Understanding MacOS File System Events with FSEventsParser

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Who am I?

- Digital Forensics Expert at G-C Partners
- Part time researcher
  - All things Forensics
- Part time programmer
  - Python
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Importance

- Small number of tools available that parse FSEvents
- Records historical file system activity over time
- Currently not being fully utilized by Mac examiners
- Contains User and OS activity
  - Creations, deletions, renames, permission changes and more.
- Identify names of files that were previously existing but have since been deleted
- Identify what changes occurred to files of interest

Agenda

- Introduction to FSEvents
- Reverse engineering FSEvents
- Decoding FSEvents
- Parsing FSEvents
- Interesting artifacts
- Caveats

Introduction to FSEvents

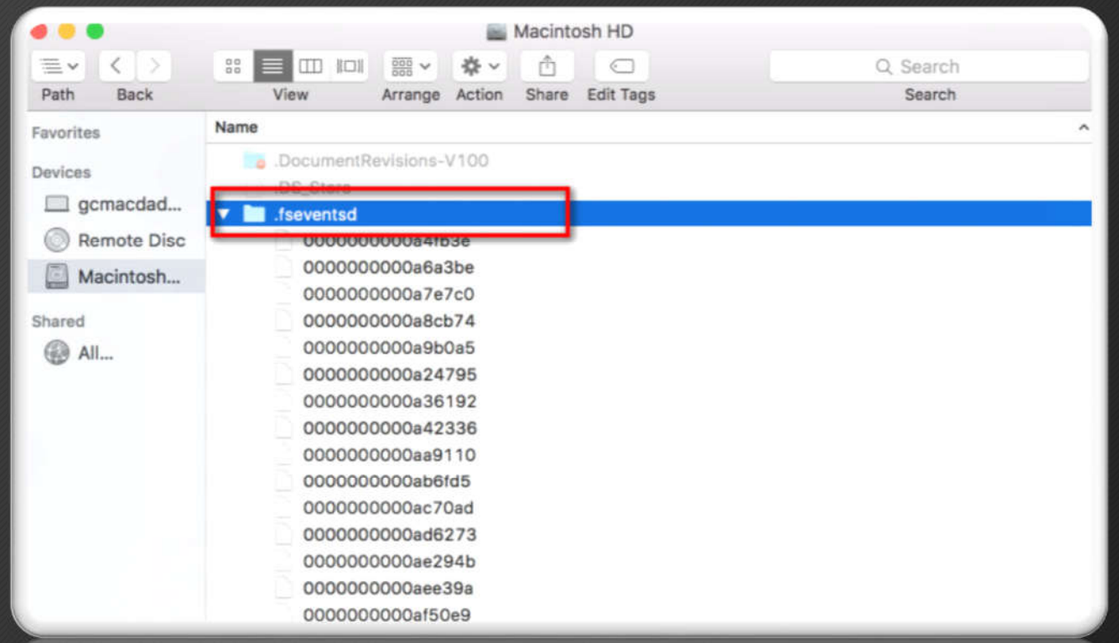
Introduction to FSEvents

- FSEvents or File System Events
- Generated by Apple OS FSEvents API
  - Introduced in 10.5 (Only directory events up to 10.6)
  - In 10.7 file events were introduced
- Stored in FSEvent log files (gzip)
  - Historical events of changes on the file system
  - Logs can span days to months
  - Records are stored alphabetically, not chronologically
- Found on MacOS devices and external devices plugged in to a Mac

Introduction to FSEvents

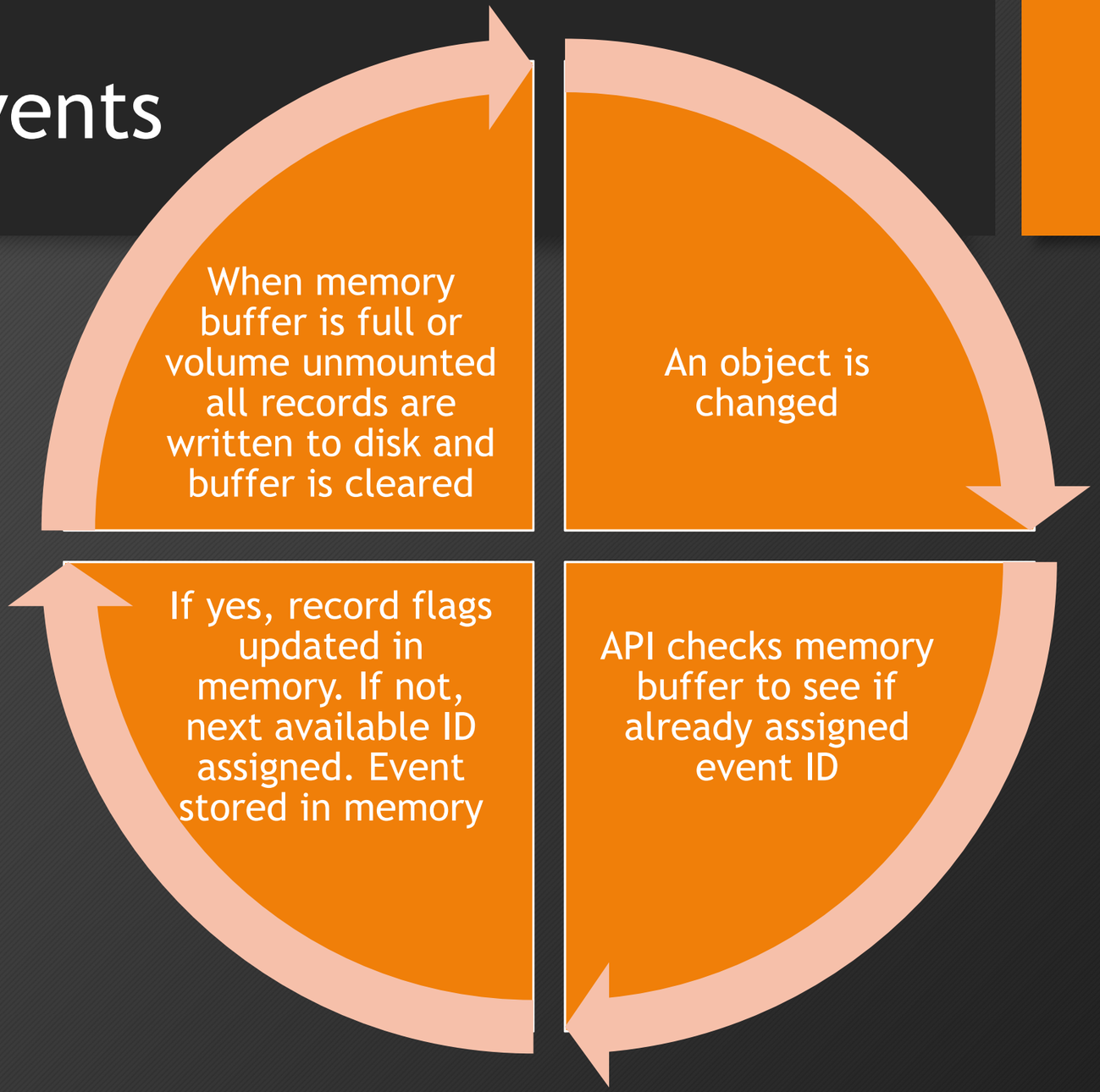
FSEvent logs

- Location in OS X:
  - /.fseventsd
- Location in iOS:
  - Data: /private/var/.fseventsd
  - System: /.fseventsd
  - Developer Patch: /DeveloperPatch/.fseventsd
- Gzip archive format
- Name is last Event ID stored in the FSevent log file plus 1.
  - E.g “00000000000a4b3e” or 674,622 decimal



Introduction to FSEvents

Lifecycle of an fsevent record



Reverse Engineering FSEvents

Reverse Engineering FSEvents

- Identifying the components of an FSEvent file
  - Undocumented
- Identifying the components of an FSEvent record
  - Undocumented
- Identifying the components of FSEvent record flags
  - Documented on Apple's developer *website, however ..
  - Documentation appears to be specific to live FSEvent monitoring and not FSEvents archived to disk
- Conducting controlled tests for each of the identified flags

*https://developer.apple.com/library/content/documentation/Darwin/Conceptual/FSEvents_ProgGuide/UsingtheFSEventsFramework/UsingtheFSEventsFramework.html

Decoding FSEvents

Decoding FSEvents

- An uncompressed FSEvent log can contain 1 or more pages with the magic header “1SLD”
- Each log can contain up to 5,000 events
- Events are ordered alphabetically by Full Path
- Each record consists of 3 components

FSEvent Record Components

Full Path	• The relative full path to the file system object that incurred a change.
Event ID	• Event ID assigned to full path on first change.
Record Flags	• Record flags indicating the type of object that was changed and what changed for it.

Decoding FSEvents

FSEvent Record Flags

- Type flags include:
  - File
  - Folder
  - Hard link
  - Symbolic link

- Reason flags include:
  - Created
  - Removed
  - Modified
  - Renamed
  - Permissions
  - Inode metadata
  - Finder information
  - Mount
  - Unmount
  - Last hard link removed
  - End of transaction
  - Document revisions

Offset	0	1	2	3	4	5	6	7	8	9	a	b	c	d	e	f	
00	31	53	4c	44	c1	66	9e	4c	5f	00	00	00	4d	79	5f	46	1 S L D Á f . L . . . . M y _ F
10	69	6c	65	5f	31	2e	74	78	74	00	8d	54	01	00	00	00	i l e _ 1 . t x t . . T . . . .
20	00	00	55	05	80	00	4d	79	5f	46	6f	6c	64	65	72	00	. . U . . . M y _ F o l d e r .
30	5d	54	01	00	00	00	00	00	c4	07	00	01	4d	79	5f	46	] T . . . . . Ä . . . M y _ F
40	6f	6c	64	65	72	2f	4d	79	5f	46	69	6c	65	5f	32	2e	o l d e r / M y _ F i l e _ 2 .
50	74	78	74	00	54	54	01	00	00	00	00	00	51	01	80	00	t x t . T T . . . . . Q . . .

	Description	Offset	Length	Data
	Page Magic Number	0x00	0x04	1SLD
	Page UNKNOWN Value	0x04	0x04	0xc1669e4c (3244727884)
	Page Size	0x08	0x04	0x0000005f (95)
	Record Full Path	0x0c	0x0d Variable	My_File_1.txt
	Null Terminator	0x19	0x01	.
	Record Event ID	0x1a	0x08	87,181
	Record Reason Flags	0x22	0x04	0x55058000
	Record Full Path	0x26	0x09 Variable	My_Folder
	Null Terminator	0x2f	0x01	.
	Record Event ID	0x30	0x08	87,133
	Record Reason Flags	0x38	0x04	0xc4070001
	Record Full Path	0x3c	0x13 Variable	My_Folder/My_File_2.txt
	Null Terminator	0x53	0x01	.
	Record Event ID	0x54	0x08	87,124
	Record Reason Flags	0x5c	0x04	0x51018000

Parsing FSEvents with FSEventsParser

Parsing FSEvents with FSEventsParser

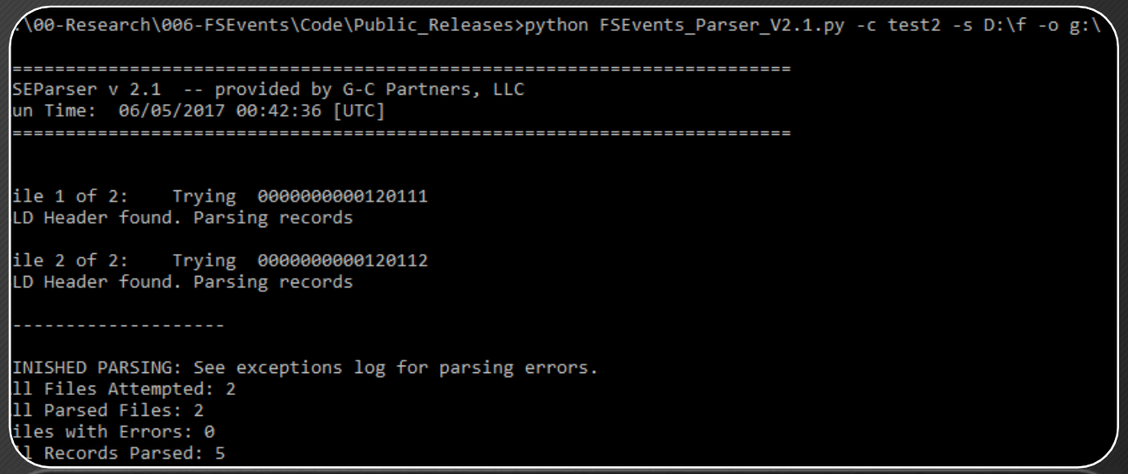
G-C Partners FSEventsParser Script

- Written for python 2.7
- Current version is 2.1
- Cross-platform compatible
  - Unix
  - Windows
- Available at https://github.com/dlcowen/FSEventsParser

Parsing FSEvents with FSEventsParser

Command Line Parsing

- Can be run against an active system's .fseventsd directory
  - Need root privileges
- Can be run against .fseventsd directory exported from a forensic image or other system



Parsing FSEvents with FSEventsParser

Output Data

- Script outputs data to:
  - SQLite3 database
  - Tab delimited TSV file
- Contains parsed record entries

event_id	filename	mask	mask_hex	record_end_offset	source	source_modified_time	other_dates
1179467	NULL	Mount;	0x00000002	25	D:\f\0000000000120111	10/22/2016 14:45	UNKNOWN
1179920	.DS_Store	Modified;InodeMetaMod;FileEvent;	0x14008000	47	D:\f\0000000000120111	10/22/2016 14:45	UNKNOWN
1179417	.Spotlight-V100/VolumeConfiguration.plist	Modified;InodeMetaMod;FileEvent;	0x14008000	101	D:\f\0000000000120111	10/22/2016 14:45	UNKNOWN
1180069	.fseventsd/sl-compat	FolderEvent;	0x00000001	45	D:\f\0000000000120112	10/22/2016 14:45	UNKNOWN
1180070	NULL	FolderEvent;EndOfTransaction;	0x00000021	58	D:\f\0000000000120112	10/22/2016 14:45	UNKNOWN

Interesting Artifacts

Record Artifacts

OS X

- Just scratching the surface of interesting artifacts:
  - .Trash activity
  - User folders activity
  - Internet activity
  - Mount events

Record Artifacts: OS X

Trash activity

- Files sent to the Trash
- Emptying the Trash

```
SELECT
	*, _ROWID_ "NAVICAT_ROWID"
FROM
	"fsevents"
WHERE
	"filename" LIKE 'Users/%/.Trash/%'
```

Record Artifacts: OS X

.Trash Folder

Removed flag

wd	filename	mask
24255026	Users/gc/.Trash/My_Tests/.DS_Store	Modified;InodeMetaMod;Removed;FileEvent;
24255452	Users/gc/.Trash/My_Tests/20160127_Tests	FolderEvent;Removed;
24255029	Users/gc/.Trash/My_Tests/20160127_Tests/.DS_Store	Removed;FileEvent;
24255032	Users/gc/.Trash/My_Tests/20160127_Tests/FSEventMonitor_v0.3_Terminal_log.txt	Removed;FileEvent;
24255449	Users/gc/.Trash/My_Tests/20160127_Tests/FSParser_Reports	FolderEvent;Removed;
24255440	Users/gc/.Trash/My_Tests/20160127_Tests/FSParser_Reports/FSEvents-EXCEPTIONS_LOG.txt	Removed;FileEvent;
24255443	Users/gc/.Trash/My_Tests/20160127_Tests/FSParser_Reports/FSEvents-Parsed_Records-tab_delimited.txt	Removed;FileEvent;
24255446	Users/gc/.Trash/My_Tests/20160127_Tests/FSParser_Reports/fsevents.sqlite	Removed;FileEvent;
24255437	Users/gc/.Trash/My_Tests/20160127_Tests/fsevents	FolderEvent;Removed;
24255035	Users/gc/.Trash/My_Tests/20160127_Tests/fsevents/00000000000094d6	Removed;FileEvent;
24255038	Users/gc/.Trash/My_Tests/20160127_Tests/fsevents/000000000000cf7a	Removed;FileEvent;
24255041	Users/gc/.Trash/My_Tests/20160127_Tests/fsevents/0000000000015233	Removed;FileEvent;
24255044	Users/gc/.Trash/My_Tests/20160127_Tests/fsevents/000000000002240c	Removed;FileEvent;
24255047	Users/gc/.Trash/My_Tests/20160127_Tests/fsevents/000000000002240d	Removed;FileEvent;
24255050	Users/gc/.Trash/My_Tests/20160127_Tests/fsevents/0000000000022e55	Removed;FileEvent;

Record Artifacts: OS X

User folders activity

- Activity in:
  - “Documents”
  - “Downloads”
  - “Desktop”

```
SELECT
      *, _ROWID_ "NAVICAT_ROWID"
FROM
      "fsevents"
WHERE
      "filename" LIKE 'Users/%/Documents/%’
      OR "filename" LIKE 'Users/%/Downloads/%’
      OR "filename" LIKE 'Users/%/Desktop/%'
```

Record Artifacts: OS X

wd	filename	mask
7747658	Users/neiko/Downloads/Microsoft_Office_2016_15.32.17030901_Installer.pkg	Renamed;FileEvent;
7751272	Users/neiko/Downloads/Unconfirmed 148620.crdownload	Modified;Renamed;Created;PermissionChange;ExtendedAttrModified;FileEvent;
7751632	Users/neiko/Downloads/navicat112_sqlite_en.dmg	Renamed;Created;PermissionChange;ExtendedAttrModified;FileEvent;
7730702	Users/neiko/Library/Containers/com.microsoft.Word/Data/Documents/whatsNewJSONCache.plist	Renamed;PermissionChange;FinderInfoMod;FileEvent;
7980785	Users/neiko/Desktop/.DS_Store	Modified;InodeMetaMod;Created;FinderInfoMod;FileEvent;
7978872	Users/neiko/Desktop/.fseventsd	FolderEvent;Renamed;InodeMetaMod;PermissionChange;ExtendedAttrModified;
7975787	Users/neiko/Desktop/.fseventsd/0000000000006211	Modified;Created;PermissionChange;FinderInfoMod;FileEvent;
7975799	Users/neiko/Desktop/.fseventsd/0000000000006212	Modified;Created;PermissionChange;FinderInfoMod;FileEvent;
7975811	Users/neiko/Desktop/.fseventsd/0000000000015401	Modified;Created;PermissionChange;FinderInfoMod;FileEvent;
7975823	Users/neiko/Desktop/.fseventsd/00000000000210fb	Modified;Created;PermissionChange;FinderInfoMod;FileEvent;
7975835	Users/neiko/Desktop/.fseventsd/000000000002df90	Modified;Created;PermissionChange;FinderInfoMod;FileEvent;
7975847	Users/neiko/Desktop/.fseventsd/000000000003cdea	Modified;Created;PermissionChange;FinderInfoMod;FileEvent;
7975859	Users/neiko/Desktop/.fseventsd/000000000004b3f0	Modified;Created;PermissionChange;FinderInfoMod;FileEvent;

Downloads

Desktop

Record Artifacts: OS X

Internet activity

- Websites visited
  - Chrome
  - Safari

```
SELECT
	*, _ROWID_ "NAVICAT_ROWID"
FROM
	"fsevents"
WHERE
	"filename" LIKE
'Users/%/Library/Caches/Metadata/Safari/History/%'
OR "filename" LIKE 'Users/%/Library/Application
Support/Google/Chrome/Default/Local Storage/%'
```

Record Artifacts: OS X

wd	filename	mask
5408233	Users/other/Library/Application Support/Google/Chrome/Default/Local Storage/https_www.netflix.com_0.localstorage-journal	Modified;InodeMetaMod;FileEvent;
5325097	Users/other/Library/Application Support/Google/Chrome/Default/Local Storage/https_www.youtube.com_0.localstorage	InodeMetaMod;Created;ExtendedAttrModified;FileEvent;
5325109	Users/other/Library/Application Support/Google/Chrome/Default/Local Storage/https_www.youtube.com_0.localstorage-journal	Modified;InodeMetaMod;Created;ExtendedAttrModified;FileEvent;
5463881	Users/other/Library/Application Support/Google/Chrome/Default/Local Storage/chrome-extension_pkedcjkdefgpdelpbcmbmeomcjbeemfm_0.localstor	Modified;InodeMetaMod;FileEvent;
5408467	Users/other/Library/Application Support/Google/Chrome/Default/Local Storage/https_www.amazon.com_0.localstorage-journal	Modified;InodeMetaMod;FileEvent;
5409287	Users/other/Library/Application Support/Google/Chrome/Default/Local Storage/https_www.netflix.com_0.localstorage	Event;
5412791	Users/other/Library/Application Support/Google/Chrome/Default/Local Storage/https_www.netflix.com_0.localstorage	aMod;FileEvent;
5481704	Users/nikki/Library/Caches/Metadata/Safari/History/http:%2F%2Fwfaa.com%2F.webhistory	Modified;Created;ExtendedAttrModified;ExtendedAttrRemoved;FileEvent;
5481716	Users/nikki/Library/Caches/Metadata/Safari/History/http:%2F%2Fwww.wfaa.com%2F.webhistory	Modified;Created;ExtendedAttrModified;ExtendedAttrRemoved;FileEvent;
5491733	Users/nikki/Library/Caches/Metadata/Safari/History/http:%2F%2Fwww.wfaa.com%2Fweather%2Fradars.webhistory	Modified;Created;ExtendedAttrModified;ExtendedAttrRemoved;FileEvent;
5493889	Users/nikki/Library/Caches/Metadata/Safari/History/http:%2F%2Fwww.wfaa.com%2Fweather%2Ftexas-radar.webhistory	Modified;Created;ExtendedAttrModified;ExtendedAttrRemoved;FileEvent;
5486606	Users/nikki/Library/Caches/Metadata/Safari/History/http:%2F%2Fwww.wfaa.com%2Fweather%2Fwfaa-weather-large-hail-damaging-wind-possible-toc	Modified;Created;ExtendedAttrModified;ExtendedAttrRemoved;FileEvent;
5504075	Users/nikki/Library/Caches/Metadata/Safari/History/https:%2F%2Fen.wikipedia.org%2Fwiki%2FWind_shear.webhistory	Modified;Created;ExtendedAttrModified;ExtendedAttrRemoved;FileEvent;
5498048	Users/nikki/Library/Caches/Metadata/Safari/History/https:%2F%2Fwww.google.com%2Fsearch?client=safari&rls=en&q=weather&ie=UTF-8&oe=UTF-8	Modified;Created;ExtendedAttrModified;ExtendedAttrRemoved;FileEvent;

Wfaa.com visited

Record Artifacts: OS X

Mount activity

- Mount activity related to:
  - DMGs
  - External devices
  - Shared network drives

```
SELECT
      *, _ROWID_ "NAVICAT_ROWID"
FROM
      "fsevents"
WHERE
      "mask" LIKE '%mount%'
```

Record Artifacts: OS X

vent_id	filename	mask	mask_hex	source_modified_time
6698195	/Volumes/Recovery HD	FolderEvent;Unmount;Removed;	0x02000005	2017-03-24 17:46:32
6691374	/home	Mount;	0x00000002	2017-03-24 17:46:32
6690718	/net	Mount;	0x00000002	2017-03-24 17:46:32
6727297	/Volumes/Recovery HD	Unmount;	0x00000004	2017-03-24 20:56:02
6757329	/private/var/setup	FolderEvent;Mount;Unmount;PermissionC		-03-24 20:56:02
6767834	/Volumes/Recovery HD	FolderEvent;Mount;Unmount;Removed;		-03-25 01:09:45
10629284	/Volumes/MachOView	Mount;	0x00000002	2016-03-21 15:29:44
444876	/Volumes/OSX_108TESt	FolderEvent;Unmount;FolderCreated;		2016-03-21 15:29:44
245516	/Volumes/OSX_108TESt 1	Mount;Unmount;		6-03-21 15:29:44
10576968	/Volumes/TEST	FolderEvent;Unmount;FolderCreated;	0x80000005	2016-03-21 15:29:44
10535360	/Volumes/Test_Folder_Actions	FolderEvent;Mount;Unmount;FolderCreated;Removed;	0x82000007	2016-03-21 15:29:44
10576969	/Volumes/UNTITLED	FolderEvent;Unmount;Removed;	0x02000005	2016-03-21 15:29:44
10625760	/Volumes/Untitled	Unmount;	0x00000004	2016-03-21 15:29:44
1419	/home	Mount;	0x00000002	2016-03-21 15:29:44
1418	/net	Mount;	0x00000002	2016-03-21 15:29:44
10640527	/Volumes/Recovery HD	FolderEvent;Mount;Unmount;Removed;	0x02000007	2016-03-23 09:58:48
10686244	/Volumes/artifacts-20160114.pkg	Mount;Unmount;	0x00000006	2016-03-23 09:58:48
10686248	/Volumes/bencode-1.0.pkg	Mount;Unmount;	0x00000006	2016-03-23 09:58:48

DMG mounted

Volumes mounted/unmounted

Record Artifacts

iOS

- iCloud synced files
- Internet activity
- Email activity

Record Artifacts: iOS

iCloud synced files

- iCloud synced files from other devices

```
SELECT
      *, _ROWID_ "NAVICAT_ROWID"
FROM
      "fsevents"
WHERE
      "filename" LIKE 'mobile/Library/Mobile
Documents/com~apple~CloudDocs/%'
```

Record Artifacts: iOS

.Trash activity from computer

event_id	filename	mask
33604138	mobile/Library/Mobile Documents/com~apple~CloudDocs/.Trash/_.fseventsd 5.30.19 PM/.00000000020d4441.icloud	Renamed;FileEvent;
33605361	mobile/Library/Mobile Documents/com~apple~CloudDocs/.Trash/_.fseventsd 5.30.19 PM/.00000000020d9d05.icloud	Renamed;FileEvent;
33605341	mobile/Library/Mobile Documents/com~apple~CloudDocs/.Trash/_.fseventsd 5.30.19 PM/.00000000020dea0e.icloud	Renamed;FileEvent;
33605331	mobile/Library/Mobile Documents/com~apple~CloudDocs/.Trash/_.fseventsd 5.30.19 PM/.00000000020e5586.icloud	Renamed;FileEvent;
33603451	mobile/Library/Mobile Documents/com~apple~CloudDocs/.Trash/_.fseventsd 5.30.19 PM/.00000000020f16ac.icloud	Renamed;FileEvent;
33604219	mobile/Library/Mobile Documents/com~apple~CloudDocs/.Trash/_.fseventsd 5.30.19 PM/.00000000020f6e68.icloud	Renamed;FileEvent;
33604177	mobile/Library/Mobile Documents/com~apple~CloudDocs/.Trash/_.fseventsd 5.30.19 PM/.0000000002100c5f.icloud	Renamed;FileEvent;
33604258	mobile/Library/Mobile Documents/com~apple~CloudDocs/.Trash/_.fseventsd 5.30.19 PM/.0000000002107919.icloud	Renamed;FileEvent;
33604893	mobile/Library/Mobile Documents/com~apple~CloudDocs/.Trash/_.fseventsd 5.30.19 PM/.000000000210bacb.icloud	Renamed;FileEvent;
33605381	mobile/Library/Mobile Documents/com~apple~CloudDocs/.Trash/_.fseventsd 5.30.19 PM/.000000000210ff8b.icloud	Renamed;FileEvent;
33603361	mobile/Library/Mobile Documents/com~apple~CloudDocs/.Trash/_.fseventsd 5.30.19 PM/.0000000002113bd4.icloud	Renamed;FileEvent;

Record Artifacts: iOS

Internet activity

- Websites visited?

```
SELECT
      *, _ROWID_ "NAVICAT_ROWID"
FROM
      "fsevents"
WHERE
      "filename" LIKE '%websitedata/local%'
```

Record Artifacts: iOS

event_id	filename	mask
3688334	mobile/Containers/Data/Application/4B88FE56-DDDE-42D9-BE34-54F61FED2D57/Library/WebKit/WebsiteData/LocalStorage/http_www.redsn0w.us_0.localstorage-journal	Modified;Created;Removed;FileEvent;
3732012	mobile/Containers/Data/Application/4B88FE56-DDDE-42D9-BE34-54F61FED2D57/Library/WebKit/WebsiteData/LocalStorage/StorageT	Modified;Created;Removed;FileEvent;
3702270	mobile/Containers/Data/Application/4B88FE56-DDDE-42D9-BE34-54F61FED2D57/Library/WebKit/WebsiteData/LocalStorage/http_ww	Modified;FileEvent;
3790959	mobile/Containers/Data/Application/4B88FE56-DDDE-42D9-BE34-54F61FED2D57/Library/WebKit/WebsiteData/LocalStorage/StorageTracker.db-journal	Modified;Created;Removed;FileEvent;
3790962	mobile/Containers/Data/Application/4B88FE56-DDDE-42D9-BE34-54F61FED2D57/Library/WebKit/WebsiteData/LocalStorage/https_www.instagram.com_0.localstorage	Modified;Created;Removed;FileEvent;
3790860	mobile/Containers/Data/Application/4B88FE56-DDDE-42D9-BE34-54F61FED2D57/Library/WebKit/WebsiteData/LocalStorage/https_www.instagram.com_0.localstorage-journal	Modified;Created;Removed;FileEvent;
3847710	mobile/Containers/Data/Application/E2DD4CDC-722A-480C-86B3-1F5BCD1E8F2F/Library/WebKit/WebsiteData/LocalStorage/StorageTracker.db-journal	Modified;Created;Removed;FileEvent;
3847983	mobile/Containers/Data/Application/E2DD4CDC-722A-480C-86B3-1F5BCD1E8F2F/Library/WebKit/WebsiteData/LocalStorage/https_m.youtube.com_0.localstorage-journal	Modified;Created;Removed;FileEvent;
3806827	mobile/Containers/Data/Application/F6142168-1D6B-44CC-8CD1-C306ED328B0C/Library/WebKit/WebsiteData/LocalStorage/StorageTracker.db-journal	Modified;Created;Removed;FileEvent;
3807598	mobile/Containers/Data/Application/F6142168-1D6B-44CC-8CD1-C306ED328B0C/Library/WebKit/WebsiteData/LocalStorage/http_pubads.g.doubleclick.net_0.localstorage	Modified;Created;FileEvent;
3806733	mobile/Containers/Data/Application/F6142168-1D6B-44CC-8CD1-C306ED328B0C/Library/WebKit/WebsiteData/LocalStorage/http_pubads.g.doubleclick.net_0.localstorage-journal	Modified;Created;Removed;FileEvent;
3807607	mobile/Containers/Data/Application/F6142168-1D6B-44CC-8CD1-C306ED328B0C/Library/WebKit/WebsiteData/LocalStorage/http_www.vox.com_0.localstorage	Modified;Created;FileEvent;
3807349	mobile/Containers/Data/Application/F6142168-1D6B-44CC-8CD1-C306ED328B0C/Library/WebKit/WebsiteData/LocalStorage/http_ww	Modified;Created;Removed;FileEvent;
3845403	mobile/Containers/Data/Application/C8F70FFA-7504-49A0-B1A9-1A5C5A7B60FB/Library/WebKit/WebsiteData/LocalStorage/StorageT	InodeMetaMod;FileEvent;
3845439	mobile/Containers/Data/Application/C8F70FFA-7504-49A0-B1A9-1A5C5A7B60FB/Library/WebKit/WebsiteData/LocalStorage/https_m.facebook.com_0.localstorage-shm	Modified;InodeMetaMod;FileEvent;
3885979	mobile/Containers/Data/Application/E2DD4CDC-722A-480C-86B3-1F5BCD1E8F2F/Library/WebKit/WebsiteData/LocalStorage/StorageTracker.db-journal	Modified;Created;Removed;FileEvent;
3886855	mobile/Containers/Data/Application/E2DD4CDC-722A-480C-86B3-1F5BCD1E8F2F/Library/WebKit/WebsiteData/LocalStorage/https_m.youtube.com_0.localstorage	Modified;FileEvent;
3886308	mobile/Containers/Data/Application/E2DD4CDC-722A-480C-86B3-1F5BCD1E8F2F/Library/WebKit/WebsiteData/LocalStorage/https_www.google.com_0.localstorage-journal	Modified;Created;Removed;FileEvent;

www.redsn0w.us visited

www.vox.com visited

Record Artifacts: iOS

Email activity

- Inbox
- Sent
- Attachments

```
SELECT
      *, _ROWID_ "NAVICAT_ROWID"
FROM
      "fsevents"
WHERE
      "filename" LIKE 'mobile/Library/Mail/%’
```

Record Artifacts: iOS

event_id	filename	mask
5428567	mobile/Library/Mail/IMAP-[redacted]/INBOX.imapmbox/Attachments/55212/4/shield.png	Renamed;FileEvent;
5428634	mobile/Library/Mail/IMAP-[redacted]@imap.gmail.com/INBOX.imapmbox/Attachments/55214/2/unknown_device.png	Renamed;FileEvent;
5428589	mobile/Library/Mail/IMAP-[redacted]@imap.gmail.com/INBOX.imapmbox/Attachments/55214/3/google_logo.png	Renamed;FileEvent;
5428653	mobile/Library/Mail/IMAP-[redacted]@imap.gmail.com/INBOX.imapmbox/Attachments/55214/4/shield.png	Renamed;FileEvent;
33902492	mobile/Library/Mail/IMAP-[redacted]/INBOX.imapmbox/Attachments/64567/2/FSEvents_Documentation.docx	Renamed;FileEvent;
33905154	mobile/Library/Mail/IMAP-[redacted]/INBOX.imapmbox/Attachments/64573/2/mime-attachment.jpg	Renamed;FileEvent;
33905245	mobile/Library/Mail/IMAP-[redacted]/INBOX.imapmbox/Attachments/64573/3/mime-attachment.jpg	Renamed;FileEvent;
33905294	mobile/Library/Mail/IMAP-[redacted]/INBOX.imapmbox/Attachments/64573/4/mime-attachment.jpg	Renamed;FileEvent;
33905343	mobile/Library/Mail/IMAP-[redacted]/INBOX.imapmbox/Attachments/64573/5/mime-attachment.jpg	Renamed;FileEvent;
33905114	mobile/Library/Mail/IMAP-[redacted]/INBOX.imapmbox/Attachments/64573/6/mime-attachment.gif	Renamed;FileEvent;
34392427	mobile/Library/Mail/IMAP-[redacted]/INBOX.imapmbox/Attachments/64618/2/[redacted].xls	Renamed;FileEvent;
36504866	mobile/Library/Mail/IMAP-[redacted]/INBOX.imapmbox/Attachments/39892/2/[redacted].xls	Removed;FileEvent;
36504854	mobile/Library/Mail/IMAP-[redacted]/INBOX.imapmbox/Attachments/49134/2/IMG_1957.JPG	Removed;FileEvent;
36504818	mobile/Library/Mail/IMAP-[redacted]/INBOX.imapmbox/Attachments/50064/1.2	FolderEvent;Removed;
36504815	mobile/Library/Mail/IMAP-[redacted]/INBOX.imapmbox/Attachments/50064/1.2/Screen Shot 2017-05-03 at 10.14.40 AM.png	Removed;FileEvent;

Caveats

Caveats

- Lost FSEvents
- Lack of timestamps
- External devices
- Anti-forensics
- Coalescing of multiple changes

Caveats: Lost FSEvents

Problem

- FSEvents are lost due to either:
  - A hard reset of a system
  - A system crash
  - Not properly unmounting a volume
  - System upgrades

Remedies

- Carve for gzip files

Caveats: Lack of Timestamps

Problem

- FSEvent Records consist of:
  - Event ID
  - Full Path
  - Flags
- Note timestamps are not mentioned

Remedies

- Use temporal data from the names of logs

wd	filename	mask	mask_hex	source_modified_time	other_dates
1054	private/var/log/DiagnosticMessages/2017.05.13.asl	Created;PermissionChange;ExtendedAttrModified;FileEvent;	0x01038000	2017-05-13 13:02:26	2017.05.13
426	private/var/log/asl/2017.05.13.G80.asl	Created;PermissionChange;ExtendedAttrModified;FileEvent;	0x01038000	2017-05-13 13:02:26	2017.05.13
519	private/var/log/powermanagement/2017.05.13.asl	Modified;Created;PermissionChange;ExtendedAttrModified;FileEvent;	0x11038000	2017-05-13 13:02:26	2017.05.13
209338	private/var/log/powermanagement/2017.05.13.asl	Modified;FileEvent;	0x10008000	2017-05-13 14:39:47	UNKNOWN
1124380	private/var/log/DiagnosticMessages/2017.05.13.asl	Modified;FileEvent;	0x10008000	2017-05-13 16:06:22	UNKNOWN
3796573	private/var/log/DiagnosticMessages/2017.05.13.asl	Modified;FileEvent;	0x10008000	2017-05-13 16:26:37	UNKNOWN
5079026	private/var/log/DiagnosticMessages/2017.05.13.asl	Modified;FileEvent;	0x10008000	2017-05-14 09:22:29	2017.05.13,2017.05.14
5078975	private/var/log/asl/2017.05.13.G80.asl	Modified;FileEvent;	0x10008000	2017-05-14 09:22:29	2017.05.13,2017.05.14
5079020	private/var/log/powermanagement/2017.05.13.asl	Modified;FileEvent;	0x10008000	2017-05-14 09:22:29	2017.05.13,2017.05.14

Caveats: External Devices

Problem

- Unsafe removal results in lost events
- Safe removal was performed, but FSEvents not finished writing to disk
- File system compatibility issues results in lost events

Remedies

- Hope that the user has properly unmounted their devices
  - Carving for those lost events might not be possible due to FSEvents being stored in memory

Caveats: Coalescing of multiple changes

Problem

- The FSEvents API coalesces multiple changes into a single record resulting in:
  - Inability to determine order of changes
  - Inability to determine frequency of changes

Remedies

- None

This file may have been created 3 times and removed twice, but we will never know

Event ID	Record Full Path	Event Reason Flags
123	Users/GC/Desktop/My_Test_File.txt	Created,Removed,Modified,FileEvent

Caveats: Anti-Forensics

Problem

- A no_log file was placed in the .fseventsd directory
  - FSEvents are not recorded for the partition
  - Note that the recovery partition on a Mac computer contains this file by default

Remedies

- None. However, this scenario is unlikely and requires root privileges and advanced knowledge of FSEvents

Questions?

- Blog: www.nicoleibrahim.com
- Code: www.github.com/dlcowen/FSEventsParser

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