APFS File System Format Reference Sheet

By: Sarah Edwards| Twitter: @iamevltwin | Email: oompa@csh.rit.edu
FOR518 - Mac and iOS Forensic Analysis & Incident Response - for518.com

Object Header (obj_phys_t)

Offset	Size (in bytes)	Field	Notes
0	8	o_cksum	Fletcher 64 Checksum
8	8	o_oid	Object ID
16	8	o_xid	Transaction ID
24	2	o_type.type	Object Type
26	2	o_type.flags	Object Flags
28	4	o_subtype	Object Subtype

Object Type (Hex)	Object Type (Dec)	Object Type/Subtype
0x0000	0	None
0x0100	1	Container Super Block
0x0200	2	B-Tree
0x0300	3	B-Tree Node
0x0500	5	Spaceman
0x0B00	11	Object Map (OMAP)
0x0D00	13	File System (Volume Super Block)
0x0E00	14	File System Tree

Container Super Block (nx_superblock_t)

Offset	Size (in bytes)	Field	Notes
32	4	magic "NXSB"	Container Magic Number: 0x4E585342 = "NXSB"
36	4	nx_block_size	Block Size (ie: 4096)
40	8	nx_block_count	Block Count (Block Count*Block Size = Container Size in Bytes
48	8	nx_features	Features
56	8	nx_read_only_ compatible_features	Read-only Compatible Features
64	8	nx_incompatable_features	Incompatible Features
72	16	nx_uuid	Container UUID (diskutil info /dev/disk#)
88	8	nx_next_oid	Next Object ID (OID)
96	8	nx_next_xid	Next Transaction ID (XID)
104	4	nx_xp_desc_blocks	Blocks used by Checkpoint Descriptor Area
108	4	nx_xp_data_blocks	Blocks used by Checkpoint Data Area
112	8	nx_xp_desc_base	Base address of Checkpoint Descriptor Area or Physical Object ID
120	8	nx_xp_data_base	Base address of Checkpoint Data Area or Physical Object ID
128	4	nx_xp_desc_next	Next Index for Checkpoint Descriptor Area
132	4	nx_xp_data_next	Next Index for Checkpoint Data Area
136	4	nx_xp_desc_index	Index for first item in Checkpoint Descriptor Area
140	4	nx_xp_desc _len	Number of blocks in Checkpoint Descriptor Area Used
144	4	nx_xp_data_index	Index for first item in Checkpoint Data Area
148	4	nx_xp_data _len	Number of blocks in Checkpoint Data Area Used
152	8	nx_spaceman_oid	Space Manager Object ID (OID)
160	8	nx_omap_oid	Container Object Map Object ID (OID)
168	8	nx_reaper_oid	Reaper Object ID (OID)
176	4	nx_test_type	Reserved for Testing
180	4	nx_max_file_systems	Maximum Number of Volumes in this Container
184	8	nx_fs_oid[0]	Array of OIDs for Volumes in this Container

Volume Super Block (apfs_superblock_t)

Offset	Size (in bytes)	Field	Notes
32	4	apfs_magic "APSB"	Volume Magic Number 0x41505342 = "APSB"
36	4	apfs_fs_index	Index in Volume Array
40	8	apfs_features	Features
48	8	apfs_readonly_compatible_features	Read-only Incompatible Features
56	8	apfs_incompatible_features	Incompatible Features
64	8	apfs_unmount_time	Timestamp when volume was last unmounted
72	8	apfs_fs_reserve_block_count	Block Pre-allocated for Volume (Default is none)
80	8	apfs_fs_quota_block_count	Maximum Block Allocated (Default is none)
88	8	apfs_fs_alloc_count	Number of blocks currently allocated
96	2	wrapped_crypto_state_t. wrapped_crypto_state.major_version	Key Encryption Metadata – Major Version
98	2	wrapped_crypto_state_t. wrapped_crypto_state.minor_version	Key Encryption Metadata – Minor Version
100	4	wrapped_crypto_state_t. wrapped_crypto_state.cpflags	Key Encryption Metadata – Encryption State Flags
104	4	wrapped_crypto_state_t. wrapped_crypto_state.persistent_class	Key Encryption Metadata – Protection Class
108	4	wrapped_crypto_state_t. wrapped_crypto_state.key_os_version	Key Encryption Metadata – Creator OS Version 0x39004313 = 19 C 57 – 19C57 – Catalina 10.15.2
112	2	wrapped_crypto_state_t. wrapped_crypto_state.key_revision	Key Encryption Metadata – Key Version
114	2	wrapped_crypto_state_t. wrapped_crypto_state.key_len	Key Encryption Metadata – Key Size (0 for no Encryption)
N/A	0	wrapped_crypto_state_t. wrapped_crypto_state.persistent_key	Key Encryption Metadata – Wrapped Key No Key field is null, see key_len above
116	4	apfs_root_tree_oid_type	Type of Root File System Tree = B-Tree
120	4	apfs_extentref_tree_oid_type	Type of Extent Reference Tree = B-Tree, Physical
124	4	apfs_snap_meta_tree_oid_type	Type of Snapshot Metadata Tree = B-Tree, Physical
128	8	apfs_omap_oid	Physical Object ID (OID) of Object Map
136	8	apfs_root_tree_oid	Virtual Object ID (OID) of Root File System Tree
144	8	apfs_extentref_tree_oid	Physical Object ID (OID) of Extent Reference Tree
152	8	apfs_snap_meta_tree_oid	Virtual Object ID (OID) of Snapshot Metadata Tree
160	8	apfs_revert_to_xid	Transaction ID (XID) that volume will revert to
168	8	apfs_revert_to_sblock_oid	Virtual Object ID (OID) of Volume Superblock to revert to
176	8	apfs_next_obj_id	Next Object ID (OID)
184	8	apfs_num_files	Number of Regular Files
192	8	apfs_num_directories	Number of Directories
200	8	apfs_num_symlinks	Number of Symbolic Links
208	8	apfs_num_other_fsobjects	Number of Other Files
216	8	apfs_num_snapshots	Number of Snapshots
224	8	apfs_total_blocks_alloced	Blocks Allocated by Volume
232	8	apfs_total_blocks_freed	Blocked Freed by Volume
240	16	apfs_vol_uuid	Volume UUID (diskutil info /dev/disk#s# [Volume])
256	8	apfs_last_mod_time	Last Modified Timestamp
264	8	apfs_fs_flags	Flags
272	32	apfs_modified_by_t.formatted_by.id[]	Format Program and Version
304	8	apfs_modified_by_t.formatted_by. timestamp	Format Timestamp
312	8	apfs_modified_by_t.formatted_by. last_xid	Format Transaction ID (XID)
320	32	apfs_modified_by_t.modified_by.id[]	Last Modified Program and Version
352	8	apfs_modified_by_t.modified_by. timestamp	Last Modified Timestamp
360	8	apfs_modified_by_t.modified_by. last_xid	Last Modified Transaction ID (XID)
368	336	apfs_modified_by_t.modified_by[1-7]	Array of apfs_modified_by_t[8]
704	256	apfs_volname	APFS Volume Name
960	4	apfs_next_doc_id	Next Document ID
964	2	apfs_role	APFS Role (None, System, Data, Preboot, VM, Recovery)
966	2	apfs_reserved	Reserved
976	8	apfs_root_to_xid	Transaction ID (XID) of Snapshot to Root
984	8	apfs_er_state_oid	Current State of Encryption/Decryption

Updated: 012020

B-Tree Node (btree_node_phys_t)

Offset	Size (in bytes)	Field	Notes
32	2	btn_flags	Flags (Leaf Node)
34	2	btn_level	Number of Child Levels below this Node
36	4	btn_nkeys	Number of Keys
40	2	btn_table_space.off	Offset to Table of Contents (after btree_node_phys_t)
42	2	btn_table_space.len	Length of Table of Contents
44	2	btn_freespace.off	Offset Key/Value Free Space
46	2	btn_freespace.len	Length of Key/Value Free Space
48	2	btn_key_free_list.off	Offset to Free Key Space
50	2	btn_key_free_list.len	Length of Free Key Space
52	2	btn_val_free_list.off	Offset to Free Value Space
54	2	btn_val_free_list.len	Length of Free Value Space

B-Tree Node – Table of Contents

Offset	Size (in bytes)	Field	Notes
TOC Entry + 2	2	key_offset	Key Offset
TOC Entry + 4	2	key_length	Key Length
TOC Entry + 6	2	value _offset	Value Offset
TOC Entry + 8	2	value_length	Value Length

B-Tree Node – File System Key

Offset	Size (in bytes)	Field
0	7	Object ID – Inode Number
7	1	Entry Kind 0x30 – Inode 0x60 – Data Stream 0x40 – Xattr (2 byte Name Length + Variable Xattr Name) 0x60 – File Extent (8 byte Logical Address

Value - Inode File Metadata

Offset	Size (in bytes)	Field	Notes
0	8	parent_id	Parent Inode Number
8	8	private_id	Inode Number
16	8	create_time	Create Timestamp
24	8	mod_time	Modification Timestamp
32	8	change_time	Change Timestamp
40	8	access_time	Access Timestamp
48	8	internal_flags	Internal Flags
56	4	nchildren or nlink	Children or Links
60	4	default_protection_class	Default Protection Class
64	4	write_generation_counter	Write Generation Counter
68	4	bsd_flags	BSD Flags
72	4	owner	Owner
76	4	group	Group
80	2	mode	File Mode
82	2	pad1	Pad1
84	8	pad2	Pad2
92	2	xf_num_exts	Number of Extended Fields
94	2	xf_used_data	Extended Fields Data Used
96	x_field_t[] = 4 bytes Each	Extended Field: x_type (1 byte), x_flags (1 byte), x_size (2 bytes)	
96	4	EXAMPLE EXTENDED FIELD: 0x04 = 4, 0x02 (Do Not Copy), 0x1100 = 17 (File Name)	
100	4	EXAMPLE EXTENDED FIELD: 0x08 = 8, 0x20 (System Field), 0x2800 = 40 (Data Stream)	
104	{17}	File Name	smudge_yoda.jpeg (w/1 padding bytes 0x00), 17 total bytes
120	{40}	Data Stream (Size: First 8 bytes, Allocated: Next 8 bytes)	0x00000000000000 – 7 unused bytes Size: 0x261C020000000000 = 138278 bytes Allocated: 0x0020020000000000 = 139264

Value – Inode File Extent

Offset	Size (in bytes)	Field
0	8	File Size
8	8	Physical Block Location
16	8	Crypto ID

APFS Format References:

- Apple File System Reference (Apple Developer Documentation)
- 2019-02-07

APFS is Little Endian & 64-bit

SANS FOR518 Reference Sheet

By: Sarah Edwards | Twitter: @iamevltwin | Email: oompa@csh.rit.edu

Directory Commands

`cd ..`	Change Directory…up one directory (../.. – two directories up)
`cd /var/log`	Change Directory…to /var/log
`cd ~`	Change Directory…to your home directory
`cd /`	Change Directory…to the root directory
`ls`	List Directory (Short Listing)
`ls -l`	List Directory (Long Listing)
`ls -a`	List Directory items…including hidden items (files beginning with ".")
`ls -lh`	List Directory items…with human readable sizes
`ls -R`	List Directory items…recursively
`open .`	Open Current Directory
`pwd`	Print Working Directory
`mkdir`	Create a Directory
`rmdir`	Remove a Directory
`rm -r`	Remove a Directory (and its contents)
`.`	Current Directory
`..`	Parent Directory

File Commands

`pico <filename>`	Open a file in a simple text editor (q – to quit editor)
`xxd <filename>`	Open a file in a hex editor
`open <filename>`	Opens a file in the default program
`open –a <programname> <filename>`	Opens a file in a specified program
`cat <filename>`	Concatenate a file to the terminal screen
`<command> | more`	Pipe command output to more to show contents screen by screen
`<command> | less`	Pipe command output to less to show contents screen by screen (and be able to go back and forth)
`rm <filename>`	Remove File
`cp <filename> <newfilename>`	Copy File
`mv <filename> <newfilename>`	Move File
`<command> > <filename>`	Redirect command output to a file
`<command> >> <filename>`	Append command output to a file
`touch <filename>`	Create an empty file
`head <filename>`	Show first 10 lines of a file
`tail <filename>`	Show last 10 lines of a file (`-f` to watch appended input)
`strings <filename>`	Show the strings of a file
`exiftool <filename>`	Show the exif/metadata of the file
`plutil –p <propertylist>`	Print the contents of a property list
`file <filename>`	Show a file signature type
`grep –i <searchterm> <filename>`	Search for term within a file (case-insensitive)
`python <file>.py`	Execute a Python program

Miscellaneous Commands

`sudo <command>`	Execute program as another user (default is root user)
`sudo -s`	Open a privileged shell
`su -`	Substitute User to root
`whoami / id`	Display Effective User ID / Show UID/GID Info
`history`	Command History
`man <command>`	Command Manual (q – to exit manual)

Terminal Shortcuts

Control + A	Jump to beginning of line
Control + E	Jump to end of of line
Tab	Tab Completion
Control + C	Kill Current Command
Command + K or Control + L	Clear Screen (or clear command)
Command + T	New Terminal Tab
Command + W	Close Terminal Tab
Command +/-	Increase or Decrease Terminal Font Size
Option + Left/Right Arrow	Move back/forth by word
Option + Click in Command Line	Put command line cursor where mouse cursor is.

Generic Tool Compilation and Installation

```
tar –xvf <archive>.tar.gz
./configure
make
sudo make install
```

Live Response

`date`	Local System Time (-u for UTC)
`hostname`	System Hostname
`uname –a`	OS & Architecture Information
`sw_vers`	macOS Version & Build
`netstat –anf inet or netstat -an`	Active Network Connections
`lsof -i`	Active Network Connections (by process)
`netstat -rn`	Routing Table
`arp –an | ndp -an`	ARP Table (IPv4 | IPv6)
`ifconfig`	Network Interface Configuration
`lsof`	List Open Files
`who –a, w`	List Logged On Users
`last`	List user logins
`ps aux`	List Processes
`system_profiler -xml –detaillevel full > file.spx`	System Profiler (XML, Full Detail Level), open with System Information.app

Disk & Partitions

`/dev/`	Device Directory
`diskutil list`	List Connected Disks
`diskutil info <disk>`	Disk Information (use Disks /dev/disk#, disk#, or partitions /dev/disk#s#)
`diskutil cs|ap list`	List partitions using CoreStorage (cs) or APFS Containers (ap)
`gpt –r show [-l]`	List partitions using GUID Partition Table Format (-l to show label rather than GUID) – 10.13+ SIP must be disabled.
`csrutil disable|enable`	Disable/Enable SIP, must reboot into Recovery Mode (Reboot, Cmd+Option+R)
`mmls <diskimage>`	Display partitions using The Sleuth Kit
`hdiutil imageinfo *.dmg`	Disk Image Information including Partition Data

Keychains

`security list-keychains`	List Keychains on a system for a logged in user
`security dump-keychains -d <keychain>`	Dump contents of a Keychain

Extended Attributes

`xattr –xl <file>`	Show Extended Attributes of a file
`xattr -p <attribute name> <file> | xxd -r -p >output_file.plist`	Extract embedded binary property list from extended attribute.
`istat /dev/disk# <CNID>`	Use The Sleuth Kit to view file information including extended attributes.
`icat /dev/disk# <CNID>-<TSK Attribute Number>`	View a specific extended attribute using The Sleuth Kit

Log Analysis

`bzcat system.log.1.bz2 system.log.0.bz2 >> system_all.log cat system.log >> system_all.log`	Create a "all-in-one" system.log file. Can also be used with `gzcat` for Gzip compressed log files.
`syslog –f <file> | –d <directory>`	View ASL File or Directory of ASL files
`syslog –T utc –F raw –d /var/log/asl`	Output ASL files the /var/log/asl directory and output in raw format with UTC timestamps.
`praudit –xn /var/audit/*`	View audit logs in XML format without user/group resolution.
`sudo log collect`	Create a logarchive bundle on live system, root required
`log show`	View logs in logarchive bundle (use with --predicate to filter)
`log stream`	View live logs (use with --predicate to filter)

Time Machine

`tmutil uniquesize <machinedirectory_path>/*`	Show the unique sizes of each snapshot
`tmutil calculatedrift <machinedirectory_path>`	Show the size changes (added/removed/changed) between each snapshot.
`tmutil compare <snapshotdirectory1> <snapshotdirectory2>`	Compare the file changes (added/removed/changed) between two snapshots..

Memory Analysis & Encrypted Containers

`vol.py --profile=<profile> -f <memory image> <plugin>`	Volatility Usage
`hdiutil attach –readonly –nomount –stdinpass filevault2image.dmg`	Mount a FileVault volume using a password
`security unlock-keychain FileVaultMaster.keychain diskutil corestorage unlockvolume <UUID> -recoverykeychain FileVaultMaster.keychain`	Access and mount a FileVault volume using a master password
`diskutil corestorage unlockvolume <UUID> -passphrase <recovery key>`	Mount a FileVault volume using the Recovery Key
`hdiutil attach -readonly -nomount -stdinpass sekretstuff_USB.dmg`	Mount an Encrypted DMG File
`strings <MemoryImage> | sort -u > dictionary.txt`	Create a dictionary file

Spotlight

`mdls <file>`	List the Spotlight metadata for a file
`mdfind "<attribute_name> == *"`	Find files based on a specific metadata query
`mdfind –onlyin /Volumes/mounted_disk`	Find files only in a certain directory or mounted image.
`mdimport –X | -A`	Print a list of attributes that can be queried.

Disk Arbitration

`sudo launchctl load /System/Library/LaunchDaemons/com.apple.diskarbitrationd.plist`	Enable
`sudo launchctl unload /System/Library/LaunchDaemons/com.apple.diskarbitrationd.plist`	Disable
`ps auxw | grep diskarbitrationd`	Determine Status

Image Mount & Eject

APFS with xmount (xmount v.0.7.*)	`$ sudo mkdir /Volumes/galaga_image/`
	`$ sudo mkdir /Volumes/galaga_mounted/`
	`$ sudo xmount --in ewf ~/FOR518/galaga.E01 --out dmg /Volumes/galaga_image/`
	`$ hdiutil attach –nomount /Volumes/galaga_image/galaga.dmg`
	`$ sudo mount_apfs –o rdonly,noexec,noowners /dev/disk# /Volumes/galaga_mounted/`

HFS+ Method 1 – xmount (xmount v.0.7.*)	`$ mkdir /Volumes/dademurphy_image/`
	`$ mkdir /Volumes/dademurphy_mounted/`
	`$ sudo xmount --in ewf ~/FOR518/dademurphy.E01 --out dmg /Volumes/dademurphy_image/`
	`$ hdiutil attach –nomount /Volumes/dademurphy_image/dademurphy.dmg`
	`$ mount_hfs –j –o rdonly,noexec,noowners /dev/disk# /Volumes/dademurphy_mounted/`

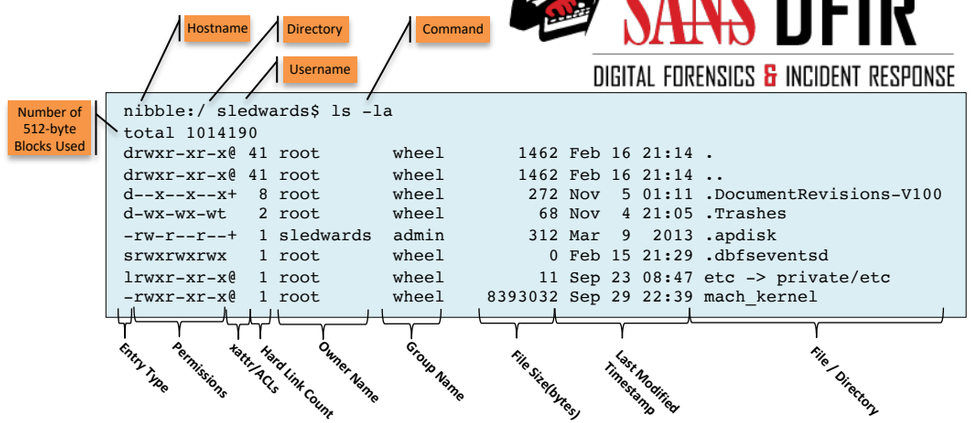
Eject Disk	`$ diskutil list`
	`$ diskutil eject /dev/disk#`
	`$ mount`
	`$ sudo umount /Volumes/galaga_image/`

Timestamp Formats

APFS	64-bit - Number of Seconds from 1/1/1970 00:00:00 UTC
HFS+/MacOS	32-bit - Number of seconds from 1/1/1904 00:00:00 UTC
UNIX Epoch	32-bit - Number of seconds from 1/1/1970 00:00:00 UTC
Mac Epoch/Mac Absolute/Cocoa/WebKit	32-bit - Number of seconds from 1/1/2001 00:00:00 UTC
Property List Dates in Xcode	Local Host System Time

FOR518 - Mac and iOS Forensic Analysis & Incident Response - for518.com

SANS DFIR
DIGITAL FORENSICS & INCIDENT RESPONSE



GPT Reference

GPT Header

Offset	Size (bytes)	Field
0	8	Signature (EFI PART)
8	4	Revision (1.0)
12	4	Size of Header (bytes)
16	4	Header CRC32
20	4	Reserved
24	8	LBA of GPT Header
32	8	LBA of Backup GPT Header
40	8	First Usable LBA
48	8	Last Usable LBA
56	16	Disk GUID
72	8	Starting LBA of GUID Partition Table (Little Endian)
80	4	Number of Partition Entries Available (Little Endian)
84	4	Size of Partition Entry
88	4	Partition Entry Array CRC32
92	Rest	Reserved

GPT Table Entry

Offset	Size (bytes)	Field
0	16	Partition Type GUID
16	16	Unique Partition GUID
32	8	Starting LBA (Little Endian)
40	8	Ending LBA (Little Endian)
48	8	Attributes
56	72	Partition Name
128	Rest	Reserved

Type	Common GPT Partition GUIDs
EFI System Partition	C12A7328-F81F-11D2-BA4B-00A0C93EC93B
HFS+ Partition	48465300-0000-11AA-AA11-00306543ECAC
Apple Boot Partition	426F6F74-0000-11AA-AA11-00306543ECAC
Apple CoreStorage (possible FileVault or Fusion Drive)	53746F72-6167-11AA-AA11-00306543ECAC
APFS Partition	7C3457EF-0000-11AA-AA11-00306543ECAC
Basic Data Partition (Boot Camp)	EBD0A0A2-B9E5-4433-87C0-68B6B72699C7