB 11-01

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