Datalore: Android Memory Analysis

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About the Speaker

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Acquisition

LiME Forensics

- Linux Memory Extractor
  - Formerly DMD
- Loadable Kernel Module
- Dump Memory directly to the SD card or over the network
  - Network dump over adb (Android Debug Bridge)
- Minimizes interaction between userland and kernelland

/proc/iomem

```
# cat /proc/iomem
02b00000-02efffff : msm_hdmi.0
03700000-039fffff : kgsl_phys_memory
03700000-039fffff : kgsl
03a00000-03a3ffff : ram_console
03b00000-03dfffff : msm_panel.0
20000000-2e7fffff : System RAM
  20028000-20428fff : Kernel text
  2044a000-2058ca13 : Kernel data
30000000-3bffffff : System RAM
a0000000-a001ffff : kgsl_reg_memory
a0000000-a001ffff : kgsl
a0200000-a0200fff : msm_serial_hs_bcm.0
a0300000-a0300fff : msm_sdcc.1
…
```

Linux Memory Extractor (LiME)

1. Parsing the kernel’s *iomem_resource* structure to learn the physical memory address ranges of system RAM.
2. Performing physical to virtual address translation for each page of memory.
3. Reading all pages in each range and writing them to either a file (typically on the device’s SD card) or a TCP socket.

LiME 1.1 Arguments

- path
  - Either a filename to write on the local system (SD Card) or tcp:<port>
- format
  - raw
    - Simply concatenates all System RAM ranges
  - padded
    - Starting from physical address 0, pads all non-System RAM ranges with 0s
  - lime
    - Each range is prepended with a fixed-sized header which contains address space information
    - Volatility address space developed to support this format
- dio (optional)
  - 1 to enable Direct IO attempt (default), 0 to disable

LiME (TCP)

```
$ adb push lime-evo.ko /sdcard/lime.ko
$ adb forward tcp:4444 tcp:4444
$ adb shell
$ su
# insmod /sdcard/lime.ko
“path=tcp:4444 format=lime”
```

Then on host:

```
$ nc localhost 4444 > evo.lime
```

LiME (SD Card)

```
$ adb push lime-evo.ko /sdcard/lime.ko
$ adb shell
$ su
# insmod /sdcard/lime.ko
“path=/sdcard/dump.lime format=lime”
```

LiME Forensics

- Free
- Open Source (GPL)
- http://code.google.com/p/lime-forensics/

- Soon
  - Video Card RAM
  - Registers
  - “Live” version

Analysis

ARM Address Space

- Official in Volatility 2.3
- Supports Fine and Course paging
  - 64K “large pages”
  - 4K “small pages”
  - 1K “tiny pages”
- No support for “Superpages”
  - Please let me know if any processors actually use this
- Windows 8 ARM???
  - TBD

Android Profiles

- Works the same way as Linux Profiles (Mostly)
- Download Kernel Source from Vender
- Kernel Config
- Cross-Compile
- ZIP(Dwarfdump + System.map)

- Not quite as easy as Linux, because you can't just type "make" and go…

ARM Compatible Plugins

- linux_arp Print the ARP table
- linux_check_afinfo Verifies the operation function pointers of network protocols
- linux_dentry_cache Gather files from the dentry cache
- linux_dmesg Gather dmesg buffer
- linux_dump_map Writes selected memory mappings to disk
- linux_find_file Recovers tmpfs filesystems from memory
- linux_ifconfig Gathers active interfaces
- linux_iomem Provides output similar to /proc/iomem
- linux_lsmod Gather loaded kernel modules
- linux_lsof Lists open files
- linux_memmap Dumps the memory map for linux tasks
- linux_mount Gather mounted fs/devices

ARM Compatible Plugins

- linux_mount_cache Gather mounted fs/devices from kmem_cache
- linux_pidhashtable Enumerates processes through the PID hash table
- linux_pkt_queues Writes per-process packet queues out to disk
- linux_proc_maps Gathers process maps for linux
- linux_psaux Gathers processes along with full command line and start time
- linux_pslist Gather active tasks by walking the task_struct->task list
- linux_pslist_cache Gather tasks from the kmem_cache
- linux_pstree Shows the parent/child relationship between processes
- linux_psxview Find hidden processes with various process listings
- linux_route_cache Recovers the routing cache from memory
- linux_sk_buff_cache Recovers packets from the sk_buff kmem_cache
- linux_slabinfo Mimics /proc/slabinfo on a running machine
- linux_tmpfs Recovers tmpfs filesystems from memory
- linux_vma_cache Gather VMAs from the vm_area_struct cache

Example 1

linux_tmpfs

linux_tmpfs

- Parse mount table
  - mount_hashtable
- Look for tmpfs superblocks
- Walks the root dentry structs
- Dumps file and directory contents to disk

linux_tmpfs Example

- Some Android phones have a tmpfs mount called /app-cache
- The stock Android browser uses this for it's Webview Cache
  - /app-cache/com.android.browser/cache/webviewCache
- Never written to disk

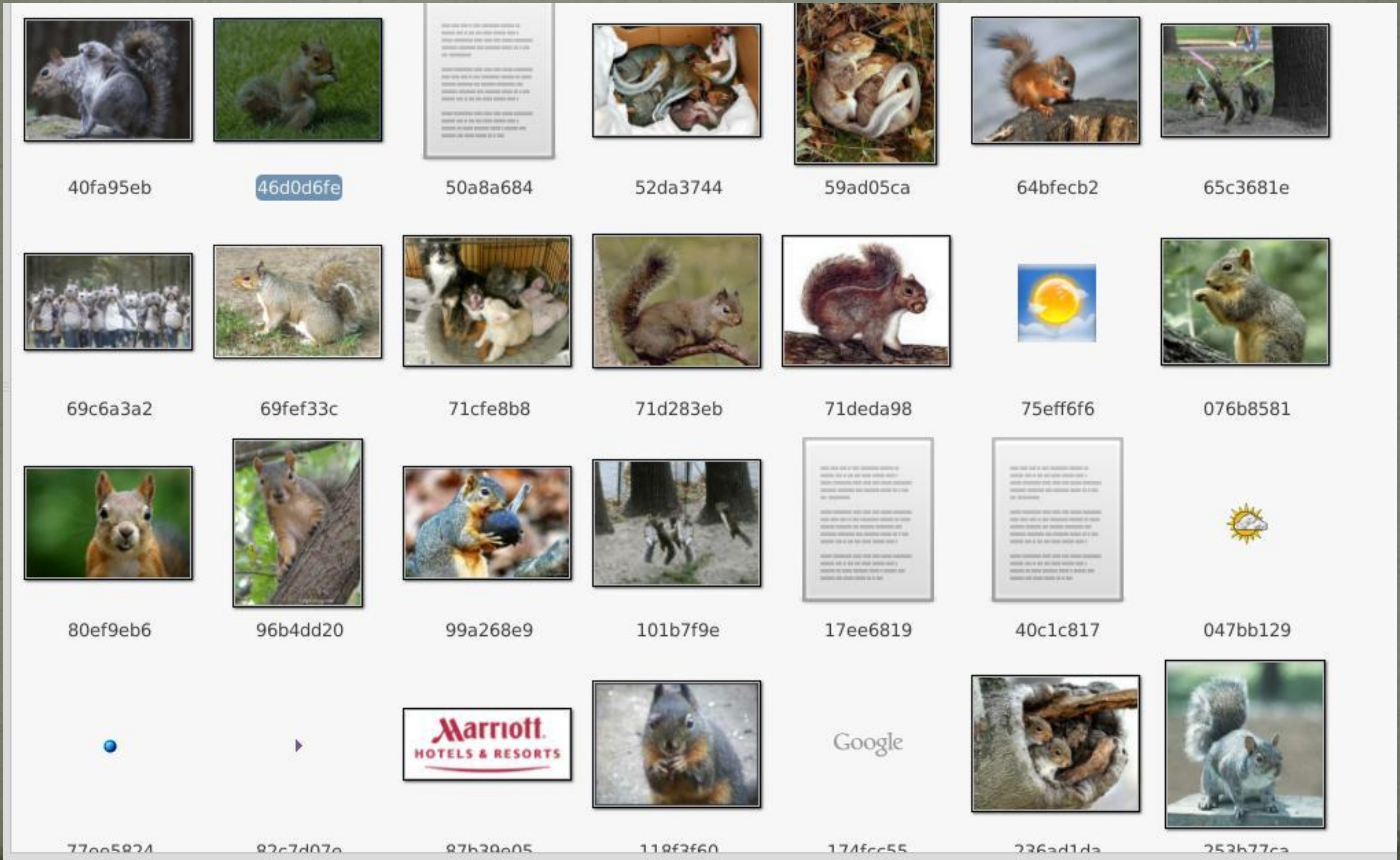
linux_tmpfs Example

```
$ python vol.py --profile=LinuxEvo4GARM -f ../Evo4G3.lime linux_tmpfs -L
Volatile Systems Volatility Framework 2.3_alpha
1 -> /mnt/sdcard/.android_secure
2 -> /dev
3 -> /app-cache
4 -> /mnt/obb
5 -> /mnt/asec
```

linux_tmpfs Example

- mkdir tmpfs-out
- python vol.py --profile=LinuxEvo4Gx86 -f ../Evo4G3.lime linux_tmpfs -S 3 -D tmpfs-out

linux_tmpfs Example



Example 2

Application Permissions

linux_find_file

- Andrew explained this

Android Security Model

- Each application digitally signed by author
- Applications assigned uid at install time
  - Usually unique per application
  - Author can request same uid to be assigned for any of his/her applications
- Linux User Access Model keeps data private by default
- Concept of “permissions”
  - Access sensitive APIs
  - Share data and functionality
  - Can be user-created

Permissions – Protection Level

Value	Meaning
"normal"	The default value. A lower-risk permission that gives requesting applications access to isolated application-level features, with minimal risk to other applications, the system, or the user. The system automatically grants this type of permission to a requesting application at installation, without asking for the user's explicit approval (though the user always has the option to review these permissions before installing).
"dangerous"	A higher-risk permission that would give a requesting application access to private user data or control over the device that can negatively impact the user. Because this type of permission introduces potential risk, the system may not automatically grant it to the requesting application. For example, any dangerous permissions requested by an application may be displayed to the user and require confirmation before proceeding, or some other approach may be taken to avoid the user automatically allowing the use of such facilities.
"signature"	A permission that the system grants only if the requesting application is signed with the same certificate as the application that declared the permission. If the certificates match, the system automatically grants the permission without notifying the user or asking for the user's explicit approval.
"signatureOrSystem"	A permission that the system grants only to applications that are in the Android system image or that are signed with the same certificates as those in the system image. Please avoid using this option, as the signature protection level should be sufficient for most needs and works regardless of exactly where applications are installed. The signatureOrSystem permission is used for certain special situations where multiple vendors have applications built into a system image and need to share specific features explicitly because they are being built together.

AndroidManifest.xml

```
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
    package="com.network.networkcase"
    android:versionCode="1"
    android:versionName="1.0">
<uses-permission android:name="android.permission.ACCESS_WIFI_STATE"></uses-permission>
<uses-permission android:name="android.permission.ACCESS_NETWORK_STATE"></uses-permission>

<permission android:protectionLevel="dangerous" android:name="com.network.networkcase.CUSTOM_PERMISSION"></permission>

  <application android:icon="@drawable/icon" android:label="@string/app_name">
    <activity android:name=".MainActivity"
          android:label="@string/app_name">
      <intent-filter>
        <action android:name="android.intent.action.MAIN" />
        <category android:name="android.intent.category.LAUNCHER" />
      </intent-filter>
    </activity>



  </application>
</manifest>
```

Packages.xml

```
<?xml version= 1.0  encoding= utf-8  standalone= yes  ?>
<packages>

<permissions>

<item name= android.permission.RECEIVE_SMS  package= android  protection= 1  />
<item name= android.permission.CALL_PHONE  package= android  protection= 1  />
<item name= android.permission.BACKUP  package= android  protection= 3  />
<item name= android.permission.READ_CALENDAR  package= android  protection= 1  />
<item name= android.permission.RECEIVE_BOOT_COMPLETED  package= android  />
<item name= android.permission.SET_TIME  package= android  protection= 3  />
<item name= android.permission.ACCESS_UPLOAD_DATA  package= com.htc.providers.uploads  protection= 2  />

</permissions>
```

Packages.xml

```
<package name= com.weather.Weather  codePath= /data/app/com.weather.Weather-2.apk      userId= 10058  ...>
<sigs count= 1 >
<cert index= 1  key= ...  />
</sigs>
<perms>
<item name= android.permission.SET_WALLPAPER  />
<item name= android.permission.SEND_SMS  />
<item name= android.permission.WRITE_EXTERNAL_STORAGE  />
<item name= android.permission.ACCESS_WIFI_STATE  />
<item name= android.permission.ACCESS_COARSE_LOCATION  />
<item name= android.permission.CALL_PHONE  />
<item name= android.permission.WRITE_CALENDAR  />
<item name= android.permission.READ_CALENDAR  />
<item name= android.permission.CAMERA  />
<item name= android.permission.INTERNET  />
<item name= android.permission.ACCESS_FINE_LOCATION  />
<item name= android.permission.VIBRATE  />
<item name= android.permission.ACCESS_NETWORK_STATE  />
<item name= android.permission.RECORD_AUDIO  />
</perms>
</package>

</packages>
```

linux_find_file Example

```
linux_find_file -F /data/system/packages.xml
```

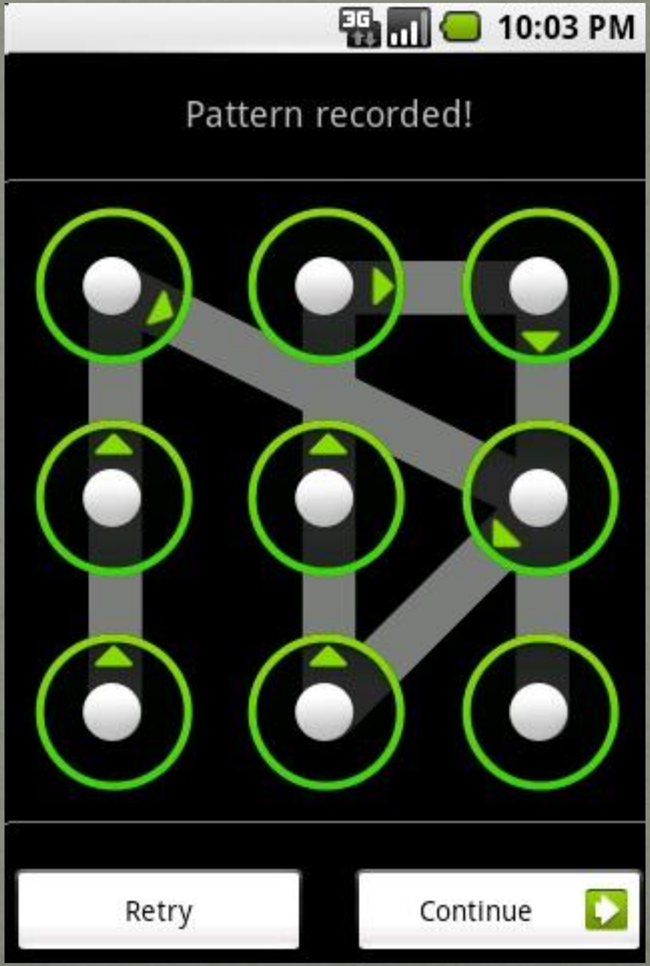
```
Inode Number    Inode
---------------- ----------
            1019 0xd3aad948
```

```
linux_find_file -i 0xd3aad948 -O packages.xml
```

Example 3

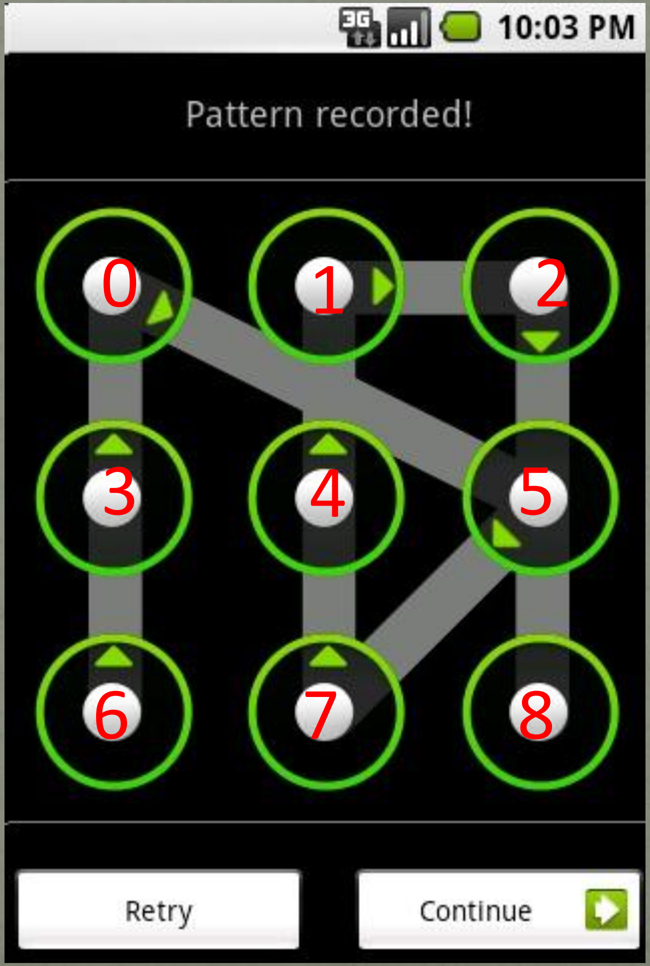
Screen Lock Password

Screen Lock



Pattern recorded!

Screen Lock



10:03 PM

Pattern recorded!

Screen Lock

- Takes sequence as a string
  - “6305741238”
- Hash It (SHA-1)
  - SHA-1(“6305741238”)
  - No Salt…
- Compare to hash in file
  - /system/gesture.key

android_screenlock

- Uses linux_find_file to pull hash from /system/gesture.key
- Looks hash -> pattern mapping in database

```
python vol.py … android_screenlock
```

```
[8, 4, 0, 1, 2, 6]
```

Screen Lock (PIN or Key)

- SHA1 hash stored in /system/password.key
- Random salt stored in database
  - /data/data/com.android.providers.settings/databases/settings.db
- SHA1(SHA1(PIN + SALT) + MD5(PIN))
  - … for some reason
- Salted, so no pre-computed tables
- Still easy enough to brute-force

Example 4

yaffs2

android_yaffs_info

- YAFFS/YAFFS2 enabled devices export a symbol called yaffs_dev_list
- yaffs_DeviceStruct
  - Tons of information about yaffs devices
  - Block Sizes
  - Group Info
  - Object Lists (Allocated and Free)
  - Stats

android_yaffs_info

- python vol.py --profile=LinuxEvo4Gx86 -f ../Evo4G2.lime android_yaffs_info

```
Device 1 "userdata"
startBlock......... 0
endBlock........... 3420
totalBytesPerChunk. 2048
nDataBytesPerChunk. 2048
chunkGroupBits..... 0
chunkGroupSize..... 1
nErasedBlocks...... 2583
nReservedBlocks.... 5
blocksInCheckpoint. 0
nTnodesCreated..... 2100
nFreeTnodes........ 6
nObjectsCreated.... 1000
nFreeObjects....... 59
```

android_yaffs_info

```
nFreeChunks........ 193765
nPageWrites........ 60896
nPageReads......... 21507
nBlockErasures..... 159
nGCCopies.......... 0
garbageCollections. 0
passiveGCs......... 0
nRetriedWrites..... 0
nShortOpCaches..... 10
nRetireBlocks...... 0
```

android_yaffs_info

```
eccFixed........... 0
eccUnfixed......... 0
tagsEccFixed....... 0
tagsEccUnfixed..... 0
cacheHits.......... 51881
nDeletedFiles...... 0
nUnlinkedFiles..... 3459
nBackgroudDeletions 0
useNANDECC......... 1
isYaffs2........... 1
inbandTags......... 0
```

Questions?

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