When Security Gets in the Way

PenTesting Mobile Apps That Use Certificate Pinning

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Outline

What is Certificate Pinning ?

- Definition and Background
- Consequences for Mobile Blackbox Testing

iOS

- Certificate Pinning Within an iOS App
- Intercepting the App's Traffic: MobileSubstrate Extension

Android

- Certificate Pinning Within an Android App
- Intercepting the App's Traffic: Custom JDWP Debugger

Conclusion

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Certificate Pinning and SSL

Hard-code in the client the SSL certificate known to be used by the server

- Pin the server's certificate itself
  - Takes the CA system out of the equation
- Pin the CA certificate used to sign the server's certificate
  - Limit trust to certificates signed by one CA or a small set of CAs

Significantly reduces the threat of a rogue CA and of CA compromise

- Implemented in Chrome 13 for Google services
- **In Mobile Apps:** Square, Twitter, Card.io…

Mobile Blackbox Testing

Intercepting the App's HTTPS traffic using a proxy

- Usually simple: Add the proxy's CA certificate to the device trust store
- This **will not work** if the App does certificate pinning

Beating certificate pinning as a penetration tester

- Change the certificate(s) or SSL validation methods within the App ?
    - Re-package and side-load the new binary
- Use a debugger ?

Introducing new tools to make this easy:

- iOS SSL Kill Switch
- Android SSL Bypass

Outline

Network Communication on iOS

Several APIs to do network communication on iOS

- NSStream, CFStream, **NSURLConnection**

Most iOS Apps use NSURLConnection

- High level API to perform the loading of a URL request
- Verifies the server's certificate for *https:* URLs
- Developers can override certificate validation
    - To disable certificate validation (for testing only!)
    - To implement certificate pinning

NSURLConnection

NSURLConnection has the following constructor:

```
• -(id)initWithRequest:(NSURLRequest *)request
                 delegate:(id <NSURLConnectionDelegate>)delegate
```

The delegate has to implement specific methods

- Those methods get called as the connection is progressing
- They define what happens during specific events
  - Connection succeeded, connection failed, etc…
- Two documented ways to do custom certificate validation

NSURLConnectionDelegate

Connection Authentication

- `connection:willSendRequestForAuthenticationChallenge:`
- `connection:canAuthenticateAgainstProtectionSpace:`
- `connection:didCancelAuthenticationChallenge:`
- `connection:didReceiveAuthenticationChallenge:`
- `connectionShouldUseCredentialStorage:`

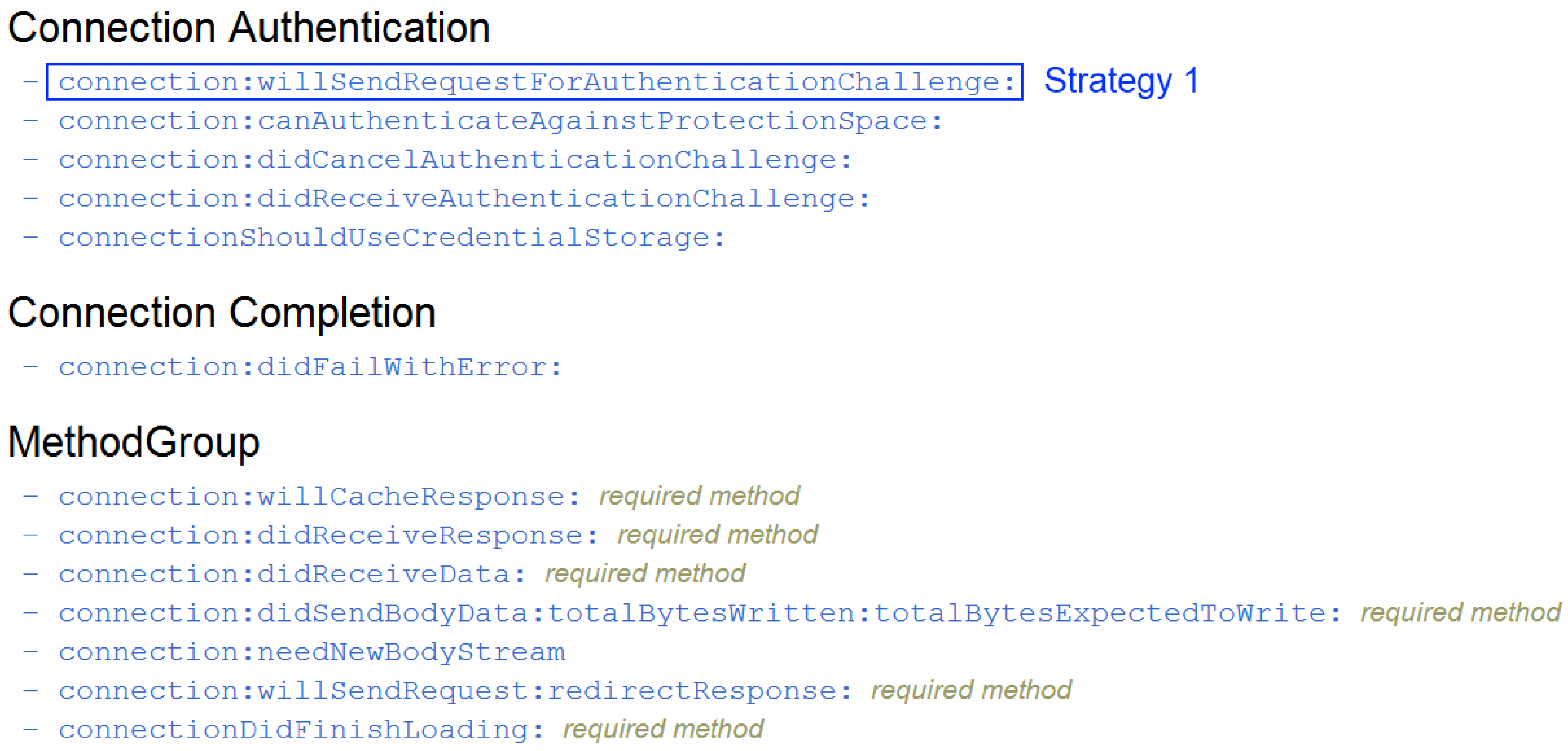
Connection Completion

- `connection:didFailWithError:`

MethodGroup

- `connection:willCacheResponse:` *required method*
- `connection:didReceiveResponse:` *required method*
- `connection:didReceiveData:` *required method*
- `connection:didSendBodyData:totalBytesWritten:totalBytesExpectedToWrite:` *required method*
- `connection:needNewBodyStream`
- `connection:willSendRequest:redirectResponse:` *required method*
- `connectionDidFinishLoading:` *required method*

Custom Certificate Validation



Connection Authentication

- connection:willSendRequestForAuthenticationChallenge: Strategy 1
- connection:canAuthenticateAgainstProtectionSpace:
- connection:didCancelAuthenticationChallenge:
- connection:didReceiveAuthenticationChallenge:
- connectionShouldUseCredentialStorage:

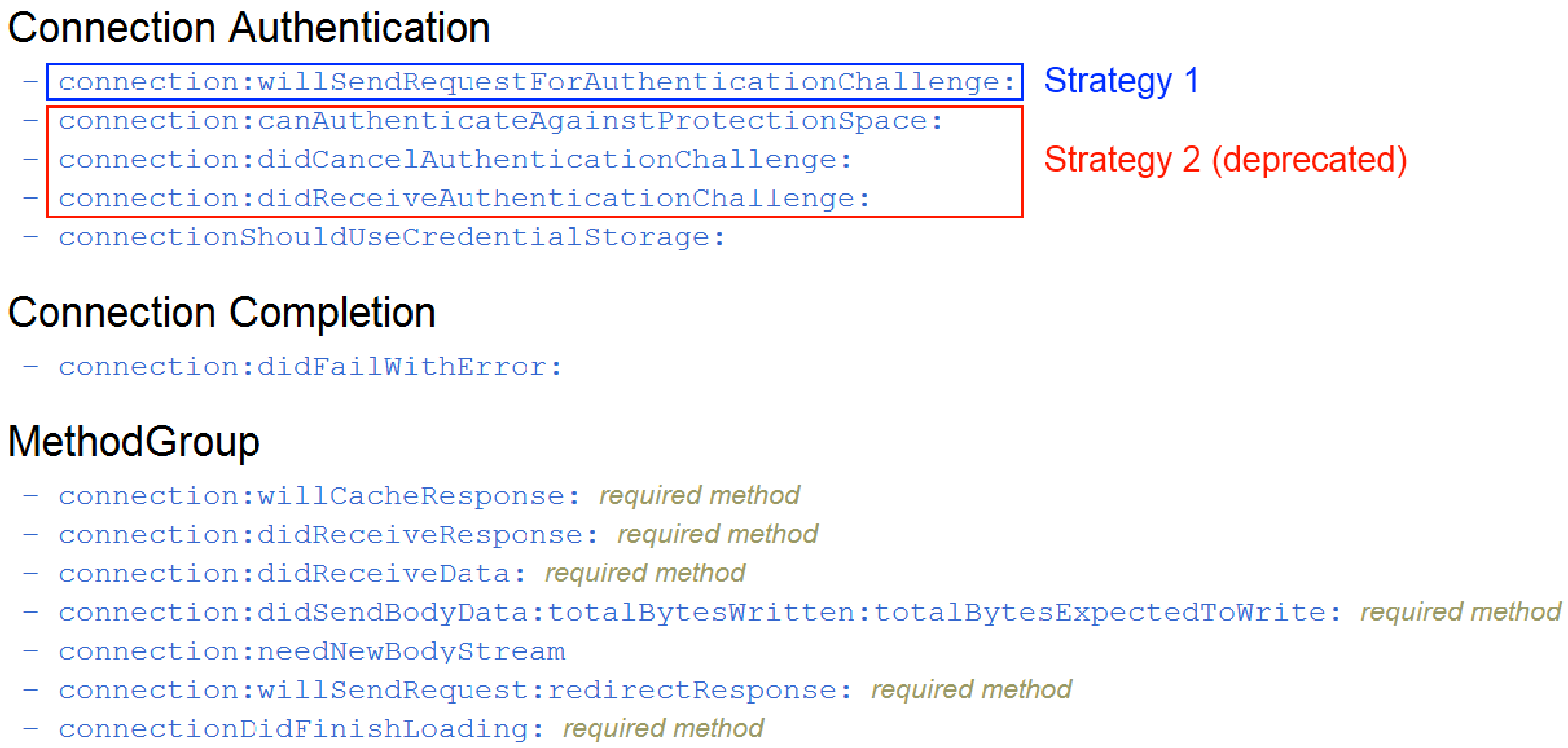
Connection Completion

- connection:didFailWithError:

MethodGroup

- connection:willCacheResponse: *required method*
- connection:didReceiveResponse: *required method*
- connection:didReceiveData: *required method*
- connection:didSendBodyData:totalBytesWritten:totalBytesExpectedToWrite: *required method*
- connection:needNewBodyStream
- connection:willSendRequest:redirectResponse: *required method*
- connectionDidFinishLoading: *required method*

Custom Certificate Validation



Connection Authentication

- `connection:willSendRequestForAuthenticationChallenge:` Strategy 1
- `connection:canAuthenticateAgainstProtectionSpace:`
- `connection:didCancelAuthenticationChallenge:` Strategy 2 (deprecated)
- `connection:didReceiveAuthenticationChallenge:`
- `connectionShouldUseCredentialStorage:`

Connection Completion

- `connection:didFailWithError:`

MethodGroup

- `connection:willCacheResponse:` *required method*
- `connection:didReceiveResponse:` *required method*
- `connection:didReceiveData:` *required method*
- `connection:didSendBodyData:totalBytesWritten:totalBytesExpectedToWrite:` *required method*
- `connection:needNewBodyStream`
- `connection:willSendRequest:redirectResponse:` *required method*
- `connectionDidFinishLoading:` *required method*

Jailbroken iOS Development

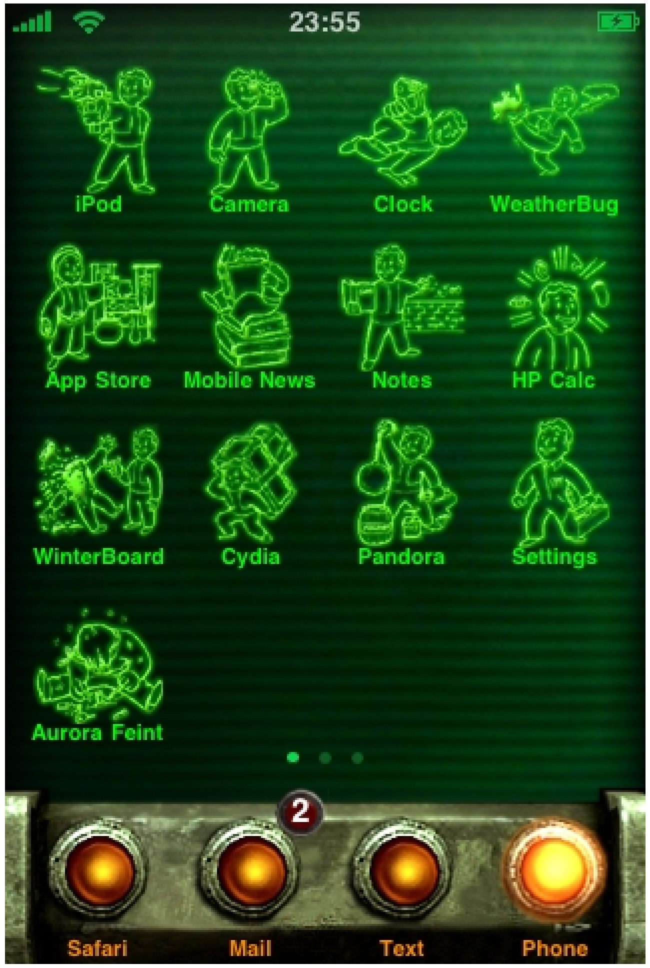
MobileSubstrate

- Available on jailbroken devices
- “de facto framework that allows 3rd-party developers to provide run-time patches to system functions”
- MobileSubstrate patches are called “extensions” or “tweaks”

MobileSubstrate Extension

One example: WinterBoard

- Hooks into the SpringBoard APIs
- Allows users to customize their home screen



iOS SSL Kill Switch

Hooking NSURLConnection's constructor

```
#import "HookedNSURLConnectionDelegate.h"


%hook NSURLConnection


// Hook into NSURLConnection's constructor
- (id)initWithRequest:(NSURLRequest *)request delegate:(id <NSURLConnectionDelegate>)delegate
{
  // Create a delegate "proxy"
  HookedNSURLConnectionDelegate* delegateProxy;
  delegateProxy = [[HookedNSURLConnectionDelegate alloc] initWithOriginalDelegate: delegate];

  return %orig(request, delegateProxy); // Call the "original" constructor
}

%end
```

iOS SSL Kill Switch

Forwarding method calls to the original delegate

```
@implementation HookedNSURLConnectionDelegate : NSObject
```

...

```
- (void)connection:(NSURLConnection *)connection didReceiveResponse:(NSURLResponse *)response
{
  // Forward the call to the original delegate
  return [origiDelegate connection:connection didReceiveResponse:response];
}
```

iOS SSL Kill Switch

Intercepting calls to certificate validation methods

```
@implementation HookedNSURLConnectionDelegate : NSObject
```

...

```
- (void)connection:(NSURLConnection *)connection
           willSendRequestForAuthenticationChallenge:(NSURLAuthenticationChallenge *)challenge
{
  // Do not forward... Accept all certificates instead
  if([challenge.protectionSpace.authenticationMethod isEqualToString:NSURLAuthenticationMethodServerTrust])
  {
    NSURLCredential* serverCred;
    serverCred = [NSURLCredential credentialForTrust:challenge.protectionSpace.serverTrust];
    [challenge.sender useCredential:serverCred forAuthenticationChallenge:challenge];
  }
}
```

iOS SSL Kill Switch

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Certificate Validation on Android

Certificate Validation and Pinning on Android

- Device trust store cannot be modified by user until Android 4.0 (ICS)
- Certificate pinning can be implemented using an App specific trust store
- Common methods of certificate pinning outlined on Moxie's blog:
    - http://blog.thoughtcrime.org/authenticity-is-broken-in-ssl-but-your-app-ha

Bypassing Certificate Pinning

Many possible ways to implement a bypass

- Decompile/Patch/Recompile/Resign/Sideload
- Custom VM/ROM with hooks built in
- Native code hooking (Mulliner) or native code debugger (gdb, vtrace)
- **JDWP debugger**

Java Debug Wire Protocol

What is the Java Debug Wire Protocol (JDWP) ?

- Standard Java debugging protocol
- Programmatic debugging through Java APIs
    - Java Debug Interface (JDI)
- Python bindings available through AndBug

```
          Components                          Debugger Interfaces

                /    |--------------|
               /     |     VM       |
 debuggee ----(      |--------------|  <------- JVM TI - Java VM Tool Interface
               \     |   back-end   |
                \    |--------------|
                /           |
 comm channel -(            |  <--------------- JDWP - Java Debug Wire Protocol
                \           |
                     |--------------|
                     | front-end    |
                     |--------------|  <------- JDI - Java Debug Interface
                     |      UI      |
                     |--------------|
```

Java Debug Wire Protocol

What can we do with a JDWP debugger?

- Normal debugging tasks: set breakpoints, step, etc…
- Once suspended we can:
    - Get the current thread, frame, frame object, local variables and arguments references
    - Load arbitrary classes, instantiate Objects, invoke methods, get and set local variables and arguments values
    - And more…

Certificate Pinning on Android

Two common ways to do SSL on Android

- **javax.net.ssl.HttpsURLConnection**
- **org.apache.http.***

Certificate pinning

- Create **SSLSocketFactory** with custom **TrustManager**

Certificate Pinning on Android

javax.net.ssl.HttpsURLConnection

1. Bundle keystore with app
2. Create **TrustManager** with keystore
3. Init **SSLContext** with **TrustManager**
4. Get **SSLSocketFactory** from **SSLContext**
5. Create **HttpsURLConnection** and set to use **SSLSocketFactory**

```
HttpsURLConnection urlConn = (HttpsURLConnection)url.openConnection();
urlConn.setSSLSocketFactory(sslContext.getSocketFactory());
```

Certificate Pinning on Android

org.apache.http.*

1. Bundle keystore with app
2. Create **TrustManager** with keystore
3. Init **SSLContext** with **TrustManager**
4. Get **SSLSocketFactory** from **SSLContext**
5. Create new **Scheme** with **SSLSocketFactory** and register with **SchemeRegistry**

```
SSLSocketFactory sf = new SSLSocketFactory(pinningSSLContext);
Scheme httpsScheme = new Scheme("https", 443, sf);
SchemeRegistry schemeRegistry = new SchemeRegistry();
schemeRegistry.register(httpsScheme);
```

JDWP - Certificate Pinning Bypass

Bypass certificate pinning with JDWP debugger

- Break on certificate pinning implementation classes/methods
- On breakpoint use JDI APIs to perform SSL bypass
  - Directly manipulate objects, local variables, call methods, etc.
  - Force use of “trust all” TrustManager

Android SSL Bypass

Simple implementation for first version

- Plugin architecture, user plugins implement
  - **setupEvents()** – set breakpoints, method entry events, etc…
  - **handleEvents()** – handle events that were set
- **SSLBypassJDIPlugin** included with tool
- Future versions will explore more comprehensive solutions

Android SSL Bypass

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Our Tools

iOS SSL Kill Switch

- Tested on iOS 4.3 and iOS 5.1
- https://github.com/iSECPartners/ios-ssl-kill-switch

Android SSL Bypass Tool

- Tested on Android 2.3.3 and 4.0.3
- https://github.com/iSECPartners/android-ssl-bypass

Comments / Ideas ?

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The End

QUESTIONS ?

Reference Material

Certificate pinning on iOS

- http://blog.securemacprogramming.com/2011/12/on-ssl-pinning-for-cocoa-touch/

MobileSubstrate

- http://iphonedevwiki.net/index.php/MobileSubstrate

Certificate pinning on Android

- http://blog.thoughtcrime.org/authenticity-is-broken-in-ssl-but-your-app-ha

iSEC Partners on GitHub

- https://github.com/iSECPartners