

Tupelo – Whole Disk Acquisition, Storage and Search

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Outline

- 1 What, Why, How
- 2 Acquisition/Analysis
- 3 Search
- 4 Availability



Tupelo - What?

- Tupelo is an open-source Java/C codebase for efficient whole disk acquisition, storage and analysis.
- Analysis step leverages existing open-source Sleuthkit disk forensics library to walk filesystems.
- Integrates with emerging standard STIX (Structured Threat Information Expression) to ingest and author shared information about malicious artifacts.
- Makes use of other Java artifacts in the disk forensics arena.



Tupelo - Why?

- If the disk whose content you wish to capture is suspected of containing malicious artifacts, how can software residing on that same disk be relied upon to present accurate disk content?
- To overcome this problem of trust, Tupelo does “dead disk acquisition”, and runs from trusted media, e.g. a bootable CD/USB. Yes, you have to power down and reboot. Alternatives?



Tupelo - How?

- Users acquire whole disk device contents, storing a copy in a *Tupelo store*.
- Data transitions from *unmanaged* (user disk) to *managed* (stored copy).
- Once stored, content is read-only, and analyzed: filesystems, un-allocated areas.
- Analysis results placed in the store alongside the data as *attributes*, key/value pairs with arbitrary values.
- Same disk can be acquired repeatedly, and many disks can be acquired.
- Store then essentially a structured (but not relational) database. The (logical) unit of storage is 'whole disk at a given time'.



Tupelo Terms, Preparation

Tupelo's command-line inspired by git (single driver program, many sub-commands). First, identify the disk to acquire and the store to hold that acquisition:

```
acquirer$ tup device add HD /dev/sda
id      = ATA-WDC-WX71C6287816           // unique!
size    = 320GB

acquirer$ tup store add ES /mounted/external/4TB
space   = 4TB
```

Device and store 'adds' associate easy-to-use names with hard-to-use names.



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Tupelo Disk Capture

True dead-filesystem capture requires a bootable Linux CD with Tupelo added. Capture (push) destination must be 'off-disk'. Both **local external drive**, remote locations work:

```
acquirer@bootCD$ tup device add HD /dev/sda
id    = ATA-WDC-WX71C6287816

acquirer@bootCD$ tup store add LAS /mounted/external/4TB
space = 4TB

acquirer@bootCD$ tup store add WS https://webAccessedTupeloStore/
space = 2.2TB

acquirer@bootCD$ tup push HD LAS ; tup push HD WS
```

Our prototype boot CD is Caine plus Tupelo.



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acquirer@bootCD$ tup push HD LAS ; tup push HD WS
```

Our prototype boot CD is Caine plus Tupelo.



Virtual Disk Capture

Tupelo also reads virtual machine data. A powered-off VM satisfies requirements for dead-filesystem capture:

```
acquirer$ tup device add XP /path/to/VirtualBox/WindowsXP-VM  
id      = VMDK-2fe54bfe  
size    = 10GB  
  
acquirer$ tup push XP WS
```

You can of course also capture a 'live system'. Trust?



Whole Disk Acquisition Is Space Efficient

A **disk push** results in a store entry tagged by what and when. Here we capture a laptop drive, dual-boot Windows/Linux, 320GB:

Acquirer@BootCD

```
acquirer$ tup push HD ES
Timestamp : 2016102301
Unmanaged : 320GB
Managed  : 197GB
Elapsed   : 8536s
```

StoreFilesystem@ExternalDrive

```
admin$ tree /path/to/TupeloStore
ATA-WDC-WX71C6287816
2016102301
    ATA-WDC-WX71C6287816-2016102301.tmd
```

Define a *grain* as a sequence of sectors, typically 128 sectors (64K). We then push the disk grain-by-grain. Can mark all-zero grains as special and compress all other grains. Result: a 123GB space saving in this case.



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Operations On Store Content: Digest

After acquisition, put on Tupelo admin hat and process the new store addition. First, we **digest** the new content. Produces an MD5 hash of each grain, so can represent 64KB in 16 bytes. Our 320GB disk digests to 16MB.

Administrator@Store

```
admin$ tup digest S 1  
Digest : 16MB
```

StoreFilesystem@ExternalDrive

```
admin$ tree /path/to/TupeloStore  
ATA-WDC-WX71C6287816  
2016102301  
    ATA-WDC-WX71C6287816-2016102301.tmd  
    ATA-WDC-WX71C6287816-2016102301.md5
```

Why digest? To make future captures of this disk further space-optimized.



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```

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Operations On Store Content: Analysis

Exposing store contents as a mount point leverages any software that can read device files, e.g. Sleuthkit. All done in-place, no need to 'inflate' anything (which costs disk!)

```
$ mkdir mnt; tup mount ES mnt
```

```
$ mmls mnt/ATA-WDC-WX71C6287816/2016102301
```

```
$ fls -o 2048 mnt/ATA-WDC-WX71C6287816/2016102301
```

```
$ fiwalk mnt/ATA-WDC-WX71C6287816/2016102301
```

```
$ autopsy mnt/ATA-WDC-WX71C6287816/2016102301 ?
```

```
$ cat mnt/ATA-WDC-WX71C6287816/2016102301 > /dev/sda !!
```



Operations On Store Content: Tupelo Additions

```
$ tup info ES
```

```
1 ATA-WDC-WX71C6287816, 2016102301 (320GB)
```

```
$ tup hashvs ES 1 ; tup hashfs ES 1
```

```
$ tup bodyfile ES 1 ; tup winrej ES 1
```

```
1 ATA-WDC-WX71C6287816, 2016102301 (320GB)
```

```
1 hashvs
```

```
2 hashfs-2048-716800 // NTFS
```

```
3 hashfs-718848-195306576 // NTFS
```

```
4 hashfs-196026368-381857792 // EXT4
```

```
5 bodyfile-2048-716800
```

```
6 bodyfile-718848-195306576
```

```
7 bodyfile-196026368-381857792
```



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  3 hashfs-718848-195306576     // NTFS
  4 hashfs-196026368-381857792  // EXT4
  5 bodyfile-2048-716800
  6 bodyfile-718848-195306576
  7 bodyfile-196026368-381857792
```



Analysis Result: Unallocated Areas

```
$ tup hashvs -p ES 1
```

START	LEN	MD5
0	1	dd834b02d5e7dbad368cc81194e75958d02e085c
0	2048	b350e07662708ed52fe0ef637e2c87370180c4b7
196025424	944	56f5073640009f85d7576781476df2ea5cb90dd9
577884160	2048	8c993a0b65f6ad7df717101db21ca09cd4d2ccee
625139712	2736	24f9417794527c5b73e92aa6d23e88ee8f6924c0

Why? To track unallocated area changes over time.



Analysis Result: File Hashes

```
$ tup hashfs -p ES 1.4
```

```
164ebd6889588da166a52ca0d57b9004 bin/bash
```

```
0a35aa198d80c3b7ebcdd0cefca38063 bin/bunzip2
```

```
ad9d7ce76bac4a59ece0a01f717ce2d5 bin/busybox
```

```
...
```

Why? To leverage efficient file identification given content hash, a common Indicator-Of-Compromise (STIX?).



Analysis Result: Sleuthkit Bodyfiles

A bodyfile captures aspects of a file: owner, permissions, timestamps, content hash:

```
$ tup bodyfile -p ES 1.3
```

```
127aa81343a7c6f665c22cb1293b0a90|/Windows/splwow64.exe|69122|  
r/rrwxrwxrwx|0|0|67072|1402952402|1427400287|1427400287|1402952402
```

```
78414f7183e7af72de7f691ed7a37b33|/Windows/TSSysprep.log|85334|  
r/rrwxrwxrwx|0|0|5949|1401489442|1428772602|1428772602|1401489442
```

```
163a95975e1d8819e653aa3e961371ca|/Windows/twain_32.dll|25115|  
r/rrwxrwxrwx|0|0|51200|1290309910|1427400032|1427400032|1290309910
```

Why? To leverage efficient lookup of file changes over time.



Normal Computer Use

Reboot to normal operations. Over time, disk content changes...

```
// Read the news, installs cookies
$ firefox news.bbc.co.uk

// Install new software, intentional
$ apt-get install octaveMatlabClone

// Install new software, un-intentional
$ attachmentInstallsMalwareAndSilencesAntiVirus
```

Next, capture whole disk again, via second Tupelo push. Can then compare disk state before, after this activity.



Repeated Acquisitions Increase Store Performance

So, disk content changed. Boot Tupelo CD, **push disk**, every Friday perhaps:

Acquirer@BootCD

```
acquirer$ tup push HD ES  
Timestamp : 2016102501  
Unmanaged : 320GB  
Managed   : 1.4GB  
Elapsed    : 4410s
```

StoreFilesystem@ExternalDrive

```
ATA-WDC-WX71C6287816  
2016102301  
    ATA-WDC-WX71C6287816-2016102301.tmd  
    ATA-WDC-WX71C6287816-2016102301.md5  
2016102501  
    ATA-WDC-WX71C6287816-2016102501.tmd
```

Note the new stored size of only 1.4GB! By retrieving the pre-computed digest and comparing grains in original and new captures, we can mark many grains in new capture 'same as parent'. Vastly improves the net space efficiency of captured disks.



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```
acquirer$ tup push HD ES
Timestamp : 2016102501
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Managed  : 1.4GB
Elapsed   : 4410s
```

StoreFilesystem@ExternalDrive

```
ATA-WDC-WX71C6287816
2016102301
  ATA-WDC-WX71C6287816-2016102301.tmd
  ATA-WDC-WX71C6287816-2016102301.md5
2016102501
  ATA-WDC-WX71C6287816-2016102501.tmd
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Operators Applied To Second Acquisition

```
admin$ tup info ES
1 ATA-WDC-WX71C6287816, 2016102301 (320GB)
  1 hashvs
  2 hashfs-2048-716800
  3 hashfs-718848-195306576
  4 bodyfile-2048-716800
  5 bodyfile-718848-195306576
2 ATA-WDC-WX71C6287816, 2016102501 (320GB)
  1 hashvs
  2 hashfs-2048-716800
  3 hashfs-718848-195306576
  4 bodyfile-2048-716800          // Diff with 1.4?
  5 bodyfile-718848-195306576    // Diff with 1.5?
```



Store Search: Indicator Of Compromise

```
$ cat iocs.stix.xml
<cybox:Object><FileObj:Hashes><cyboxCommon:Hash>
<cyboxCommon:Simple_Hash_Value>
  e83cf86a39caf748d2199dc8d3b92e60
</cyboxCommon:Simple_Hash_Value>
</cyboxCommon:Hash></FileObj:Hashes></cybox:Object>

admin$ tup search ES iocs.stix.xml
Hit: e83cf86a39caf748d2199dc8d3b92e60
(ATA-WDC-WX71C6287816, 2016102501) WINDOWS/system32/mstc.exe
```



Store Search: Context Of Compromise

By differencing stored bodyfiles, can see what other files appeared with the IOC hit:

```
admin$ tup bodyfile -d ES 2.3 1.3
e83cf86a39caf748d2199dc8d3b92e60|/WINDOWS/system32/mstc.exe|
10858|r/rrwxrwxrwx|0|0|181248|
1477446120|1477446120|1477446120|1321483658

732cfc10b216a79e8ae5cd186015b476|
/Documents and Settings/apluw/Application Data/FNTCACHE.BIN|
10862|r/rrwxrwxrwx|0|0|32|
1477446128|1477446128|1477446128|1456262350
```

First file is bot-net malware binary. Second file is its keystroke log.



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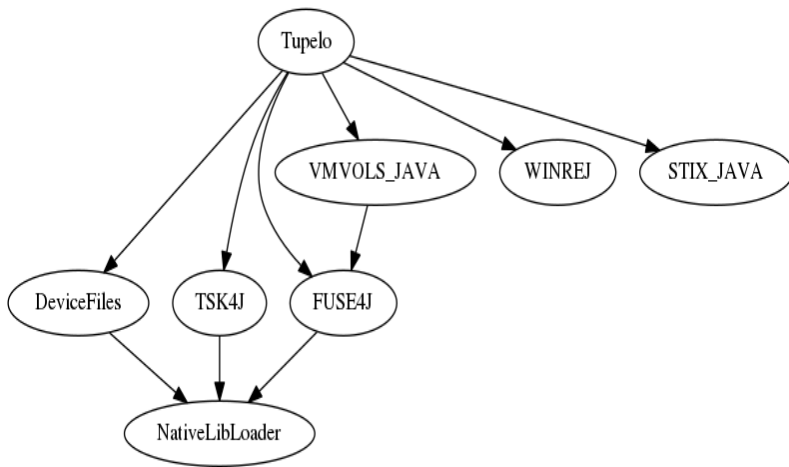
```
admin$ tup bodyfile -d ES 2.3 1.3
e83cf86a39caf748d2199dc8d3b92e60|/WINDOWS/system32/mstc.exe|
10858|r/rrwxrwxrwx|0|0|181248|
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Tupelo Software Composition, Dependencies



Each is a public git repo, with one or more Java/Maven artifacts. Use in other projects!



Talk Is Cheap. Where Is The Code?

Tupelo and several Java libraries on which it depends are open-source:

github.com/UW-APL-EIS/tupelo Main Tupelo logic. Disk acquire, differencing, stores.

github.com/UW-APL-EIS/vmvols-java - Virtual machine disk access to host software.

github.com/UW-APL-EIS/winrej - Windows registry hive parser.

github.com/uw-dims/tsk4j - Java bindings to Sleuthkit.

github.com/uw-dims/stix-java - Java bindings to STIX.

github.com/uw-dims/fuse4j - Java bindings to FUSE.

github.com/uw-dims/device-files - Reads disk serial number, size.

github.com/uw-dims/java-native-loader - Framework for split Java/C codebases.

