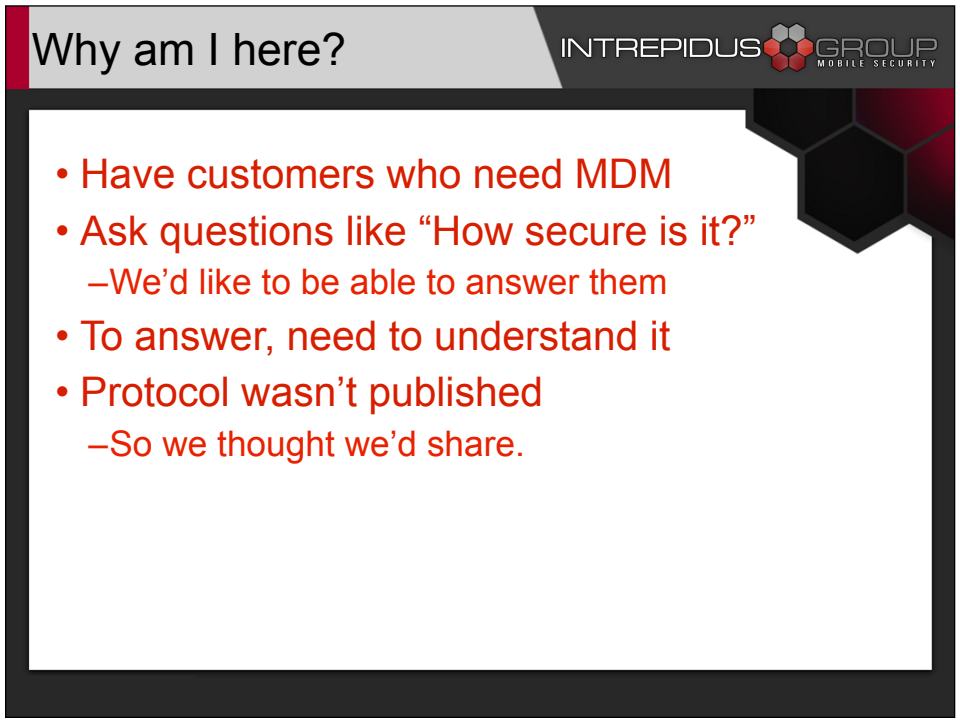
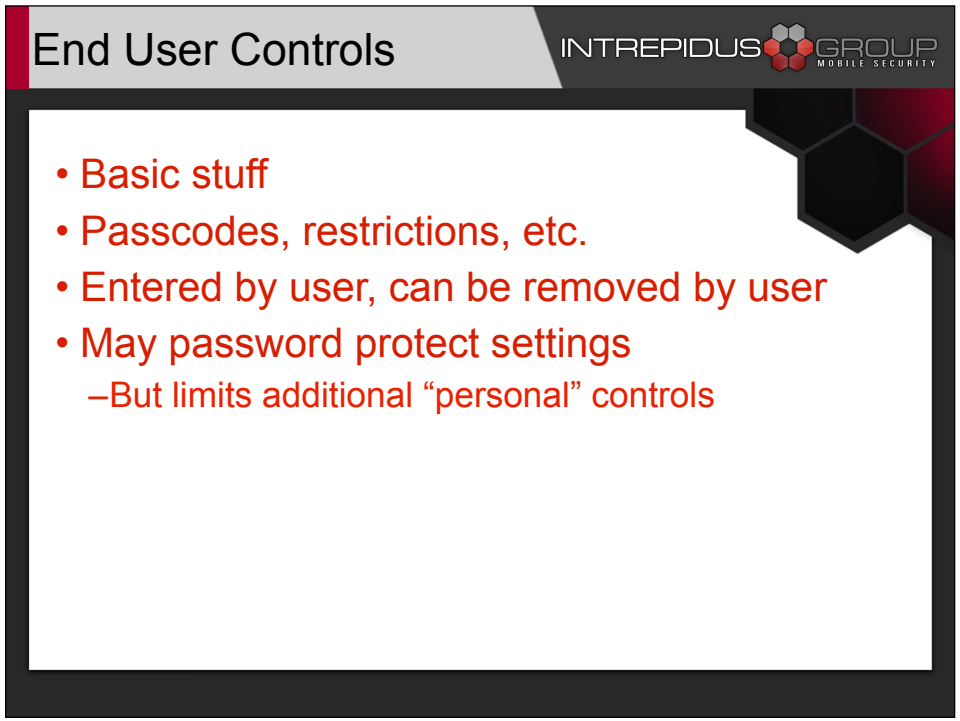


So why am I here today?

In a nutshell, we have customers who need mobile device management capabilities, especially for iOS platforms. As security consultants helping them to design the most secure deployment possible, they naturally ask us "How secure IS this system?" And, frankly, we'd like to be able to give them a good answer.

But to answer that question well, we have to understand just how MDM works. Unfortunately, the protocol hasn't been openly published, so not many people really understand it that well. We understand it (at least, we feel like we do), and so we thought we'd share so that others can build on our knowledge and better help their organizations and customers.

To understand just what MDM is actually providing for us, let's talk for a moment about iOS configuration management in general.



At its most basic level, iStuff are controlled by the primary user of that device. This is basic stuff -- locking the device with a passcode, restricting use of certain applications (so your kids can't buy apps, for example), or configuring email or VPN accounts.

These settings are entered by the user, so they can be removed by the user. The user (or their IT department) may restrict access to certain settings with a password, but then that may also limit other things the user may do.

Configuration Profiles

- Good for IT management
- Install standard profile on many devices
- Can be locked with password
  - –But won't preclude other personalizations
- Most-restrictive superset of settings
  - –If user chooses "simple passcode" ...
  - –But management profile requires complex....
  - –....management wins!

One of the best reasons to consider standardized profiles is because they can make things much easier for management. Rather than relying on users to update policies, or having admins manually enter policy changes on devices, a single profile can be saved to disk and then loaded onto devices.

These profiles can also be locked, so the user can't remove them. But unlike locking settings within the Settings application, this lock only applies to the settings within the profile. So the user is still free to make other personalizations that don't conflict with the installed profile.

In cases where there are conflicts, the most secure setting wins out in the end.

IPCU

- iPhone Configuration Utility (IPCU)
  - –Windows, OS X
  - –Install profiles, certificates
  - –Transfer profiles via USB
- Many new controls not available on device
  - –More supported VPNs
  - –Extensive passcode controls
  - –More extensive restrictions
  - –Safari controls

The easiest way to create standardized profiles is via the iPhone Configuration Utility. This free application lets you create and install profiles, install provisioning profiles (for application development and enterprise deployment), etc.

Profiles can be installed to devices via USB, or they can be distributed via a web server (user simply taps on a URL and it downloads and installs the profile).

Additionally, the IPCU provides access to controls and settings not available directly on the device, including better VPN support, extensive passcode controls, and some more detailed Safari security settings.

New in iOS 5

- Restrictions:
  - –Force password for all iTunes purchases
  - –Restrict Siri, iCloud backup / sync / photo stream
  - –Restrict diagnostic data, reject untrusted SSL
- Mail:
  - –Restrict moving email between accounts
  - –Use account in Mail.app only (no 3rd party apps)

Not many features were added in iOS5 as far as restrictions / controls. Here are some of the more interesting ones.

In particular, the enhancements to Mail controls are interesting: Now you can prevent a user from dragging an email out of a corporate account and into a personal one (they can still, obviously, forward the email). You can also restrict use of an account to the Mail app only, which prevents other applications from forwarding data out through that account.

Over-the Air Delivery

- No USB connection necessary
  - –No need to push a cart thru the building
  - –Can use simple web links to download profile
- More secure OTA method
  - –Documented by Apple
  - –Uses SCEP to establish secure exchange
  - –Not easy to implement
    - Apple suggests MS or Cisco SCEP servers
- Still need user to visit link and install profile

Of course, creating the standardized profile is only half the problem. For a large enterprise, the prospect of pushing a cart through the building and manually connecting each device via USB to load up current profiles is...well...pretty much a non-starter.

Distributing them through an online link is much better, but that still has some concerns (such as controlling access to the profiles, etc.). Some of these concerns are addressed in a more formal Over-the-Air system, as documented by Apple. This approach is more secure (using on-the-fly exchanges of certificates via Simple Certificate Exchange Protocol, for one), but because of the use of SCEP, its complexity level is pretty high.

And in either case, you still need for the end user to actively visit a link and install the profile. And if they know the profile is going to disable YouTube, how many do you think will willingly click on it?

So this is where MDM comes in.

MDM Basics

INTREPIDUS GROUP MOBILE SECURITY

- OTA + Push Notifications
- Sends profiles directly to device
- Can update enterprise in minutes
- No reliance on end-user
  - –However, user can remove MDM
- Same configuration features as IPCU
  - –Including extended configuration options
- Additional management and control features

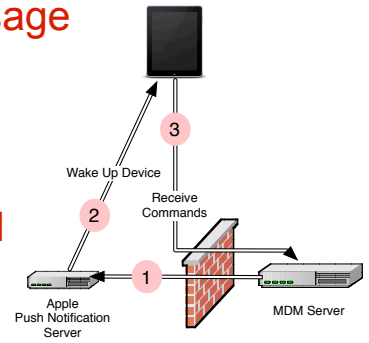
In many ways, MDM is just the OTA framework, paired with Push notifications (with a few new features thrown in).

Using MDM, the server can push profiles directly to devices, potentially updating an entire enterprise in just minutes (device availability and network vagaries notwithstanding). Best of all, though, there's no reliance on the end user to initiate the updates. They all happen without the user's interaction (though some commands require the device to be unlocked first).

MDM also permits remotely querying the device for settings, listing of applications, etc., and adds remote controls like locking and wiping.

Overview

- Enroll device
  - –Installs profile linking device to MDM
- MDM server pushes message
  - –“Hey, call me”
- Device connects to server
  - –“You rang?”
- Server provides command
- Device sends response



First, the device has to enroll with MDM (essentially, installing a configuration profile that links the device to the MDM server).

Once that’s complete, the flow of control is like this:
* The server queues up a command for the device
* It then sends a notification to the device via the Apple Push Notification Service (APNS)
* The device receives the notification, and contacts the server
* Once connected to the server, it downloads (and acts upon) the queued command

Notifications - Client

- Device connects to Apple using SSL
- Two-way certificate validation
- Apple provides unique token to device
  - –Apps forward token to service providers
- Device leaves connection open
- Notifications flow from Apple to device

Before we get to the meat of the MDM commands, let’s look more closely at APNS.

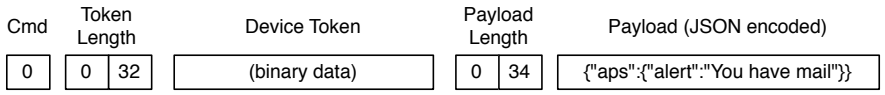
The APNS connection is the only long-term connection established for MDM, and serves as the conduit for all kinds of notification traffic to the device.

When creating the APNS connection, the device first checks Apple’s SSL certificate. The Apple server also checks that the device itself has a valid certificate (which was provided to the device, by Apple, when the device was activated). So getting into the middle of this exchange should actually be pretty difficult.

Once the connection is established, applications request, through the connection, unique Device Tokens, which they then forward to their service provider.

Notifications - Server

- Short message
  - –Payload <= 256 bytes
- Sent in JSON format
- Addressed by the DeviceToken
- Signed by originator and sent to Apple



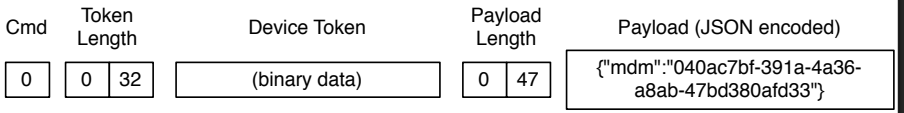
(image source: Apple)

Once the provider has the Device Token, they can send push notifications to the device. The payload is JSON formatted, and total length (including JSON structure) limited to 256 bytes. The Device Token and some framing information are prepended to the payload, and the whole bit is wrapped and signed by the Push Notification certificate obtained from Apple.

Once received by Apple, the notification is sent to whichever device corresponds to the Device Token (presuming it's got an active APNS session), and thus, the notification is delivered.

MDM Notifications

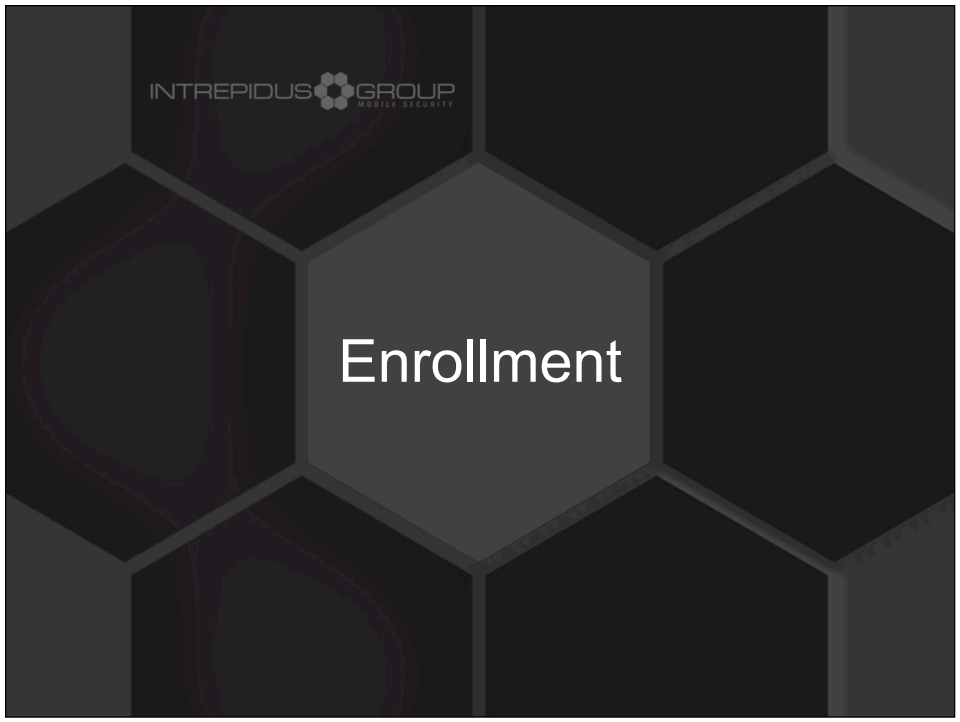
- Does not have the "aps{}" field
- Instead, single string "mdm"
- Value is another token, "PushMagic"
- PushMagic, DeviceToken, and Certificate ID
  - –Together authenticate MDM push message



MDM notifications are pretty similar, but instead of the top-level "aps{}" dictionary, the payload contains only a top-level string named "mdm". The contents of that string are another token provided by the device during enrollment, the "Push Magic" token.

So the device needs to have match three items in order for a push notification to trigger an MDM response: The Device Token (without which the notification will never reach the device), and the Push Magic token (without which the MDM client will just discard the notification). Finally, the "Subject Name / User ID" field in the push notification certificate used to sign the notification must match the "Topic" field in the MDM profile.

These three items, especially the User ID on the certificate signed by Apple, together make it fairly difficult (if not impossible) to forge a push notification to the MDM client on the device.



Enrollment Profile

- Easily created in IPCU
- URLs for enrollment and server
  - –iOS 5 requires SSL, iOS4 works with just http://
- Associate with MDM's push certificate
- Provide identity certificate to device
- Set MDM rights over device
- Can install OTA, or via USB

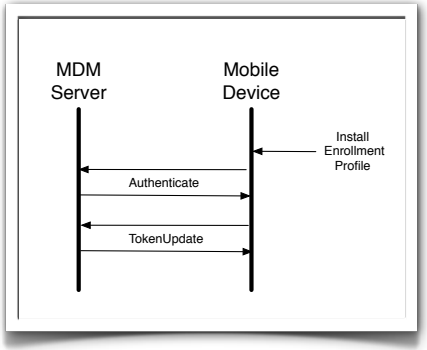
I just mentioned PushMagic being sent during enrollment. So let's talk about enrollment.

The enrollment profile, pushed from a server to the device, defines some key items: The URLs needed to access the service, the topic (User ID) for the Push Notification certificate, a certificate to uniquely identify the device, and rights the device offers to the MDM service.

Upon receipt of this profile, the device then connects to the server and authenticates, then provides the necessary tokens to the server.

Enrollment - Network

- Authenticate
  - –Identifies device to server
  - –MDM server may decline
- TokenUpdate
  - –Sends tokens to server
  - –Enables push notification
  - –Keys to unlock device



The enrollment profile can be installed through IPCU directly, or through an IPCU-created profile pulled off a web link, or by another process hosted on the MDM server.

Once the profile is installed, the device sends the Authenticate message, then in a separate connection, the TokenUpdate message.

Authenticate

- HTTP PUT to “Check In” URL

```
PUT: /checkin
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE plist PUBLIC
   "-//Apple//DTD PLIST 1.0//EN"
   "http://www.apple.com/DTDs/PropertyList-1.0.dtd">
<plist version="1.0">
   <dict>
      <key>MessageType</key>
      <string>Authenticate</string>
      <key>Topic</key>
      <string>com.example.mdm.pushcert</string>
      <key>UDID</key>
      <string> [ redacted ] </string>
   </dict>
</plist>
```

The first step is the device authenticating itself to the server. It’s not so much a secure authentication as it is a simple identification, but it provides the server a chance, based on the Topic and UDID provided, to accept or reject the enrollment request. This can be used to prevent just anyone from enrolling with the corporate MDM server. (additional steps at a more user-friendly level, such as web-based authentication panels with real usernames/passwords, are also possible, and can be used prior to creating an enrollment profile).

The data is presented to the server over HTTP (perhaps SSL-encryped), using PUT, to the URL specified in the enrollment profile’s “Check In” field. The data itself is an Apple Property List (.plist) file, XML formatted. [key elements of the data are highlighted here in red]

Authenticate Response

- Server can decline enrollment
- A blank plist is a valid “ok” response

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE plist PUBLIC
   "-//Apple Computer//DTD PLIST 1.0//EN"
   "http://www.apple.com/DTDs/PropertyList-1.0.dtd">
<plist version="1.0">
   <dict></dict>
</plist>
```

If the server accepts the enrollment request, it doesn’t need to provide anything beyond a simple, blank .plist file.

Token Update

- Via HTTP PUT to /checkin
- Blank plist also a valid response

```
<dict>
   <key>MessageType</key>
   <string>TokenUpdate</string>
   <key>PushMagic</key>
   <string> [ uuid string ] </string>
   <key>Token</key>
   <data> [ 32 byte string, base64 encoded ] </data>
   <key>Topic</key>
   <string>com.example.mdm.pushcert</string>
   <key>UDID</key>
   <string> [ redacted ] </string>
   <key>UnlockToken</key>
   <data> [ long binary string encoded in base64 ] </data>
</dict>
```

The next step is for the client device to provide some additional special data to the server. This is the source of the aforementioned PushMagic string, as well as the DeviceToken provided by Apple when connecting to APNS, and the Push Notification “Topic” string. These three items permit the server to send MDM notifications to the device, and without it, MDM simply won’t work.

The last, most interesting item here is the UnlockToken. As best as I can determine, this (about 2kb) binary stream includes an actual key to an escrow keybag on the device. This token is used to clear the passcode on a locked device.

Again, this message is sent via HTTP PUT over the “Check In” URL. And, again, all the server needs to respond with is a blank .plist.

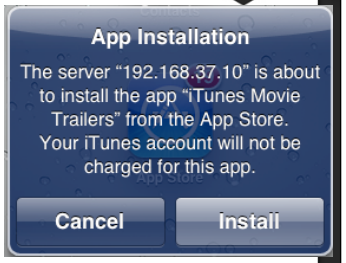
Command List

- Configuration
  - –Install and Remove Configuration Profiles
  - –Install and Remove Provisioning Profiles
- Status
  - –Device Information, Security Info, Restrictions
  - –List Apps, Certs, Profiles, Provisioning Profiles
- Control
  - –Device Lock
  - –Clear Passcode
  - –Erase Device

There are a total of 14 commands available to the MDM service. Roughly, I've grouped them into 3 categories: Those which modify the configuration of a device, those that query the device for some kind of status or informational data, and those that actually remotely control the device.

New in iOS 5

- Configuration
  - –Install, update, remove applications
  - –Apply Configuration Settings
  - –Apply Redemption Code
- Status
  - –List Managed Applications
- Check out
  - –If device manually removes MDM control, sends a "CheckOut" message to the /checkin url

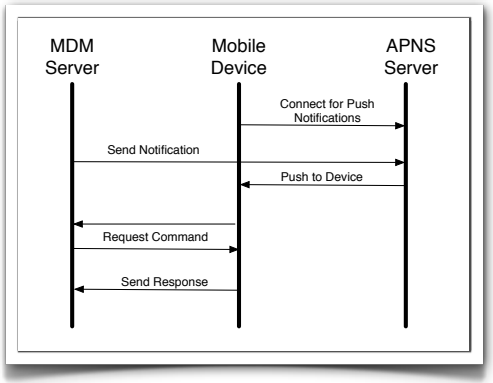


The "InstallApplication" command has two forms: One provides an app ID from the app store, the other provides a link to a Manifest.plist file (which includes data about the app and links to a .ipa file). For app store apps, the user must still enter their Apple ID and password, for custom apps, the app is immediately installed (after the user authorizes it).

[There is a command for "ApplyRedemptionCode," but I haven't figured out how to make that work. I suspect that you'd begin an install with an App Store ID, then send the redemption code, but I'm not sure (plus, I believe it requires Volume Purchase Plan codes, and since I'm not in the VPP, it's kind of difficult to test).]

Command Flow

- First, device connects to APNS server
- Four connections per command:
  - –Server to APNS
  - –APNS to Device
  - –Device to Server
    - Receives Command
  - –Device to Server
    - Provides response



First, the device must make the persistent connection to Apple, to receive push notifications. Then, for every command the MDM server sends, four total connections are created: The server sending the message to Apple, Apple sending it down (the already established) connection to the device, then the device asking for (and receiving) the command from the server, and finally the device providing an response to the server.

Client Initial Connection

- Simple “status” message
- Identifies self via UDID
- Triggers server to provide command

```
<plist version="1.0">
<dict>
   <key>Status</key>
   <string>Idle</string>
   <key>UDID</key>
   <string> [ redacted ] </string>
</dict>
</plist>
```

Now that the device is fully enrolled, it can respond to push notifications by contacting the “Server URL” address. When connecting, the client PUTs a simple message identifying “Status = Idle”, and the server responds with a command, again in a .plist format.

The client executes the command, and responds with a simple acknowledgement message, or with appropriate data as requested by the server.

Command Format

- Command in “RequestType” field
- CommandUUID field mandatory
  - –Content optional
  - –Allows matching of commands and responses

```
<dict>
  <key>Command</key>
  <dict>
    <key>RequestType</key>
    <string>ClearPasscode</string>
    <key>UnlockToken</key>
    <data>[ redacted ] </data>
  </dict>
  <key>CommandUUID</key>
  <string>69c4597f-4640-437c-8fac-b341af659212</string>
</dict>
```

The commands are framed in .plist format. A top-level key “Command” is made up of a dictionary of key/value pairs. Usually this will include only the single key “RequestType,” which has as its value the actual command being sent. In some cases, additional parameters will get added as peers to the RequestType key.

The command also includes a UUID string that uniquely identifies the instance of the command. This is useful for matching up responses with the command that caused them to be sent, especially when several commands may be queued up but aren’t necessarily delivered, or processed, in order.

In practice, this field can actually be left blank, however it’s probably best practice to fill it with some random (or controllable) UUID.

Generic Response

- Returned for many commands
  - –Basically, anything other than a query cmd
- If not Acknowledged, likely will get error msg

```
<plist version="1.0">
<dict>
   <key>CommandUUID</key>
   <string>69c4597f-4640-437c-8fac-b341af659212</string>
   <key>Status</key>
   <string>Acknowledged</string>
   <key>UDID</key>
   <string> [ redacted ] </string>
</dict>
</plist>
```

The standard response is simply an acknowledgment of the command. If the command caused an error, then an error code and strings (localized and in US English) are returned in the plist data. For those commands which require a more detailed response, a more detailed plist file is returned.

Response - Device Info

```
{'CommandUUID': '105ac7bd-5bce-430c-a675-38ea890526f6',
 'QueryResponses': {'AvailableDeviceCapacity': 12.210990905761719,
                    'BluetoothMAC': '--redacted--',
                    'BuildVersion': '8J3',
                    'CarrierSettingsVersion': '10.0',
                    'CurrentMCC': '000',
                    'CurrentMNC': '00',
                    'DataRoamingEnabled': False,
                    'DeviceCapacity': 14.020820617675781,
                    'DeviceName': 'IG Chantilly',
                    'IMEI': '--redacted--',
                    'IsRoaming': True,
                    'Model': 'MC823LL',
                    'ModelName': 'iPad',
                    'ModemFirmwareVersion': '07.11.01',
                    'OSVersion': '4.3.3',
                    'ProductName': 'iPad1,1',
                    'SIMCarrierNetwork': 'AT&T',
                    'SerialNumber': '--redacted--',
                    'UDID': '--redacted--',
                    'WiFiMAC': '--redacted--'},
 'Status': 'Acknowledged',
 'UDID': '--redacted--'}
```

And here's the result from just such a call: The "DeviceInformation" command. Several parameters are available to be queried, and those that pertain (or have a value) to the device queried are returned in this structure. This includes some identifying information, such as IMEI, Serial Number, UDID, MAC addresses, Phone Number, and so forth.

Believe it or not, we now know enough to create our own server.

DIY Server

INTREPIDUS GROUP MOBILE SECURITY

- Fewer than 500 lines of python
- Uses standard libraries, plus:
  - –web.py
  - –APNSWrapper.py
  - –OpenSSL (command-line)
- Simple command and response console
  - –Send a command
  - –Look at the response

DIY Server

- Very rough:
  - –Implements all commands
  - –But not all responses
  - –Only one device at a time -- “last in wins”
- No guarantees
- Good starting point for experimentation
- Available online (along with slides, etc.)
  - –Link at end of presentation

It’s a pretty rough server, designed only for testing MDM and researching how it works. It implements all the commands, but not all the responses (for example, it doesn’t provide, nor respond to, error messages).

It’s also only capable of tracking a single device at a time -- so the last device that gets enrolled, that’s the one you’re controlling. :) (be careful, for example, if two people are experimenting with the server at the same time, that you don’t accidentally wipe the other’s device thinking it was your own).

MDM Limitations

- User can terminate MDM relationship
  - –Will lose whatever MDM installed
  - –Corporate profile settings, etc.
  - –But now the device tells MDM when that happens
- Doesn’t address co-mingling of data
  - –Will probably require multi-user model
- Can’t detect jailbreak
- Needs push notification certificate
  - –Much lower barrier now

The MDM system is not without some limitations, however. First, the user can terminate the MDM relationship at any time by simply deleting the MDM profile. Any profiles which had been installed by MDM (web clips, account information for corporate email, etc.) also get deleted. MDM also doesn’t address the co-mingling of data, such as easily dragging messages from the corporate account to a personal email account.

There was talk that Apple had included a jailbreak detection command in an earlier version of MDM, but it's not there now. Third party services can install their own clients to supplement the MDM feature set, and some of these do their own jailbreak detection, but there’s nothing built into the MDM system to do so.

Finally, you need the push notification certificate. This is now a much lower barrier, though.

Missing Features

- Change (not just erase) passcode
- Can’t disable microphone
- Some basic settings not available in MDM
  - –PictureFrame restriction
  - –Can’t lock down accounts
- Geolocation not available
  - –Find My iPhone appears to use different system

Beyond the limitations, there are some simple features that’d be nice to have. For example, it’d be great if the MDM could not just clear the passcode, but set a whole new one. This would be useful for a corporate device where the owner is leaving the company, and we want to lock them out of the device but not wipe it quite yet.

You also can’t lock down the creation of accounts, though that feature does exist in the Settings application.

It’d be nice to disable the microphone, for some environments, and finally, geolocation does not appear to be available through MDM. You need the Find My iPhone system to do that.

Interesting Bugs?

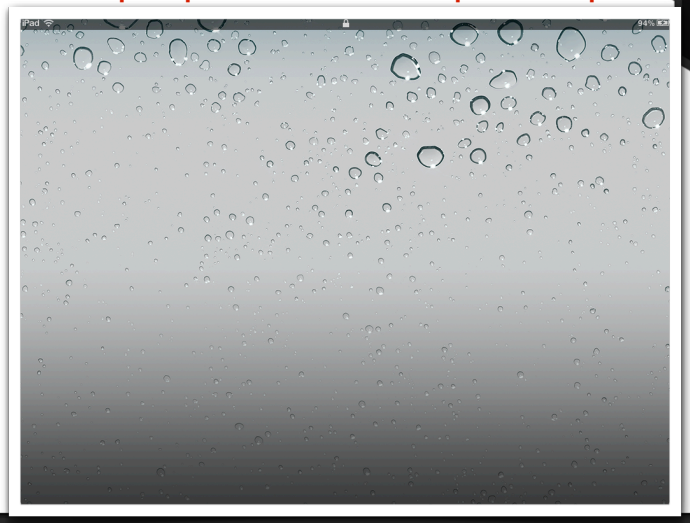
- Clearing passcode delay bug
  - –Doesn’t immediately interrupt delay
  - –Doesn’t clear failure count
    - Don’t mistype your new passcode the first time
    - Otherwise count continues, you’re delayed again

First, after several passcode failures, a delay gets added between attempts. If MDM clears it, the device won't immediately open -- the current passcode entry delay must first timeout (which can be up to an hour).

Worse, the failure count doesn’t appear to be cleared. So you get unlocked, into the device, and set a new passcode. Then if you lock it, and immediately mistype the passcode, you’re back where you started -- if you had 7 failures before, then that’s # 8, and you now have to wait 15 minutes to try again.

Lock Out Bug

- Clear simple passcode with panel up



Another bug: when you have a simple passcode, and it’s cleared while the numeric keypad is up. When that happens, entering any random 4-digit code will let you in, while hitting “cancel” kills the panel, but also kills the “swipe to unlock”. So the device is locked, at a (mostly) blank screen, and you can’t do anything at all other than power-cycle it.

Security Concerns

- No command authentication
  - –“Sign message” option not enforced
- SSL authentication
  - –Appears to accept any cert with ‘trusted’ root
  - –MITM likely possible
- Configuration not protected on filesystem

The profile has the option to “sign messages,” but even when that’s set the device accepts plain, unsigned commands with no real authentication.

It also appears that there’s not much authentication for SSL -- it just checks for a validly rooted cert. So MITM attacks are likely possible.

Finally, the MDM configuration is not protected by the FileProtection system -- so it’s readable without the passcode. Several techniques exist whereby a locked device can be booted into a special mode, providing access to the filesystem, which means that MDM details can be read, or potentially even changed.

Possible Attacks

- Can’t forge APNS, so need to MITM
- Downgrade security requirements
- Multi-stage malware install
  - –Push provisioning profile
  - –Push webclip
  - –User clicks webclip & installs program
    - Combine with social engineering encouragement
  - –Even easier with new InstallApplication command
- Denial of Service

You could downgrade security requirements on the device, such as reducing passcode complexity requirements.

A multi-step attack could install a profile that includes a signed provisioning profile, and a webclip placed on the user’s home screen. When the user taps on the webclip, it installs a custom app, which might include malware payloads.

Finally, great mayhem: If you can manage to position your MITM server “just outside” the legitimate MDM server (that is, MITM at the enterprise level, not just against a single targeted device) ... then you could conceivably just intercept all the devices doing a daily checkin and make them all..er...erase themselves.

There are a couple of very good points, though: You can't install a profile on a locked device (if there's a passcode), nor can you induce a locked device to resend you the unlock token. (Again, my theory is that the token is a key to an escrow keybag, and once the device is locked, such keys are wiped from memory, so it should be impossible for the device to provide the unlock key when it's locked). Also, though MDM can list the profiles installed on a device, it can't actually read the contents of those profiles. So it might see a profile named "Corporate Email Settings," but the details like the server name, userids, passwords, etc., won't be returned via the MDM call.

Overwrite MDM Profile

- Can’t install profile on locked device
- Can install when device unlocked
- If you reinstall the MDM profile....
- ....it re-enrolls in MDM.
- Which sends a new UnlockToken

As I was finishing up the first draft of these slides, I was testing some limitations of profile installation. And accidentally installed the MDM profile (instead of the profile I used in the demo). Imagine my shock when I saw new tokens appear in my debug window.

Evil Maid Attack

1. Get device to talk to your sever
2. Install copy of MDM profile
3. Receive new UnlockToken
4. Send ClearPasscode
5. Copy device, leave

The “Evil Maid” attack has been known for some years now. It exemplifies the dangers associated with physical access to a device -- if you can touch it, you can own it. In the traditional attack, a bribed hotel maid (or someone disguised as one) boots a computer using full disk encryption from a USB fob, installing malware to the root partition / boot sector. That malware eventually collects the password to decrypt the drive, providing the attacker with access to the data. This is simply an iOS version of the attack, using MDM as the main attack vector.

Man in the Middle

- Use standard MITM techniques
  - –Wi-Fi trickery, forge SSL cert, etc.
- Or, since you have physical access to device:
  - –Get onto device
  - –Add entries to /etc/hosts
  - –Install your own certificate

There are many ways to get into the middle of the MDM conversation. If the MDM server uses HTTPS (and it should), then some SSL trickery may be required, either to exploit weaknesses in certificate validation, or to somehow get a forged (but apparently signed) cert, or to place a rogue CA cert onto the device.

Duplicate MDM Profile

- Gain access to device filesystem
  - –Use DFU / tethered boot magic
- Retrieve copy of MDM profile “stub”
  - –In /var/mobile/Library/ConfigurationProfiles
- Extract original MDM profile from stub
  - –It’s in there, base-64 encoded
- Might be able to get from the legit server

The tricky bit is that the profile being re-installed must match *exactly* with what the device already has. This is made much easier by the fact that a copy of the profile is stored on the device, and can be easily retrieved.

Alternatively, if every single device in an organization uses the same profile to install MDM (using SCEP services instead of bundling a device identity cert), then it might be possible to simply acquire a copy from another device. (This could make the “Evil Lackey” variant described later much easier to accomplish.)

Push Profile to Device

- Can't send the push message
- But can instruct device to poll
  - –MDMOutstandingActivities.plist
    - The "Status: Idle" message
  - –Place into ConfigurationProfiles folder
  - –Device will poll MDM server
- If command is "InstallProfile":
  - –Device responds "Not Now"
  - –Waits until unlocked, then tries again

No matter what we retrieve from the device, it's unlikely we'll be able to forge the push messages through Apple. So the attacker could simply wait for the legitimate MDM server to send a push message, or we could force a poll of the server by adding a special file to the device.

Once the device sees that file, it contacts the server. If the server then responds with the installation command for our MDM profile copy, the device will say "Not Now" and refuse to install. But as soon as the device is unlocked, it will remember that it deferred a profile, contact the server, and complete the command.

Re-Installing MDM

- If device receives new MDM profile
  - –Fails: "Device already managed by MDM"
- Unless new profile exactly matches old
  - –Then, the device silently re-enrolls
  - –Sends Token, PushMagic, and UnlockToken
- Since we're MITM, those come to us
- Can't use the APNS tokens
  - –Don't have right push cert

Normally, installing a new MDM profile will result in an error from the device. But as mentioned, if the profile exactly matches, then the device will simply "re-enroll" in the same service. It does this silently, without any indication to the user at all.

Since the MDM server is being impersonated by the attacker, now the attacker gets the new UnlockToken. (They also get a new APNS Token and PushMagic string, but those are useless without the right APNS certificate).

Send Clear Passcode

- Wait for another chance at device
- DFU boot, force MDM poll
- Evil server sends ClearPasscode
- Now device fully unlocked
  - –Browse everything
  - –Better yet, backup entire device and run

Now the attacker has the unlock token for the device. They need only to wait until the device is left unattended again. Then they get back into the device (through the DFU tethering magic), force the MDM server poll, and send the ClearPasscode command with the Unlock Token. At this point, the device is unlocked, and all protected data (email, account passwords, etc.) are available to the attacker.

Covering Your Tracks

- But now there's no passcode!
  - –The victim will suspect
- Replay TokenUpdate to real MDM
  - –Now the corporate server can talk to it again
  - –Most importantly, it can unlock the device again
- Set a bogus passcode
  - –User returns to device, can't unlock it
  - –Eventually calls for help
  - –They unlock it remotely
  - –Everyone forgets this ever happened

Looking ahead at what happens next, one might realize "But wait! There's no passcode left on the device. Won't the victim know something's wrong?" So you set a bogus password, and replay the TokenUpdate command to the device's legitimate, real MDM server. Now the MDM server has the current push and unlock tokens, and when the user can't get in, they simply call the help desk and get it unlocked remotely. Chances are pretty good nobody will ever remember this even happened....

Isn't this a bit crazy?

- Yes. Yes, it is.
- For a high-value target, not unheard of.
- Levels of difficulty:
  - –Access via DFU: ***Pretty difficult***
  - –Putting server in middle: ***Moderate***
  - –Executing the commands: ***Easy***
  - –Duplicating the unlocked device: ***Trivial***
  - –General logistics: ***Moderate to Difficult***

Crazier than "Normal" Evil Maid?

Yes. But maybe not by much.

This is not an easy attack to pull off. It requires a fair degree of technical sophistication, especially around the DFU-based access to the filesystem. That's not to mention the logistical difficulties of gaining access to the room (and making sure the device is even in there to begin with!).

Demo: Evil Maid

Evil Lackey

- Change:
  - –"Hotel" to "Office"
  - –"Maid" to "Passed-over Deputy to the Deputy"
  - –"Hotel Bar" to "Office Gym"
- Advantages:
  - –Longer time-frame for attack
  - –Better understand MDM setup in use
  - –With patience, can execute attack w/out DFU
    - MITM target device
    - Wait for legit server to send push notifications

An alternative attack can take place within the office environment itself. This may actually have several advantages over the "Traveling CEO" attack, in particular since the attacker will have more regular, long-term access to the device, so the attack need not be rushed.

Also, if the attacker is able to better understand how the MDM system is configured at that site (especially if they have their own device they can experiment and test with), it might even be possible to execute the attack without the complexities of the DFU Tethered Boot trick. Simply acquire the enrollment profile directly from the MDM server, set up a MITM server that forwards all non-target MDM traffic to the real server, and then wait for the real server to send out regularly scheduled commands. (If, for example, you discover that the server refreshes device information every Monday night at 8, then just time your attack for then and let the MDM server cause the target device to poll your MITM server).

Fixes?

- Better use of SSL
  - –Remember certificates (connections, commands)
- Require user acknowledgment for re-enroll
  - –So tokens don't get sent silently

Fortunately, I think that fixes to this (and other MDM issues) can be pretty easily accomplished by Apple.

Better use of SSL-based authentication, both at the client to server level, and at the command level, would also raise the bar for MITM attacks. Finally, whenever the device enrolls in MDM (and thus sends an Unlock Token to a 3rd party), the user should be directly notified, especially if the device already appears to be enrolled.

It'd probably be nice to add some kind of authentication to the EraseDevice call...perhaps requiring the UnlockToken. Though there may be valid reasons why the current method was chosen.

But that's not all....

- Remember I said:
  - "Can't install a profile to a locked device"

Keybags

- Literally a container of encryption keys
- Used to decrypt protected data
- (Also used for syncing and for remote unlock)

- Lock: delete in-memory bag
- Unlock: decrypt copy with passcode and load into memory

The keybag contains keys used to decrypt data on the device stored with the various protection classes, for both files and keychain entries. For example, data marked as "ProtectionComplete" is encrypted whenever the device is locked. The key to decrypt this data is stored in the keybag.

When you lock the device, the unencrypted keybag in memory is deleted, which means the device no longer has access to keys for the protected data. They simply don't exist in memory. So the device can no longer access those protected files.

When you unlock the device, an encrypted copy of the keybag is decrypted using the passcode, and loaded into memory, restoring the keys for current use.

New Bug

- MDM sends “Clear Passcode”
- Device loads unlocked keybag
- But doesn’t set “keybag in memory” flag
  - (Note: Inference. I don’t really know how it works)
- User sets new passcode and locks
- Device looks locked...but....
- ...device never clears in memory keybag

- SO DEVICE NOT COMPLETELY LOCKED

I don't know exactly how this bug works, but my supposition is this: There's some flag that indicates that an unlocked keybag is currently loaded into memory. When you unlock a device, and it decrypts the keybag, this flag is set. Then, when you lock it again, the operating system looks at that flag. If it's set, then it knows there's a keybag in memory that needs to be deleted, and so it clears it.

It appears that this flag isn't set when the keybag in memory was loaded through the MDM "ClearPasscode" command. So the device doesn't even realize that the keybag is in memory, so it never takes steps to clear it. Which means the keys remain available, and operations which don't require direct user access (the screen is still locked) will succeed even for what should be protected data.

Implications

- Device appears locked to user
- Processes “privileged” MDM commands
  - –Can Install Profile, and re-enroll in MDM
- Access protected files via ssh (jb, obv.)
- Backup to a new desktop (if not encrypted)
- etc..

- Doesn’t survive a second lock or power cycle
- Bug is reasonably repeatable

Though the device appears locked (and cannot be accessed through the screen), the data is no longer protected because the keys remain in memory. So operations like sync, installing profiles, etc., can all succeed.

However, once the device has been unlocked and locked again, it's no longer broken -- becuase unlocking the device via the screen sets that (possibly imaginary) flag, which then ensures the keybag is erased the next time it's locked. (and, obviously, turning the device off clears the keybag from memory as well).

So What?

- Couldn’t think of any useful “application”
- But implications are interesting
  - –When you lock the device....
  - –....you expect the keys to be thrown away
  - –....and encryption to be enforced.
- What’s the mechanism for this bug?
  - –Can it be triggered in userland?
  - –Could an app periodically trigger the bug?
    - Would ensure it appears locked, but not truly secure

To Sum Up...

So... “How secure is it?”

- Actually, not too bad.
- Some limitations and some holes
  - –No serious conceptual flaws
  - –Issues should be reasonably easy to fix
- Protocol pretty straightforward
  - –Now openly documented
- Hope this serves as catalyst for research

Bibliography / Links

INTREPIDUS GROUP MOBILE SECURITY

- Apple docs:
  - Troubleshooting Push Notifications
  - Local and Push Notification Programming Guide
  - Over-the-Air Profile Delivery and Configuration
- APNS library for Python (google code)
- White paper, slides, and current code:

  github.com/intrepidusgroup/imdmtools

david.schuetz@intrepidusgroup.com @schuetzdj