SHINING A LIGHT ON SPOTLIGHT

LEVERAGING APPLE'S DESKTOP SEARCH UTILITY TO RECOVER DELETED FILE METADATA ON MACOS

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MAIN POINTS

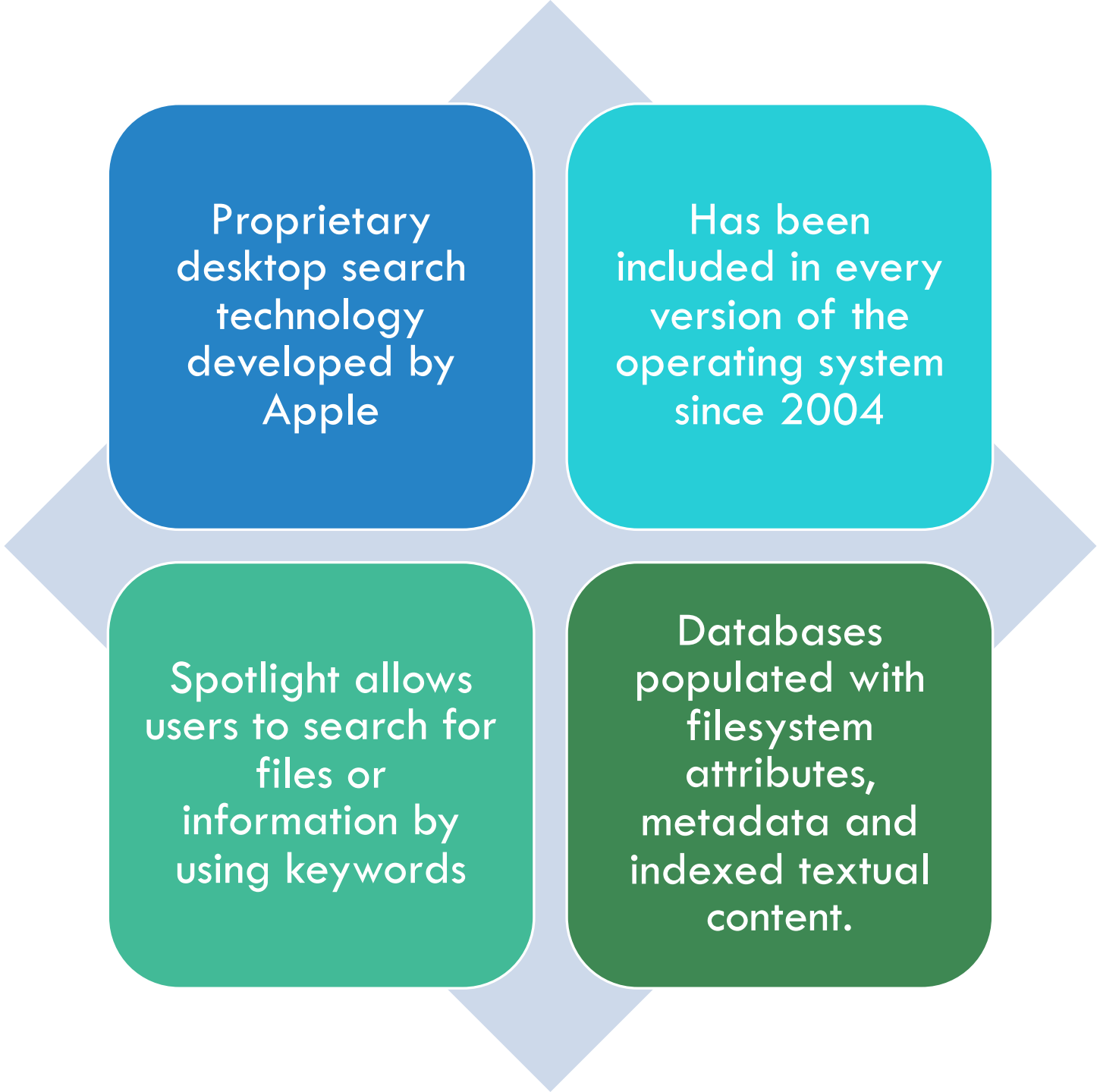
Background

Experiment Design

Results

Summary

WHAT IS SPOTLIGHT?



WHAT IS SPOTLIGHT?

WHY THIS SUBJECT

Over the last 15 years, the popularity and Market share of Apple devices and computers has steadily increased

- Number of submissions to the lab has increased.
- Kudos applied to owning such products.

My interest in the subject began in 2011

- Keyword hits within the Spotlight directories
- No tools available to parse the data
- No published research regarding the structure of the database

In 2013 504ensics announced Spotlight Inspector

- It disappeared shortly afterwards
- A tool to parse the database offline
- The structure was not revealed
- It was unknown if the tool was able to recover deleted records

By 2016, the method of examining Spotlight had not progressed:

- Use of Apple API to query extant records
- MDLS command using BASH

```
84. # Create an array containing files scanned within start directory
85. array=()
86.
87. while IFS= read -r -d $'\0';
88. do
89.     array+=("$REPLY")
90. done < <(find ${DIR} -type f -print0)
91.
92. # number of files
93. COUNT=${#array[@]}
94.
95. echo ${COUNT} File'('s')' Found
96. echo Exporting Reports...
97.
98. for VALUE in "${array[@]}"
99. do
100.        # Filepath Name with String Replacement
101.        # replace every '\' with '|'
102.        PNAME=${VALUE//\//|}
103.        # mdls for each
104.        mdls "${VALUE}" > $OUTPUT/MDLS_REPORTS_"${PNAME}".txt
105.        echo ...
106.    done
107.
108.    echo Script Completed - ${COUNT} Reports Exported
109.    exit
```

WHY THIS SUBJECT

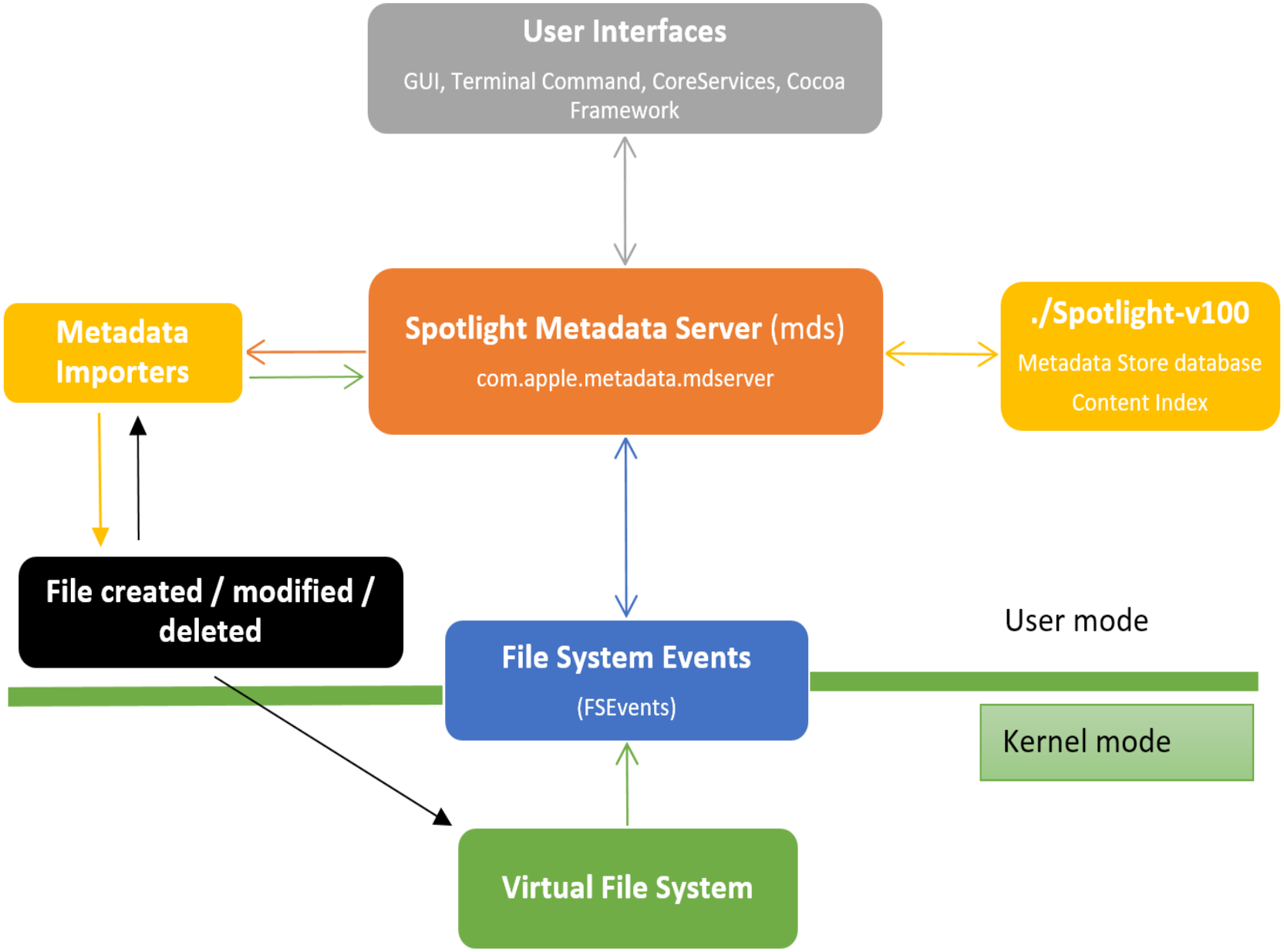
Metadata

- Is and always will be of great interest to digital forensic investigations
- To make the most if it, the method metadata is stored within files and data repositories must be:
  - **Understood**
  - **Tested** and
  - Shown to be to be **Reliable**

Parsing Data

- Parsing data from an unknown data format is inherently dangerous
- Incorrect linkage of records or incomplete data parsing can cause the data recovered to be:
  - **Misunderstood** and
  - Cause an **incorrect conclusion** to be drawn.

SPOTLIGHT COMPONENTS



FSEVENTS

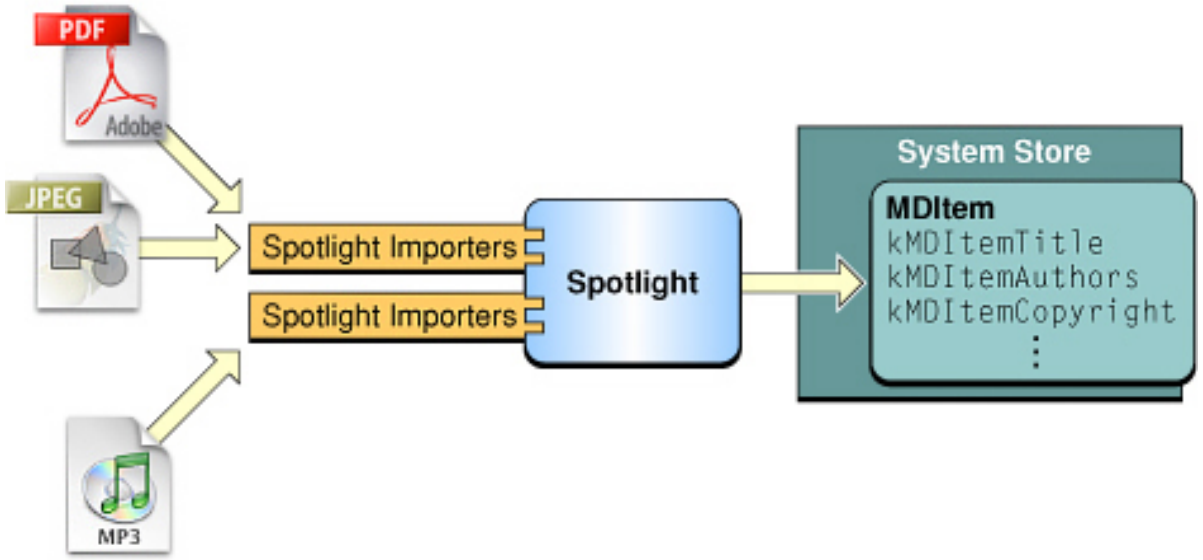
Event Type	Description
FSE_CREATE_FILE	File created
FSE_DELETE	File/directory removed/deleted
FSE_STAT_CHANGED	Change to status structure e.g. object's permission change
FSE_RENAME	File/directory renamed
FSE_CONTENT_MODIFIED	File content modified
FSE_EXCHANGE	Contents of two files were swapped through the exchangedata() system call
FSE_FINDER_INFO_CHANGED	File/directory Finder information changed e.g. label colour changed
FSE_CREATE_DIR	Folder created
FSE_CHOWN	Filesystem objects ownership changed
FSE_XATTR_MODIFIED	File/directory extended attributes modified
FSE_XATTR_REMOVED	File/directory extended attributes removed

METADATA IMPORTERS

Populate the content index store and metadata store database

A worker process, ‘mdworker’, launches the correct importer via a notification.

Each importer then extracts the metadata and contextual list of words, passing it back to the MDS for it to populate the stores



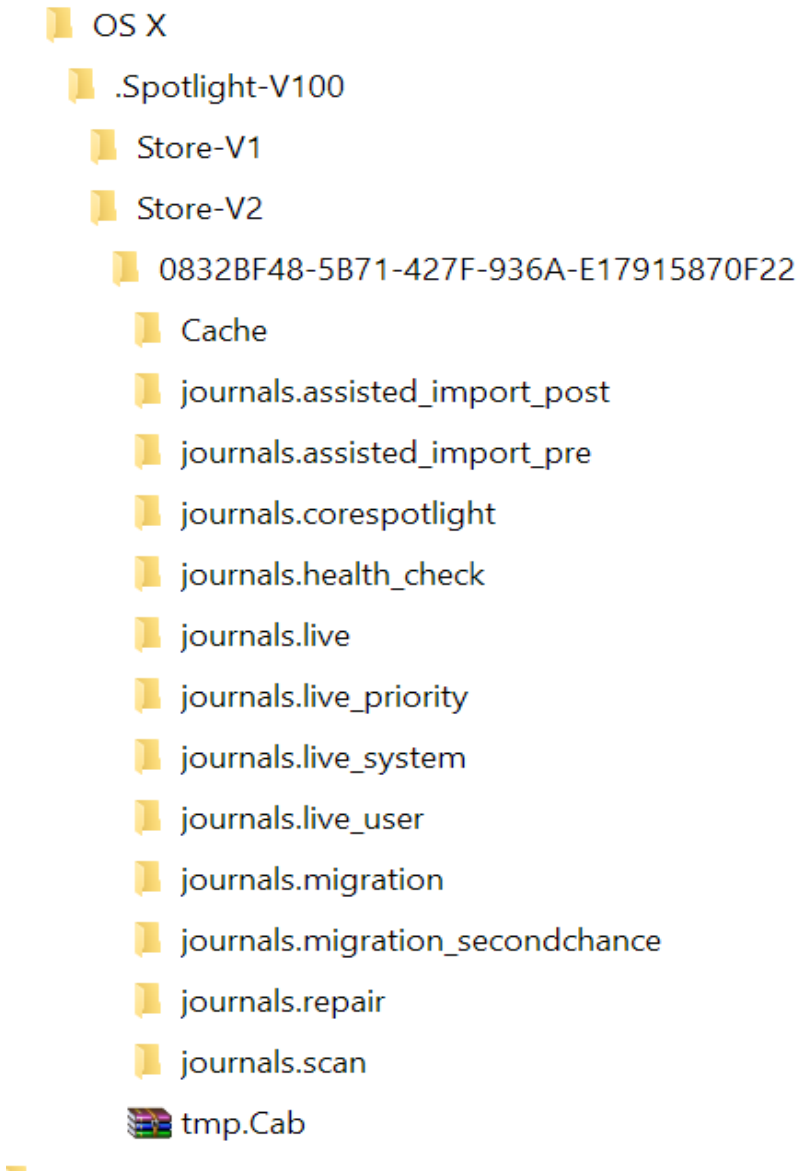
SPOTLIGHT STORE ARTEFACTS

The Spotlight-V100 directory is located in the root of the volume contains the Spotlight store.

Stores are only created on volumes where the operating system had read/write permissions.

Its presence indicates that the volume has been indexed

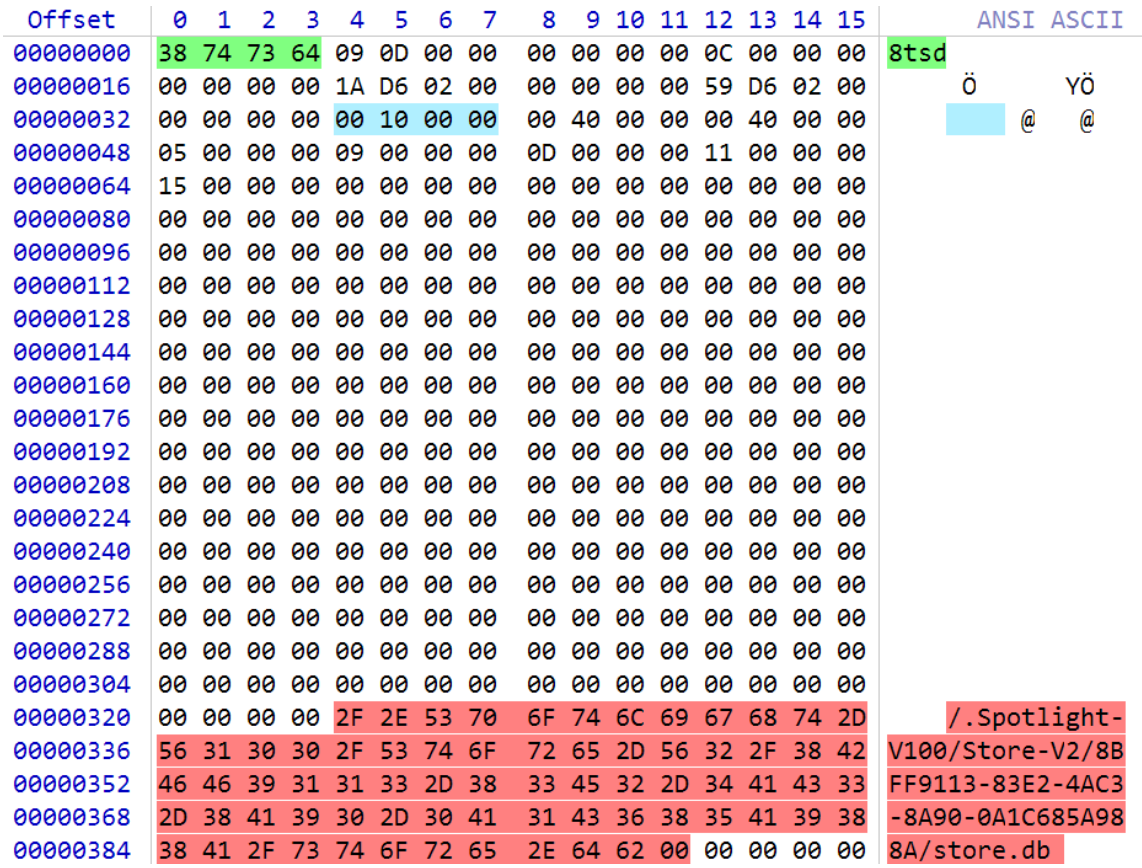
The property list file: *VolumeConfiguration.plist* details the location of all the Spotlight stores being held on the local system



METADATA STORE DATABASE (STORE.DB)

Used as Spotlight's central database repository for storing extracted metadata values.

A proprietary database whose structure is not published or described.



Offset	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	ANSI ASCII
00000000	38	74	73	64	09	0D	00	00	00	00	00	00	0C	00	00	00	8tsd
00000016	00	00	00	00	1A	D6	02	00	00	00	00	00	59	D6	02	00	Ö YÖ
00000032	00	00	00	00	00	10	00	00	00	40	00	00	00	40	00	00	@ @
00000048	05	00	00	00	09	00	00	00	0D	00	00	00	11	00	00	00	
00000064	15	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000080	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000096	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000112	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000128	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000144	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000160	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000176	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000192	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000208	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000224	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000240	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000256	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000272	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000288	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000304	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000320	00	00	00	00	2F	2E	53	70	6F	74	6C	69	67	68	74	2D	/.Spotlight-
00000336	56	31	30	30	2F	53	74	6F	72	65	2D	56	32	2F	38	42	V100/Store-V2/8B
00000352	46	46	39	31	31	33	2D	38	33	45	32	2D	34	41	43	33	FF9113-83E2-4AC3
00000368	2D	38	41	39	30	2D	30	41	31	43	36	38	35	41	39	38	-8A90-0A1C685A98
00000384	38	41	2F	73	74	6F	72	65	2E	64	62	00	00	00	00	00	8A/store.db

WHAT'S ALREADY OUT THERE?

Existing research has provided an understanding of the metadata attributes stored within the metadata store database (store.db).

Current methods of extracting information from the database make use of the Spotlight technology itself, with queries sent from an investigation workstation to perform live searches.

This approach has enabled forensic analysts to extract metadata records for extant files but not for deleted files.

No research was found that:

- **Proves deleted records are recoverable either directly from the metadata store or from unallocated space on the filesystem.**
- **Describes the structure of the metadata store database (store.db).**

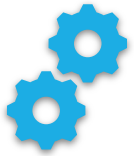
APPROACH TO THIS WORK

Establish the structure of the spotlight database

- In order to identify records related to files

Establish what happens to deleted records

- Are deleted records are recoverable from the spotlight database (store.db)
- How long are deleted records recoverable before being lost
- What happens if a user intentionally destroys the spotlight index
- Can deleted versions of the database or database pages be recovered within unallocated areas



Virtualise Mac OS X machines

Populate the file system and the spotlight database with identifiable files (file name, file size, metadata, dates and times)

Develop Scripts that enable me to process the database structures that:

automate the identification and carving of database structures (i.e. pages, headers, records)

Process compressed or encrypted content

Identify offsets/relative offsets for records/flags

Exploit the newly discovered database structure to

Locate deleted records within the database and parse the information from them

Search for deleted databases within unallocated clusters

EXPERIMENT DESIGN

EXPERIMENT DESIGN

Experiment	Summary
01	Persistence of metadata records within the metadata store and unused space on the filesystem
02	Persistence of records **on mounted volumes**
03	Persistence of records **on mounted volumes that are shared across two operating systems**
04	Persistence of records **when the Spotlight indices are deleted using the mdutil terminal command**
05	Persistence records **when the Spotlight indices are deleted via the Spotlight management GUI interface**
06	Persistence of records **when the Spotlight indices are deleted using the mdutil terminal command and re-populated with ever increasing number of files.**
07	Creation of metadata records for **the purposes of reverse engineering the metadata store structure**
08	Persistence of records **when the operating system is upgraded (minor/major)**
09	Persistence of records **within the unused space of ten casework forensic images**

EXPERIMENT RESULTS

STORE.DB DATABASE PAGES

Three main types of database pages identified

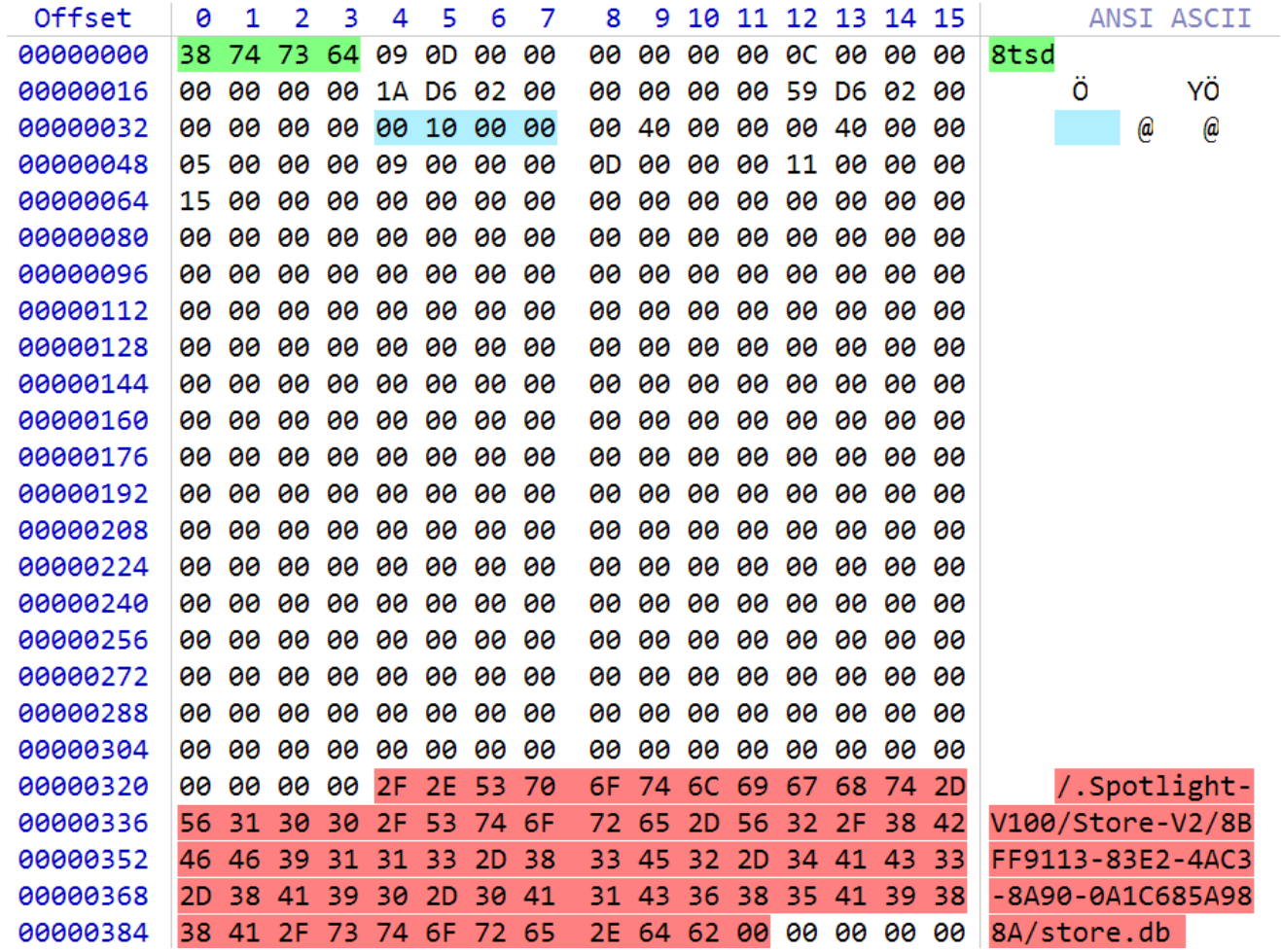
Each identifiable by the 4-byte signature located at relative offset 0.

Page Header String (Hexadecimal)	Offset	Size (bytes)	String ASCII	Page Type
38 74 73 64	00	4	8tsd	Header Page
32 6D 62 64	00	4	2mbd	Map Page
32 70 62 64	00	4	2pbd	Data Page

STORE.DB HEADER PAGE

The first page encountered is identified as the database header.

In experiments, this page has consistently been 4096 bytes in length.



Offset	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	ANSI ASCII
00000000	38	74	73	64	09	0D	00	00	00	00	00	00	0C	00	00	00	8tsd
00000016	00	00	00	00	1A	D6	02	00	00	00	00	00	59	D6	02	00	Ö YÖ
00000032	00	00	00	00	00	10	00	00	00	40	00	00	00	40	00	00	@ @
00000048	05	00	00	00	09	00	00	00	0D	00	00	00	11	00	00	00	
00000064	15	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000080	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000096	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000112	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000128	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000144	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000160	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000176	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000192	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000208	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000224	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000240	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000256	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000272	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000288	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000304	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	
00000320	00	00	00	00	2F	2E	53	70	6F	74	6C	69	67	68	74	2D	/.Spotlight-
00000336	56	31	30	30	2F	53	74	6F	72	65	2D	56	32	2F	38	42	V100/Store-V2/8B
00000352	46	46	39	31	31	33	2D	38	33	45	32	2D	34	41	43	33	FF9113-83E2-4AC3
00000368	2D	38	41	39	30	2D	30	41	31	43	36	38	35	41	39	38	-8A90-0A1C685A98
00000384	38	41	2F	73	74	6F	72	65	2E	64	62	00	00	00	00	00	8A/store.db

Offset	Bytes	Description
00	4 bytes	Header String recorded as 8tsd
36	4 bytes	Database Header Page Size
324	variable	Path to store.db on volume. String null terminated

STORE.DB MAP PAGE

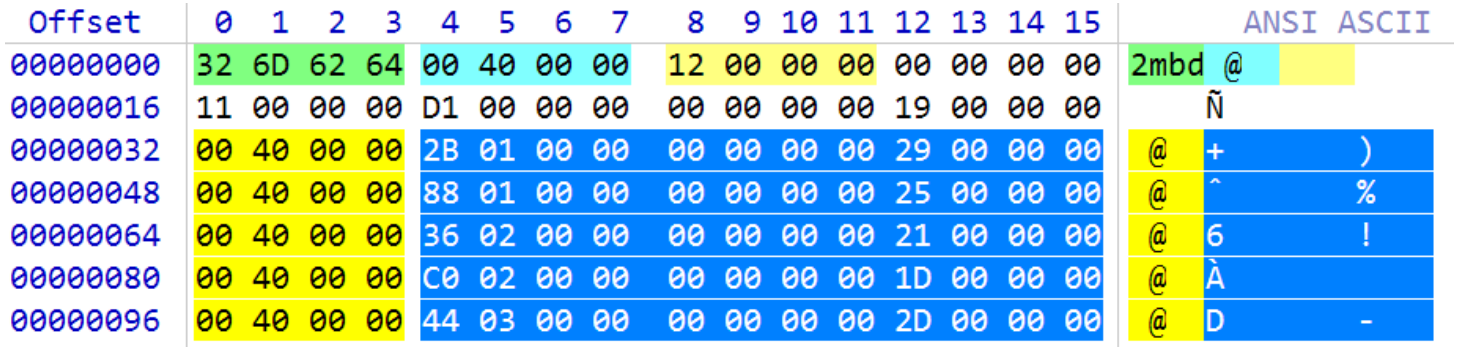
The second type of page encountered has been identified as the database map.

This describes each data page encountered within the database

The first 32 bytes provide information regarding the page.

Starting at offset 32, each data page is described by 16 bytes.

The first 4 bytes declare the size of each data page with the remaining 12 bytes unknown.

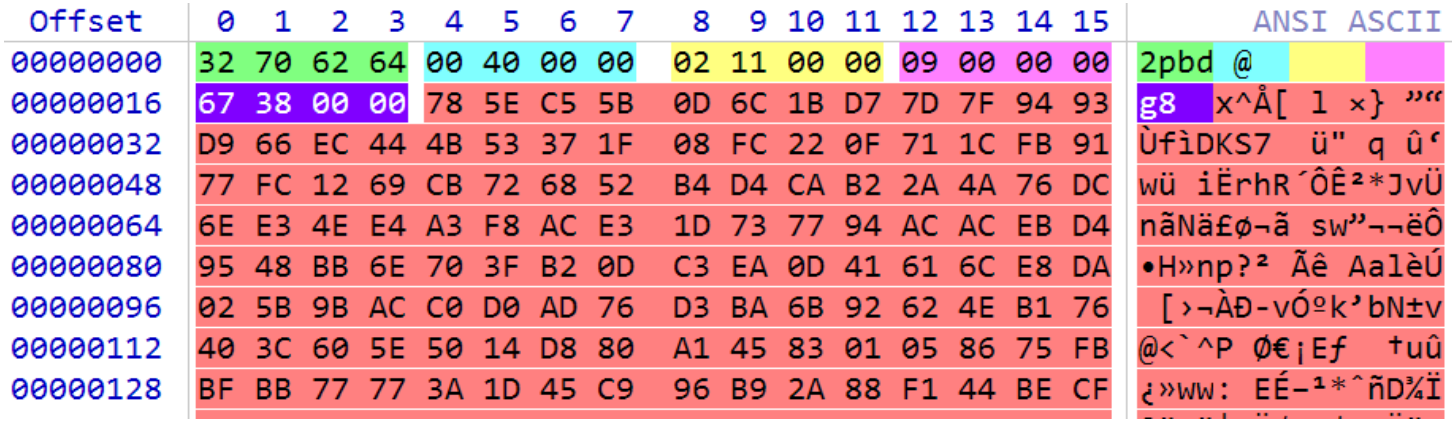


Offset	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	ANSI ASCII
00000000	32	6D	62	64	00	40	00	00	12	00	00	00	00	00	00	00	2mbd @
00000016	11	00	00	00	D1	00	00	00	00	00	00	00	19	00	00	00	Ñ
00000032	00	40	00	00	2B	01	00	00	00	00	00	00	29	00	00	00	@ +)
00000048	00	40	00	00	88	01	00	00	00	00	00	00	25	00	00	00	@ ˆ %
00000064	00	40	00	00	36	02	00	00	00	00	00	00	21	00	00	00	@ 6 !
00000080	00	40	00	00	C0	02	00	00	00	00	00	00	1D	00	00	00	@ À
00000096	00	40	00	00	44	03	00	00	00	00	00	00	2D	00	00	00	@ D -

Offset	Bytes	Description
00	4 bytes	Header String recorded as 2mbd
04	4 bytes	Page Size always observed as 16384 bytes in length
08	4 bytes	Number of pages contained within the map
32	16 bytes	Start of the page map entries.

STORE.DB DATA PAGE

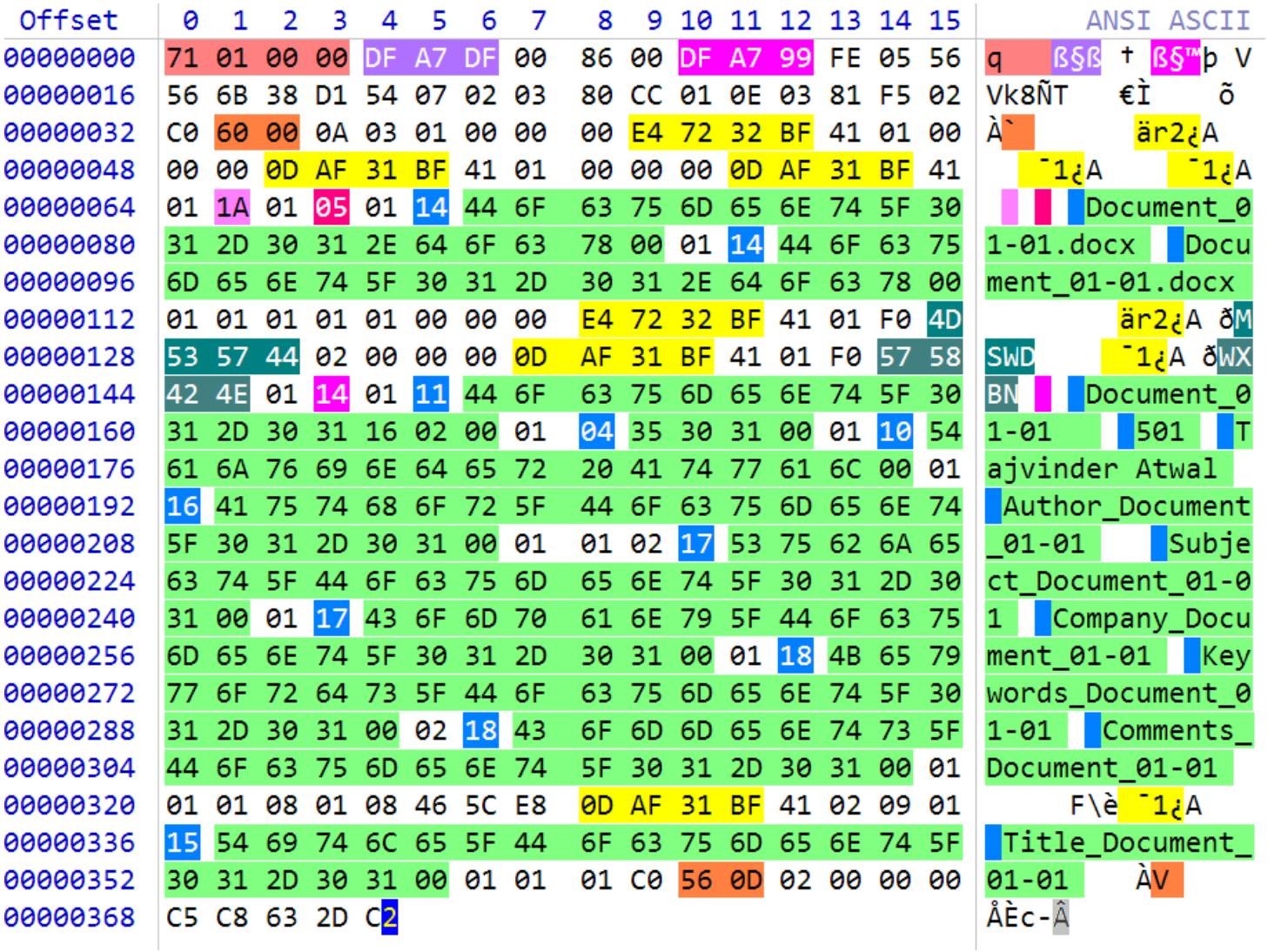
- These pages contain different types of data described further in the paper but in this talk we will concentrate on the metadata pages
- The header of the data pages are identical
- The key records used for parsing all data pages are found within the first 20 bytes



Offset	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	ANSI ASCII
00000000	32	70	62	64	00	40	00	00	02	11	00	00	09	00	00	00	2pbd @
00000016	67	38	00	00	78	5E	C5	5B	0D	6C	1B	D7	7D	7F	94	93	g8 x^Å[l ×} ”“
00000032	D9	66	EC	44	4B	53	37	1F	08	FC	22	0F	71	1C	FB	91	ÙfìDKS7 ü" q û‘
00000048	77	FC	12	69	CB	72	68	52	B4	D4	CA	B2	2A	4A	76	DC	wü iËrhR´ÔÊ²*JvÜ
00000064	6E	E3	4E	E4	A3	F8	AC	E3	1D	73	77	94	AC	AC	EB	D4	nãNä£ø¬ã sw”¬¬ëÔ
00000080	95	48	BB	6E	70	3F	B2	0D	C3	EA	0D	41	61	6C	E8	DA	•H»np?² Ãê AalèÚ
00000096	02	5B	9B	AC	C0	D0	AD	76	D3	BA	6B	92	62	4E	B1	76	[›¬ÀÐ-vÓºk’bN±v
00000112	40	3C	60	5E	50	14	D8	80	A1	45	83	01	05	86	75	FB	@<`^P Ø€¡Eƒ †uû
00000128	BF	BB	77	77	3A	1D	45	C9	96	B9	2A	88	F1	44	BE	CF	¿»ww: EÉ-¹*ˆñD¾Ï

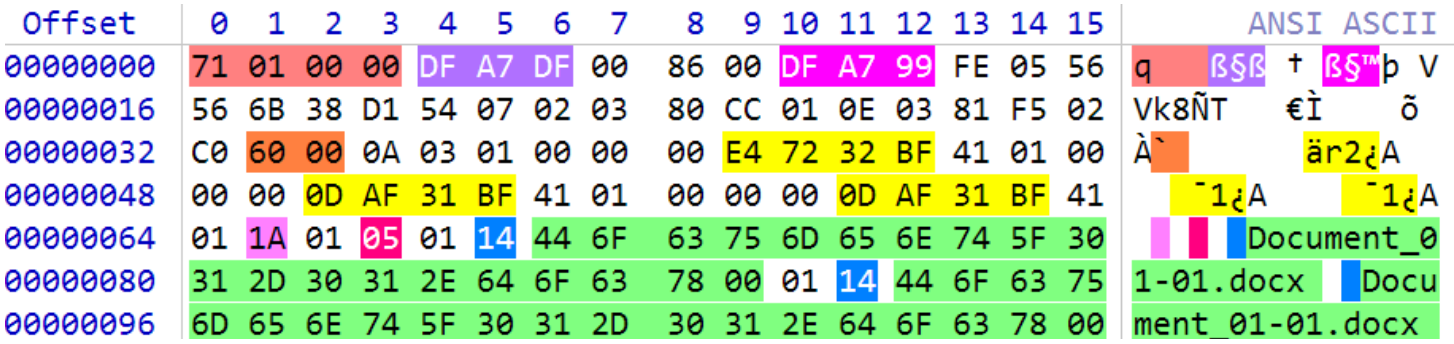
Offset	Bytes	Description
00	4 bytes	Header String recorded as 2pbd
04	4 bytes	Page Size (Physical)
08	4 bytes	Size (Allocated)
12	4 bytes	Record page sub-type
16	4 bytes	Size (Uncompressed)
20	variable	Data

STORE.DB DATA PAGE (DECOMPRESSED)



Offset	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	ANSI ASCII
00000000	71	01	00	00	DF	A7	DF	00	86	00	DF	A7	99	FE	05	56	q ßSß † ßS™þ V
00000016	56	6B	38	D1	54	07	02	03	80	CC	01	0E	03	81	F5	02	Vk8ÑT €Ì õ
00000032	C0	60	00	0A	03	01	00	00	00	E4	72	32	BF	41	01	00	À` är2¿A
00000048	00	00	0D	AF	31	BF	41	01	00	00	00	0D	AF	31	BF	41	¯1¿A ¯1¿A
00000064	01	1A	01	05	01	14	44	6F	63	75	6D	65	6E	74	5F	30	Document_0
00000080	31	2D	30	31	2E	64	6F	63	78	00	01	14	44	6F	63	75	1-01.docx Docu
00000096	6D	65	6E	74	5F	30	31	2D	30	31	2E	64	6F	63	78	00	ment_01-01.docx
00000112	01	01	01	01	01	00	00	00	E4	72	32	BF	41	01	F0	4D	är2¿A ðM
00000128	53	57	44	02	00	00	00	0D	AF	31	BF	41	01	F0	57	58	SWD ¯1¿A ðWX
00000144	42	4E	01	14	01	11	44	6F	63	75	6D	65	6E	74	5F	30	BN Document_0
00000160	31	2D	30	31	16	02	00	01	04	35	30	31	00	01	10	54	1-01 501 T
00000176	61	6A	76	69	6E	64	65	72	20	41	74	77	61	6C	00	01	ajvinder Atwal
00000192	16	41	75	74	68	6F	72	5F	44	6F	63	75	6D	65	6E	74	Author_Document
00000208	5F	30	31	2D	30	31	00	01	01	02	17	53	75	62	6A	65	_01-01 Subje
00000224	63	74	5F	44	6F	63	75	6D	65	6E	74	5F	30	31	2D	30	ct_Document_01-0
00000240	31	00	01	17	43	6F	6D	70	61	6E	79	5F	44	6F	63	75	1 Company_Docu
00000256	6D	65	6E	74	5F	30	31	2D	30	31	00	01	18	4B	65	79	ment_01-01 Key
00000272	77	6F	72	64	73	5F	44	6F	63	75	6D	65	6E	74	5F	30	words_Document_0
00000288	31	2D	30	31	00	02	18	43	6F	6D	6D	65	6E	74	73	5F	1-01 Comments_
00000304	44	6F	63	75	6D	65	6E	74	5F	30	31	2D	30	31	00	01	Document_01-01
00000320	01	01	08	01	08	46	5C	E8	0D	AF	31	BF	41	02	09	01	F\è ¯1¿A
00000336	15	54	69	74	6C	65	5F	44	6F	63	75	6D	65	6E	74	5F	Title_Document_
00000352	30	31	2D	30	31	00	01	01	01	C0	56	0D	02	00	00	00	01-01 ÀV
00000368	C5	C8	63	2D	C2												ÅÈc-Â

STORE.DB DATA PAGE (DECOMPRESSED)



Offset	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	ANSI ASCII
00000000	71	01	00	00	DF	A7	DF	00	86	00	DF	A7	99	FE	05	56	q ßSß † ßS™þ V
00000016	56	6B	38	D1	54	07	02	03	80	CC	01	0E	03	81	F5	02	Vk8ÑT €Ì õ
00000032	C0	60	00	0A	03	01	00	00	00	E4	72	32	BF	41	01	00	À` är2¿A
00000048	00	00	0D	AF	31	BF	41	01	00	00	00	0D	AF	31	BF	41	¯1¿A ¯1¿A
00000064	01	1A	01	05	01	14	44	6F	63	75	6D	65	6E	74	5F	30	Document_0
00000080	31	2D	30	31	2E	64	6F	63	78	00	01	14	44	6F	63	75	1-01.docx Docu
00000096	6D	65	6E	74	5F	30	31	2D	30	31	2E	64	6F	63	78	00	ment_01-01.docx

Of particular interest, is the existence of the Catalog Node ID (CNID) and Parent CNID markers found within the records.

- It is similar in structure to a network database
- Each record maintains a relationship with its parent
- It allows a hierarchical arrangement of records to be built.

The Catalog Node ID is used by the HFS+ filesystem to uniquely identify each file/folder on the system.

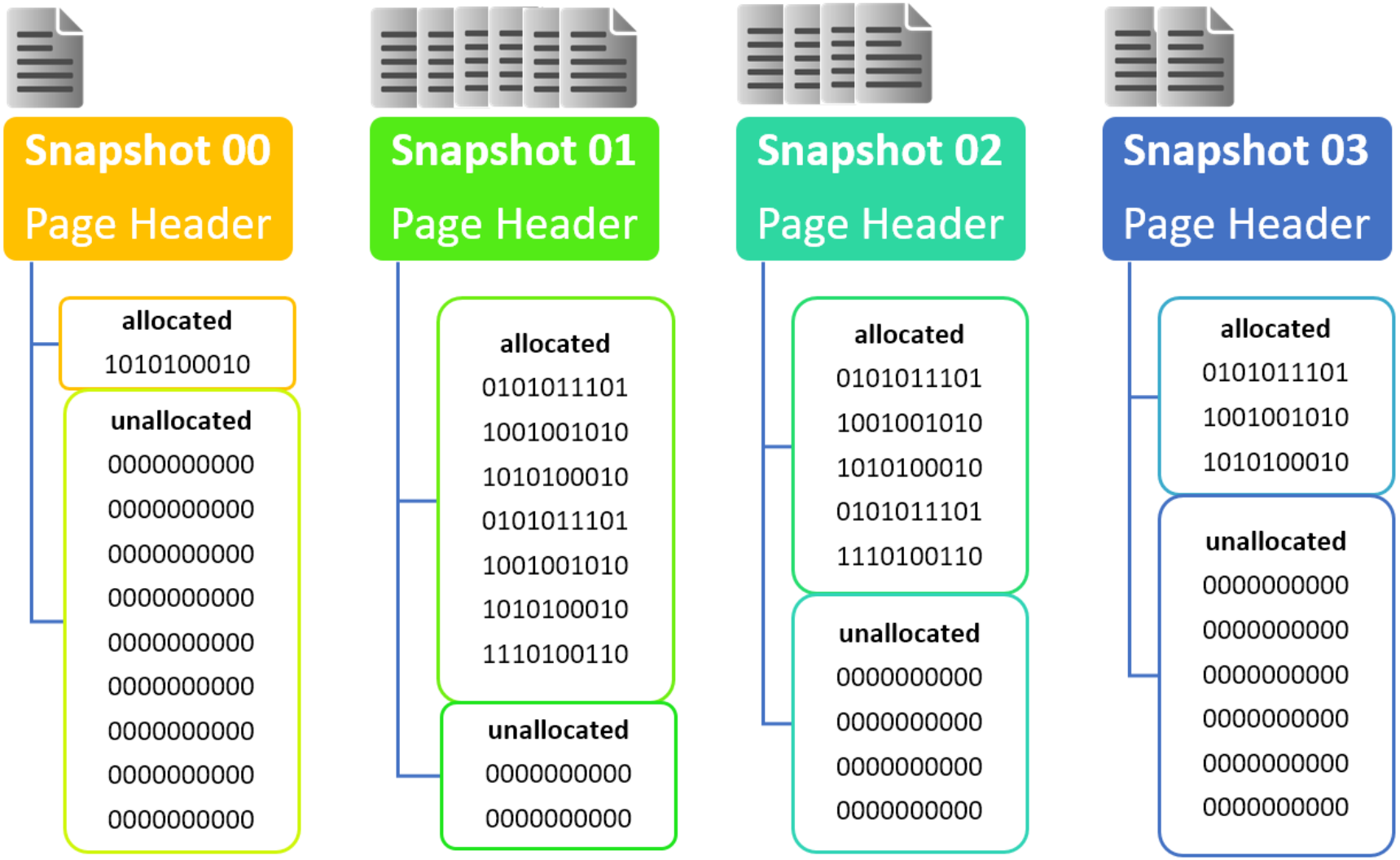
- An important feature is that they are not reused until exhausted
- New files created on an HFS+ filesystem are given the next consecutive CNID, even if an earlier one has been made available because of a deletion.

Why is this important?

- **We can use it to identify deleted files, files that no longer exist within the current `$Catalog` main index found within HFS+**
- **We can re-create directory structures**

EXPERIMENT 1

Snapshot	Items added or removed	macOS 10.12		OS X 10.11		OS X 10.8		macOS 10.12	OS X 10.11	OS X 10.8
		store.db records	*.store.db records*	*store.db records*	*.store.db records*	*store.db records*	*.store.db records*	*unallocated records*		
00		185882	185882	165116	165115	127423	127519	0	0	0
01	+885	185988	185988	165315	165906	127722	127746	0	0	0
02	-502	185988	186936	165315	165906	127722	127746	0	0	0
03		186434	186434	165560	165560	127722	127746	0	0	0
04		186434	186434	165560	165560	128038	128038	0	0	0
05		186434	186434	165560	165562	128038	128040	0	0	0
06		186434	186434	165568	165568	128143	128145	0	0	0
07		186434	186435	165568	165568	128143	128145	0	0	0
08	+1215	186434	186435	165568	167995	128143	130600	0	0	0
09	-740	186434	187907	165568	166691	129112	129111	0	0	1425
10		186434	187167	165568	166676	129112	129112	717	0	1425
11		186434	187167	165568	166684	129112	129111	345	0	1425
12		186434	187167	166684	166684	129111	129111	0	0	1426
13		186434	187167	166684	166684	129111	129111	0	0	1426
14		187167	187167	166684	166684	129111	129111	0	0	1426
15	+1639	187167	188780	166690	166468	131145	130083	1001	1902	1171
16		187167	188780	166690	167494	131145	129924	957	1902	1171


Snapshot 00
Page Header
allocated
1010100010
unallocated
0000000000
0000000000
0000000000
0000000000
0000000000
0000000000
0000000000
0000000000
0000000000
Snapshot 01
Page Header
allocated
0101011101
1001001010
1010100010
0101011101
1001001010
1010100010
1110100110
unallocated
0000000000
0000000000
Snapshot 02
Page Header
allocated
0101011101
1001001010
1010100010
0101011101
1110100110
unallocated
0000000000
0000000000
0000000000
0000000000
Snapshot 03
Page Header
allocated
0101011101
1001001010
1010100010
unallocated
0000000000
0000000000
0000000000
0000000000
0000000000
0000000000

EXPERIMENT 2

Snapshot	Count	exFAT		FAT32		HFS+		exFAT	FAT32	HFS+
		store.db records	.store.db records	store.db records	.store.db records	store.db records	.store.db records	unallocated records		
00	**2**	2	2	2	2	2	2	0	0	0
01	**2753**	2738	2738	2753	2753	2753	2753	0	0	0
02	**350**	350	350	**2753**	350	350	350	0	0	0
03	**350**	350	350	**2753**	350	350	350	0	0	0
04	**350**	350	350	**2753**	350	350	350	0	0	0
05	**350**	350	350	**2753**	350	350	350	0	0	0
06	**350**	350	350	**2753**	350	350	350	0	0	0
07	**0**	350	100	**2753**	100	350	2	35	41	314

EXPERIMENT 3

Snapshot	Count	exFAT		FAT32		exFAT	FAT32
		store.db records	.store.db records	store.db records	.store.db records	unallocated records	
00	2	2	2	2	2	0	0
01	2753	7	1526	7	1480	0	0
02	377	483	483	392	392	107	380
03	377	483	483	392	392	107	380
04	2	483	481	392	390	107	380
05	157	125	125	24	24	107	778
06	157	130	130	24	24	107	778

EXPERIMENTS 4, 5 AND 6

Filesystem	Notes	store.db records	.store.db records	unallocated records	Snapshot
HFS+	Standard build	185882	185882	0	00
HFS+	2876 extant files 24 folders	188922	186160	0	01
HFS+	2876 extant files 24 folders	deleted	deleted	375082	02

Snapshot	store.db records	.store.db Records	unallocated records
00	185882	185882	0
01	Database not available	Database not available	371912
02	Database not available	Database not available	378015
03	Database not available	Database not available	416192
04	Database not available	Database not available	392192
05	188950	188950	108017

Snapshot	CNID store.db	CNID .store.db	store.db records	.store.db records	unallocated records
00	440303	440304	185882	185882	0
01	461015	461016	186231	186231	66329
02	458655	458656	186039	186039	371317
03	462371	462372	186984	186984	392753
04	465046	465047	189011	189011	406146
05	465200	465201	189011	189011	757481

EXPERIMENT 8

Snapshot	.store.db CNID	.store.db starting extent	store.db CNID	store.db starting extent	unallocated records
macOS 10.11.6	425716	29,246,544	425715	29,246,536	0
updated to					
macOS 10.12	425716	29,246,544	425715	29,246,536	194779
OS X 10.7.5	332525	20,393,376	332524	20,393,312	35
updated to					
OS X 10.12.6	332525	20,393,376	332524	20,393,312	139987
OS X 10.8.5	328294	24,960,656	328293	24,960,648	0
updated to					
OS X 10.12.6	328294	24,960,656	328293	24,960,648	108418

EXPERIMENT 9

URN	OS X Version \ Source[7]	Pages recovered	unallocated records
01	Time Machine Backup Drive	314	N/A
02	Time Capsule	1045	N/A
03	Mac OS X 10.4.6	0	
04	Mac OS X 10.5.8	3022	N/A
05	Mac OS X 10.5.8	21	N/A
06	Mac OS X 10.6.8	405	53,855
07	Mac OS X 10.6.8	143	87
08	Mac OS X 10.7.5	3477	61,808
09	Mac OS X 10.7.5	852	7,518
10	Mac OS X 10.8.5	526	219757
11	Mac OS X 10.9.5	1406	461917
12	Mac OS X 10.9.5	1303	300142
13	Mac OS X 10.12.6	2019	490,130
14	Apple hard disk drive formatted for use on a windows system	1004	255,724

OUTCOME

The structure of the metadata store database has been analysed and partially decoded

Experiments used to reveal that records persist for a period of time within one of the copies of the database

Once a record is deleted it is no longer recoverable from within the database but may still be recovered from the copy or from unallocated clusters.

Deleted pages from the database, are recoverable from unused space on the filesystem.

If the Operating system undergoes a major update it appears that a copy of the metadata store is created before being deleted.

These database pages can be recovered from unused space on the filesystem

If the Spotlight index is reset re-indexed or recreated, the whole metadata store is deleted. These database pages can be recovered from unused space on the filesystem

INTERESTED IN LEARNING MORE?

Digital Investigation

- Atwal, T. S., Scanlon, M. and Le-Khac, N-A. **Shining a Light on Spotlight: Leveraging Apple's Desktop Search Utility to Recover Deleted File Metadata on macOS**, *Digital Investigation, April 2019*
- Khatri, Yogesh. **Investigating spotlight internals to extract metadata.** Digital Investigation, March 2019.

GitHub

- https://github.com/tajatwal
- https://github.com/ydkhatri

SHINING A LIGHT ON SPOTLIGHT

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