

NIST SPECIAL PUBLICATION 1800-21

Mobile Device Security

Corporate-Owned Personally-Enabled (COPE)

Includes Executive Summary (A); Approach, Architecture, and Security Characteristics (B); and How-To Guides (C)

Joshua M. Franklin
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<https://www.nccoe.nist.gov/projects/building-blocks/mobile-device-security/enterprise>



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The MITRE Corporation
McLean, Virginia

**Former employee; all work for this
publication was done while at employer.*

DRAFT

July 2019



U.S. Department of Commerce
Wilbur Ross, Secretary

National Institute of Standards and Technology
Walter Copan, NIST Director and Undersecretary of Commerce for Standards and Technology

Mobile Device Security

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Volume A:
Executive Summary

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1 Executive Summary

- 2 ▪ Mobile devices provide access to workplace data and resources that are vital for organizations
3 to accomplish their mission while providing employees the flexibility to perform their daily
4 activities. Securing these devices is essential to the continuity of business operations.
- 5 ▪ While mobile devices can increase organizations' efficiency and employee productivity, they can
6 also leave sensitive data vulnerable. Addressing such vulnerabilities requires mobile device
7 management tools to help secure access to the network and resources. These tools are different
8 from those required to secure the typical computer workstation.
- 9 ▪ To address the challenge of securing mobile devices while managing risks, the National
10 Cybersecurity Center of Excellence (NCCoE) at the National Institute of Standards and
11 Technology (NIST) built a laboratory environment to explore how various mobile security
12 technologies can be integrated within an enterprise's network.
- 13 ▪ This NIST Cybersecurity Practice Guide demonstrates how organizations can use standards-
14 based, commercially available products to help meet their mobile device security and privacy
15 needs.

16 CHALLENGE

17 Mobile devices are a staple within modern workplaces. As employees use these devices to perform
18 everyday enterprise tasks, organizations are challenged with ensuring that devices regularly process,
19 modify, and store sensitive data securely. These devices bring unique threats to the enterprise and
20 should be managed in a manner distinct from traditional desktop platforms. This includes securing
21 against different types of network-based attacks on mobile devices that have an always-on connection
22 to the internet.

23 Managing the security of workplace mobile devices and minimizing the risk posed can be challenging
24 because there are many mobile device security tools available. Proper implementation is difficult to
25 achieve for an end user because the method of implementation varies considerably from tool to tool. In
26 addition, unfamiliarity with the threats to mobile devices can further compound these implementation
27 difficulties.

28 SOLUTION

29 To address the challenge of securing mobile devices within an enterprise, NIST built an example solution
30 in a lab environment at the NCCoE to demonstrate mobile management tools that enterprises can use
31 to secure their networks. These technologies are configured to protect organizational assets and end-
32 user privacy, providing methodologies to enhance the security and privacy posture of the adopting
33 organization.

34 Both Apple iOS and Android devices are used in the example solution, which includes detailed device
35 configurations and enterprise mobility management policies provisioned to the devices. The foundation
36 of this architecture is based on federal U.S. guidance, including that from NIST 800 series publications,
37 National Information Assurance Partnership, U.S. Department of Homeland Security, and the Federal

38 Chief Information Officers Council. These standards, best practices, and certification programs help
39 ensure the confidentiality and integrity of enterprise data on mobile systems.

40 This guide provides:

- 41 ▪ a detailed example solution and capabilities that address risk and implementation of security
42 controls
- 43 ▪ a demonstration of the approach using commercially available products
- 44 ▪ how-to instructions for implementers and security engineers, with instructions on integrating
45 and configuring the example solution into their organization's enterprise in a manner that can
46 achieve security goals with minimum impact on operational processes

47 The NCCoE sought existing technologies that provided the following capabilities:

- 48 ▪ enhanced protection of data that resides on the mobile device
- 49 ▪ centralization of management systems to deploy policies and configurations to devices
- 50 ▪ ability to evaluate the security of mobile applications
- 51 ▪ inhibition of the eavesdropping of mobile device data when traversing a network
- 52 ▪ privacy settings that protect end-user data
- 53 ▪ protection from phishing attempts

54 Commercial, standards-based products such as the ones we used are readily available and interoperable
55 with existing information technology (IT) infrastructure and investments.

56 While the NCCoE used a suite of commercial products to address this challenge, this guide does not
57 endorse these particular products, nor does it guarantee compliance with any regulatory initiatives. Your
58 organization's information security experts should identify the products that will best integrate with
59 your existing tools and IT system infrastructure. Your organization can adopt this solution or one that
60 adheres to these guidelines in whole, or you can use this guide as a starting point for tailoring and
61 implementing parts of a solution.

62 **BENEFITS**

63 The NCCoE's practice guide *Mobile Device Security: Corporate-Owned Personally-Enabled (COPE)* can
64 help your organization:

- 65 ▪ reduce adverse effects on the organization if a device is compromised
- 66 ▪ reduce capital investment by embracing modern enterprise mobility models
- 67 ▪ apply robust, standards-based technologies using industry best practices
- 68 ▪ reduce privacy risks to users through privacy protections
- 69 ▪ provide users with enhanced protection against loss of personal and business data when a
70 device is stolen or misplaced
- 71 ▪ deploy enterprise management technologies to improve the security of enterprise networks,
72 devices, and applications

- 73 ▪ reduce risk so that employees can access the necessary data from nearly any location, using a
74 wide selection of mobile devices and networks
- 75 ▪ enhance visibility for system administrators into mobile security events, quickly providing
76 notification and identification of device and data compromise
- 77 ▪ implement government standards for mobile security

78 **SHARE YOUR FEEDBACK**

79 You can view or download the guide at [https://www.nccoe.nist.gov/projects/building-blocks/mobile-](https://www.nccoe.nist.gov/projects/building-blocks/mobile-device-security/enterprise)
80 [device-security/enterprise](https://www.nccoe.nist.gov/projects/building-blocks/mobile-device-security/enterprise). Help the NCCoE make this guide better by sharing your thoughts with us as
81 you read the guide. If you adopt this solution for your own organization, please share your experience
82 and advice with us. We recognize that technical solutions alone will not fully enable the benefits of our
83 solution, so we encourage organizations to share lessons learned and best practices for transforming the
84 processes associated with implementing this guide.

85 To provide comments or to learn more by arranging a demonstration of this example implementation,
86 contact the NCCoE at mobile-nccoe@nist.gov.

87 **TECHNOLOGY PARTNERS/COLLABORATORS**

88 Organizations participating in this project submitted their capabilities in response to an open call in the
89 Federal Register for all sources of relevant security capabilities from academia and industry (vendors
90 and integrators). The following respondents with relevant capabilities or product components (identified
91 as “Technology Partners/Collaborators” herein) signed a Cooperative Research and Development
92 Agreement (CRADA) to collaborate with NIST in a consortium to build this example solution.



94 Certain commercial entities, equipment, products, or materials may be identified by name or company
95 logo or other insignia in order to acknowledge their participation in this collaboration or to describe an
96 experimental procedure or concept adequately. Such identification is not intended to imply special
97 status or relationship with NIST or recommendation or endorsement by NIST or NCCoE; neither is it
98 intended to imply that the entities, equipment, products, or materials are necessarily the best available
99 for the purpose.

The National Cybersecurity Center of Excellence (NCCoE), a part of the National Institute of Standards and Technology (NIST), is a collaborative hub where industry organizations, government agencies, and academic institutions work together to address businesses’ most pressing cybersecurity challenges. Through this collaboration, the NCCoE develops modular, easily adaptable example cybersecurity solutions demonstrating how to apply standards and best practices using commercially available technology.

LEARN MORE

Visit <http://www.nccoe.nist.gov>
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Mobile Device Security

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Volume B:
Approach, Architecture, and Security Characteristics

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DISCLAIMER

Certain commercial entities, equipment, products, or materials may be identified by name or company logo or other insignia in order to acknowledge their participation in this collaboration or to describe an experimental procedure or concept adequately. Such identification is not intended to imply special status or relationship with NIST or recommendation or endorsement by NIST or NCCoE; neither is it intended to imply that the entities, equipment, products, or materials are necessarily the best available for the purpose.

National Institute of Standards and Technology Special Publication 1800-21B Natl. Inst. Stand. Technol. Spec. Publ. 1800-21B, 148 pages, (July 2019), CODEN: NSPUE2

FEEDBACK

You can improve this guide by contributing feedback. As you review and adopt this solution for your own organization, we ask you and your colleagues to share your experience and advice with us.

Comments on this publication may be submitted to: mobile-nccoe@nist.gov.

Public comment period: July 22, 2019 through September 23, 2019

All comments are subject to release under the Freedom of Information Act.

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1 **NATIONAL CYBERSECURITY CENTER OF EXCELLENCE**

2 The National Cybersecurity Center of Excellence (NCCoE), a part of the National Institute of Standards
3 and Technology (NIST), is a collaborative hub where industry organizations, government agencies, and
4 academic institutions work together to address businesses’ most pressing cybersecurity issues. This
5 public-private partnership enables the creation of practical cybersecurity solutions for specific
6 industries, as well as for broad, cross-sector technology challenges. Through consortia under
7 Cooperative Research and Development Agreements (CRADAs), including technology partners—from
8 Fortune 50 market leaders to smaller companies specializing in information technology security—the
9 NCCoE applies standards and best practices to develop modular, easily adaptable example cybersecurity
10 solutions using commercially available technology. The NCCoE documents these example solutions in
11 the NIST Special Publication 1800 series, which maps capabilities to the NIST Cybersecurity Framework
12 and details the steps needed for another entity to re-create the example solution. The NCCoE was
13 established in 2012 by NIST in partnership with the State of Maryland and Montgomery County,
14 Maryland.

15 To learn more about the NCCoE, visit <https://www.nccoe.nist.gov>. To learn more about NIST, visit
16 <https://www.nist.gov>.

17 **NIST CYBERSECURITY PRACTICE GUIDES**

18 NIST Cybersecurity Practice Guides (Special Publication 1800 series) target specific cybersecurity
19 challenges in the public and private sectors. They are practical, user-friendly guides that facilitate the
20 adoption of standards-based approaches to cybersecurity. They show members of the information
21 security community how to implement example solutions that help them align more easily with relevant
22 standards and best practices, and provide users with the materials lists, configuration files, and other
23 information they need to implement a similar approach.

24 The documents in this series describe example implementations of cybersecurity practices that
25 businesses and other organizations may voluntarily adopt. These documents do not describe regulations
26 or mandatory practices, nor do they carry statutory authority.

27 **ABSTRACT**

28 Mobile devices provide access to workplace data and resources that are vital for organizations to
29 accomplish their mission while providing employees the flexibility to perform their daily activities.
30 Securing these devices is essential to the continuity of business operations.

31 While mobile devices can increase organizations’ efficiency and employee productivity, they can also
32 leave sensitive data vulnerable. Addressing such vulnerabilities requires mobile device management
33 tools to help secure access to the network and resources. These tools are different from those required
34 to secure the typical computer workstation.

35 To address the challenge of securing mobile devices while managing risks, the NCCoE at NIST built a
 36 reference architecture to show how various mobile security technologies can be integrated within an
 37 enterprise's network.

38 This NIST Cybersecurity Practice Guide demonstrates how organizations can use standards-based,
 39 commercially available products to help meet their mobile device security and privacy needs.

40 **KEYWORDS**

41 *Bring your own device; BYOD; corporate-owned personally-enabled; COPE; mobile device management;*
 42 *mobile device security, on-premise.*

43 **ACKNOWLEDGMENTS**

44 We are grateful to the following individuals for their generous contributions of expertise and time.

Name	Organization
Donna Dodson	NIST
Vincent Sritapan	Department of Homeland Security, Science and Technology Directorate
Jason Frazell	Appthority (acquired by Symantec)
Joe Middlyng	Appthority (acquired by Symantec)
Chris Gogoel	Kryptowire
Tom Karygiannis	Kryptowire
Tim LeMaster	Lookout
Victoria Mosby	Lookout
Michael Carr	MobileIron
Walter Holda	MobileIron
Farhan Saifudin	MobileIron

Name	Organization
Jeff Lamoureaux	Palo Alto Networks
Sean Morgan	Palo Alto Networks
Kabir Kasargod	Qualcomm
Viji Raveendran	Qualcomm
Lura Danley	The MITRE Corporation
Eileen Durkin	The MITRE Corporation
Sallie Edwards	The MITRE Corporation
Marisa Harriston	The MITRE Corporation
Nick Merlino	The MITRE Corporation
Doug Northrip	The MITRE Corporation
Titilayo Ogunyale	The MITRE Corporation
Oksana Slivina	The MITRE Corporation
Tracy Teter	The MITRE Corporation
Paul Ward	The MITRE Corporation

45 The Technology Partners/Collaborators who participated in this build submitted their capabilities in
46 response to a notice in the Federal Register. Respondents with relevant capabilities or product
47 components were invited to sign a Cooperative Research and Development Agreement (CRADA) with
48 NIST, allowing them to participate in a consortium to build this example solution. We worked with:

Technology Partner/Collaborator	Build Involvement
Appthority	Appthority Cloud Service, Mobile Threat Intelligence
Kryptowire	Kryptowire Cloud Service, Application Vetting
Lookout	Lookout Cloud Service/Lookout Agent Version 5.10.0.142 (iOS), 5.9.0.420 (Android), Mobile Threat Defense
MobileIron	MobileIron Core Version 9.7.0.1, MobileIron Agent Version 11.0.1A (iOS), 10.2.1.1.3R (Android), Enterprise Mobility Management
Palo Alto Networks	Palo Alto Networks PA-220
Qualcomm	Qualcomm Trusted Execution Environment (version is device dependent)

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205 1 Summary

206 This National Institute of Standards and Technology (NIST) Cybersecurity Practice Guide seeks to address
207 mobile device security implementation challenges in several ways: by analyzing a set of mobile security
208 and privacy threats; exploring mitigating technologies; and describing a reference design based upon
209 those technologies to help mitigate the identified threats.

210 Incorporating mobile devices into the organizational enterprise provides greater flexibility in how
211 employees access organizational resources. For some organizations, this flexibility supports a hybrid
212 approach enhancing their traditional in-office processes with more responsive communication and
213 adaptive workflows.

214 For others, this flexibility, combined with growing mobile functionality, fosters a mobile-first approach in
215 which their employees primarily communicate and collaborate using mobile devices. However, some of
216 the features that make mobile devices increasingly flexible and functional also make them challenging to
217 deploy and manage with security in mind.

218 Further, organizations are becoming progressively cognizant of the privacy implications for their
219 employees that arise from using mobile security technologies. Therefore, developing a successful mobile
220 deployment strategy requires organizations to evaluate their security and privacy requirements.

221 Although organizations may be aware of the security and privacy risks that can be introduced by mobile
222 devices, addressing them strategically and technically can pose a barrier to implementing mobile device
223 security capabilities. This barrier is particularly challenging for businesses to overcome. As a result, they
224 may choose to enable mobile access with minimal acceptable use policies, employee awareness, or
225 security controls to limit implementation challenges.

226 To help address mobile device security and privacy risks, this document's reference design provides:

- 227 ▪ a description of a mobile deployment strategy featuring an on-premises enterprise mobility
228 management (EMM) solution integrated with cloud- and agent-based mobile security
229 technologies to help deploy a set of security and privacy capabilities in support of a corporate-
230 owned personally-enabled (COPE) mobile device usage scenario
- 231 ▪ a series of How-To Guides—step-by-step instructions covering the initial setup (installation or
232 provisioning) and configuration for each component of the architecture—to help security
233 engineers rapidly deploy and evaluate our example solution in their test environment

234 The example solution of our reference design uses standards-based, commercially available products. It
235 can be used directly by any organization with a COPE usage scenario by implementing a security
236 infrastructure that supports integration of on-premises with cloud-hosted mobile security technologies.
237 Alternatively, an organization may use our reference design and example solution in whole or part as

238 the basis for a custom solution that realizes the security and privacy characteristics that best support its
239 unique mobile device usage scenario.

240 **1.1 Challenge**

241 Mobile devices are a staple within modern workplaces, and as employees use these devices to perform
242 everyday enterprise tasks, organizations are challenged with ensuring that devices regularly process,
243 modify, and store sensitive data securely. They bring unique threats to the enterprise and need to be
244 managed differently from traditional desktop platforms.

245 Due to their unique capabilities, mobile devices' specific security challenges can include:

- 246 ▪ securing their always-on-connections to the internet from network-based attacks
- 247 ▪ securing the data on devices to prevent compromise via malicious applications
- 248 ▪ protecting them from phishing attempts that try to collect user credentials or entice a user to
249 install software
- 250 ▪ selecting from the many mobile device management tools available and implementing their
251 protection capabilities consistently
- 252 ▪ identifying threats to mobile devices and how to mitigate them

253 Given these challenges, managing the security of workplace mobile devices and minimizing the risk
254 posed can be complex. By providing an example solution that organizations can make immediate use of,
255 this guide provides an example solution to help simplify deployment of mobile device security
256 capabilities.

257 **1.2 Solution**

258 In our lab at the National Cybersecurity Center of Excellence (NCCoE), NIST engineers built an
259 environment that contains an example solution for managing the security of mobile devices. In this
260 guide, we show how an enterprise can leverage this infrastructure to implement on-premises enterprise
261 mobility management (EMM), mobile threat defense (MTD), mobile threat intelligence (MTI),
262 application vetting, secure boot/image authentication, and virtual private network (VPN) services.

263 Further, these technologies were configured to protect organizational assets and end-user privacy,
264 providing methodologies to enhance the security posture of the adopting organization. The foundation
265 of this architecture is based on federal United States guidance, including that from the NIST 800 series
266 publications [1], the National Information Assurance Partnership (NIAP) [2], the Department of
267 Homeland Security [3], and the Federal Chief Information Officers (CIO) Council [4]. These standards,
268 best practices, and certification programs help ensure the confidentiality, integrity, and availability of
269 enterprise data on mobile systems.

270 This guide provides:

- 271 ▪ a detailed example solution with capabilities that mitigate common mobile threats
- 272 ▪ a demonstration of an approach that uses commercially available products
- 273 ▪ step-by-step installation how-to guidance for implementers, which is designed to easily
- 274 integrate with existing systems to improve the organization’s mobile security posture with
- 275 minimal disruption to operations

276 The NCCoE sought existing technologies that provided the following capabilities:

- 277 ▪ ability to help protect data resident on the mobile device
- 278 ▪ utilization of centralized management systems to deploy policies and configurations to devices
- 279 ▪ vetting the security of mobile applications
- 280 ▪ ability to help protect data from eavesdropping while traversing a network
- 281 ▪ privacy settings to enable the predictability, manageability, and disassociability of end-users’
- 282 personally identifiable information (PII)

283 Commercial, standards-based products such as the ones we used are readily available and interoperable
284 with existing information technology (IT) infrastructure and investments.

285 1.2.1 Standards and Guidance

286 The following standards and guidance have been consulted for this publication:

- 287 ▪ NIST Cybersecurity Framework Version 1.1 [5]
- 288 ▪ NIST Mobile Threat Catalogue [6]
- 289 ▪ NIST Risk Management Framework [7]
- 290 ▪ NIST Special Publication (SP) 1800-4, *Mobile Device Security: Cloud and Hybrid Builds* [8]
- 291 ▪ NIST SP 800-30 Revision 1, *Guide for Conducting Risk Assessments* [9]
- 292 ▪ NIST SP 800-37 Revision 2, *Risk Management Framework for Information Systems and*
- 293 *Organizations* [10]
- 294 ▪ NIST SP 800-46 Revision 2, *Guide to Enterprise Telework, Remote Access, and Bring Your Own*
- 295 *Device (BYOD) Security* [11]
- 296 ▪ NIST SP 800-52 Revision 1, *Guidelines for the Selection, Configuration, and Use of Transport*
- 297 *Layer Security (TLS) Implementations* [12]
- 298 ▪ NIST SP 800-53 Revision 4, *Security and Privacy Controls for Federal Information Systems and*
- 299 *Organizations* [13]
- 300 ▪ NIST SP 800-63-3, *Digital Identity Guidelines* [14]
- 301 ▪ NIST SP 800-113, *Guide to SSL VPNs* [15]

- 302 ▪ NIST SP 800-114 Revision 1, *User’s Guide to Telework and Bring Your Own Device (BYOD)*
303 Security [16]
- 304 ▪ NIST SP 800-124 Revision 1, *Guidelines for Managing the Security of Mobile Devices in the*
305 Enterprise [17]
- 306 ▪ NIST SP 800-163 Revision 1, *Vetting the Security of Mobile Applications* [18]
- 307 ▪ NIST SP 800-171, *Protecting Controlled Unclassified Information in Nonfederal Systems and*
308 Organizations [19]
- 309 ▪ NIST SP 800-181, *National Initiative for Cybersecurity Education (NICE) Cybersecurity Workforce*
310 Framework [20]
- 311 ▪ Center for Internet Security [21]
- 312 ▪ Executive Office of the President, Bring Your Own Device Toolkit [22]
- 313 ▪ Federal Chief Information Officers (CIO) Council and Department of Homeland Security (DHS)
314 Mobile Security Reference Architecture, Version 1.0 [23]
- 315 ▪ Digital Services Advisory Group and Federal Chief Information Officers Council, *Government Use*
316 of Mobile Technology Barriers, Opportunities, and Gap Analysis [24]
- 317 ▪ International Organization for Standardization (ISO), International Electrotechnical Commission
318 (IEC) 27001:2013, *Information technology–Security techniques–Information security*
319 *management systems–Requirements* [25]
- 320 ▪ Mobile Computing Decision Example Case Study [26]
- 321 ▪ Mobile Services Category Team (MSCT) Advanced Technology Academic Research Center
322 (ATARC), *Mobility Strategy Development Guidelines Working Group Document* [27]
- 323 ▪ MSCT ATARC, *Mobile Threat Protection App Vetting and App Security Working Group Document*
324 [28]
- 325 ▪ MSCT, *Device Procurement and Management Guidance* [29]
- 326 ▪ MSCT, *Mobile Device Management (MDM), MDM Working Group Document* [30]
- 327 ▪ MSCT, *Mobile Services Roadmap, MSCT Strategic Approach* [31]
- 328 ▪ NIAP U.S. Government Approved Protection Profile—*Extended Package for Mobile Device*
329 Management Agents Version 3.0 [32]
- 330 ▪ NIAP U.S. Government Approved Protection Profile—*Protection Profile for Mobile Device*
331 Fundamentals Version 3.1 [33]
- 332 ▪ NIAP U.S. Government Approved Protection Profile—*Protection Profile for Mobile Device*
333 Management Version 3.0 [34]
- 334 ▪ NIAP Product Compliant List [35]

335 ▪ United States Office of Management and Budget (OMB), Category Management Policy 16-3:
336 Improving the Acquisition and Management of Common Information Technology: Mobile
337 Devices and Services [36]

338 ▪ The United States Government Configuration Baseline (USGCB) [37]

339 ▪ United State Department of Homeland Security (DHS) Study on Mobile Device Security [38]

340 Note that Defense Federal Acquisition Regulation Supplement regulations are out of scope for this
341 effort.

342 1.3 Benefits

343 The potential business benefits of the example solution explored by this project are to:

344 ▪ provide users with enhanced protection against both malicious applications and loss of personal
345 and business data when a device is stolen or misplaced

346 ▪ reduce adverse effects on an organization if a device is compromised

347 ▪ reduce capital investment by embracing modern enterprise mobility models

348 ▪ provide visibility for system administrators into mobile security events, enabling automated
349 identification and notification of a compromised device

350 ▪ provide modular architecture based on technology roles while remaining vendor-agnostic

351 ▪ facilitate multiple mobile device usage scenarios using COPE devices

352 ▪ apply robust, standards-based technologies using industry best practices

353 ▪ demonstrate secure mobile access to organizational resources such as intranet, email, contacts,
354 and calendar

355 ▪ illustrate the application of the NIST Risk Management Framework to mobility scenarios

356 2 How to Use This Guide

357 This NIST Cybersecurity Practice Guide demonstrates a standards-based reference design and provides
358 users with the information they need to replicate how to improve mobile device security with on-
359 premises mobile device management solutions. This reference design is modular and can be deployed in
360 whole or in part.

361 This guide contains three volumes:

362 ▪ NIST SP 1800-21A: *Executive Summary*

363 ▪ NIST SP 1800-21B: *Approach, Architecture, and Security Characteristics* – what we built and why
364 **(you are here)**

365 ▪ NIST SP 1800-21C: *How-To Guides* – instructions for building the example solution

366 Depending on your role in your organization, you might use this guide in different ways:

367 **Business decision makers, including chief security and technology officers**, will be interested in the
368 *Executive Summary, NIST SP 1800-21A*, which describes the following topics:

369 ▪ challenges that enterprises face in securing mobile devices from threats that are distinct from
370 traditional desktop platforms

371 ▪ example solution built at the NCCoE

372 ▪ benefits of adopting the example solution

373 **Technology or security program managers** who are concerned with how to identify, understand, assess,
374 and mitigate risk will be interested in this part of the guide, *NIST SP 1800-21B*, which describes what we
375 did and why. The following sections will be of particular interest:

376 ▪ [Section 3.4](#), Risk Assessment, provides a description of the risk analysis we performed

377 ▪ [Section 4.3](#), Security Control Map, maps the security characteristics of this example solution to
378 cybersecurity standards and best practices

379 You might share the *Executive Summary, NIST SP 1800-21A*, with your leadership team members to help
380 them understand the importance of adopting standards-based solutions to improve mobile device
381 security with on-premises mobile device management solutions.

382 **IT professionals** who want to implement an approach like this will find the whole practice guide useful.
383 You can use the how-to portion of the guide, *NIST SP 1800-21C*, to replicate all or parts of the build
384 created in our lab. The how-to portion of the guide provides specific product installation, configuration,
385 and integration instructions for implementing the example solution. We do not re-create the product
386 manufacturers' documentation, which is generally widely available. Rather, we show how we
387 incorporated the products together in our environment to create an example solution.

388 This guide assumes that IT professionals have experience implementing security products within the
389 enterprise. While we have used a suite of commercial products to address this challenge, this guide does
390 not endorse these particular products. Your organization can adopt this solution or one that adheres to
391 these guidelines in whole, or you can use this guide as a starting point for tailoring and implementing
392 parts of this guide's example solution for on-premises mobile device security management. Your
393 organization's security experts should identify the products that will best integrate with your existing
394 tools and IT system infrastructure. We hope that you will seek products that are congruent with
395 applicable standards and best practices. Section 3.6, Technologies, lists the products we used, and
396 Appendix H maps them to the cybersecurity controls provided by this reference solution.

397 A NIST Cybersecurity Practice Guide does not describe "the" solution, but a possible solution. This is a
398 draft guide. We seek feedback on its contents and welcome your input. Comments, suggestions, and

399 success stories will improve subsequent versions of this guide. Please contribute your thoughts to
 400 mobile-nccoe@nist.gov.

401 2.1 Typographic Conventions

402 The following table presents typographic conventions used in this volume.

Typeface/ Symbol	Meaning	Example
<i>Italics</i>	file names and path names; references to documents that are not hyperlinks; new terms; and placeholders	For detailed definitions of terms, see the <i>NCCoE Glossary</i> .
Bold	names of menus, options, command buttons, and fields	Choose File > Edit .
Monospace	command-line input, onscreen computer output, sample code examples, and status codes	<code>mkdir</code>
Monospace Bold	command-line user input contrasted with computer output	<code>service sshd start</code>
blue text	link to other parts of the document, a web URL, or an email address	All publications from NIST's NCCoE are available at https://www.nccoe.nist.gov .

403 3 Approach

404 The NIST build team surveyed reports of mobile device security trends and openly invited the mobile
 405 device security community—including vendors, researchers, administrators, and users—to engage in a
 406 discussion about pressing cybersecurity challenges. The community expressed two significant messages.

407 First, administrators experienced confusion about which policies and standards—out of myriad
 408 sources—should be implemented. Second, mobile device users were frustrated by the degrees to which
 409 enterprises have control over their mobile devices and maintain visibility into their personal activity.

410 Therefore, the NIST build team reviewed the primary standards, best practices, and guidelines from
411 government sources and implemented a COPE usage scenario within this build. Additionally, this effort
412 highlights several security characteristics and capabilities that are documented within the Mobile Device
413 Security for Enterprises building block [39].

414 **3.1 Audience**

415 This practice guide is for organizations that want to enhance mobile device deployment and
416 management security, principally smartphones and tablets. It is intended for executives, security
417 managers, engineers, administrators, and others who are responsible for acquiring, implementing, and
418 maintaining mobile enterprise technology, including centralized device management, application
419 vetting, and endpoint protection systems.

420 This document will be of particular interest to system architects already managing mobile deployment
421 solutions and those looking to deploy mobile devices in the near term. It assumes readers have a basic
422 understanding of mobile device technologies and enterprise security principles. Please refer to [Section 2](#)
423 for how different audiences can effectively use this guide.

424 **3.2 Scope**

425 The scope of this build includes managing mobile smartphones and tablets with on-premises EMM.
426 Laptops are excluded from the scope of this publication, as the security controls available today for
427 laptops differ significantly from those available for smartphones and tablets, although this is changing
428 with the emergence of unified endpoint management capabilities.

429 Devices with minimal computing capability are also excluded, including feature phones, wearables, and
430 devices classified as part of the Internet of Things. Classified systems, devices, data, and applications are
431 not addressed within this publication.

432 The build team devised a fictional scenario centered around a mock organization (Orvilia Development)
433 to provide context to our risk assessment and to enable us to architect a reference design to solve
434 common enterprise mobile security challenges. Use of a scenario like Orvilia Development's exemplifies
435 the issues that an organization may face when addressing common enterprise mobile security
436 challenges. We intend for the example solution proposed in this practice guide to be broadly applicable
437 to enterprises, including both the public and private sectors.

438 To focus specifically on mobile device threats that Orvilia may be exposed to with its recent
439 organizational changes, the example solution does not specifically focus on insider threat events with
440 corresponding mitigations.

441 Additional options for deployment of Android, Apple, and Samsung Knox managed devices are discussed
442 in Appendix D.

443 3.2.1 Orvilia Development

444 The fictional organization, Orvilia Development, is a small start-up company providing IT services to
445 many private sector organizations. Its service offerings include developing scalable web applications,
446 improving existing IT systems, project management, and procurement. Orvilia recently won its first
447 government contract. Given the organization's current security posture, particularly in its use of mobile
448 devices, complying with government regulations and heightened cybersecurity standards presents it
449 with new challenges.

450 Orvilia has a simple deployment of on-premises IT resources. It hosts its own Microsoft Active Directory
451 domain, Microsoft Exchange email server, and web-based resources for employees, such as timekeeping
452 and travel support. All enterprise resources can be directly accessed by employees locally or remotely
453 from any internet-connected device by using password-based authentication. Orvilia also provides its
454 employees with corporate-owned mobile devices. These may be used for personal activity, including
455 phone calls, instant messaging, and installation and use of social applications. Employees also regularly
456 work outside the office and frequently use public Wi-Fi networks at hotels, airports, and coffee shops.

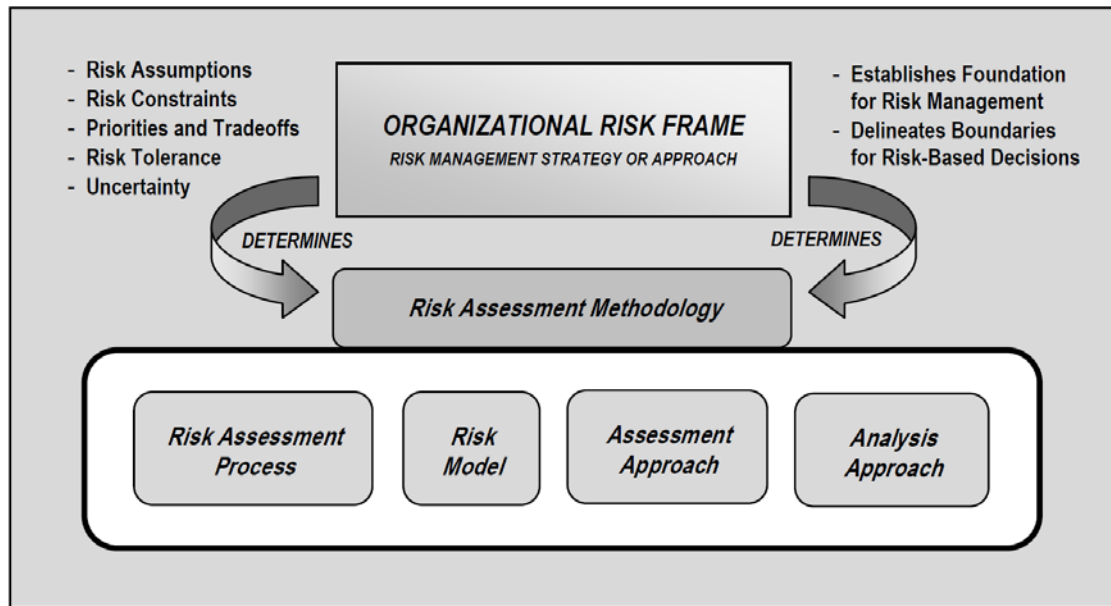
457 Orvilia's mobile device deployment practice is still developing; it has minimal mobile device policies and
458 has not implemented any additional security mechanisms such as enterprise mobility management. All
459 policy and security enforcement actions are performed manually on an ad-hoc basis. Employees are
460 expected to secure their own COPE devices, for instance via the timely installation of operating system
461 (OS) updates, and to exercise good judgment regarding any personal use.

462 However, no mechanisms have been put into place to prevent or detect misuse or device compromise.
463 Further, corporate policy prohibits access to the corporate network from personally owned mobile
464 devices, but no technical safeguards have been implemented to prevent employees from doing so. This
465 posture had been promoted based on the organization's small size, high level of employee technical
466 acumen, and lack of awareness that it has been significantly impacted by any cybersecurity incidents.

467 However, Orvilia's new status as a contractor to a civilian government agency calls for it to achieve and
468 maintain compliance with government policies, which require compliance with cybersecurity best
469 practices and applicable standards. For example, Orvilia is required to secure its access to and storage of
470 sensitive government information, which its employees will need to access from their mobile devices,
471 both locally at agency sites and remotely from Orvilia or during travel.

472 In addition to meeting compliance requirements rising from its contractual obligations to a government
473 agency, Orvilia leadership is concerned about the potential for future incidents where nation-state
474 malicious actors might obtain sensitive government data from unsecured devices and infrastructure.
475 Therefore, a risk assessment as described in NIST SP 800-30 Revision 1, *Guide for Conducting Risk*
476 *Assessments* [9] was performed using the risk management concepts shown in Figure 3-1.

477 Figure 3-1 Risk Management Approach



478 The risk assessment revealed that Orvilia’s current mobile infrastructure places the organization at risk
 479 of intrusion and compromise of sensitive data. The results of the risk assessment process are presented
 480 in Appendix E.

481 Based on the risk assessment findings, Orvilia chose to invest in security improvements to its mobile
 482 infrastructure. Details of Orvilia’s new mobile device security infrastructure are provided in [Section 4](#). As
 483 described in Section 4’s architecture design, Orvilia’s new infrastructure addressed the concerns
 484 identified in its risk assessment. Orvilia’s risk assessment team reviewed guidance by standards
 485 organizations and government agencies as part of its process and identified the standards and guidance
 486 identified in [Section 1.2.1](#) as applicable to its organizational mobile use case.

487 3.3 Assumptions

488 This project is guided by the following assumptions:

- 489 ▪ The solution was developed in a lab environment based on a typical organization’s IT enterprise.
 490 It does not reflect the complexity of a production environment.
- 491 ▪ An organization has access to the skills and resources required to implement a mobile device
 492 security solution.
- 493 ▪ The benefits of adopting this particular mobile device security solution outweigh any additional
 494 performance, reliability, or security risks that may be introduced. However, we draw the
 495 reader’s attention to the fact that implementation of any security controls has the potential to

496 increase or decrease the attack surface within an enterprise, the actual impact of which will vary
497 from organization to organization. Because the organizational environment in which this build
498 could be implemented represents a greater level of complexity than is captured in the current
499 guide, we assume that organizations will first examine the implications for their current
500 environment before implementing any part of the proposed solution.

- 501 ▪ Organizations have either already invested or are willing to invest in the security of mobile
502 devices used within their organization and of their IT systems more broadly. As such, we assume
503 they either have the technology in place to support this implementation or have access to the
504 off-the shelf information security technology used in this build, which we assume will perform as
505 described by the respective product vendor.
- 506 ▪ Organizations have familiarized themselves with existing standards and any associated
507 guidelines (e.g., NIST Cybersecurity Framework [5], NIST SP 800-124 Revision 1 [17], NIST SP
508 1800-4 [8]) relevant to implementation of the solution proposed in this practice guide. We also
509 assume that any existing technology to be used in the proposed solution has been implemented
510 in a manner consistent with these standards.
- 511 ▪ Organizations have instituted relevant mobile device security policies and that these will be
512 updated based on implementation of this solution.

513 3.3.1 Systems Engineering

514 Some organizations use a systems engineering-based approach in planning and implementing their IT
515 projects. Organizations wishing to implement IT systems are encouraged to conduct robust
516 requirements development, taking into consideration the operational needs of each system stakeholder.

517 The information contained within Section 4 of this volume provides architecture details to help
518 understand the operational capabilities of the example solution. Guidance is also provided in standards
519 such as the ISO/IEC/Institute of Electrical and Electronics Engineers 15288:2015, *Systems and software
520 engineering—System life cycle processes* [40]; and NIST SP 800-160, *Systems Security Engineering:
521 Considerations for a Multidisciplinary Approach in the Engineering of Trustworthy Secure Systems* [41],
522 which provide guidance in this endeavor. With these standards, organizations can choose to adopt only
523 those sections that are relevant to their environment and business context.

524 3.4 Risk Assessment

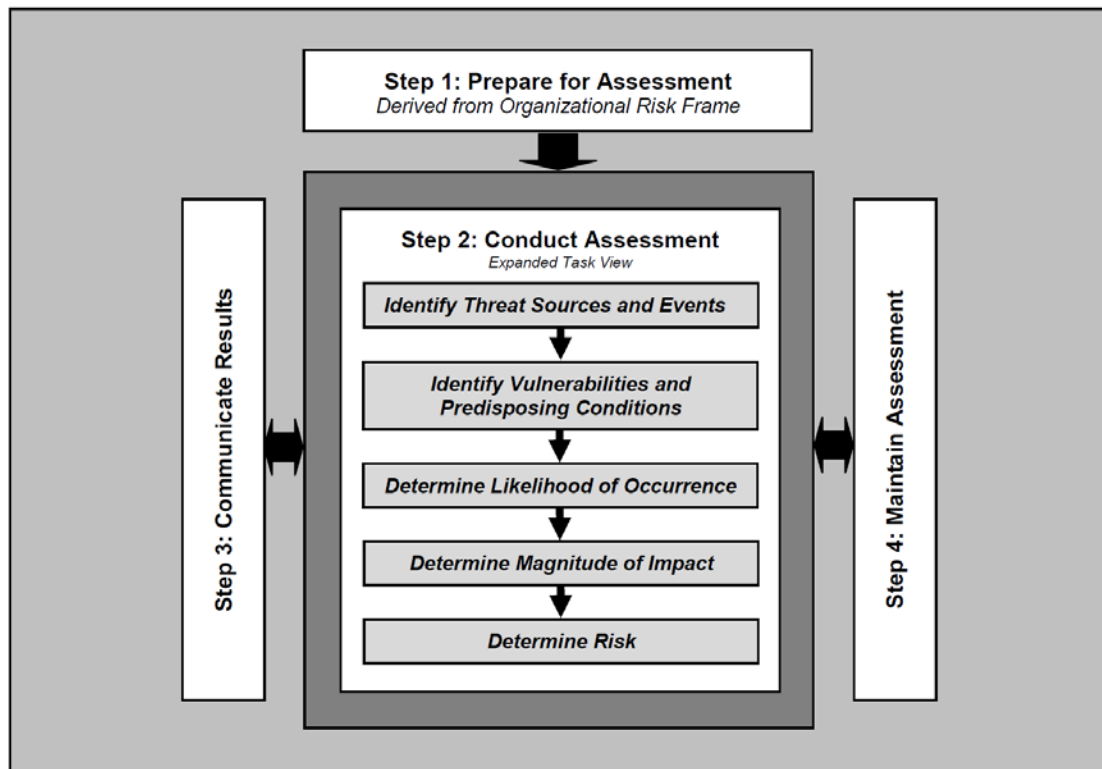
525 NIST SP 800-30 Revision 1, *Guide for Conducting Risk Assessments* [9], states that risk is “a measure of
526 the extent to which an entity is threatened by a potential circumstance or event, and typically a function
527 of: (i) the adverse impacts that would arise if the circumstance or event occurs; and (ii) the likelihood of
528 occurrence.” The guide further defines risk assessment as “the process of identifying, estimating, and
529 prioritizing risks to organizational operations (including mission, functions, image, reputation),
530 organizational assets, individuals, other organizations, and the Nation, resulting from the operation of

531 an information system. Part of risk management incorporates threat and vulnerability analyses, and
532 considers mitigations provided by security controls planned or in place.”

533 The NCCoE recommends that any discussion of risk management, particularly at the enterprise level,
534 begins with a comprehensive review of NIST SP 800-37 Revision 2, *Risk Management Framework for*
535 *Information Systems and Organizations* [10]—material that is available to the public. The Risk
536 Management Framework (RMF) guidance [7], as a whole, proved to be invaluable in giving us a baseline
537 to assess risks, from which we developed the project, the security characteristics of the build, and this
538 guide.

539 This section provides information on the risk assessment process employed to improve the mobile
540 security posture of Orvilia Development. Typically, a NIST SP 800-30 Revision 1-based risk assessment
541 follows a four-step process as shown in Figure 3-2: Prepare for assessment, conduct assessment,
542 communicate results, and maintain assessment. Full details of the risk assessment can be found in the
543 Risk Assessment Appendix.

544 **Figure 3-2 Risk Assessment Process**



545 The purpose of the risk assessment of Orvilia Development is to identify and document new risks to its
546 mission resulting from Orvilia’s new status as a contractor to government agencies.

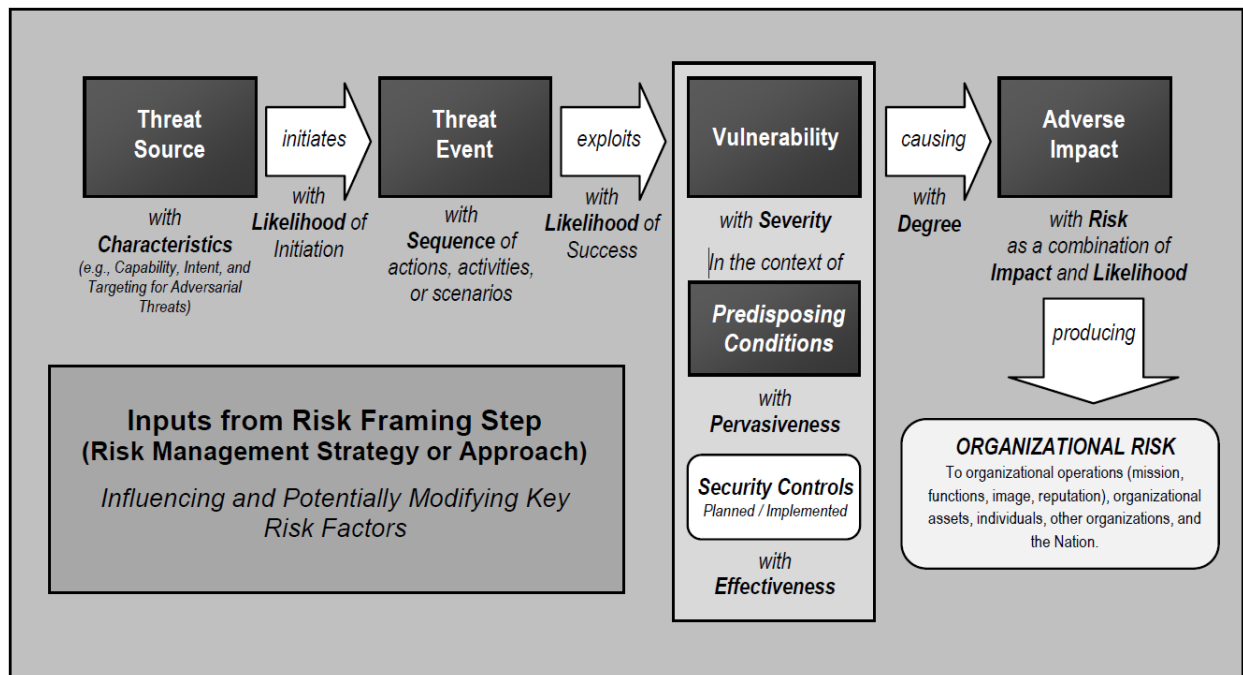
547 **3.4.1 Risk Assessment of the Fictional Organization Orvilia Development**

548 This risk assessment is scoped to Orvilia’s mobile deployment, which consists of mobile devices used to
 549 access Orvilia enterprise resources along with any backend IT components used to manage or provide
 550 services to those mobile devices.

551 Risk assessment assumptions and constraints were developed using a NIST SP 800-30 Revision 1 Generic
 552 Risk Model as shown in Figure 3-3 to identify the following necessary components of the risk
 553 assessment:

- 554 ▪ threat sources
- 555 ▪ threat events
- 556 ▪ vulnerabilities
- 557 ▪ predisposing conditions
- 558 ▪ security controls
- 559 ▪ adverse impacts
- 560 ▪ organizational risks

561 **Figure 3-3 NIST 800-30 Generic Risk Model**



562 3.4.2 Development of Threat Event Descriptions

563 Orvilia examined the sample tables in NIST SP 800-30 Revision 1—Table E-1, Table E-2, Table E-3, Table
 564 E-4, and Table E-5—and analyzed the sources of mobile threats. Using this process, Orvilia leadership
 565 identified the potential mobile device threat events that are described in the following subsections. A
 566 mapping of the threat events considered in this guide’s example solution to the Mobile Threat
 567 Catalogue can be found in Table 3-1.

568 **A note about selection of the threat events:** These threat events were developed by identifying threats
 569 from the NIST Mobile Threat Catalogue [6] that would have the ability to significantly disrupt Orvilia’s
 570 processes. In the interest of brevity, we limited our identified threat events of concern to those that
 571 were presumed to average a foreseeably high likelihood of occurrence and high potential for adverse
 572 impact in Orvilia’s specific scenario. The threats from the NIST Mobile Threat Catalogue that could have
 573 less impact to Orvilia were not prioritized as high and did not become part of the following 12 threat
 574 events that Orvilia prioritized for inclusion in its mobile device security architecture.

575 **Table 3-1 Threat Event Mapping to the Mobile Threat Catalogue**

Threat Event	NIST Mobile Threat Catalogue Threat ID
TE-1	APP-2, APP-12
TE-2	AUT-9
TE-3	APP-5, AUT-10, APP-31, APP-40, APP-32, APP-2
TE-4	STA-9, APP-4, STA-16, STA-0, APP-26
TE-5	APP-32, APP-36
TE-6	STA-7, EMM-3
TE-7	CEL-18, APP-0, LPN-2
TE-8	AUT-2, AUT-4
TE-9	APP-9, AUT-0
TE-10	EMM-5
TE-11	PHY-0
TE-12	EMM-9

576 *3.4.2.1 Threat Event 1—Unauthorized Access to Sensitive Information via a Malicious or*
577 *Privacy-Intrusive Application*

578 **Summary:** A mobile application can attempt to collect and exfiltrate any information to which it has
579 been granted access. This includes any information generated during use of the application (e.g., user
580 input), user-granted permissions (e.g., contacts, calendar, call logs, camera roll), and general device data
581 available to any application (e.g., International Mobile Equipment Identity, device make and model,
582 serial number). Further, if a malicious application exploits a vulnerability in other applications, the OS, or
583 device firmware to achieve privilege escalation, it may gain unauthorized access to any data stored on or
584 otherwise accessible through the device.

585 Risk Assessment Analysis:

586 Overall Likelihood: Very High

587 *Justification:* Employees have easy access to download any applications at any time. If an employee
588 requires an application that provides a desired function, the employee can download that application
589 from any available source (trusted or untrusted). If an application performs an employee’s desired
590 function, they may download an application from an untrusted source and have no regard for granted
591 privacy intrusive permissions.

592 Level of Impact: High

593 *Justification:* Employees may download an application from an untrusted source and have no regard for
594 granted privacy intrusive permissions. This poses a threat for sensitive corporate data, as some
595 applications may include features that access corporate data, unbeknownst to the user.

596 *3.4.2.2 Threat Event 2—Theft of Credentials Through a Short Message Service (SMS) or*
597 *Email Phishing Campaign*

598 **Summary:** Malicious actors may create fraudulent websites that mimic the appearance and behavior of
599 legitimate ones and entice users to authenticate to them by distributing phishing messages over SMS or
600 email. Effective use of social engineering techniques such as impersonating an authority figure or
601 creating a sense of urgency may compel users to forgo scrutiny of the message and proceed to
602 authenticate to the fraudulent website; it then captures and stores the user’s credentials before
603 (usually) forwarding them to the legitimate website to allay suspicion.

604 Risk Assessment Analysis:

605 Overall Likelihood: Very High

606 *Justification:* Phishing campaigns are a common threat that occurs almost daily.

607 Level of Impact: High

608 *Justification:* A successful phishing campaign could provide the malicious actor with corporate
609 credentials, allowing access to sensitive corporate data, or personal credentials that could lead to
610 compromise of corporate data or infrastructure via other means.

611 *3.4.2.3 Threat Event 3—Malicious Applications Installed via Uniform Resource Locators* 612 *(URLs) in SMS or Email Messages*

613 **Summary:** Malicious actors may send users SMS or email messages that contain a URL where a
614 malicious application is hosted. Generally, such messages are crafted using social engineering
615 techniques designed to dissuade recipients from scrutinizing the nature of the message, thereby
616 increasing the likelihood they access the URL using their mobile device. If they do, it will attempt to
617 download and install the application. Effective use of social engineering by the attacker will further
618 compel an otherwise suspicious user to grant any trust required by the developer and all permissions
619 requested by the application. Granting the former facilitates the installation of other malicious
620 applications by the same developer, and granting the latter increases the potential for the application to
621 do direct harm.

622 Risk Assessment Analysis:

623 Overall Likelihood: High

624 *Justification:* Installation of malicious applications via URLs is less common than traditional phishing
625 attempts. The process for sideloading applications requires much more user input and consideration
626 (e.g., trusting the developer certificate) than standard phishing, which solely requests a username and
627 password. A user may proceed through the process of sideloading an application to acquire a desired
628 capability from an application.

629 Level of Impact: High

630 *Justification:* Once a user installs a malicious sideloaded application, this could provide a malicious actor
631 with full access to a mobile device, and therefore access to corporate data and credentials, without the
632 user's knowledge.

633 *3.4.2.4 Threat Event 4—Confidentiality and Integrity Loss due to Exploitation of Known* 634 *Vulnerability in the OS or Firmware*

635 **Summary:** When malware successfully exploits a code execution vulnerability in the mobile OS or device
636 drivers, the delivered code generally executes with elevated privileges and then issues commands in the
637 context of the root user or the OS kernel. These commands may be enough for some to accomplish their
638 goal, but advanced malicious actors will usually attempt to install additional malicious tools and to
639 establish a persistent presence. If successful, the malicious actor will be able to launch further attacks
640 against the user, the device, or any other systems the device connects to. As a result, any data stored
641 on, generated by, or accessible to the device at that time—or in the future—may be compromised.

642 Risk Assessment Analysis:

643 Overall Likelihood: High

644 *Justification:* Many public vulnerabilities specific to mobile devices have been seen over the years, such
645 as Stagefright. Users jailbreak iOS devices and root Android devices to download third-party applications
646 and apply unique settings/configurations that the device would not typically be able to apply/access.

647 Level of Impact: High

648 *Justification:* Exploiting a vulnerability allows circumventing traditional security controls and modifying
649 protected device data that should not be modified. Jailbroken and rooted devices exploit kernel
650 vulnerabilities and allow third-party applications/services root access that can also be used to bypass
651 security controls built-in or applied to a mobile device.

652 *3.4.2.5 Threat Event 5—Violation of Privacy via Misuse of Device Sensors*

653 **Summary:** Malicious actors with access (authorized or unauthorized) to device sensors (microphone,
654 camera, gyroscope, Global Positioning System [GPS] receiver, and radios) can use them to conduct
655 surveillance. It may be directed at the user, as when tracking the device location, or it may be applied
656 more generally, as when recording any nearby sounds. Captured sensor data may be immediately useful
657 to a malicious actor, such as a recording of an executive meeting. Alternatively, the data may be
658 analyzed in isolation or in combination with other data to yield sensitive information. For example,
659 audio recordings of on-device or proximate activity can be used to probabilistically determine user
660 inputs to touchscreens and keyboards—essentially turning the device into a remote keylogger.

661 Risk Assessment Analysis:

662 Overall Likelihood: Very High

663 *Justification:* This has been seen on public application stores in the past, with simple applications
664 allegedly being data collection applications for nation-states [42]. As mentioned in Threat Event 1,
665 unbeknownst to the user, a downloaded application may be granted privacy intrusive permissions that
666 allow access to device sensors.

667 Level of Impact: High

668 *Justification:* When the sensors are being misused, the user is typically not alerted. This allows collection
669 of sensitive enterprise data, such as location, without knowledge of the user.

670 *3.4.2.6 Threat Event 6—Compromise of the Integrity of the Device or Its Network*
671 *Communications via Installation of Malicious EMM/MDM, Network, VPN Profiles,*
672 *or Certificates*

673 **Summary:** Malicious actors who successfully install an EMM/MDM, network, or VPN profile or
674 certificate onto a device will gain a measure of additional control over the device or its communications.
675 Presence of an EMM/MDM profile will allow an attacker to misuse existing OS application programming
676 interfaces (APIs) to send the device a wide variety of commands. This may allow a malicious actor to
677 obtain device information; install or restrict applications; or remotely locate, lock, or wipe the device.
678 Malicious network profiles may allow a malicious actor to automatically compel the device to connect to
679 access points under their control to achieve a man-in-the-middle attack on all outbound connections.
680 Alternatively, VPN profiles assist in the undetected exfiltration of sensitive data by encrypting it, thus
681 hiding it from network scanning tools. Additionally, malicious certificates may allow the malicious actor
682 to compel the device to automatically trust connections to malicious web servers, wireless access
683 points, or installation of applications under the attacker’s control.

684 Risk Assessment Analysis:

685 Overall Likelihood: Moderate

686 *Justification:* Unlike installation of an application, installation of EMM/MDM, network, VPN profiles, and
687 certificates requires additional effort and understanding from the user to properly implement.

688 Level of Impact: Very High

689 *Justification:* If a malicious actor were able to install malicious configuration profiles or certificates, they
690 would be able to perform actions such as decrypt network traffic and possibly even control the device.

691 *3.4.2.7 Threat Event 7—Loss of Confidentiality of Sensitive Information via Eavesdropping*
692 *on Unencrypted Device Communications*

693 **Summary:** Malicious actors can readily eavesdrop on communication over unencrypted, wireless
694 networks such as public Wi-Fi access points, which are commonly provided by coffee shops and hotels.
695 While a device is connected to such a network, a malicious actor would gain unauthorized access to any
696 data sent or received by the device for any session not already protected by encryption at either the
697 transport or application layers. Even if the transmitted data were encrypted, an attacker would be privy
698 to the domains, internet protocol (IP) addresses, and services (as indicated by port numbers) to which
699 the device connects; such information could be used in future watering hole attacks or man-in-the-
700 middle attacks against the device user.

701 Additionally, visibility into network layer traffic enables a malicious actor to conduct side-channel
702 attacks against its encrypted messages, which can still result in a loss of confidentiality. Further,

703 eavesdropping on unencrypted messages during a handshake to establish an encrypted session with
704 another host or endpoint may facilitate attacks that ultimately compromise security of the session.

705 Risk Assessment Analysis:

706 Overall Likelihood: High

707 *Justification:* Users require network access to retrieve email and access cloud services and other
708 necessary data on the internet. Users can connect to readily available free internet access in public
709 venues such as coffee shops, hotels, and airports.

710 Level of Impact: High

711 *Justification:* Users may connect to unencrypted wireless networks, and many applications do not
712 properly encrypt network communications. Improper use of encryption, or lack thereof, allows a
713 malicious actor to eavesdrop on network traffic.

714 *3.4.2.8 Threat Event 8—Compromise of Device Integrity via Observed, Inferred, or Brute-*
715 *Forced Device Unlock Code*

716 **Summary:** A malicious actor may be able to obtain a user’s device unlock code by direct observation,
717 side-channel attacks, or brute-force attacks. Both the first and second can be attempted with at least
718 proximity to the device; only the third technique requires physical access. However, side-channel attacks
719 that infer the unlock code by detecting taps and swipes to the screen can be attempted by applications
720 with access to any peripherals that detect sound or motion (microphone, gyroscope, or accelerometer).
721 Once the device unlock code has been obtained, a malicious actor with physical access to the device will
722 gain immediate access to any data or functionality not already protected by additional access control
723 mechanisms. Additionally, if the user employs the device unlock code as a credential to any other
724 systems, the attacker may further gain unauthorized access to those systems.

725 Risk Assessment Analysis:

726 Overall Likelihood: High

727 *Justification:* Unlike shoulder-surfing to observe a user’s passcode, brute-force attacks are not as
728 common or successful due to the built-in deterrent mechanisms. These mechanisms include exponential
729 back-off/lockout period and device wipes after a certain number of failed unlock attempts.

730 Level of Impact: High

731 *Justification:* If a malicious actor can successfully unlock a device without the user’s permission, they
732 could have full control over the user’s corporate account and thus gain unauthorized access to corporate
733 data.

734 *3.4.2.9 Threat Event 9—Unauthorized Access to Backend Services via Authentication or*
735 *Credential Storage Vulnerabilities in Internally Developed Applications*

736 **Summary:** If a malicious actor gains unauthorized access to a mobile device, the attacker also has access
737 to the data and applications on that mobile device. The mobile device may contain an organization’s in-
738 house applications and can subsequently gain access to sensitive data or backend services. This could
739 result from weaknesses or vulnerabilities present in the authentication or credential storage
740 mechanisms implemented within an in-house application.

741 Risk Assessment Analysis:

742 Overall Likelihood: Very High

743 *Justification:* Often applications include hard-coded credentials for the default password of the
744 administrator account. Default passwords are readily available online. These passwords may not be
745 changed to allow for ease of access and to eliminate the pressure of remembering a password.

746 Level of Impact: High

747 *Justification:* Successful extraction of the credentials allows an attacker to gain unauthorized access to
748 enterprise data.

749 *3.4.2.10 Threat Event 10—Unauthorized Access of Enterprise Resources from an*
750 *Unmanaged and Potentially Compromised Device*

751 **Summary:** An employee who accesses enterprise resources from an unmanaged mobile device may
752 expose the enterprise to vulnerabilities that may compromise enterprise data. Unmanaged devices do
753 not benefit from security mechanisms deployed by the organization such as mobile threat defense,
754 mobile threat intelligence, application vetting services, and mobile security policies. These unmanaged
755 devices limit an organization’s visibility into the state of a mobile device, including if the device is
756 compromised by a malicious actor. Therefore, users who violate security policies to gain unauthorized
757 access to enterprise resources from such devices risk providing attackers with access to sensitive
758 organizational data, services, and systems.

759 Risk Assessment Analysis:

760 Overall Likelihood: Very High

761 *Justification:* This may occur accidentally when an employee attempts to access their email.

762 Level of Impact: High

763 *Justification:* Unmanaged devices pose a sizable security risk because the enterprise has no visibility into
764 their security or risk posture. Due to this lack of visibility, a compromised device may allow an attacker
765 to attempt to exfiltrate sensitive enterprise data.

766 *3.4.2.11 Threat Event 11—Loss of Organizational Data Due to a Lost or Stolen Device*

767 **Summary:** Due to the nature of the small form factor of mobile devices, they are easy to misplace or be
768 stolen. A malicious actor who gains physical custody of a device with inadequate security controls may
769 be able to gain unauthorized access to sensitive data or resources accessible to the device.

770 Risk Assessment Analysis:

771 Overall Likelihood: Very High

772 *Justification:* Mobile devices are small and very easy to misplace. Enterprise devices may be lost or
773 stolen at the same frequency as personally owned devices.

774 Level of Impact: High

775 *Justification:* Similar to Threat Event 9, if a malicious actor can gain access to the device, they could
776 potentially have access to sensitive corporate data.

777 *3.4.2.12 Threat Event 12—Loss of Confidentiality of Organizational Data Due to Its*
778 *Unauthorized Storage in Non-Organizationally Managed Services*

779 **Summary:** If employees violate data management policies by using unmanaged services to store
780 sensitive organizational data, this data will be placed outside organizational control, where the
781 organization can no longer protect its confidentiality, integrity, or availability. Malicious actors who
782 compromise the unauthorized service account or any system hosting that account may gain
783 unauthorized access to the data.

784 Further, storage of sensitive data in an unmanaged service may subject the user or the organization to
785 prosecution for violation of any applicable laws (e.g., exportation of encryption) and may complicate
786 efforts by the organization to achieve remediation or recovery from any future losses, such as those
787 resulting from the public disclosure of trade secrets.

788 Risk Assessment Analysis:

789 Overall Likelihood: High

790 *Justification:* This could occur either intentionally or accidentally (e.g., taking a screenshot and backup
791 up pictures to an unmanaged cloud service).

792 Level of Impact: High

793 *Justification:* Storage in unmanaged services presents a risk to the confidentiality and availability of
794 corporate data because the corporation would no longer control it.

795 3.4.3 Identification of Vulnerabilities and Predisposing Conditions

796 In [Section 3.2.1](#), we identified vulnerabilities and predisposing conditions that increase the likelihood
 797 that identified threat events will result in adverse impacts for Orvilia Development. Each vulnerability or
 798 predisposing condition is listed in Table 3-2 along with the corresponding threat events and ratings of
 799 threat pervasiveness. More details on the use of threat event ratings can be found in the Risk
 800 Assessment Appendix.

801 **Table 3-2 Identify Vulnerabilities and Predisposing Conditions**

Vulnerability ID	Vulnerability or Predisposing Condition	Resulting Threat Events	Pervasiveness
VULN-1	Email and other enterprise resources can be accessed from anywhere, and only username/password authentication is required.	TE-2, TE-10, TE-11	Very High
VULN-2	Public Wi-Fi networks are regularly used by employees for remote connectivity from their corporate mobile devices.	TE-7	Very High
VULN-3	No EMM/MDM deployment exists to enforce and monitor compliance with security-relevant policies on corporate mobile devices.	TE-1, TE-3, TE-4, TE-5, TE-6, TE-7, TE-8, TE-9, TE-11, TE-12	Very High

802 3.4.4 Summary of Risk Assessment Findings

803 Table 3-3 summarizes the risk assessment findings. More detail about the methodology used to rate
 804 overall likelihood, level of impact, and risk can be found in the Risk Assessment Appendix.

805 **Table 3-3 Summary of Risk Assessment Findings**

Threat Event	Vulnerabilities, Predisposing Conditions	Overall Likelihood	Level of Impact	Risk
TE-1: Unauthorized access to sensitive information via a malicious or privacy-intrusive application	VULN-3	Very High	High	High

Threat Event	Vulnerabilities, Predisposing Conditions	Overall Likelihood	Level of Impact	Risk
TE-2: Theft of credentials through an SMS or email phishing campaign	VULN-1	Very High	High	High
TE-3: Malicious applications installed via URLs in SMS or email messages	VULN-3	High	High	High
TE-4: Confidentiality and integrity loss due to exploitation of known vulnerability in the OS or firmware	VULN-3	High	High	High
TE-5: Violation of privacy via misuse of device sensors	VULN-3	Very High	High	High
TE-6: Compromise of the integrity of the device or its network communications via installation of malicious EMM/MDM, network, VPN profiles, or certificates	VULN-3	Moderate	Very High	High
TE-7: Loss of confidentiality of sensitive information via eavesdropping on unencrypted device communications	VULN-2, VULN-3	High	High	High
TE-8: Compromise of device integrity via observed, inferred, or brute-forced device unlock code	VULN-3	High	High	High
TE-9: Unauthorized access to backend services via authentication or credential storage vulnerabilities in internally developed applications	VULN-3	Very High	High	High
TE-10: Unauthorized access of enterprise resources from an unmanaged and potentially compromised device	VULN-1	Very High	High	High

Threat Event	Vulnerabilities, Predisposing Conditions	Overall Likelihood	Level of Impact	Risk
TE-11: Loss of organizational data due to a lost or stolen device	VULN-1, VULN-3	Very High	High	High
TE-12: Loss of confidentiality of organizational data due to its unauthorized storage in non-organizationally managed services	VULN-3	High	High	High

806 **Note 1:** Risk is stated in qualitative terms based on the scale in Table I-2 of Appendix I in NIST Special
807 Publication 800-30 Revision 1 [9].

808 **Note 2:** The risk rating itself is derived from both the overall likelihood and level of impact using Table I-
809 2 of Appendix I in NIST Special Publication 800-30 Revision 1 [9]. Because these scales are not true
810 interval scales, the combined overall risk ratings from Table I-2 do not always reflect a strict
811 mathematical average of these two variables. This is demonstrated in the table above where levels of
812 moderate weigh more heavily than other ratings.

813 **Note 3:** Ratings of risk relate to the probability and level of adverse effect on organizational operations,
814 organizational assets, individuals, other organizations, or the nation. Per NIST SP 800-30 Revision 1,
815 adverse effects (and the associated risks) range from negligible (i.e., very low risk), limited (i.e., low),
816 serious (i.e., moderate), severe or catastrophic (i.e., high), to multiple severe or catastrophic effects (i.e.,
817 very high).

818 3.4.5 Privacy Risk Assessment

819 This section describes the privacy risk assessment conducted on Orvilvia's enterprise security
820 architecture. To perform the privacy risk assessment, the NIST Privacy Risk Assessment Methodology
821 (PRAM) was used. The PRAM is a tool for analyzing, assessing, and prioritizing privacy risks to help
822 organizations determine how to respond and select appropriate solutions. The PRAM can also serve as a
823 useful communication tool to convey privacy risks within an organization. A blank version of the PRAM is
824 available for download on NIST's website [43].

825 The PRAM uses the privacy risk model and privacy engineering objectives described in NIST Internal
826 Report (NISTIR) 8062, *An Introduction to Privacy Engineering and Risk Management in Federal Systems*
827 [44], to analyze for problematic data actions. Data actions are any system operations that process PII.
828 Processing can include collection, retention, logging, analysis, generation, transformation or merging,

829 disclosure, transfer, and disposal of PII. A problematic data action is one that could cause an adverse
830 effect for individuals. The PRAM activities identified the following potential problems for individuals.

831 *3.4.5.1 Potential Problems for Individuals*

832 Three data actions were identified in the PRAM that have the potential to create problems for
833 individuals. Those three data actions, along with their risk assessment analysis, follow:

- 834 ▪ blocking access and wiping devices
- 835 ▪ employee monitoring
- 836 ▪ data sharing across parties

837 *3.4.5.1.1 Data Action 1: Blocking Access and Wiping Devices*

838 Employees are likely to use their devices for both personal and work-related purposes. Therefore, in a
839 system that features the capability to wipe a device entirely, there could be an issue of employees losing
840 personal data. This is a potential problem for individuals because employee use of work devices for both
841 personal and work-related purposes is common.

842 Devices that might pose a risk to the organization's security posture can be blocked from accessing
843 enterprise resources or wiped and reset to factory setting defaults, which could result in loss of
844 information contained on the device. Potential options for minimizing the impact to the employee
845 include:

- 846 ▪ blocking the device's access to enterprise resources until it is granted access permission again
- 847 ▪ selectively wiping elements of the device without removing all data on the device. Within the
848 example solution, this option is available for iOS devices.
- 849 ▪ advising employees to back up the personal data maintained on devices
- 850 ▪ limiting staff with the ability to perform wipes or block access

851 *3.4.5.1.2 Data Action 2: Employee Monitoring*

852 Employees may not be aware of the monitoring of their interactions with the system and may not want
853 this monitoring to occur. Employer-owned or -controlled networks like Orvilia's often can monitor
854 activities, and many do on a regular basis.

855 The assessed infrastructure offers Orvilia a number of security capabilities, including reliance on
856 comprehensive monitoring capabilities. A significant amount of data relating to employees, their
857 devices, and their activities is collected and analyzed by multiple parties. Potential options for
858 minimizing the impact to the employee include:

- 859 ▪ limit staff with ability to review data about employees and their devices
- 860 ▪ develop organization policies and techniques to limit collection of specific data elements

- 861 ▪ develop organization policies and techniques regarding disposal of PII

862 3.4.5.1.3 Data Action 3: Data Sharing Across Parties

863 Data transmission about individuals and their devices among a variety of different parties could be
864 confusing for employees who might not know who has access to different information about them.

865 The infrastructure involves several parties that serve different purposes supporting Orvilia’s security
866 objectives. As a result, a significant flow of data about individuals and their devices occurs across various
867 parties.

868 If a wide audience of administrators and co-workers know which of their colleagues are conducting
869 activity on their devices that triggers security alerts, it could lead to undesired outcomes such as
870 employee embarrassment. Potential options for minimizing the impact to the employee include:

- 871 ▪ developing organization policies and techniques for the de-identification of data
- 872 ▪ using encryption
- 873 ▪ limiting or disabling access to data
- 874 ▪ developing organization policies and techniques to limit the collection of specific data elements
- 875 ▪ using contracts to limit third-party data processing

876 Additional information regarding these potential problems for individuals and potential options for
877 minimizing the impact to the employees is provided in the Privacy Risk Assessment Appendix.

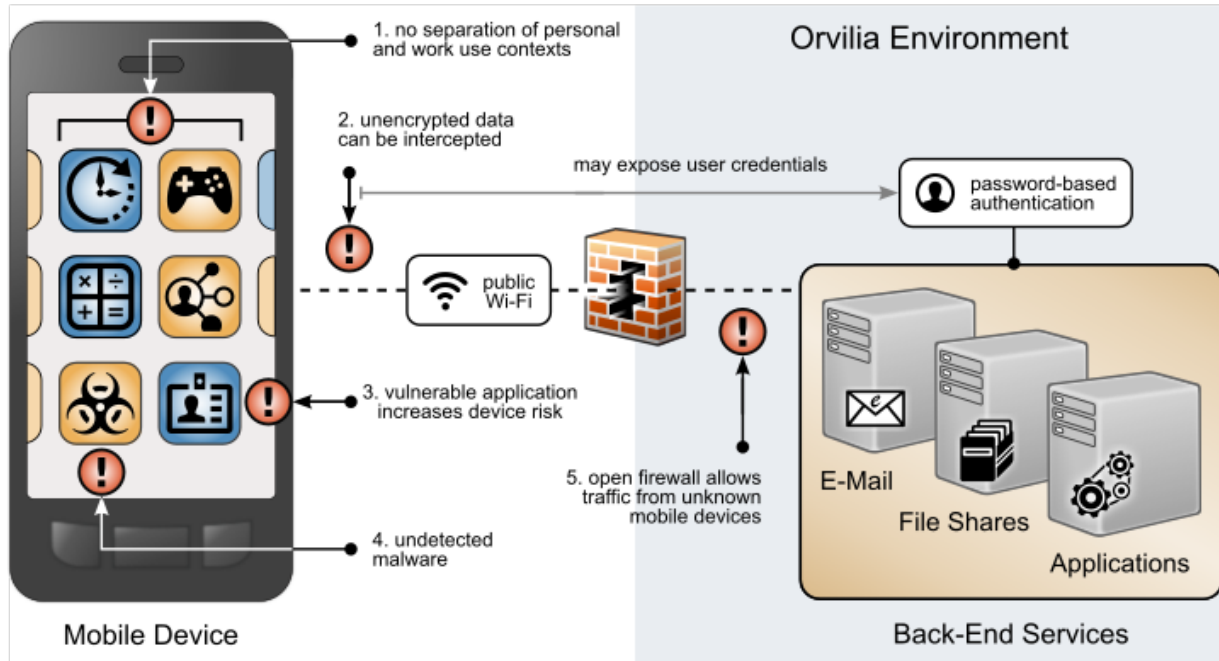
878 3.5 Preliminary Solution Goals

879 This section describes the preliminary solution goals for revising Orvilia’s mobile security architecture.
880 Here is an overview of the security issues identified within Orvilia’s original (also known as current)
881 mobile device infrastructure architecture. To address these issues, a list of security goals was developed
882 to provide a high-level overview of factors that could be applied to improve the security of Orvilia’s
883 mobile architecture.

884 3.5.1 Current Architecture

885 Prior to investing in security improvements to their mobile infrastructure—as identified based on the
886 aforementioned risk assessment—Orvilia Development had not implemented a mobile security strategy.
887 Several weaknesses were identified based on their use of mobile devices. A subset of these weaknesses
888 is presented in Figure 3-4.

889 Figure 3-4 Orvilia's Mobile Deployment Before Security Enhancements



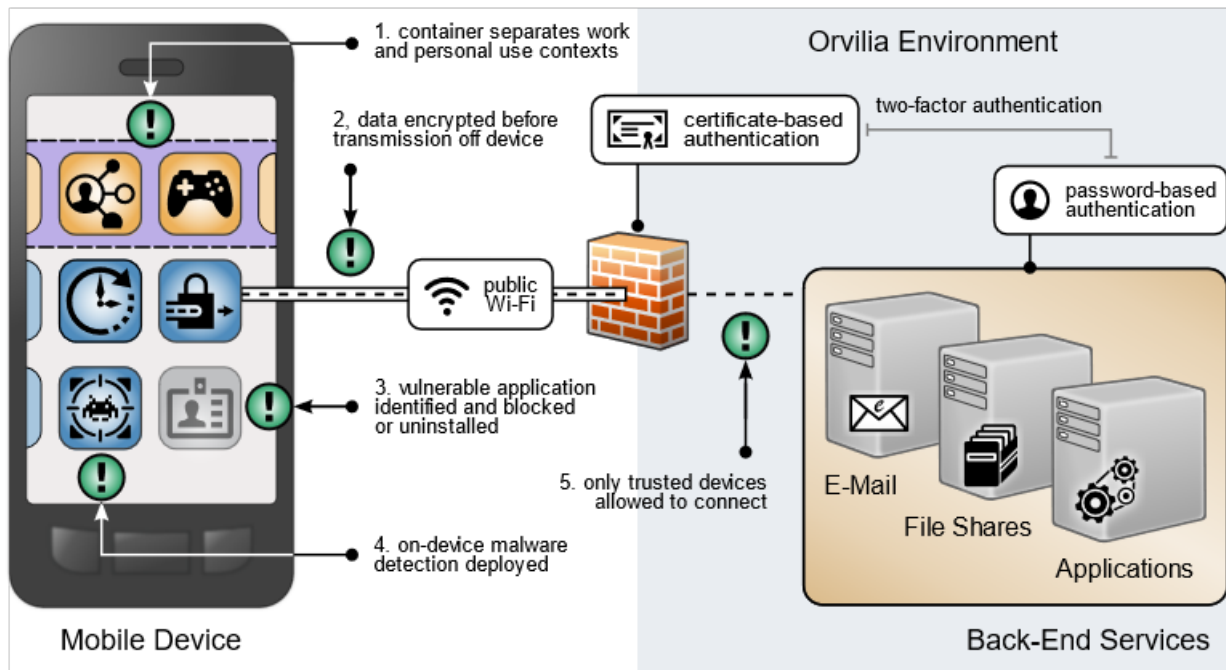
890

891 The following issues are highlighted in Figure 3-4 with a red exclamation mark:

- 892
- 893
- 894
- 895
- 896
- 897
- 898
- 899
- 900
- 901
- 902
- 903
1. Organizational and personal data can become commingled if either the same application is used in both contexts or if multiple applications access shared device resources (e.g., contacts or calendar).
 2. Mobile devices are connecting to Orvilia from unencrypted public Wi-Fi hot spots; data transmitted prior to a secure connection is subject to eavesdropping, including passwords.
 3. Applications for work or personal use may contain unidentified vulnerabilities or weaknesses that increase the risk of device compromise.
 4. Applications may be obtained outside official application stores, increasing the risk that they are malware in disguise.
 5. Because mobile devices can connect from unknown locations, firewall rules must allow inbound connections from unrecognized, potentially malicious IP addresses.

904 **3.5.2 Preliminary Security Goals**

905 In considering improvement to the security of their current deployment, Orvilia was able to identify
 906 high-level preliminary security goals to correct these shortcomings, as illustrated in Figure 3-5.

907 **Figure 3-5 Orvilia’s Preliminary Security Goals**

908 The following strategies are highlighted in Figure 3-5 with a green exclamation mark:

- 909
- 910
- 911
- 912
- 913
- 914
- 915
- 916
- 917
- 918
- 919
1. Organizational and personal information can be separated by restricting data flow between organizationally managed and unmanaged applications. Sensitive data is protected from crossing between work and personal contexts.
 2. Mobile devices can connect to Orvilia over a VPN or similar solution to encrypt all data before it is transmitted from the device, protecting otherwise unencrypted data from interception.
 3. Identifying applications with significant vulnerabilities or weaknesses facilitates blocking or uninstalling those applications from managed devices, reducing their risk to the organization.
 4. Malware detection could be deployed to devices to identify malicious applications and facilitate remediation.

920 5. Mobile devices can be provisioned with a security certificate that allows them to be
921 identified and authenticated at the connection point, which combines with user
922 credentials to create two-factor authentication from mobile devices.

923 These high-level goals, obtained from a review of their current mobile security posture, provide
924 examples of why a thorough risk assessment process is beneficial to organizations implementing mobile
925 device security capabilities.

926 **3.6 Technologies**

927 This section describes the mobile-specific technology components used within this example solution.
928 These technologies were selected to address the preliminary security goals and threat events identified
929 in the risk assessment. This section provides a brief description of each technology and discusses the
930 security capabilities that each component provides to address Orvilia’s security issues. For additional
931 information, Appendix H provides the technologies used in this project and provides a mapping between
932 the specific product used and the cybersecurity standards and best practices that the product provides
933 in the example solution discussed in this guide.

934 **3.6.1 Architecture Components**

935 The security components in this section are combined into a cohesive enterprise security architecture to
936 enable enterprises to address mobile security threats and provide secure access to enterprise resources
937 from mobile devices. The security components described in this section provide protection for the
938 following enterprise architecture components that are accessed by Orvilia’s users with their mobile
939 devices.

- 940 ▪ email/Outlook Web Access–contacts
- 941 ▪ private chat server
- 942 ▪ travel support
- 943 ▪ organization intranet (e.g., internal announcements, organizational charts, policies)
- 944 ▪ time reporting

945 ***3.6.1.1 Trusted Execution Environment***

946 A trusted execution environment (TEE) is “a tamper-resistant processing environment that runs on a
947 separation kernel. It guarantees the authenticity of the executed code, the integrity of the runtime
948 states (e.g., central processing unit registers, memory and sensitive I/O), and the confidentiality of its
949 code, data and runtime states stored on a persistent memory. In addition, it shall be able to provide
950 remote attestation that proves its trustworthiness for third-parties [45].”

951 *3.6.1.2 Enterprise Mobility Management*

952 Organizations use Enterprise Mobility Management solutions to secure the mobile devices of users who
953 are authorized to access organizational resources. Such solutions generally have two main components.
954 The first is a backend service that mobile administrators use to manage the policies, configurations, and
955 security actions applied to registered mobile devices. The second is an on-device agent, usually in the
956 form of a mobile application, that integrates between the mobile OS and solution's backend service.
957 Alternatively, iOS supports a web-based EMM enrollment use case.

958 At a minimum, an EMM solution can perform MDM functions, which include the ability to provision
959 configuration profiles to devices, enforce security policies on devices, and monitor compliance with
960 those policies by devices. The on-device MDM agent can typically notify the device user of any
961 noncompliant settings and may be able to remediate some noncompliant settings automatically. The
962 organization can use policy compliance data to inform its access control decisions so that it grants access
963 only to a device that demonstrates the mandated level of compliance with the security policy that
964 applies to it.

965 EMM solutions commonly include any of the following: mobile application management, mobile content
966 management, and implementations of or integrations with device- or mobile OS-specific
967 containerization solutions, such as Samsung Knox. These capabilities can be used to manage installation
968 and usage of applications based on the applications' trustworthiness and work relevance. Additionally,
969 they can control how managed applications access and use organizational data and possibly strengthen
970 the separation between a user's personal and professional usage of the device.

971 Further, EMM solutions often have integrations with a diverse set of additional tools and security
972 technologies that enhance their capabilities. An example is an EMM embedded with a mobile threat
973 defense tool that serves to perform on-device behavioral-based threat-detection and to trigger policy
974 remediation without the need to communicate to any server or service outside the device. This type of
975 integration allows one application, the EMM agent, to manage, detect, and remediate device, network,
976 application, malware, and spear phishing attacks. Additionally, because the remediation is autonomous
977 at the device (does not require reaching a policy server), it has the advantage in addressing network-
978 based threat vectors such as Pineapple or Stingray impersonation of valid Wi-Fi or cellular networks
979 [46].

980 For further reading, NIST SP 800-124 Revision 1, *Guidelines for Managing the Security of Mobile Devices*
981 *in the Enterprise* [17], provides additional information on mobile device management with EMM
982 solutions. Further, NIAP's *Protection Profile for Mobile Device Management Version 4.0* [47] describe
983 important capabilities and security requirements to look for in EMM systems.

984 *3.6.1.3 Virtual Private Network*

985 A VPN gateway increases the security of remote connections from authorized mobile devices to an
986 organization's internal network. A VPN is a virtual network, built on top of existing physical networks,
987 which can provide a secure communications mechanism for data and control information transmitted
988 between networks. VPNs are used most often to protect communications carried over public networks
989 such as the internet. A VPN can provide several types of data protection, including confidentiality,
990 integrity, data origin authentication, replay protection, and access control that help reduce the risks of
991 transmitting data between network components.

992 VPN connections apply an additional layer of encryption to the communication between remote devices
993 and the internal network, and VPN gateways can enforce access control decisions by limiting which
994 devices or applications can connect to it. Integration with other security mechanisms allows a VPN
995 gateway to base access control decisions on more risk factors than it may be able to collect on its own;
996 examples include a device's level of compliance with mobile security policies or the list of installed
997 applications (blacklisted applications) as reported by an integrated EMM.

998 NIAP's *Extended Package for VPN Gateways* [48], in combination with the internationally and
999 collaboratively developed *Protection Profile for Network Devices* [49], describes important capabilities
1000 and security requirements to expect from VPN gateways.

1001 *3.6.1.4 Mobile Application Vetting Service*

1002 Mobile application vetting services use a variety of static, dynamic, and behavioral techniques to
1003 determine if an application demonstrates any behaviors that pose a security or privacy risk. The risk may
1004 be to a device owner or user, to parties that own data on the device, or to external systems to which the
1005 application connects. The set of detected behaviors is often aggregated to generate a singular score that
1006 estimates the level of risk (or conversely, trustworthiness) attributed to an application. Clients can often
1007 adjust the values associated with given behaviors (e.g., hard-coded cryptographic keys) to tailor the
1008 score for their unique risk posture. Those scores may be further aggregated to present a score that
1009 represents the overall risk or trustworthiness posed by the set of applications currently installed on a
1010 given device.

1011 Mobile applications, malicious or benign, have high potential to negatively impact both security and user
1012 privacy. A malicious application can contain code intended to exploit vulnerabilities present in
1013 potentially any targeted hardware, firmware, or software on the device. Alternatively, or in conjunction
1014 with exploit code, a malicious application may misuse any device, personal, or behavioral data to which
1015 it has been explicitly or implicitly granted access, such as contacts, clipboard data, or location services.
1016 Benign applications may still present vulnerabilities or weaknesses that malicious applications can
1017 exploit to gain unauthorized access to its data or functionality. Further, benign applications may place
1018 user privacy at risk by collecting more information than is necessary for the application to deliver
1019 functionality desired by the user.

1020 While not specific to applications, some services may include device-based risks (e.g., lack of disk
1021 encryption or vulnerable OS version) in their analysis to provide a more comprehensive assessment of
1022 the risk or trustworthiness presented by a device when running an application or service.

1023 NIAP does not provide a Protection Profile for application vetting services themselves. However, NIAP's
1024 *Protection Profile for Application Software* [50] describes security requirements to be expected from
1025 mobile applications. Many mobile application vetting vendors provide capabilities to automate
1026 evaluation of applications against NIAP's requirements.

1027 *3.6.1.5 Mobile Threat Defense*

1028 MTD generally takes the form of an application that is installed on the device, which provides the widest
1029 and most timely access to information about what activity is taking place. Ideally, the MTD solution will
1030 be able to detect unwanted activity and properly inform the user so they can act to prevent or limit the
1031 harm an attacker could cause. Additionally, MTD solutions may integrate with EMM solutions to
1032 leverage the EMM agent's on-device capabilities, such as blocking a malicious application from being
1033 launched until the user can remove it.

1034 MTD products typically analyze device-based threats, application-based threats, and network-based
1035 threats. Device-based threats include outdated operating system versions and insecure configuration
1036 settings. Application-based threats include the issues discussed above regarding the mobile application
1037 vetting service, though sometimes without the same breadth or depth found in services dedicated to
1038 application vetting. Network-based threats include use of unencrypted or public Wi-Fi networks and
1039 attacks such as active attempts to intercept and decrypt network traffic.

1040 *3.6.1.6 Mobile Threat Intelligence*

1041 In this guide, we describe mobile threat intelligence as actionable information that mobile
1042 administrators can use to make changes to their security configuration to improve their posture relative
1043 to recent discoveries. Intelligence data include malicious URLs, IP addresses, domain names, and
1044 application names or package/bundle IDs, as well as malware signatures or vulnerabilities in
1045 applications, mobile devices, device platform services, or mobile security products. This list is not all-
1046 encompassing, as any recent information that could inform rapid changes to enable an enterprise to
1047 better secure a mobile deployment against novel or newly enhanced threats is equally applicable to the
1048 term. This capability may be found in various other types of technology, such as MTD and other network
1049 analysis tools.

1050 *3.6.1.7 Native Mobile OS Capabilities*

1051 Native mobile OS capabilities are available without the use of additional security features. They are
1052 included as part of the mobile device's core capabilities. The following mobile OS capabilities can be
1053 found in mobile devices, particularly smartphones.

1054 3.6.1.7.1 Secure Boot

1055 Secure boot is a general term that refers to a system architecture designed to prevent and detect any
1056 unauthorized modification to the boot process. A system that successfully completes a secure boot has
1057 loaded its start-up sequence information into a trusted operating system. A common mechanism is for
1058 the first program executed (a boot loader) to be immutable (stored on read-only memory or
1059 implemented strictly in hardware). Further, the integrity of mutable code is cryptographically verified
1060 prior to execution by either immutable or verified code. This process establishes a chain of trust that can
1061 be traced back to immutable, implicitly trustworthy code. Use of an integrated TEE as part of a secure
1062 boot process is preferable to an implementation that uses software alone [51].

1063 3.6.1.7.2 Device Attestation

1064 This is an extension of the secure boot process that involves the operating system (or more commonly,
1065 an integrated TEE) providing cryptographically verifiable proof that it has a known and trusted identity
1066 and is in a trustworthy state, which means all software running on the device is free from unauthorized
1067 modification.

1068 Device attestation requires cryptographic operations using an immutable private key that can be verified
1069 by a trusted third party, which is typically the original equipment manufacturer of the TEE (e.g.,
1070 Qualcomm or Samsung) or device platform vendor (e.g., Google, Apple, or Microsoft). Proof of
1071 possession of a valid key establishes the integrity of the first link in a chain of trust that preserves the
1072 integrity of all other pieces of data used in the attestation. It will include unique device identifiers,
1073 metadata, and the results of integrity checks on mutable software, and possibly metrics from the boot
1074 or attestation process itself [51].

1075 3.6.1.7.3 Device Management and MDM API

1076 Mobile operating systems and platform-integrated firmware (e.g., Samsung Knox) provide a number of
1077 built-in security features that are generally active by default. Examples include disk and file-level
1078 encryption, verification of digital signatures for installed software and updates, a device unlock code,
1079 remote device lock, and automatic device wipe following a series of failed device unlock attempts. Some
1080 of these features are directly configurable by the user via a built-in application or through a service
1081 provided by the device platform vendor (e.g., Google, Apple, or Microsoft).

1082 Additionally, mobile operating systems expose an API to MDM products that allow an organization that
1083 manages a device to have greater control over these and many more settings that might not be directly
1084 accessible to the device user. Management APIs allow enterprises using integrated EMM or MDM
1085 products to manage devices more effectively and efficiently than they could by using the built-in
1086 application alone.

1087 4 Architecture

1088 This example solution consists of the six mobile security technologies described in [Section 3.6](#): trusted
 1089 execution environment, enterprise mobility management, virtual private network, mobile application
 1090 vetting service, mobile threat defense, and mobile threat intelligence. Table 4-1, Commercially Available
 1091 Products Used, identifies the commercially available products used in this example solution and how
 1092 they aligned with the six mobile security technologies.

1093 **Table 4-1 Commercially Available Products Used**

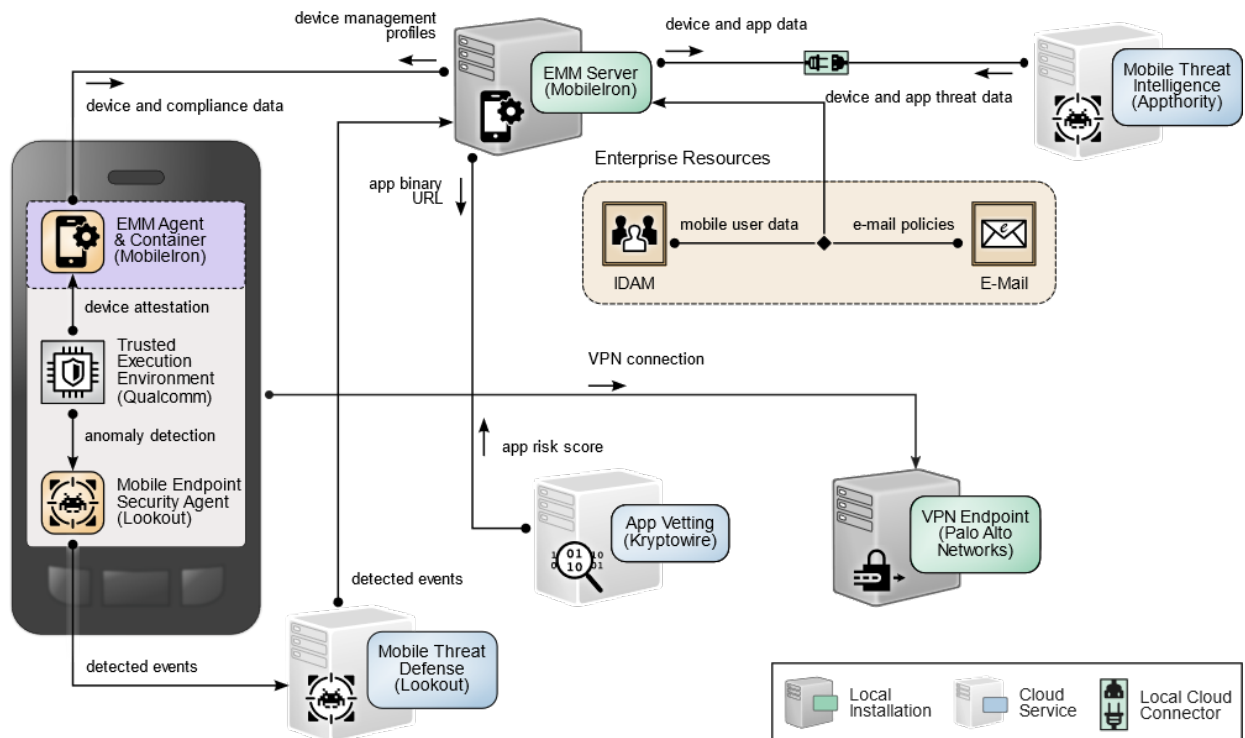
Commercially Available Product	Mobile Security Technology
Appthority Cloud Service	Mobile threat intelligence
Kryptowire Cloud Service	Mobile application vetting service
Lookout Cloud Service/Lookout Agent Version 5.10.0.142 (iOS), 5.9.0.420 (Android)	Mobile threat defense
MobileIron Core Version 9.7.0.1 MobileIron Agent Version 11.0.1A (iOS), 10.2.1.1.3R (Android)	Enterprise mobility management
Palo Alto, PA-220 Version 8.1.1	Virtual private network
Qualcomm, (version is mobile device dependent)	Trusted execution environment

1094 These components are further integrated with broader on-premises security mechanisms and a VPN
 1095 gateway as shown in Figure 4-1. This integrated solution provides a broad range of capabilities to help
 1096 securely provision and manage devices, protect against and detect device compromise, and help provide
 1097 security-enhanced access to enterprise resources by only authorized mobile users and devices.

1098 Organizations exploring the use of on-premises EMM technology should be aware they will be
 1099 responsible for installing and configuring the on-premises instances of the EMM technology. This will
 1100 include the software licenses that must be paid for directly by the organization for any underlying
 1101 platforms or components. Pre-built software images and containers may be available that can help ease
 1102 installation and configuration work. As a recommended best practice, if prebuilt containers and images
 1103 are used, it is recommended that they be checked for common software vulnerabilities.

1104 On-premises mobile device management solutions offer the benefit that enterprise data resides within
 1105 the organization. Allowed devices may still send and receive information from the mobile device
 1106 solution that they are authorized to obtain. Organizations that are interested can explore monitoring
 1107 data flows from the EMM to other devices. Additionally, on-premises mobile device management
 1108 solutions provide the organization with the capability to maintain physical security of the EMM.

1109 **Figure 4-1 Example Solution Architecture**



1110 4.1 Architecture Description

1111 The NCCoE worked with industry subject matter experts to develop an open, standards-based,
 1112 commercially available architecture that addresses the risks identified during the risk assessment
 1113 process in [Section 3.4](#).

1114 Where possible, the architecture uses components that are present on NIAP's Product Compliant List
 1115 [35], meaning the product has been successfully evaluated against a NIAP-approved Protection Profile
 1116 [50]. NIAP collaborates with a broad community, including industry, government, and international
 1117 partners, to publish technology-specific security requirements and tests in the form of Protection
 1118 Profiles. The requirements and tests in these Protection Profiles are intended to ensure that evaluated
 1119 products address identified security threats.

1120 The example solution architecture supports its desired security characteristics as a result of the
1121 following integrations.

1122 4.1.1 Enterprise Integration

1123 This example solution extends central identity and access management to mobile devices via an
1124 integration between both MobileIron Core and Palo Alto Networks GlobalProtect with Microsoft Active
1125 Directory Domain Services (ADDS). The integrity of identification and authentication by mobile devices
1126 to the enterprise is further enhanced by using device certificates issued by local Microsoft Active
1127 Directory Certificate Services (ADCS).

1128 By integrating with Active Directory (AD), MobileIron Core allows administrators to authorize select
1129 groups of users to register a mobile device, limiting mobile access to only those users who require it.
1130 Additionally, different security policies, device configurations, and authorized applications can be
1131 deployed to different AD groups, allowing administrators to centrally manage distinct mobile use cases.
1132 MobileIron Core queries AD using the lightweight directory access protocol.

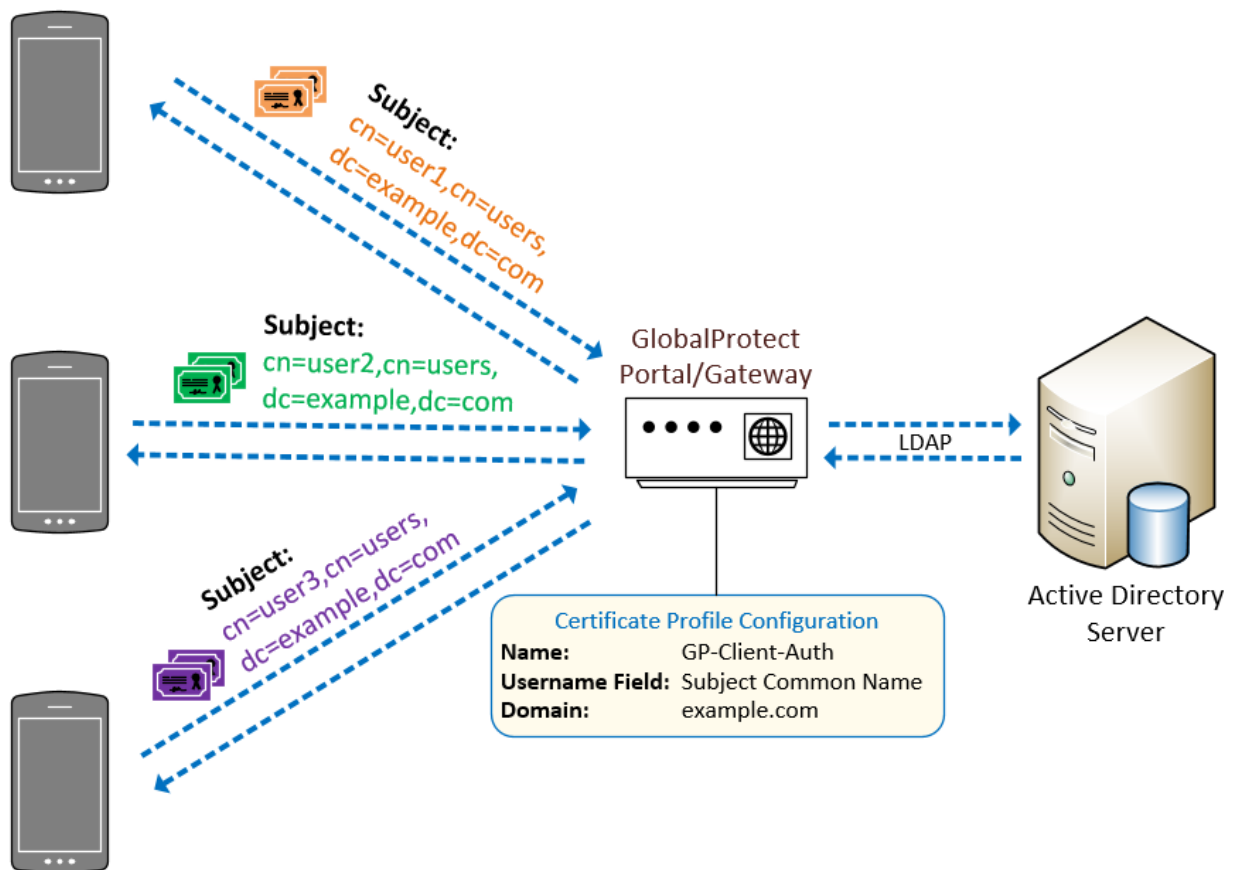
1133 Through its integration with ADCS, MobileIron Core automatically configures devices to obtain locally
1134 managed device certificates by using the Simple Certificate Enrollment Protocol (SCEP). Our example
1135 solution mitigates the potential of remote exploitation of SCEP by restricting certificate enrollment to
1136 mobile devices that are connected to a dedicated enterprise-managed Wi-Fi network that allows devices
1137 to access only MobileIron Core and the Network Device Enrollment Service server. Further, this example
1138 solution uses a dynamic SCEP scheme, in which MobileIron Core supplies a registered mobile device
1139 with a onetime password to include in its SCEP request, thus helping prevent unknown and untrusted
1140 devices that gain unauthorized access to the dedicated Wi-Fi network from obtaining a trusted device
1141 certificate.

1142 The example solution's chosen certificate enrollment configuration includes the mobile user's User
1143 Principal Name (UPN) in the device certificate's Subject Alternative Name field, which the Palo Alto
1144 Networks GlobalProtect VPN gateway uses to perform identity verification and enforce access control
1145 for the unique combination of mobile user and device.

1146 MobileIron Core-registered devices also utilize the device certificate indirectly to enhance the security of
1147 remote connections to the enterprise in two ways. First, communication with MobileIron Core (which
1148 must be accessible from the internet in the demilitarized zone) is secured using two-way Transport Layer
1149 Security (TLS). This protects MobileIron Core from establishing secure connections with untrusted
1150 mobile devices. Second, the device certificate is used in the GlobalProtect VPN configuration, which
1151 restricts access to the VPN to only trusted devices. Further, GlobalProtect uses the device user's UPN to
1152 grant appropriate access to enterprise resources based on the device user's UPN through its integration
1153 with ADDS.

1154 As shown in Figure 4-2 [52], devices present the certificates to the VPN and EMM authentication
 1155 services after the certificate have been successfully issued. The GlobalProtect VPN authenticates the
 1156 device user by mapping the common name field in the client certificate to an account stored in the local
 1157 ADDS. On successful authentication, the GlobalProtect application prompts the user to authenticate
 1158 using a second factor—their Active Directory domain password. Once this is verified, GlobalProtect
 1159 establishes a tunnel with the gateway and is assigned an IP address from the IP pool in the gateway's
 1160 tunnel configuration.

1161 **Figure 4-2 Example Solution Gateway Architecture**



1162 4.1.2 Mobile Component Integration

1163 This section describes how the various mobile technology components integrate with one another. The
 1164 majority of these components integrate with the EMM, MobileIron. MobileIron supports the integration
 1165 of third-party cloud services through a defined API. MobileIron Core authenticates external systems by
 1166 using basic authentication, so TLS protects the confidentiality of API account credentials and

1167 MobileIron’s responses to clients’ RESTful calls. MobileIron API client accounts for Kryptowire, Lookout
1168 Mobile Endpoint Security, and Appthority Mobile Threat Protection (MTP) are each assigned
1169 administrative roles that grant the minimum set of permissions necessary to achieve integration [53],
1170 [54].

1171 *4.1.2.1 Appthority–MobileIron*

1172 The Appthority application reputation service provides an integration with MobileIron Core systems
1173 through implementation of connector software provided by Appthority. The connector provides the
1174 code that exercises the APIs provided by MobileIron Core and the Appthority cloud service. In this
1175 integration, an API user was created within the MobileIron Core system and assigned specific roles
1176 required for successful operation of the application vetting service. Automatic syncing between the
1177 Appthority service and MobileIron Core system can occur on a configurable basis. Specifically, the
1178 application and device inventory data are synced between the two systems. In this integration, syncing
1179 occurs every hour, but this value should be adjusted to fit the needs of the organization.

1180 In this example solution, the integration provides the primary security benefit of compliance
1181 enforcement and remediation escalation. In the initial step of the process, the application inventory is
1182 gathered from the MobileIron Core system, and each application is assigned a threat measurement
1183 score. If an application is installed on a device that is not compliant with the configured policy,
1184 Appthority MTP communicates with the MobileIron Core system to identify those devices, which
1185 triggers MobileIron compliance enforcement actions.

1186 *4.1.2.2 Lookout–MobileIron*

1187 The Lookout mobile threat defense service provides integration with MobileIron Core systems through
1188 implementation of connector software provided by Lookout. The connector provides the code that
1189 exercises the APIs provided by MobileIron Core and the Lookout cloud service. This integration allows
1190 Lookout to retrieve device details as well as application inventory information and to apply labels to
1191 devices as necessary.

1192 Following analysis, Lookout uses the API to apply specific labels to devices to categorize them based on
1193 risk posture, which is calculated based on the severity of issues detected on the device. MobileIron can
1194 then automatically respond to application of specific labels based on built-in compliance actions. This
1195 allows administrators to configure exactly how MobileIron will respond to devices in the following
1196 categories:

- 1197 ▪ Pending–Lookout not yet activated
- 1198 ▪ Secured–Lookout active
- 1199 ▪ Threats Present–Lookout has detected threats
- 1200 ▪ Deactivated–Lookout has been deactivated

- 1201 ▪ Low Risk—devices with a low risk score in Lookout
- 1202 ▪ Moderate Risk—devices with a moderate risk score in Lookout
- 1203 ▪ High Risk—devices with a high-risk score in Lookout

1204 4.1.2.3 *Kryptowire—MobileIron*

1205 Kryptowire obtains device details, such as device platform, OS version, and the universally unique
1206 identifiers assigned to each registered device by MobileIron Core to enable clear identification of a
1207 particular device across systems. Kryptowire obtains the inventory of applications from all of the devices
1208 enrolled in MobileIron. Kryptowire performs static, dynamic, and behavioral binary code analysis on
1209 mobile applications against government (NIAP) and industry (The Open Web Application Security
1210 Project, or OWASP) [55] standards. Kryptowire provides both a detailed security analysis, provides
1211 pass/fail evidence down to the line of code, and provides a summary weighted risk score for each
1212 application. Mobile application administrators can use these detailed reports to inform decisions on
1213 which applications are trusted and compliant with enterprise security and privacy policies and which are
1214 restricted for enterprise or personal use.

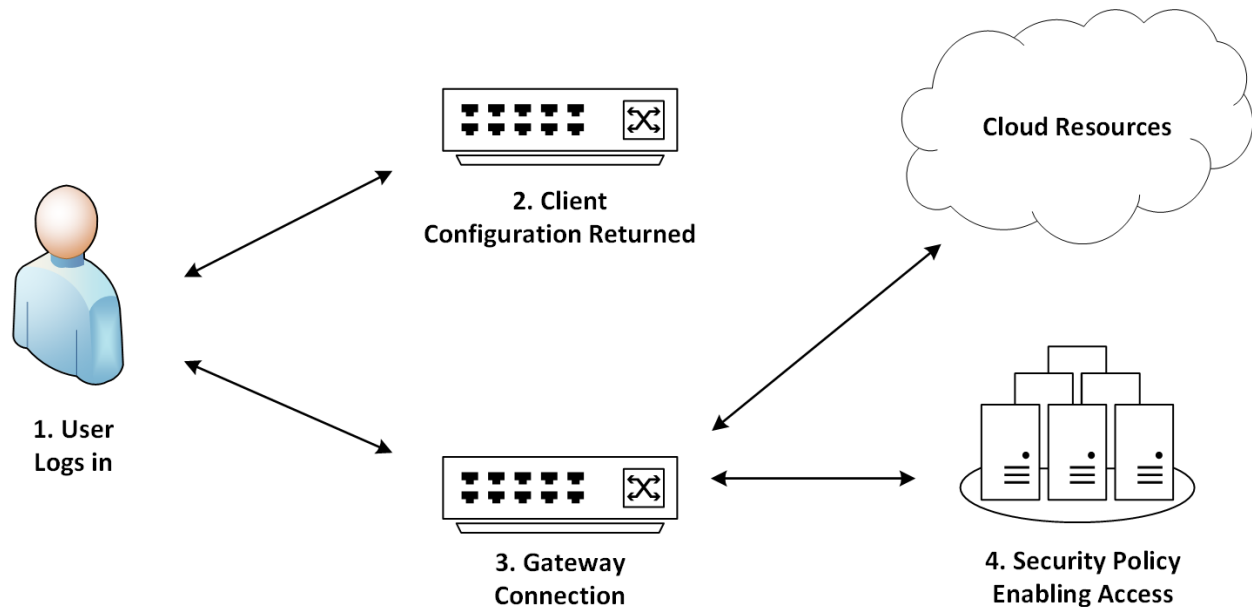
1215 4.1.2.4 *Palo Alto Networks—MobileIron*

1216 Palo Alto Networks' GlobalProtect VPN is used to secure remote connections from mobile devices.
1217 MobileIron Core offers specific configuration options for the GlobalProtect client available on Android
1218 and iOS that facilitates secure deployment of VPN clients and enablement of VPN access using
1219 certificate-based authentication to the GlobalProtect gateway. Details of the certificate enrollment
1220 process are provided in Section 4.1.1.

1221 The VPN architecture used in this example solution is composed of two components of the Palo Alto
1222 Networks next-generation firewall—a GlobalProtect portal and a GlobalProtect gateway. The portal
1223 provides the management functions for VPN infrastructure. Every endpoint that participates in the
1224 GlobalProtect network receives configuration information from the portal, including information about
1225 available gateways as well as any client certificates that may be required to connect to the GlobalProtect
1226 gateway(s). The gateway provides security enforcement for traffic from GlobalProtect applications. It is
1227 configured to provide access to specific enterprise resources only to mobile device users after a
1228 successful authentication and authorization decision.

1229 The VPN tunnel negotiation between the VPN endpoint/mobile device and the VPN gateway is
1230 presented in Figure 4-3 [56]. It demonstrates a user logging into the system (1), the portal returning the
1231 client configuration (2), the agent automatically connecting to the gateway and establishing a VPN
1232 tunnel (3), and the gateway's security policy enabling access to internal and external applications (4).

1233 Figure 4-3 Example Solution VPN Architecture



1234 For our example solution, we chose to enforce an always-on VPN configuration. This configuration
 1235 causes registered devices to establish a VPN connection to the GlobalProtect gateway whenever they
 1236 have network connectivity—this occurs over cellular or Wi-Fi and is persistent across device reboot. This
 1237 configuration affords devices with the greatest degree of protection, as additional Palo Alto Networks
 1238 services can be extended to GlobalProtect. This example solution uses URL filtering, which blocks mobile
 1239 devices from accessing blacklisted internet domains or any domain that Palo Alto Networks associates
 1240 with active exploits (e.g., phishing campaigns, watering hole attacks, botnet command and control). NIST
 1241 SP 800-46 Revision 2, *Guide to Enterprise Telework, Remote Access, and BYOD Security* [11], describes
 1242 the most common VPN options used for remote workers.

1243 4.1.2.4.1 FIPS Compliance

1244 Any sensitive information passing over the internet, wireless networks, and other untrusted networks
 1245 should have its confidentiality and integrity preserved through cryptography [11]. While federal
 1246 agencies are required to use cryptographic algorithms that are NIST-approved and contained in Federal
 1247 Information Processing Standards (FIPS)-validated modules, adoption of these standards is available to
 1248 private and commercial organizations [57]. This example solution uses these best practices to the extent
 1249 possible in the following ways:

- 1250 ▪ *FIPS-CC* mode in the GlobalProtect VPN appliance is enabled, which requires TLS 1.1 (or above)
 1251 and limits the public key use to FIPS-approved algorithms. This example solution's
 1252 implementation uses the highest version of TLS available, with TLS 1.2 being the minimum

1253 acceptable version. A full list of security functions can be found on the Palo Alto Networks FIPS-
1254 CC Security Functions documentation site [58].

- 1255 ▪ As described in Section 4.1.1, dynamic SCEP challenges are enabled.

1256 To align our example solution with guidance in NIST SP 800-52 Revision 1, *Guidelines for the Selection,*
1257 *Configuration, and Use of Transport Layer Security (TLS) Implementations* [12], this example solution
1258 implements the following configuration:

- 1259 ▪ The GlobalProtect portal and gateway restrict the list of cipher suites available to the client
1260 application by using a TLS service profile. The minimum version of TLS is set to 1.2 as
1261 recommended by NIST SP 800-52.

- 1262 ▪ The GlobalProtect portal and gateway server certificates use 2048-bit RSA key modulus signed
1263 with *sha256WithRSAEncryption* algorithm.

1264 *4.1.2.5 iOS and Android EMM Integration*

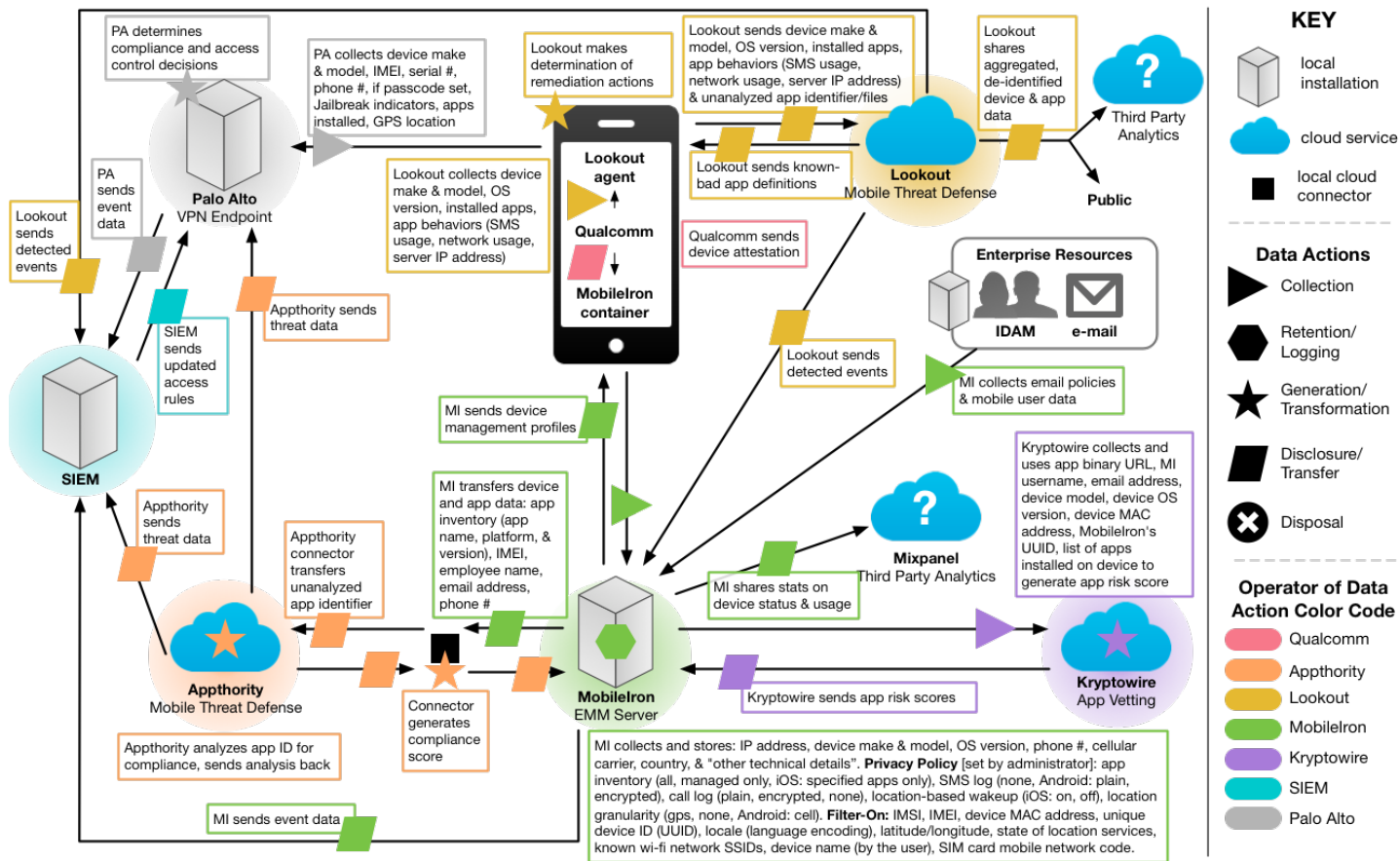
1265 iOS and Android-based devices both integrate directly with EMM solutions, providing enterprise-level
1266 management of security controls based on policy. iOS devices are managed by configuration profiles.
1267 Configuration profiles can force security policies such as VPN usage, enterprise Kerberos support, and
1268 access to cloud services. iOS further incorporates a set of additional security controls in what is termed
1269 *supervised* mode, which denotes a corporately owned device. Typically, organizations choose to use the
1270 Device Enrollment Program [59] for large-scale deployments of iOS devices in *supervised* mode due to
1271 the reduction of labor involved in manually configuring each device. However, due to the small number
1272 of devices in our reference design, we have configured *supervised* mode using the Apple Configurator 2
1273 tool [60]. A full description of iOS capabilities can be found in the iOS Security Guide [61].

1274 Similarly, Android-based devices offer security controls that an EMM can leverage for enterprise
1275 deployments. The Android Enterprise program by Google is available on devices with Android 5.0
1276 (Lollipop) and higher. An EMM deploys a device policy controller [62] as part of its on-device agent that
1277 controls local device policies and system applications on devices. Android Enterprise supports COPE and
1278 BYOD deployment scenarios through work-managed [63] and work-profile [64] device solutions. In
1279 work-managed mode, the device is corporately owned, and the entire device is managed by the
1280 enterprise, whereas work profiles can be added to personally owned devices. A newer mode introduced
1281 in Android 8.0 supports a combination of work-managed and work profiles on the same device [65]. In
1282 this scenario, the device is corporately owned, in that device level controls such as device wipe and reset
1283 to factory default settings are available. A work profile is also created to keep enterprise applications
1284 and data separate from any personal data. This scenario allows for some flexibility of the device owner
1285 to permit personal use of the device while retaining device controls and is the chosen deployment of
1286 this reference implementation.

1287 **4.2 Enterprise Security Architecture Privacy Data Map**

1288 Orvilia performed a privacy analysis using both the information gathered in the initial PRAM effort and the identified mobile security
 1289 technologies included in the revised architecture. The output from the PRAM activities, including data flows between the components, along
 1290 with their on-premises or cloud-based location, resulted in the information contained in Figure 4-4. For additional information on the PRAM
 1291 activities, see the Privacy Risk Assessment Appendix.

1292 **Figure 4-4 NIST Privacy Risk Assessment Methodology Data Map for Orvilia’s Enterprise Security Architecture**



1293 **4.3 Security Control Map**

1294 Using the developed risk information as input, the security characteristics of the solution were
1295 identified. A security control map was developed documenting the example solution’s capabilities with
1296 applicable Subcategories from the NIST Cybersecurity Framework Version 1.1 [5]; NIST SP 800-53
1297 Revision 4, *Security and Privacy Controls for Federal Information Systems and Organizations* [13];
1298 International Organization for Standardization (ISO), International Electrotechnical Commission (IEC)
1299 27001:2013, *Information technology—Security techniques—Information security management systems –*
1300 *Requirements* [25]; the Center for Internet Security’s Control set [21] Version 6; and NIST SP 800-181,
1301 *National Initiative for Cybersecurity Education (NICE) Cybersecurity Workforce Framework* [20].

1302 The security control map identifies the security characteristic standards mapping for the products as
1303 they were used in the example solution. The products may be capable of additional capabilities not used
1304 in this example solution. For that reason, it is recommended the mapping not be used as a reference for
1305 all of the security capabilities these products may be able to address. The security control map can be
1306 found in Table H-1.

1307 **5 Security Characteristic Analysis**

1308 The purpose of the security characteristic analysis is to understand the extent to which the project
1309 meets its objective of demonstrating how to increase the security of mobile devices within an enterprise
1310 by deploying EMM, MTD, MTI, application vetting, secure boot/image authentication, and VPN services.

1311 **5.1 Assumptions and Limitations**

1312 The security characteristic analysis has the following limitations:

- 1313 ▪ It is neither a comprehensive test of all security components nor a red-team exercise.
- 1314 ▪ It cannot identify all weaknesses.
- 1315 ▪ It does not include the lab infrastructure. It is assumed those systems are hardened. Testing
1316 these devices would reveal only weaknesses in implementation that would not be relevant to
1317 those adopting this reference architecture.

1318 **5.2 Build Testing**

1319 Functional testing was used to confirm the example solution’s capabilities. We use the test activities to
1320 demonstrate Orvilia’s susceptibility to the threat before implementing the architecture detailed in this
1321 practice guide. We use the test activities again after implementing the architecture to demonstrate that
1322 the threats have been appropriately addressed.

1323 5.2.1 Threat Event 1 —Unauthorized Access to Sensitive Information via a Malicious 1324 or Privacy-Intrusive Application

1325 **Summary:** Unauthorized access to sensitive information via a malicious or privacy-intrusive application
1326 is tested. We tested this threat by placing a mock sensitive enterprise contact list and calendar entries
1327 on devices, then attempted to install and use applications on the Apple App Store and Google Play Store
1328 [66] that access and back up those entries. Ideally, the enterprise’s security architecture would either
1329 detect or prevent use of these applications, or it would block the applications from accessing enterprise-
1330 controlled contact list and calendar entries.

1331 **Test Activity:**

1332 Install an iOS or Android application that accesses the contact and calendar entries and backs them up
1333 to a cloud service. We have no reason to believe these applications are malicious. However, the
1334 behavior of accessing and backing up enterprise-controlled data (contacts and calendar entries) without
1335 authorization presents an activity that should be mitigated by this example solution’s security
1336 architecture.

1337 **Desired Outcome:** The enterprise’s security architecture should identify the presence of the applications
1338 and the fact that they access contact and calendar entries. The security architecture should block these
1339 applications from installing, block them from running, or detect their presence and cause another
1340 appropriate response to occur, such as blocking the mobile device from accessing enterprise resources
1341 until the applications are removed.

1342 Alternatively, built-in device mechanisms such as Apple’s managed applications functionality and
1343 Google’s Android enterprise work profile functionality could be used to separate the contact and
1344 calendar entries associated with enterprise email accounts, so they can be accessed only by enterprise
1345 applications (applications authorized and managed by the EMM), not applications manually installed by
1346 the user. The user should not have the ability to manually provision their enterprise email account. The
1347 account should be able to be provisioned only by the EMM, enabling enterprise controls on the
1348 enterprise contact list and calendar data. However, in this practice guide build, we chose to make the
1349 devices fully managed, not divided into separate enterprise and personal areas.

1350 **Observed Outcome:** Appthority identified the presence of applications that have access to sensitive
1351 data and updated the device labels in MobileIron Core.

1352 5.2.2 Threat Event 2 —Theft of Credentials Through an SMS or Email Phishing 1353 Campaign

1354 **Summary:** A fictitious phishing event was created where protection against theft of credentials through
1355 an SMS or email phishing campaign was tested.

1356 **Test Activity:**

- 1357 ▪ Establish a web page with a form that impersonates an enterprise login prompt.
- 1358 ▪ Send the web page’s URL via SMS or email and attempt to collect and use enterprise login
- 1359 credentials.

1360 **Desired Outcome:** The enterprise’s security architecture should block the user from browsing to known

1361 malicious websites. Additionally, the enterprise should use multifactor authentication or phishing-

1362 resistant authentication methods, such as those based on public key cryptography, so that either there

1363 is no password for a malicious actor to capture, or capturing the password is insufficient to obtain access

1364 to enterprise resources.

1365 **Observed Outcome:** The example solution used Palo Alto Networks’ next-generation firewall. The

1366 firewall includes PAN-DB, a URL filtering service that automatically blocks known malicious URLs. The

1367 URL filtering database is updated regularly to help protect users from malicious URLs. The next-

1368 generation firewall blocked the attempt to visit the phishing site. However, if the malicious URL were

1369 not present in PAN-DB, the user would be allowed to access the website.

1370 5.2.3 Threat Event 3—Malicious Applications Installed via URLs in SMS or Email

1371 Messages

1372 **Summary:** Unauthorized applications, not present on the official Apple App Store or Google Play Store,

1373 are installed via URL links in SMS, email messages, or third-party websites.

1374 **Test Activity (Android):**

- 1375 ▪ Send an email to the user containing a link (<https://f-droid.org/Fdroid.apk>) to the F-Droid APK
- 1376 (Android Application Package) file with a message urging the user to click on the link to install
- 1377 the application.
- 1378 ▪ On the device, if not already enabled, attempt to enable the Unknown Sources toggle setting in
- 1379 the device security settings to allow installing applications from sources other than the Google
- 1380 Play Store.
- 1381 ▪ On the device, read the received email, click on the link, and attempt to install the F-Droid
- 1382 application.
- 1383 ▪ Observe whether the F-Droid application could be successfully installed. If so, observe whether
- 1384 the enterprise detected and responded to installation of the unauthorized application.

1385 **Test Activity (iOS):**

- 1386 ▪ Send an email to the user containing a link to an iOS application available for installation from
- 1387 the iosninja.io website, along with a message urging the user to click on the link to install the
- 1388 application.
- 1389 ▪ On the device, read the received email, click on the link, and attempt to install the application.

1390 ▪ On the device, attempt to explicitly trust the developer’s signing certificate. Then attempt to run
1391 the application.

1392 ▪ Observe whether the application could run. If so, observe whether the enterprise detected and
1393 responded to installation of the unauthorized application.

1394 **Desired Outcome:** The device does not allow the user to install the unauthorized application. If the
1395 application is somehow installed, its presence should be detected, and an appropriate response should
1396 occur, such as blocking the device from accessing enterprise resources until the application is removed.

1397 **Observed Outcome:** On iOS devices, Lookout detected that an application had been sideloaded, and it
1398 applied a label to the device. MobileIron then quarantined the device until the threat was resolved.

1399 On iOS devices, MobileIron has a configuration option that prohibited the user from trusting the
1400 developer certificate.

1401 On Android devices, MobileIron has a configuration option that prohibited the user from enabling
1402 Unknown Sources on the device.

1403 5.2.4 Threat Event 4 —Confidentiality and Integrity Loss due to Exploitation of 1404 Known Vulnerability in the OS or Firmware

1405 **Summary:** When malware successfully exploits a code execution vulnerability in the mobile OS or device
1406 drivers, the delivered code generally executes with elevated privileges and issues commands in the
1407 context of the root user or the OS kernel.

1408 **Test Activity:** Attempt to access enterprise resources from a mobile device with known vulnerabilities
1409 (e.g., running an older, unpatched version of iOS or Android).

1410 **Desired Outcome:** The enterprise’s security architecture should identify the presence of devices that are
1411 running an outdated version of iOS or Android susceptible to known vulnerabilities. It should be
1412 possible, when warranted by the risks, to block devices from accessing enterprise resources until system
1413 updates are installed.

1414 **Observed Outcome:** Lookout identified that devices were running outdated operating systems. This
1415 information was communicated to MobileIron, which subsequently automatically quarantined the
1416 devices until the operating system was updated.

1417 5.2.5 Threat Event 5 —Violation of Privacy via Misuse of Device Sensors

1418 **Summary:** There is collection of location, camera, or microphone data by an application that has no
1419 need to access this data.

1420 Note: Not all applications that have access to location, camera, or microphone data are malicious.
 1421 However, when an application is found to be collecting this information, additional vetting or testing
 1422 may be required to determine the intent of its use and to then determine if the application is malicious.

1423 **Test Activity:** Upload the application to Kryptowire; observe the output report.

1424 **Desired Outcome:** Output report identifies the use of location, camera, or microphone use by the
 1425 application.

1426 **Observed Outcome:** The Kryptowire report identified the use of location sensor, camera, or microphone
 1427 by the application.

1428 5.2.6 Threat Event 6—Compromise of the Integrity of the Device or Its Network 1429 Communications via Installation of Malicious EMM/MDM, Network, VPN 1430 Profiles, or Certificates

1431 **Summary:** There is compromise of the integrity of the device or its network communications via
 1432 installation of malicious EMM/MDM, network, VPN profiles, or certificates using a man-in-the-middle
 1433 approach.

1434 **Test Activity:**

- 1435 ▪ Install mitmproxy (<https://mitmproxy.org/>) on a computer (we used a Mac) connected to the
 1436 same Wi-Fi network as the mobile devices.
- 1437 ▪ Install mitmproxy's CA certificate (stored at `~/mitmproxy/mitmproxy-ca-cert.cer` on our Mac)
 1438 onto the mobile devices being tested. iOS- and Android-specific instructions are found below.
- 1439 ▪ Configure the computer as necessary to run mitmproxy in transparent mode, as described in
 1440 <https://docs.mitmproxy.org/stable/howto-transparent/>.
- 1441 ▪ To illustrate a malicious actor's ability to manipulate network traffic, we downloaded the
 1442 mitmproxy `internet_in_mirror` script from
 1443 [https://github.com/mitmproxy/mitmproxy/blob/master/examples/simple/internet_in_mirror.p](https://github.com/mitmproxy/mitmproxy/blob/master/examples/simple/internet_in_mirror.py)
 1444 y. It performs a mirror reflection of the content of all websites.
- 1445 ▪ Run mitmproxy in transparent mode and using the `internet_in_mirror` script: `mitmproxy -mode`
 1446 transparent -ssl-insecure -showhost -s internet_in_mirror.py
- 1447 ▪ Rather than perform an intrusive attack such as address resolution protocol spoofing, we
 1448 manually configured each mobile device's Wi-Fi network settings to change the default
 1449 gateway's (sometimes referred to as router in the network settings) IP address to the
 1450 computer's IP address rather than the router's IP address. This configuration change forced all
 1451 the network traffic from each device through the computer.

1452 **Test Activity (Android):**

- 1453 ▪ Place mitmproxy’s CA certificate as an attachment within an email message.
- 1454 ▪ Open the email message on the Android device and click on the attachment to attempt to install
1455 the CA certificate.
- 1456 ▪ Modify the device’s Wi-Fi network settings to manually change the default gateway’s IP address
1457 to the address of the computer running mitmproxy.
- 1458 ▪ Browse to a hypertext transfer protocol secure (https) website (e.g.,
1459 <https://www.nccoe.nist.gov>), and observe whether the content has been reversed, illustrating
1460 that the man-in-the-middle attack on a TLS-protected connection was successful.

1461 **Test Activity (iOS):**

- 1462 ▪ Use Apple Configurator 2 on a Mac, or another tool, to create an iOS configuration profile
1463 containing mitmproxy’s CA certificate. The configuration profile used in testing was named
1464 Enterprise Access. The configuration profile was signed using a key associated with an Apple
1465 free developer account certificate. The signature was optional (Configuration profiles do not
1466 have to be signed).
- 1467 ▪ Send the configuration profile as an attachment within an email message.
- 1468 ▪ Open the email message and attempt to click on the attachment to install the configuration
1469 profile. Attempt to follow the prompts to complete the profile installation.
- 1470 ▪ Attempt to enable the CA certificate in the iOS device’s Certificate Trust Settings.

1471 **Desired Outcome:** The enterprise’s security architecture should block installation of unauthorized
1472 configuration profiles (iOS) or CA certificates (Android). Alternatively, the security architecture may
1473 detect the presence of unauthorized configuration profiles or CA certificates and perform another
1474 appropriate action, such as blocking the device from accessing enterprise resources until the
1475 configuration profile or CA certificate is removed. The architecture should also detect attempted man-
1476 in-the-middle attacks.

1477 **Observed Outcome:** Lookout detected a man-in-the-middle attack on both iOS and Android devices.
1478 Lookout also detected the unknown configuration profile on iOS.

1479 **5.2.7 Threat Event 7—Loss of Confidentiality of Sensitive Information via**
1480 **Eavesdropping on Unencrypted Device Communications**

1481 **Summary:** Malicious actors can readily eavesdrop on communication over unencrypted, wireless
1482 networks such as public Wi-Fi access points, which are commonly provided by coffee shops and hotels.
1483 While a device is connected to such a network, a malicious actor would gain unauthorized access to any
1484 data sent or received by the device for any session not already protected by encryption at either the
1485 transport or application layers.

1486 **Test Activity:** Test if applications will attempt to establish an http or unencrypted connection.

1487 **Desired Outcome:** Be alerted when applications attempt to make an unencrypted connection or prevent
1488 the application from being able to do so.

1489 Appthority can determine if applications will attempt to establish an http or unencrypted connection.

1490 iOS and Android also can require a secure connection for an application. (When it tries to connect to the
1491 server if it is unencrypted, it will just drop the connection.)

1492 **Observed Outcome:** On both iOS and Android, Appthority detected a “sends data unencrypted” threat
1493 for an application. Transferring data over unencrypted connections could result in the loss of
1494 confidentiality of information being transmitted by that application.

1495 5.2.8 Threat Event 8—Compromise of Device Integrity via Observed, Inferred, or 1496 Brute-Forced device Unlock Code

1497 **Summary:** A malicious actor may be able to obtain a user’s device unlock code by direct observation,
1498 side-channel attacks, or brute-force attacks.

1499 **Test Activity:**

- 1500 ▪ Attempt to completely remove the device unlock code. Observe whether the attempt succeeds.
- 1501 ▪ Attempt to set the device unlock code to “1234,” a weak four-digit personal identification
1502 number (PIN). Observe whether the attempt succeeds.
- 1503 ▪ Attempt to continuously unlock the device, confirming the device is factory reset after 10 failed
1504 attempts.

1505 **Desired Outcome:** Policies set on the device by the EMM (MobileIron) should require a device unlock
1506 code to be set, prevent the device unlock code from being removed, require a minimum complexity for
1507 the device unlock code, and factory reset the device after 10 failed unlock attempts.

1508 Additionally, Lookout can identify and report devices that have the lock screen disabled.

1509 **Observed Outcome:** MobileIron applied a policy to the devices that enforced a mandatory PIN and
1510 device wipe capability after 10 failed unlock attempts. Further, Lookout reports when the device has the
1511 lock screen disabled. For both devices, all data was erased after 10 failed unlock attempts.

1512 The option to remove the unlock PIN/passcode had been disabled. Upon attempting to set the PIN to
1513 something simple, such as a PIN with repetitious or consecutive characters, an error was displayed,
1514 informing the user they cannot use the PIN they entered.

1515 **5.2.9 Threat Event 9—Unauthorized Access to Backend Services via authentication**
1516 **or credential Storage Vulnerabilities in Internally Developed Applications**

1517 **Summary:** If a malicious actor gains unauthorized access to a mobile device, the attacker also has access
1518 to the data and applications on that mobile device. The mobile device may contain an organization’s in-
1519 house applications and can subsequently gain access to sensitive data or backend services.

1520 **Test Activity:** Application was submitted to Appthority for analysis of credential weaknesses.

1521 **Desired Outcome:** Discover and report credential weaknesses.

1522 **Observed Outcome:** Appthority recognized within an application that it uses hard-coded credentials.
1523 The application’s use of hard-coded credentials could introduce vulnerabilities if the hard-coded
1524 credentials were used for access to enterprise resources by unauthorized entities.

1525 **5.2.10 Threat Event 10 —Unauthorized Access of Enterprise Resources from an**
1526 **Unmanaged and Potentially Compromised Device**

1527 **Summary:** An employee that accesses enterprise resources from an unmanaged mobile device may
1528 expose the enterprise to vulnerabilities that may compromise enterprise data. Unmanaged devices do
1529 not benefit from security mechanisms deployed by the organization such as mobile threat defense,
1530 mobile threat intelligence, application vetting services, and mobile security policies. These unmanaged
1531 devices limit an organization’s visibility into the state of a mobile device, including if the device is
1532 compromised by an attacker.

1533 **Test Activity:** Attempt to directly access enterprise services, e.g., Exchange email server or corporate
1534 VPN, on a mobile device that is not enrolled into the EMM system.

1535 **Desired Outcome:** Enterprise services should not be accessible from devices that are not enrolled into
1536 the EMM system. Otherwise, the enterprise is not able to effectively manage devices to prevent threats.

1537 **Observed Outcome:** Devices that were not enrolled in MobileIron were unable to access enterprise
1538 resources as the GlobalProtect VPN gateway prevented the devices from authenticating without proper
1539 client certificates, only obtainable through enrolling in the EMM.

1540 **5.2.11 Threat Event 11—Loss of Organizational Data due to a Lost or Stolen Device**

1541 **Summary:** Due to the nature of the small form factor of mobile devices, they are easy to misplace or be
1542 stolen. A malicious actor who gains physical custody of a device with inadequate security controls may
1543 be able to gain unauthorized access to sensitive data or resources accessible to the device.

1544 **Test Activity:** Attempt to download enterprise data onto a mobile device that is not enrolled into the
1545 EMM system (may be performed in conjunction with TE-10). Attempt to remove (in conjunction with TE-
1546 8) the device unlock code or demonstrate that the device does not have a device unlock code in place.

1547 Attempt to locate and wipe the device through the EMM console (it will fail if the device is not enrolled
1548 in the EMM).

1549 **Desired Outcome:** It should be possible to locate or wipe EMM-enrolled devices in response to a report
1550 that they have been lost or stolen. As demonstrated by TE-10, only EMM-enrolled devices should be
1551 able to access enterprise resources. As demonstrated by TE-8, EMM-enrolled devices can be forced to
1552 have a screen lock with a passcode of appropriate strength, which helps resist exploitation (including
1553 loss of organizational data) if the device has been lost or stolen.

1554 Should the device be unreachable by the EMM (e.g., disconnected from all networking), EMM control
1555 and corporate data will be removed after 10 failed unlock attempts.

1556 **Observed Outcome (Enrolled Devices):** Enrolled devices are protected. An enterprise policy requiring a
1557 personal identification number/lock screen is present, and therefore the enterprise data on the device
1558 could not be accessed. After 10 attempts to access the device, the device was wiped. Additionally, the
1559 device was remotely wiped after it was reported as lost to enterprise mobile device service
1560 management.

1561 **Observed Outcome (Unenrolled Devices):** As shown in Threat Event 10, only enrolled devices can access
1562 enterprise services. When the device attempted to access enterprise data, no connection to the
1563 enterprise services was available. Because the device cannot access the enterprise, enterprise
1564 information would not be located on the device.

1565 5.2.12 Threat Event 12—Loss of Confidentiality of Organizational Data due to Its 1566 Unauthorized Storage in Non-Organizationally Managed Services

1567 **Summary:** If employees violate data management policies by using unmanaged services to store
1568 sensitive organizational data, this data will be placed outside organizational control, where the
1569 organization can no longer protect its confidentiality, integrity, or availability. Malicious actors who
1570 compromise the unauthorized service account or any system hosting that account may gain
1571 unauthorized access to the data.

1572 **Test Activity:** Connect to the enterprise VPN. Open an enterprise website or application. Attempt to
1573 extract enterprise data by taking a screenshot, or copy/paste and send it via an unmanaged e-mail
1574 account.

1575 **Desired Outcome:** Screenshots and other data-sharing actions will be prohibited by the EMM while
1576 using managed applications.

1577 **Observed Outcome:** Through MobileIron restriction and lockdown policies, an administrator prevented
1578 the following actions on devices:

1579 **Android**

- 1580 ▪ copy/paste
- 1581 ▪ screen capture
- 1582 ▪ data transfer over near-field communication
- 1583 ▪ data transfer over Universal Serial Bus
- 1584 ▪ Bluetooth

1585 **iOS**

- 1586 ▪ screen capture and recording (iOS 9+)
- 1587 ▪ AirDrop
- 1588 ▪ iCloud Backup
- 1589 ▪ iCloud Documents and data access
- 1590 ▪ managed applications storing data in iCloud
- 1591 ▪ data flow between managed and unmanaged applications
- 1592 ▪ hand-off

1593 These restrictions prohibited the user from executing common data leakage methods.

1594 **5.3 Scenarios and Findings**

1595 One aspect of our security evaluation involved assessing how well the reference design addresses the
1596 security characteristics it was intended to support. The Cybersecurity Framework Subcategories were
1597 used to provide structure to the security assessment by consulting the specific sections of each standard
1598 that are cited in reference to a Subcategory. The cited sections provide validation points that the
1599 example solution would be expected to exhibit. Using the Cybersecurity Framework Subcategories as a
1600 basis for organizing our analysis allowed us to systematically consider how well the reference design
1601 supports the intended security characteristics.

1602 This section provides the scenarios and findings for the security and privacy characteristics the example
1603 solution was intended to support. They include:

- 1604 ▪ development of the Cybersecurity Framework and NICE Framework mappings
- 1605 ▪ threat event scenarios and example solution architecture mitigations
- 1606 ▪ data action scenarios and potential mitigations that organizations could employ

1607 5.3.1 Cybersecurity Framework and NICE Framework Work Roles Mappings

1608 While the example solution was being developed, the Cybersecurity Framework Subcategory mappings
1609 were developed into a table mapping for organizations implementing the example solution's
1610 capabilities.

1611 As the example solution's products were installed, configured, and used in the example solution
1612 architecture, the example solution's functions and their corresponding Cybersecurity Framework
1613 Subcategories, along with other guidance alignment, were determined and documented.

1614 This mapping became an important resource to the example solution contained in this practice guide
1615 because it provides the ability to communicate with the organization's stakeholders about the security
1616 controls that the example solution can help mitigate, and the workforce requirements that the example
1617 solution will require.

1618 The example solution's products, security control, and workforce mapping can be found in Table H-1.

1619 5.3.2 Threat Event Scenarios and Findings

1620 As part of the findings, the threat events were mitigated in the example solution architecture using the
1621 concepts and technology shown in Table 5-1. Each threat event was matched with functions that helped
1622 mitigate the risks posed by the threat event.

1623 Note: While not demonstrated in the table, TEE provided tamper-resistant processing environment
1624 capabilities that helped mitigate mobile device runtime and memory threats in the example solution.

1625 **Table 5-1 Threat Event Scenarios and Findings Summary**

Threat Event	How the Example Solution Architecture Helps Mitigate the Threat Event	The Technology Function That Helps Mitigate the Threat Event
Threat Event 1: Unauthorized access to sensitive information via a malicious or privacy-intrusive application	Ensured administrators have insight into what corporate data applications can access.	MTI
Threat Event 2: Theft of credentials through an SMS or email phishing campaign	Utilized PAN-DB to block known malicious websites.	Firewall

Threat Event	How the Example Solution Architecture Helps Mitigate the Threat Event	The Technology Function That Helps Mitigate the Threat Event
Threat Event 3: Malicious applications installed via URLs in SMS or email messages	Disabled installing applications from unknown sources.	EMM
Threat Event 4: Confidentiality and integrity loss due to exploitation of known vulnerability in the OS or firmware	Quarantined noncompliant device until its operating system was updated.	EMM
Threat Event 5: Violation of privacy via misuse of device sensors	Application vetting reports indicated the sensors to which an application requested access.	MTI
Threat Event 6: Compromise of the integrity of the device or its network communications via installation of malicious EMM/MDM, network, VPN profiles, or certificates	Detected a man-in-the-middle attack by using Lookout. Lookout detected the unauthorized configuration profile on iOS.	MTD
Threat Event 7: Loss of confidentiality of sensitive information via eavesdropping on unencrypted device communications	Application vetting reports indicated if an application sent data without proper encryption.	Application Vetting
Threat Event 8: Compromise of device integrity via observed, inferred, or brute-forced device unlock code	Enforced mandatory device wipe capabilities after 10 failed unlock attempts.	EMM
Threat Event 9: Unauthorized access to backend services via authentication or credential storage vulnerabilities in internally developed applications	Application vetting reports indicated if an application used credentials improperly.	MTI
Threat Event 10: Unauthorized access of enterprise resources from an unmanaged and potentially compromised device	Devices not enrolled in the EMM system were not able to connect to the corporate VPN.	VPN

Threat Event	How the Example Solution Architecture Helps Mitigate the Threat Event	The Technology Function That Helps Mitigate the Threat Event
Threat Event 11: Loss of organizational data due to a lost or stolen device	Enterprise data was protected by enforced passcode policies and device wipe capabilities.	EMM
Threat Event 12: Loss of confidentiality of organizational data due to its unauthorized storage in non-organizationally managed services	Policies that enforce data loss prevention were pushed to devices.	EMM

1626 5.3.3 Data Action Scenarios and Findings

1627 The results of the PRAM found that three data actions were especially relevant to the build. Potential
 1628 mitigations that could be used by an organization to lessen their impact were identified by the PRAM as
 1629 shown below. Further details on the PRAM's findings can be found in Appendix F.

1630 **Table 5-2 Data Action Scenarios and Findings Summary**

Data Action	Data Action Description	How the Data Action Could Be Mitigated
Data Action 1: Blocking access and wiping devices	Employees are likely to use their devices for both personal and work-related purposes. Therefore, in a system that features the capability to wipe a device entirely, there could be an issue of employees losing personal data.	<p>Block the device's access to enterprise resources until it is granted access permission again.</p> <p>Selectively wipe elements of the device without removing all data on the device. Within the example solution, this option is available for iOS devices.</p> <p>Advise employees to back up the personal data maintained on devices.</p> <p>Limit staff with the ability to perform wipes or block access.</p>

Data Action	Data Action Description	How the Data Action Could Be Mitigated
Data Action 2: Employee monitoring	Employer-owned or controlled networks monitor activities on a regular basis. Employees may not be aware of the monitoring of their interactions with the system and may not want this monitoring to occur.	<p>Limit staff with ability to review data about employees and their devices.</p> <p>Develop organizational policies and techniques to limit collection of specific data elements.</p> <p>Develop organizational policies and techniques regarding disposal of PII.</p>
Data Action 3: Data sharing across parties	Data transmission about individuals and their devices among a variety of different parties could be confusing for employees who might not know who has access to different information about them.	<p>Develop organizational policies and techniques for de-identification of data.</p> <p>Use encryption.</p> <p>Limit or disable access to data.</p> <p>Develop organizational policies and techniques to limit collection of specific data elements.</p> <p>Use contracts to limit third-party data processing.</p>

1631 6 Conclusion

1632 This document provides an overview of the Risk Management Framework and the Privacy Risk
 1633 Assessment Methodology, an explanation of mobile device security concepts, and an example solution
 1634 for organizations implementing a COPE deployment.

1635 Our fictitious Orvilia Development organization started with a mobile device infrastructure that was
 1636 lacking mobile device security architecture concepts. It employed a risk management and privacy
 1637 methodology to understand the current gaps in its architecture and methods to enhance the security of
 1638 its systems.

1639 After identifying the core threat events from the risk assessment, the appropriate mobile device security
 1640 technologies were applied. These included an on-premises EMM solution integrated with cloud- and

1641 agent-based mobile security technologies to help deploy a set of security and privacy capabilities in
1642 support of a usage scenario.

1643 The practice guide also includes in Volume C a series of How-To Guides—step-by-step instructions
1644 covering the initial setup (installation or provisioning) and configuration for each component of the
1645 architecture—to help security engineers rapidly deploy and evaluate our example solution in their test
1646 environment.

1647 The example solution of our reference design uses standards-based, commercially available products. It
1648 can be used directly by any organization with a COPE usage scenario by implementing a security
1649 infrastructure that supports an integration of on-premises with cloud-hosted mobile security
1650 technologies. The practice guide provides a reference design and example solution that an organization
1651 may use in whole or in parts as the basis for a custom solution that realizes the security and privacy
1652 characteristics that best support its unique mobile device usage scenario.

1653 **7 Future Build Considerations**

1654 A topic of interest for a future build is a BYOD scenario. This entails protecting corporate data on
1655 personally owned devices that employees will use for work as well as personal activity. Another area of
1656 interest is a thin client deployed to mobile devices. The thin client would allow the employee to access a
1657 virtual device contained within the corporate infrastructure to access enterprise data and resources,
1658 ensuring that no corporate data ever resides on the physical device.

1659 Further, examination of emerging 5G technologies as they relate to mobile device security is a new field
1660 that presents a wide breadth of research opportunities.

1661 **Appendix A List of Acronyms**

AD	Active Directory
ADCS	Active Directory Certificate Services
ADDS	Active Directory Domain Services
API	Application Programming Interface
ATARC	Advanced Technology Academic Research Center
ATT&CK	Adversarial Tactics, Techniques, and Common Knowledge
BYOD	Bring Your Own Device
CIO	Chief Information Officer
CIS	Center for Internet Security
COMSEC	Communications Security
COPE	Corporate-Owned Personally-Enabled
CSP	Credential Service Provider
CVE	Common Vulnerabilities and Exposures
DHS	Department of Homeland Security
DMZ	Demilitarized Zone
EMM	Enterprise Mobility Management
FedRAMP	Federal Risk and Authorization Management Program
FIPS	Federal Information Processing Standards
GPS	Global Positioning System
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMEI	International Mobile Equipment Identity
IP	Internet Protocol
IPS	Intrusion Protection System
IR	Interagency Report
ISO	International Organization for Standardization
IT	Information Technology
MDM	Mobile Device Management
MTC	Mobile Threat Catalogue

MTD	Mobile Threat Defense
MTI	Mobile Threat Intelligence
MTP	Mobile Threat Protection
MSCT	Mobile Services Category Team
NCCoE	National Cybersecurity Center of Excellence
NIAP	National Information Assurance Partnership
NICE	National Initiative for Cybersecurity Education
NIST	National Institute of Standards and Technology
NVD	National Vulnerability Database
OS	Operating System
PII	Personally Identifiable Information
PRAM	Privacy Risk Assessment Methodology
RMF	Risk Management Framework
ROM	Read-only Memory
SCEP	Simple Certificate Enrollment Protocol
SIEM	Security Information and Event Management
SMS	Short Message Service
SP	Special Publication
TE	Threat Event
TEE	Trusted Execution Environment
TLS	Transport Layer Security
UPN	User Principal Name
URL	Uniform Resource Locator
VPN	Virtual Private Network

1663 **Appendix B** **Glossary**

Access Management	Access Management is the set of practices that enables only those permitted the ability to perform an action on a particular resource. The three most common Access Management services you encounter every day perhaps without realizing it are: Policy Administration, Authentication, and Authorization [67].
Agent	A host-based IPS program that monitors and analyzes activity and performs preventive actions; OR a program or plug-in that enables an SSL VPN to access non-Web-based applications and services [15]
Application Layer	Layer of the TCP/IP protocol stack that sends and receives data for particular applications such as DNS, HTTP, and SMTP [15]
App-Vetting Process	The process of verifying that an app meets an organization's security requirements. An app vetting process comprises app testing and app approval/rejection activities [18].
Blacklist	A list of discrete entities, such as hosts or applications that have been previously determined to be associated with malicious activity [68]
Brute-Force Attack	In cryptography, an attack that involves trying all possible combinations to find a match [69]
Chief Information Officers (CIO) Council	The CIO Council is the principal interagency forum for improving agency practices related to the design, acquisition, development, modernization, use, sharing, and performance of Federal information resources [70].
Cryptographic Algorithm	A well-defined computational procedure that takes variable inputs, including a cryptographic key, and produces an output [68]
Cryptographic Key	A value used to control cryptographic operations, such as decryption, encryption, signature generation, or signature verification [71]

Cryptography	The discipline that embodies the principles, means, and methods for the transformation of data in order to hide their semantic content, prevent their unauthorized use, or prevent their undetected modification [68]
Common Vulnerabilities and Exposures	A dictionary of common names for publicly known information system vulnerabilities [72]
Data Action	System operations that process PII [44]
Demilitarized Zone (DMZ)	A network created by connecting two firewalls. Systems that are externally accessible but need some protections are usually located on DMZ networks [73].
Disassociability	Enabling the processing of PII or events without association to individuals or devices beyond the operational requirements of the system [44]
Encryption	The cryptographic transformation of data to produce ciphertext [68]
Enterprise Mobility Management	Enterprise Mobility Management (EMM) systems are a common way of managing mobile devices in the enterprise. Although not a security technology by itself, EMMs can help to deploy policies to an enterprise's device pool and to monitor device state [6].
Identity Verification	Confirmation, through the provision of objective evidence, that specified requirements have been fulfilled (e.g., an entity's requirements have been correctly defined, or an entity's attributes have been correctly presented; or a procedure or function performs as intended and leads to the expected outcome). Adapted from Verification [68].
Impact	The effect on organizational operations, organizational assets, individuals, other organizations, or the Nation (including the national security interests of the United States) of a loss of confidentiality, integrity, or availability of information or an information system [13]

Key Logger	A remote program designed to record which keys are pressed on a computer keyboard used to obtain passwords or encryption keys and thus bypass other security measures [74]
Malware	Software or firmware intended to perform an unauthorized process that will have adverse impact on the confidentiality, integrity, or availability of an information system. A virus, worm, Trojan horse, or other code-based entity that infects a host. Spyware and some forms of adware are also examples of malicious code [13].
Man-in-the-Middle Attack	An attack in which an attacker is positioned between two communicating parties in order to intercept and/or alter data traveling between them. In the context of authentication, the attacker would be positioned between claimant and verifier, between registrant and CSP during enrollment, or between subscriber and CSP during authenticator binding [71].
Mobile Device Management (MDM)	The administration of mobile devices such as smartphones, tablets, computers, laptops, and desktop computers. MDM is usually implemented through a third-party product that has management features for particular vendors of mobile devices [18].
Network Layer	Layer of the TCP/IP protocol stack that is responsible for routing packets across networks [15]
Phishing	An attack in which the subscriber is lured (usually through an email) to interact with a counterfeit verifier/RP and tricked into revealing information that can be used to masquerade as that subscriber to the real verifier/RP [71]
Predisposing Conditions	A condition that exists within an organization, a mission/business process, enterprise architecture, or information system including its environment of operation, which contributes to (i.e., increases or decreases) the likelihood that one or more threat events, once initiated, will result in undesirable consequences or adverse impact to organizational operations and assets, individuals, other organizations, or the Nation [9]

Privacy Risk Assessment Methodology (PRAM)	The PRAM is a tool that applies the risk model from NISTIR 8062 and helps organizations analyze, assess, and prioritize privacy risks to determine how to respond and select appropriate solutions. The PRAM can help drive collaboration and communication between various components of an organization, including privacy, cybersecurity, business, and IT personnel [75].
Read-Only Memory	ROM is a pre-recorded storage medium that can only be read from and not written to [76].
Red Team Exercise	An exercise, reflecting real-world conditions, that is conducted as a simulated adversarial attempt to compromise organizational missions and/or business processes to provide a comprehensive assessment of the security capability of the information system and organization [13]
Replay Resistance	Protection against the capture of transmitted authentication or access control information and its subsequent retransmission with the intent of producing an unauthorized effect or gaining unauthorized access [19]
Risk	A measure of the extent to which an entity is threatened by a potential circumstance or event, and typically a function of: (i) the adverse impacts that would arise if the circumstance or event occurs; and (ii) the likelihood of occurrence [9]
Risk Assessment	The process of identifying risks to organizational operations (including mission, functions, image, reputation), organizational assets, individuals, other organizations, and the Nation, resulting from the operation of an information system. Part of risk management, incorporates threat and vulnerability analyses, and considers mitigations provided by security controls planned or in place. Synonymous with risk analysis [13]
Risk Management Framework	The Risk Management Framework (RMF) provides a structured, yet flexible approach for managing the portion of risk resulting from the incorporation of systems into the mission and business processes of the organization [77].
Sandbox	A restricted, controlled execution environment that prevents potentially malicious software, such as mobile code, from accessing any system resources except those for which the software is authorized (Under Sandboxing) [68].

Security Control	A safeguard or countermeasure prescribed for an information system or an organization designed to protect the confidentiality, integrity, and availability of its information and to meet a set of defined security requirements [13]
Side-Channel Attacks	An attack enabled by leakage of information from a physical cryptosystem. Characteristics that could be exploited in a side-channel attack include timing, power consumption, and electromagnetic and acoustic emissions [71].
Social Engineering	The act of deceiving an individual into revealing sensitive information, obtaining unauthorized access, or committing fraud by associating with the individual to gain confidence and trust [71]
Threat	Any circumstance or event with the potential to adversely impact organizational operations (including mission, functions, image, or reputation), organizational assets, individuals, other organizations, or the Nation through an information system via unauthorized access, destruction, disclosure, or modification of information, and/or denial of service [9]
Threat Events	An event or situation that has the potential for causing undesirable consequences or impact [9]
Threat Intelligence	Threat information that has been aggregated, transformed, analyzed, interpreted, or enriched to provide the necessary context for decision-making processes [78]
Threat Sources	The intent and method targeted at the intentional exploitation of a vulnerability or a situation and method that may accidentally trigger a vulnerability. Synonymous with threat agent [13]
Transport Layer	Layer of the TCP/IP protocol stack that is responsible for reliable connection-oriented or connectionless end-to-end communications [15]
Transport Layer Security (TLS)	A security protocol providing privacy and data integrity between two communicating applications. The protocol is composed of two layers: the TLS Record Protocol and the TLS Handshake Protocol [68].

Trusted Certificate	A certificate that is trusted by the Relying Party on the basis of secure and authenticated delivery. The public keys included in trusted certificates are used to start certification paths. Also known as a “trust anchor” [79]
Unmanaged Device	A device inside the assessment boundary that is either unauthorized or, if authorized, not assigned to a person to administer [80]
Virtual Private Network	Protected information system link utilizing tunneling, security controls, and endpoint address translation giving the impression of a dedicated line [68]
Vulnerability	Weakness in an information system, system security procedures, internal controls, or implementation that could be exploited by a threat source [9]
Watering Hole	Watering hole attacks involve attackers compromising one or more legitimate Web sites with malware in an attempt to target and infect visitors to those sites [81].

1664 **Appendix C** **References**

- [1] National Institute of Standards and Technology (NIST), "NIST Computer Security Resource Center," [Online]. Available: <https://csrc.nist.gov/publications/sp800>. [Accessed 11 March 2019].
- [2] National Information Assurance Partnership (NIAP), "NIAP Home Page," [Online]. Available: <https://www.niap-ccevs.org>. [Accessed 11 March 2019].
- [3] Department of Homeland Security, "Home Page," [Online]. Available: <https://www.dhs.gov/>. [Accessed 15 May 2019].
- [4] Federal Chief Information Officers (CIO) Council, "Federal CIO Home Page," [Online]. Available: <https://www.cio.gov/>. [Accessed 11 March 2019].
- [5] National Institute of Standards and Technology (NIST), "NIST Cybersecurity Framework, Framework for Improving Critical Infrastructure Cybersecurity, Version 1.1," 16 April 2018. [Online]. Available: <https://www.nist.gov/cyberframework>. [Accessed 20 April 2018].
- [6] National Institute of Standards and Technology (NIST), "Mobile Threat Catalogue," [Online]. Available: <https://pages.nist.gov/mobile-threat-catalogue/>. [Accessed 8 March 2019].
- [7] National Institute of Standards and Technology (NIST), "Risk Management Framework (RMF) Overview," [Online]. Available: <https://csrc.nist.gov/Projects/Risk-Management/rmf-overview>. [Accessed 8 March 2019].
- [8] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 1800-4, Mobile Device Security: Cloud and Hybrid Builds," 21 February 2019. [Online]. Available: <https://www.nccoe.nist.gov/projects/building-blocks/mobile-device-security/cloud-hybrid>. [Accessed 8 March 2019].
- [9] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 800-30 Revision 1, Guide for Conducting Risk Assessments," September 2012. [Online]. Available: <https://csrc.nist.gov/publications/detail/sp/800-30/rev-1/final>. [Accessed 26 November 2018].

- [10] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 800-37, Revision 2, Risk Management Framework for Information Systems and Organizations, A System Life Cycle Approach for Security and Privacy," December 2018. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-37r2.pdf>. [Accessed 11 March 2019].
- [11] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 800-46 Revision 2, Guide to Enterprise Telework, Remote Access, and Bring Your Own Device (BYOD) Security," July 2016. [Online]. Available: <https://csrc.nist.gov/publications/detail/sp/800-46/rev-2/final>. [Accessed 8 March 2019].
- [12] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 800-52, Revision 1, Guidelines for the Selection, Configuration, and Use of Transport Layer Security (TLS) Implementations," April 2014. [Online]. Available: <https://csrc.nist.gov/publications/detail/sp/800-52/rev-1/final>. [Accessed 11 March 2019].
- [13] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 800-53 Revision 4, Security and Privacy Controls for Federal Information Systems and Organizations," 22 January 2015. [Online]. Available: <https://csrc.nist.gov/publications/detail/sp/800-53/rev-4/final>. [Accessed 23 January 2019].
- [14] National Institute of Standards and Technology (NIST), "Digital Identity Guidelines," June 2017. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-63-3.pdf>. [Accessed 8 March 2019].
- [15] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 800-113 Guide to SSL VPNs," July 2008. [Online]. Available: <https://csrc.nist.gov/publications/detail/sp/800-113/final>. [Accessed 8 March 2019].
- [16] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 800-114 Revision 1, User's Guide to Telework and Bring Your Own Device (BYOD) Security," July 2016. [Online]. Available: <https://csrc.nist.gov/publications/detail/sp/800-114/rev-1/final>. [Accessed 8 March 2019].

- [17] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 800-124 Revision 1, Guidelines for Managing the Security of Mobile Devices in the Enterprise," June 2013. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-124r1.pdf>. [Accessed 8 March 2019].
- [18] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 800-163 Revision 1, Vetting the Security of Mobile Applications," April 2019. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-163r1.pdf>. [Accessed 26 April 2019].
- [19] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 800-171, Protecting Controlled Unclassified Information in Nonfederal Systems and Organizations," December 2016. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-171r1.pdf>. [Accessed 8 March 2019].
- [20] National Institute of Standards and Technology (NIST), "NIST SP 800-181, National Initiative for Cybersecurity Education (NICE) Cybersecurity Workforce Framework," August 2017. [Online]. Available: <https://csrc.nist.gov/publications/detail/sp/800-181/final>. [Accessed 1 May 2019].
- [21] Center for Internet Security, "Center for Internet Security Home Page," [Online]. Available: <https://www.cisecurity.org/>. [Accessed 29 April 2019].
- [22] Executive Office of the President, "Bring Your Own Device, A Toolkit to Support Federal Agencies Implementing Bring Your Own Device (BYOD) Programs," 23 August 2012. [Online]. Available: <https://obamawhitehouse.archives.gov/digitalgov/bring-your-own-device>. [Accessed 15 April 2019].
- [23] Federal CIO Council and Department of Homeland Security, "Mobile Security Reference Architecture Version 1.0," 23 May 2013. [Online]. Available: <https://s3.amazonaws.com/sitesusa/wp-content/uploads/sites/1151/2016/10/Mobile-Security-Reference-Architecture.pdf>. [Accessed 8 March 2019].

- [24] Digital Services Advisory Group and Federal Chief Information Officers Council, "Government Use of Mobile Technology Barriers, Opportunities, and Gap Analysis," December 2012. [Online]. Available: https://s3.amazonaws.com/sitesusa/wp-content/uploads/sites/1151/2016/10/Government_Mobile_Technology_Barriers_Opportunities_and_Gaps.pdf. [Accessed 8 March 2019].
- [25] International Organization for Standardization, "ISO/IEC 27001:2013 Information technology - Security techniques -- Information security management systems -- Requirements," October 2013. [Online]. Available: <https://www.iso.org/standard/54534.html>. [Accessed 26 June 2019].
- [26] "Mobile Computing Decision," [Online]. Available: <https://s3.amazonaws.com/sitesusa/wp-content/uploads/sites/1151/2016/10/Mobile-Security-Decision-Framework-Appendix-B.pdf>. [Accessed 8 March 2019].
- [27] Mobile Services Category Team (MSCT) Advanced Technology Academic Research Center (ATARC), "Mobility Strategy Development Guidelines Working Group Document," June 2017. [Online]. Available: https://hallways.cap.gsa.gov/app/#/gateway/mobile-services-category-team/9658/docs/12997/Agency_Mobility_Strategy_Deliverable.pdf. [Accessed 8 March 2019].
- [28] Mobile Services Category Team (MSCT) Advanced Technology Academic Research Center (ATARC), "Mobile Threat Protection App Vetting and App Security Working Group Document," July 2017. [Online]. Available: https://hallways.cap.gsa.gov/app/#/gateway/mobile-services-category-team/9658/docs/12996/Mobile_Threat_Protection_Deliverable.pdf. [Accessed 8 March 2019].
- [29] Mobile Services Category Team (MSCT), "Device Procurement and Management Guidance," November 2016. [Online]. Available: <https://hallways.cap.gsa.gov/app/#/gateway/information-technology/4485/mobile-device-procurement-and-management-guidance>. [Accessed 8 March 2019].
- [30] Mobile Services Category Team (MSCT), "Mobile Device Management (MDM) MDM Working Group Document," August 2017. [Online]. Available: https://s3.amazonaws.com/sitesusa/wp-content/uploads/sites/1197/2017/10/EMM_Deliverable.pdf. [Accessed 8 March 2019].
- [31] Mobile Services Category Team (MSCT), "Mobile Services Roadmap (MSCT Strategic Approach)," 23 September 2016. [Online]. Available: <https://atarc.org/project/mobile-services-roadmap-msct-strategic-approach/>. [Accessed 8 March 2019].

- [32] National Information Assurance Partnership (NIAP), "NIAP U.S. Government Approved Protection Profile - Extended Package for Mobile Device Management Agents Version 3.0," 21 November 2016. [Online]. Available: <https://www.niap-ccevs.org/Profile/Info.cfm?PPID=403&id=403>. [Accessed 8 March 2019].
- [33] National Information Assurance Partnership (NIAP), "U.S. Government Approved Protection Profile - Protection Profile for Mobile Device Fundamentals Version 3.1," 16 June 2017. [Online]. Available: <https://www.niap-ccevs.org/Profile/PP.cfm>. [Accessed 8 March 2019].
- [34] National Information Assurance Partnership (NIAP), "U.S. Government Approved Protection Profile - Protection Profile for Mobile Device Management Version 3.0," 21 November 2016. [Online]. Available: <https://www.niap-ccevs.org/Profile/PP.cfm>. [Accessed 8 March 2019].
- [35] National Information Assurance Partnership (NIAP), "Product Compliant List," [Online]. Available: <https://www.niap-ccevs.org/Product/>. [Accessed 8 March 2019].
- [36] United States Office of Management and Budget (OMB), "Category Management Policy 16-3: Improving the Acquisition and Management of Common Information Technology: Mobile Devices and Services," 4 August 2016. [Online]. Available: https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/memoranda/2016/m_16_20.pdf. [Accessed 8 March 2019].
- [37] National Institute of Standards and Technology (NIST), "United States Government Configuration Baseline (In Development)," [Online]. Available: <https://csrc.nist.gov/Projects/United-States-Government-Configuration-Baseline>. [Accessed 8 March 2019].
- [38] Department of Homeland Security (DHS), "DHS Study on Mobile Device Security," April 2017. [Online]. Available: <https://www.dhs.gov/publication/csd-mobile-device-security-study>. [Accessed 8 March 2019].
- [39] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Mobile Device Security for Enterprises Building Block Version 2 Final Draft," 12 September 2014. [Online]. Available: <https://www.nccoe.nist.gov/sites/default/files/library/project-descriptions/mds-project-description-final.pdf>. [Accessed 26 November 2018].

- [40] International Organization for Standardization / International Electrotechnical Commission / Institute of Electrical and Electronics Engineers (ISO/IEC/IEEE), "International Organization for Standardization / International Electrotechnical Commission / Institute of Electrical and Electronics Engineers (ISO/IEC/IEEE) 15288:2015, Systems and software engineering – System life cycle processes," 2015. [Online]. Available: <https://www.iso.org/standard/63711.html>. [Accessed 26 November 2018].
- [41] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 800-160 Volume 1: Systems Security Engineering: Considerations for a Multidisciplinary Approach in the Engineering of Trustworthy Secure Systems," November 2016. [Online]. Available: <https://csrc.nist.gov/publications/detail/sp/800-160/vol-1/final>. [Accessed 26 November 2018].
- [42] Tech Times, "Flashlight apps are spying on users Android, iOS, Windows Phone smartphones, is yours on the list?," 26 October 2014. [Online]. Available: <https://www.techtimes.com/articles/18762/20141026/flashlight-apps-are-spying-on-users-android-ios-windows-phone-smartphones-is-yours-on-the-list.htm>. [Accessed 13 May 2019].
- [43] National Institute of Standards and Technology (NIST), "NIST Privacy Risk Assessment Methodology (PRAM)," [Online]. Available: <https://www.nist.gov/itl/applied-cybersecurity/privacy-engineering/resources>. [Accessed 17 July 2019].
- [44] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Internal Report (NISTIR) 8062, An Introduction to Privacy Engineering and Risk Management in Federal Systems," January 2017. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/ir/2017/NIST.IR.8062.pdf>. [Accessed 28 November 2018].
- [45] M. A. A. B. Mohamed Sabt, "Trusted Execution Environment: What It is, and What It is Not. 14th IEEE International Conference on Trust, Security and Privacy in Computing and Communications, Helsinki, Finland," August 2015. [Online]. Available: https://hal.archives-ouvertes.fr/hal-01246364/file/trustcom_2015_tee_what_it_is_what_it_is_not.pdf. [Accessed 28 November 2018].
- [46] Zimperium, "MobileIron Threat Defense, Mobile Device Security & MDM," [Online]. Available: <https://www.zimperium.com/partners/mobileiron>. [Accessed 22 May 2019].

- [47] National Information Assurance Partnership (NIAP), "U.S. Government Approved Protection Profile - Extended Package for Mobile Device Management Agents Version 3.0," 21 November 2016. [Online]. Available: <https://www.niap-ccevs.org/Profile/PP.cfm>. [Accessed 28 November 2018].
- [48] National Information Assurance Partnership (NIAP), "U.S. Government Approved Protection Profile - Extended Package for VPN Gateways Version 2.1," 8 March 2017. [Online]. Available: <https://www.niap-ccevs.org/Profile/PP.cfm>. [Accessed 28 November 2018].
- [49] National Information Assurance Partnership (NIAP), "U.S. Government Approved Protection Profile - Collaborative Protection Profile for Network Devices Version 2.0 + Errata 20180314," 14 March 2018. [Online]. Available: <https://www.niap-ccevs.org/Profile/PP.cfm>. [Accessed 28 November 2018].
- [50] National Information Assurance Partnership, "Approved Protection Profiles," [Online]. Available: <https://www.niap-ccevs.org/Profile/PP.cfm>. [Accessed 11 March 2019].
- [51] Qualcomm, "Qualcomm Secure Boot and Image Authentication Technical Overview," [Online]. Available: <https://www.qualcomm.com/media/documents/files/secure-boot-and-image-authentication-technical-overview.pdf>. [Accessed 16 April 2019].
- [52] Palo Alto Networks, "Remote Access VPN (Certificate Profile)," [Online]. Available: <https://docs.paloaltonetworks.com/globalprotect/8-0/globalprotect-admin/globalprotect-quick-configs/remote-access-vpn-certificate-profile.html#>. [Accessed 16 April 2019].
- [53] MobileIron, "Admin Google Android Google Apps API," [Online]. Available: http://mi.extendedhelp.mobileiron.com/45/all/en/desktop/Google_Apps_API.htm. [Accessed 16 April 2019].
- [54] MobileIron, "MobileIron unified endpoint security platform," [Online]. Available: <https://www.mobileiron.com/en/unified-endpoint-management/platform>. [Accessed 16 April 2019].
- [55] Open Web Application Security Project (OWASP), [Online]. Available: https://www.owasp.org/index.php/Main_Page. [Accessed 3 May 2019].
- [56] Palo Alto Networks, "Always On VPN Configuration," [Online]. Available: <https://docs.paloaltonetworks.com/globalprotect/7-1/globalprotect-admin/globalprotect-quick-configs/always-on-vpn-configuration>. [Accessed 4 April 2019].

- [57] National Institute of Standards and Technology (NIST), "Cryptographic Module Validation Program," [Online]. Available: <https://csrc.nist.gov/projects/cryptographic-module-validation-program/standards>. [Accessed 11 March 2019].
- [58] Palo Alto Networks, "FIPS-CC Security Functions documentation site," [Online]. Available: <https://docs.paloaltonetworks.com/pan-os/8-0/pan-os-admin/certifications/fips-cc-security>. [Accessed 11 March 2019].
- [59] Apple Computer, "Apple at Work," [Online]. Available: <https://www.apple.com/business/it/>. [Accessed 11 March 2019].
- [60] Apple Computer, "Apple Configurator 2," [Online]. Available: <https://itunes.apple.com/us/app/apple-configurator-2/id1037126344?mt=12>. [Accessed 13 March 2019].
- [61] Apple Computer, "iOS Security iOS 12.3," November 2018. [Online]. Available: https://www.apple.com/business/site/docs/iOS_Security_Guide.pdf. [Accessed 19 July 2019].
- [62] Android.com, "Build a device policy controller," [Online]. Available: <https://developer.android.com/work/dpc/build-dpc>. [Accessed 13 March 2019].
- [63] Google.com, "Android Enterprise Fully managed device," [Online]. Available: <https://developers.google.com/android/work/requirements/fully-managed-device>. [Accessed 13 March 2019].
- [64] Google.com, "Android Enterprise Work profile," [Online]. Available: <https://developers.google.com/android/work/requirements/work-profile>. [Accessed 13 March 2019].
- [65] Android.com, "Work profiles on fully managed devices," [Online]. Available: <https://developers.google.com/android/work/requirements/work-profile>. [Accessed 13 March 2019].
- [66] Google.com, "Backup Your Mobile," [Online]. Available: <https://play.google.com/store/apps/details?id=com.backupyourmobile>. [Accessed 13 March 2019].
- [67] IDManagement.gov, "Federal Identity, Credential, and Access Management Architecture," [Online]. Available: <https://arch.idmanagement.gov/services/access/>. [Accessed 10 May 2019].

- [68] Committee on National Security Systems, "Committee on National Security Systems (CNSS) Glossary, Publication 4009," 6 April 2015. [Online]. Available: <https://www.cnss.gov/CNSS/issuances/Instructions.cfm>. [Accessed 1 May 2019].
- [69] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Internal Report (NISTIR) 8053, De-Identification of Personal Information," October 2015. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/ir/2015/NIST.IR.8053.pdf>. [Accessed 13 May 2019].
- [70] General Services Administration, "Chief Information Officers Council (CIOC)," [Online]. Available: <https://www.gsa.gov/about-us/organization/office-of-governmentwide-policy/office-of-shared-solutions-and-performance-improvement/chief-information-officers-council-cioc>. [Accessed 13 May 2019].
- [71] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 800-63-3, Digital Identity Guidelines," 1 December 2017. [Online]. Available: <https://csrc.nist.gov/publications/detail/sp/800-63/3/final>. [Accessed 31 January 2019].
- [72] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 800-126 Revision 3, The Technical Specification for the Security Content Automation Protocol (SCAP)," February 2018. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-126r3.pdf>. [Accessed 13 May 2019].
- [73] National Institute of Standards and Technology (NIST), "NISTIR 7711 Security Best Practices for the Electronic Transmission of Election Materials for UOCAVA Voters," September 2011. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/Legacy/IR/nistir7711.pdf>. [Accessed 13 May 2019].
- [74] National Institute of Standards and Technology (NIST), "NIST Special Publication 800-82 Revision 2, Guide to Industrial Control Systems (ICS) Security," May 2015. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-82r2.pdf>. [Accessed 1 May 2019].
- [75] National Institute of Standards and Technology (NIST), "Risk Assessment Tools," [Online]. Available: <https://www.nist.gov/itl/applied-cybersecurity/privacy-engineering/collaboration-space/browse/risk-assessment-tools>. [Accessed 13 May 2019].

- [76] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication 800-88, Revision 1, Guidelines for Media Sanitization," December 2014. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-88r1.pdf>. [Accessed 13 May 2019].
- [77] National Institute of Standards and Technology (NIST), "Risk Management Framework: Quick Start Guide," [Online]. Available: <https://csrc.nist.gov/projects/risk-management/risk-management-framework-quick-start-guides>. [Accessed 13 May 2019].
- [78] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 800-150, Guide to Cyber Threat Information Sharing," October 2016. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-150.pdf>. [Accessed 13 May 2019].
- [79] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Special Publication (SP) 800-32, Introduction to Public Key Technology and the Federal PKI Infrastructure," February 2001. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-32.pdf>. [Accessed 1 May 2019].
- [80] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Interagency Report (NISTIR) 8011 Volume 1, Automation Support for Security Control Assessments," June 2017. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/ir/2017/NIST.IR.8011-1.pdf>. [Accessed 13 May 2019].
- [81] United States Department of Homeland Security, "ICS-CERT Monitor," October, November, December 2013. [Online]. Available: https://ics-cert.us-cert.gov/sites/default/files/Monitors/ICS-CERT_Monitor_Oct-Dec2013.pdf. [Accessed 10 May 2019].
- [82] Android, "Android zero-touch enrollment," [Online]. Available: <https://www.android.com/enterprise/management/zero-touch/>. [Accessed 8 April 2019].
- [83] Google, "Android's enterprise requirements," [Online]. Available: <https://support.google.com/work/android/answer/6174145?hl=en>. [Accessed 16 April 2019].
- [84] Apple, "Business Support," [Online]. Available: <https://support.apple.com/business>. [Accessed 8 April 2019].

- [85] Apple, "Configuration Profile," 25 March 2019. [Online]. Available: <https://developer.apple.com/business/documentation/Configuration-Profile-Reference.pdf>. [Accessed 16 April 2019].
- [86] Samsung, "Knox Mobile Enrollment," [Online]. Available: <https://www.samsungknox.com/en/solutions/it-solutions/knox-mobile-enrollment>. [Accessed 16 April 2019].
- [87] Samsung, "Secured by Knox," [Online]. Available: <https://www.samsungknox.com/en/secured-by-knox>. [Accessed 16 April 2019].
- [88] Samsung, "Devices built on Knox," [Online]. Available: <https://www.samsungknox.com/en/knox-platform/supported-devices>. [Accessed 16 April 2019].
- [89] The MITRE Corporation, "ATT&CK," 21 November 2018. [Online]. Available: <https://attack.mitre.org/>.
- [90] National Institute of Standards and Technology (NIST), "National Institute of Standards and Technology (NIST) Interagency Report (NISTIR) 8144 (DRAFT), Assessing Threats to Mobile Devices & Infrastructure: the Mobile Threat Catalogue," [Online]. Available: <https://csrc.nist.gov/publications/detail/nistir/8144/draft>. [Accessed 21 November 2018].
- [91] The MITRE Corporation, "ATT&CK for Mobile," [Online]. Available: <https://attack.mitre.org/resources/mobile-introduction/>. [Accessed 21 November 2018].
- [92] The MITRE Corporation, "Common Vulnerabilities and Exposures (CVEs)," [Online]. Available: <http://cve.mitre.org/>. [Accessed 24 02 2019].
- [93] FedRAMP, "FedRAMP Home Page," [Online]. Available: <https://www.fedramp.gov/>. [Accessed 24 02 2019].
- [94] National Institute of Standards and Technology (NIST), "NIST Information Technology Laboratory National Vulnerability Database," [Online]. Available: <https://nvd.nist.gov/>. [Accessed 21 November 2018].
- [95] Android Open Source Project, "Pixel/Nexus Security Bulletins," [Online]. Available: <https://source.android.com/security/bulletin/pixel/>. [Accessed 26 November 2018].
- [96] Apple Computers, "Apple Security Updates," [Online]. Available: <https://support.apple.com/en-us/HT201222>. [Accessed 26 November 2018].

- [97] Apple, "Managing Devices & Corporate Data on iOS," July 2018. [Online]. Available: https://www.apple.com/business/resources/docs/Managing_Devices_and_Corporate_Data_on_iOS.pdf. [Accessed 6 March 2019].
- [98] Samsung, "Android Security Updates," [Online]. Available: <https://security.samsungmobile.com/securityUpdate.smsb>. [Accessed 26 November 2018].
- [99] Samsung, "Knox Mobile Enrollment," [Online]. Available: <https://www.samsungknox.com/en/solutions/it-solutions/knox-mobile-enrollment>. [Accessed 8 April 2019].
- [100] Palo Alto Networks, "Wildfire Malware Analysis," [Online]. Available: <https://www.paloaltonetworks.com/products/secure-the-network/wildfire.html>. [Accessed 16 April 2019].

1665

1666

1667 **Appendix D Android, Apple, and Samsung Knox Mobile** 1668 **Enrollment**

1669 Device enrollment and management capabilities are available when deploying mobile devices in bulk.
1670 Certain settings can be preloaded, and devices can ship preconfigured for enterprise management. iOS-,
1671 Android-, and Samsung Knox-based devices integrate directly with Enterprise Mobility Management
1672 (EMM) solutions, providing enterprise-level management of security controls based on policy.

1673 **D.1 Android Devices**

1674 For Android devices, zero-touch enrollment provides an option different from the manual setup of
1675 Android devices. Android-based devices offer security controls that an EMM can leverage for enterprise
1676 deployments. The Android Enterprise program by Google is available on devices with Android 5.0
1677 (Lollipop) and higher. An EMM deploys a device policy controller as part of its on-device agent that
1678 controls local device policies and system applications on devices. Android Enterprise supports corporate-
1679 owned personally-enabled and bring your own device deployment scenarios through work-managed
1680 and work-profile device solutions [82], [83].

1681 **D.2 iOS Devices**

1682 For iOS devices, Apple Configurator supports Volume Purchase and Device Enrollment Program
1683 scenarios. Apple Business Manager provides a mobile device management solution to assist
1684 organizations in deploying iOS devices. iOS devices are managed by configuration profiles. Configuration
1685 profiles can force security policies such as virtual private network usage, enterprise Kerberos support,
1686 and access to cloud services. iOS further incorporates a set of additional security controls in what is
1687 termed supervised mode, which denotes a corporately owned device. Typically, organizations choose to
1688 use the Device Enrollment Program for large-scale deployments of iOS devices in supervised mode due
1689 to the reduction of labor involved in manually configuring each device. However, due to the small
1690 number of devices in our reference design, we have configured supervised mode using the Apple
1691 Configurator 2 tool. A more detailed description of iOS capabilities can be found in the iOS Security
1692 Guide [84], [85].

1693 **D.3 Samsung Knox Devices**

1694 Samsung Knox Mobile Enrollment provides the ability to add Samsung devices to the enterprise without
1695 manually enrolling each device. Samsung Knox Mobile Enrollment works on Samsung Galaxy devices
1696 running Android Lollipop or higher. It allows remote provisioning of devices when they connect to Wi-Fi
1697 or cellular networks. Samsung Knox Mobile Enrollment works with a number of EMM solutions,
1698 including cloud-based options [86], [87], [88].

1699

1700 **Appendix E Risk Assessment**

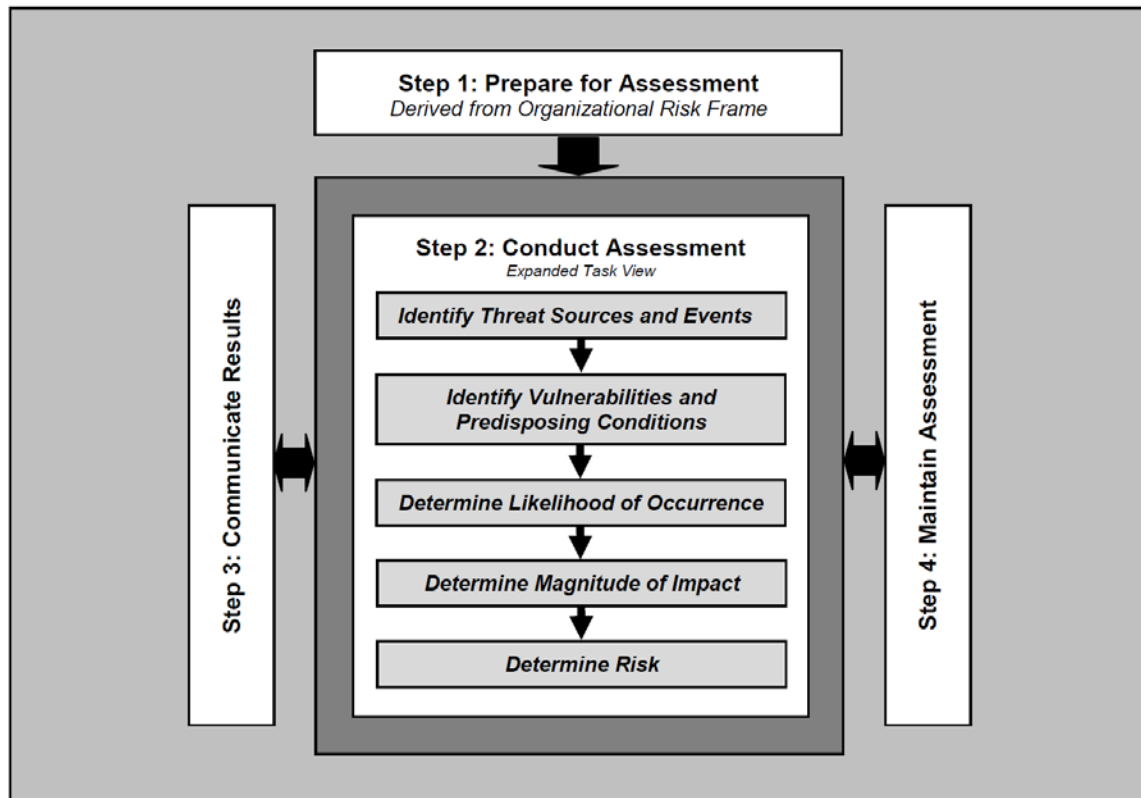
1701 **E.1 Risk Assessment**

1702 NIST SP 800-30 Revision 1, *Guide for Conducting Risk Assessments*, [9] states that risk is “a measure of
1703 the extent to which an entity is threatened by a potential circumstance or event, and typically a function
1704 of: (i) the adverse impacts that would arise if the circumstance or event occurs; and (ii) the likelihood of
1705 occurrence.” The guide further defines risk assessment as “the process of identifying, estimating, and
1706 prioritizing risks to organizational operations (including mission, functions, image, reputation),
1707 organizational assets, individuals, other organizations, and the Nation, resulting from the operation of
1708 an information system. Part of risk management incorporates threat and vulnerability analyses, and
1709 considers mitigations provided by security controls planned or in place.”

1710 The NCCoE recommends that any discussion of risk management, particularly at the enterprise level,
1711 begins with a comprehensive review of NIST SP 800-37 Revision 2, *Risk Management Framework for*
1712 *Information Systems and Organizations*—material that is available to the public. The Risk Management
1713 Framework (RMF) guidance, as a whole, proved to be invaluable in giving us a baseline to assess risks,
1714 from which we developed the project, the security characteristics of the build, and this guide.

1715 This section details the risk assessment undertaken to improve the mobile security posture of the
1716 fictional organization Orvilia Development. Typically, a National Institute of Standards and Technology
1717 (NIST) Special Publication (SP) 800-30 Revision 1-based risk assessment follows a four-step process as
1718 shown in Figure E-1: Prepare for assessment, conduct assessment, communicate results, and maintain
1719 assessment.

1720 Figure E-1 Risk Assessment Process



1721 To provide the most value in this exercise:

- 1722
- 1723 ■ We focused on the preparation, which established the context of the risk assessment.
 - 1724 ■ We conducted the risk assessment, which produced a list of information security risks that were prioritized by risk level and used to inform risk response decisions.
 - 1725 ■ We followed the process detailed in Section 3 of NIST SP 800-30 Revision 1 [9] to perform a risk
 - 1726 assessment of the current mobile infrastructure.

1727 We recommend that organizations performing a risk assessment communicate results and perform
 1728 maintenance of the risk assessment, but these activities were deemed out of scope for this project. The
 1729 following tasks were used during the assessment process.

1730 E.1.1 Task 1-1: Risk Assessment Purpose

1731 *Identify the purpose of the risk assessment in terms of the information that the assessment is intended to*
 1732 *produce and the decisions the assessment is intended to support.*

1733 The purpose of the risk assessment of Orvilia Development was to identify and document new risks to
1734 its mission resulting from addition of a mobility program.

1735 The results of the risk assessment informed decisions to Orvilia’s mobility deployment that included:

- 1736 ▪ implementation of new security mechanisms
- 1737 ▪ configuration changes to existing infrastructure
- 1738 ▪ updates to security and appropriate-use policies relevant to their mobility program

1739 E.1.2 Task 1-2: Risk Assessment Scope

1740 *Identify the scope of the risk assessment in terms of organizational applicability, time frame supported,*
1741 *and architectural/technology considerations.*

1742 **Organizational Applicability:**

1743 The scope of this risk assessment was limited to systems impacted by inclusion of a mobility program; it
1744 did not include existing information technology (IT) infrastructure to which no impact was anticipated.
1745 With their original architecture, Orvilia deployed corporate-owned personally-enabled (COPE) devices.
1746 Orvilia employees utilized mobile devices for local and remote work activities and limited personal
1747 activities (e.g., phone calls, messaging, social applications, and personal emails).

1748 With Orvilia’s new government contract, this risk assessment also evaluated Orvilia’s mobile
1749 deployment regarding its ability to access and store government data while meeting applicable
1750 information security and privacy requirements.

1751 While not directly associated with risk assessment activities, Orvilia will be required to demonstrate
1752 compliance with government standards and policies established to improve data security. Therefore,
1753 Orvilia needed to determine how compliance with government policy and application of its standards
1754 would best align with its strategy to identify, protect against, detect, respond to, and recover from threats
1755 related to its mobility program.

1756 **Time Frame Supported:**

1757 Because this was the first risk assessment performed by Orvilia, the process was more time-intensive
1758 than it will be in future risk management cycles. Orvilia completed the initial risk assessment within six
1759 months.

1760 **Architectural and Technology Considerations:**

1761 This risk assessment was scoped to Orvilia’s mobile deployment, which constitutes mobile devices used
1762 to access Orvilia enterprise resources along with any backend IT components used to manage or provide
1763 services to those mobile devices.

1764 The following provide an overview of the mobile deployment components involved in the original
1765 (current) Orvilia architecture.

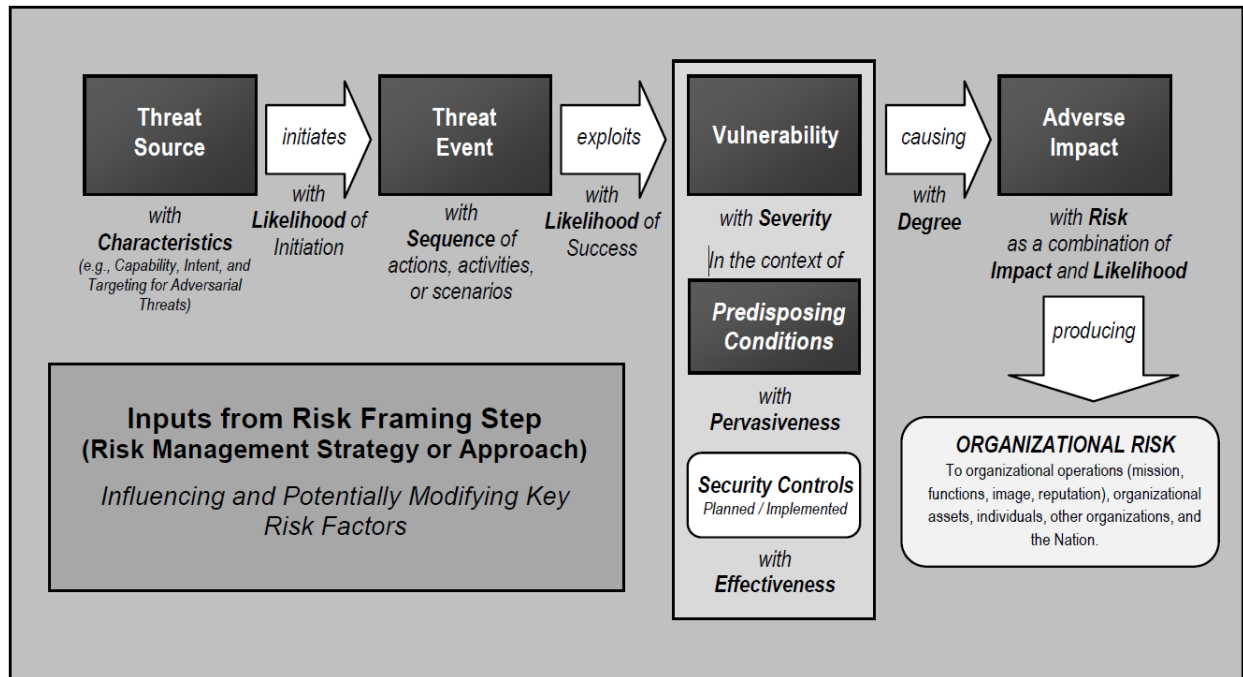
- 1766 ▪ **Mobile Device:** A mobile device is a small form factor device with a rich operating system, at
1767 least one wireless network interface, and the ability to run applications. These features are
1768 considered essential for Orvilia to have portable and efficient access to enterprise data.
- 1769 ▪ **Communication Networks and Data Transmission:** Mobile devices will establish connections to
1770 the internet by using their cellular or Wi-Fi adapters. As connections may be made to unsecured
1771 access points or may traverse untrusted networks, consideration will be given to the risks
1772 associated with the security of those connections and the data transmitted over them.
1773 Additionally, the organization will need to consider risks arising from permitting inbound
1774 connections by mobile devices via the internet.
- 1775 ▪ **Public Application Stores:** With a COPE deployment strategy, employees will have the option to
1776 download any mobile application available from official platform application stores (e.g., Google
1777 Play Store). While those platforms analyze applications for malicious behaviors, it is still possible
1778 for such applications to exceed Orvilia’s needs for user privacy or pose a risk to the devices or
1779 data. Therefore, risks from such applications should be included in this assessment.
- 1780 ▪ **Device and Operating System (OS) Vendor Infrastructure:** The hardware, firmware, and
1781 software that compose each model of mobile device can vary, particularly those from different
1782 manufacturers and vendors, which may incorporate technology that is exclusive to their
1783 products. It will be important to select devices that demonstrate security mechanisms that align
1784 with the organization’s risk mitigation strategy. However, risks that are specific to given device
1785 components (e.g., chipsets or driver versions) will be out of scope for this assessment.
- 1786 ▪ **Enterprise Systems:** If a potentially compromised mobile device can connect to the enterprise, it
1787 poses direct risks to any systems it can reach or data it can access. Such systems will reasonably
1788 include on-premises mobile application stores, mobile management technologies, email servers,
1789 file servers, and intranet web servers. Subsequent compromise of any of these systems may
1790 cascade to others not directly reachable by the mobile device. Risks to all such systems by a
1791 mobile device should be included in this assessment.

1792 E.1.3 Task 1-3: Risk Assessment Assumptions and Constraints

1793 *Identify the specific assumptions and constraints under which the risk assessment is conducted.*

1794 Risk assessment assumptions and constraints were developed using a NIST SP 800-30 Revision 1 Generic
1795 Risk Model as shown in Figure E-2.

1796 Figure E-2 NIST 800-30 Generic Risk Model



1797 *E.1.3.1 Risk Assessment Assumptions*

1798 Some of the threats and their resulting risks and impacts span several levels. In cases where these risks
 1799 and impacts have several possible levels, it was assumed that Orville would document these using a
 1800 high-water mark methodology. This assumption of greatest risk then provided the basis for risk
 1801 mitigation activities. For example, where the threat risk could pose a moderate, high, or very high
 1802 outcome, the very high outcome was selected, and these very high risks were prioritized for mitigation.

1803 *E.1.3.2 Risk Assessment Constraints*

1804 Information regarding the following were used as input for the constraints for the risk assessment.

- 1805 ▪ threat sources
- 1806 ▪ threat events
- 1807 ▪ vulnerabilities and predisposing conditions
- 1808 ▪ likelihood
- 1809 ▪ impacts
- 1810 ▪ risk assessment and analysis approaches
- 1811 ▪ resources available for the assessment

- 1812 ▪ skills and expertise

1813 **Threat Sources**

1814 Orvilia’s executives and managers identified two threat sources as possible concerns. Orvilia’s technical
1815 staff were provided security control mappings identified within this guide to help them understand the
1816 additional security that the example solution could provide to Orvilia as they implemented the example
1817 solution.

1818 Additionally, due to the cybersecurity-focused scope of the risk assessment, non-adversarial threat
1819 sources (e.g., unintentional hardware, software, or system design and architecture shortcoming threats)
1820 were not considered.

1821 As identified in Section E.1.6, Task 2-1: Identify and Characterize Threat Sources of Concern, the risk
1822 assessment identified the following threat sources of concern:

- 1823 ▪ Orvilia’s competitors
- 1824 ▪ nation-state actors

1825 **Threat Events**

- 1826 ▪ Threat events were described at a high level and in general terms within the risk assessment.
1827 Similar threat events were combined into a single, broader threat.
- 1828 ▪ Only those threat events that have been previously observed by an authoritative source were
1829 considered (e.g., reported as already having occurred by other organizations), drawing primarily
1830 from the NIST National Cybersecurity Center of Excellence Mobile Threat Catalogue [6].
- 1831 ▪ Threat events involving exploitation of vulnerabilities within the cellular network, including a
1832 mobile device’s cellular baseband, reasonably exceeded Orvilia’s ability to directly identify and
1833 mitigate them and were not further assessed.
- 1834 ▪ Threat events involving exploitation of vulnerabilities in low-level hardware, firmware, and
1835 device controllers reasonably exceeded Orvilia’s ability to directly identify and mitigate them
1836 and were not further assessed.
- 1837 ▪ Threat events involving exploitation of vulnerabilities in the supply chain reasonably exceeded
1838 Orvilia’s ability to directly identify and mitigate them and were not further assessed.

1839 **Vulnerabilities and Predisposing Conditions**

- 1840 ▪ Mobile device vulnerabilities considered during this risk assessment included those in mobile
1841 operating systems and mobile applications, including third-party software libraries.
- 1842 ▪ Vulnerabilities in commonly used noncellular network protocols such as Bluetooth and Wi-Fi
1843 were considered.

1844 ▪ Vulnerabilities related to a potential Enterprise Mobility Management (EMM) system were
1845 considered.

1846 ▪ Additional information and determinations were made via Appendix F of NIST SP 800-30
1847 Revision 1.

1848 **Likelihood**

1849 ▪ Likelihood determinations were made via Appendix G of NIST SP 800-30 Revision 1.

1850 Note: The rating of overall likelihood is derived from the Likelihood of Initiation and Likelihood that
1851 Threat Events Result from Adverse Impacts using Table G-5 of Appendix G in NIST SP 800-30 Revision 1
1852 [9]. Ratings of the latter two variables relied heavily on the subjective judgment of Orvilia employees.

1853 **Impacts**

1854 ▪ Impact determinations were made via Appendix H of NIST SP 800-30 Revision 1.

1855 Note: Ratings of impact relied heavily on the subjective judgment of Orvilia employees.

1856 **Risk Assessment and Analysis Approaches**

1857 ▪ This risk assessment focused on identifying an initial set of threats to Orvilia’s mobile
1858 deployment.

1859 ▪ Approaches for describing threats and their impact were informed by the Adversarial Tactics,
1860 Techniques, and Common Knowledge (ATT&CK) Framework [89].

1861 ▪ The rating of Risk was derived from both the overall likelihood and level of impact using Table I-
1862 2 of Appendix I in NIST SP 800-30 Revision 1 [9].

1863 **Resources Available for the Assessment**

1864 ▪ Orvilia ensured the appropriate staff with the requisite expertise were available to conduct the
1865 assessment within the time allotted.

1866 ▪ Orvilia provided funding for the risk analysis staff.

1867 ▪ Orvilia staff who conducted the risk assessment had the necessary information systems and
1868 software.

1869 **Skills and Expertise**

1870 ▪ Risk assessments were conducted by experts leveraging industry best practices and NIST risk
1871 assessment frameworks.

1872 **E.1.4 Task 1-4: Risk Assessment Threat, Vulnerability, and Impact Sources**

1873 *Identify the sources of descriptive threat, vulnerability, and impact information to be used in the risk*
1874 *assessment.*

1875 Orvilia used the following methods to identify mobile infrastructure threats, vulnerabilities, and impacts.

1876 *E.1.4.1 Sources of Threats*

1877 This risk assessment identified NIST’s Mobile Threat Catalogue (MTC) [6], along with its associated NIST
1878 Interagency Report 8144, *Assessing Threats to Mobile Devices & Infrastructure* [90], and MITRE’s
1879 ATT&CK Mobile Profile [91] as credible sources for threat information. Each entry in the MTC contains
1880 several pieces of information: an identifier, a category, a high-level description, details on its origin,
1881 exploit examples, Common Vulnerabilities and Exposures [92] examples, possible countermeasures, and
1882 academic references.

1883 MITRE’s ATT&CK is a curated knowledge base and model for cyber-adversary behavior. ATT&CK details
1884 specific techniques that can be used by cyber adversaries. Each technique entry typically includes a
1885 detailed technical description, mitigations, detection analytics, examples of use by malicious actors, and
1886 references. The ATT&CK model organizes these techniques into high-level malicious actor tactical
1887 objectives, referred to as tactics. A primary use case for ATT&CK is use by organizations to assess the
1888 state of their cybersecurity defenses and prioritize deployment of defensive capabilities. The ATT&CK
1889 Mobile Profile describes tactics and techniques specific to the mobile environment.

1890 Due to Orvilia’s current use of cloud services, it identified the outputs of the Federal Risk and
1891 Authorization Management Program [93] and associated NIST SP 800-53 security controls as being in
1892 scope for this risk assessment.

1893 *E.1.4.2 Sources of Vulnerabilities*

1894 Vulnerabilities are commonly associated with mobile operating systems, device drivers, mobile
1895 applications, and third-party libraries. However, vulnerabilities can be present in any level of the mobile
1896 technology stack. For up-to-date information regarding vulnerabilities, this risk assessment identified
1897 the National Vulnerability Database (NVD) [94] as a credible source of information. The NVD is the U.S.
1898 government repository of standards-based vulnerability management data. Use of NVD was
1899 supplemented by review of individual vendor vulnerability disclosures such as those published in the
1900 Pixel/Nexus Security Bulletins [95] for Android, Apple security updates [96] for iOS, Managing Devices &
1901 Corporate Data on iOS [97], and Android Security Updates [98] for Android-based Samsung devices.

1902 *E.1.4.3 Sources of Impacts*

1903 This risk assessment identified the scenario described in Section E.1.2 as the primary source of impact
1904 determination information. The scenario identified the following systems as being critical to the
1905 organization’s mission:

- 1906 ▪ Microsoft Active Directory domain
- 1907 ▪ Microsoft Exchange email server

- 1908 ▪ timekeeping web application
- 1909 ▪ travel support web application
- 1910 ▪ corporately owned mobile devices

1911 An example of a successful attack against a mobile device is one that could be used to glean the
 1912 credentials for the travel support web application and use them to penetrate the application server.
 1913 While Orvilia can absorb minimal downtime to the web application, the attacker could use this position
 1914 to gain a foothold in the Orvilia infrastructure to laterally move to more critical systems in the
 1915 environment, such as the email server. Compromise of the email server would have high impact,
 1916 possibly causing serious harm to the organization.

1917 **E.1.5 Task 1-5: Risk Assessment Risk Model and Analytic Approach Identification**

1918 *Identify the risk model and analytic approach to be used in the risk assessment.*

1919 In this risk assessment, the analytic approach used qualitative (i.e., subjective) ratings of risk (i.e., very
 1920 low, low, moderate, high, and very high). The approach was primarily threat oriented, as described in
 1921 section E.1.6.

1922 **E.1.6 Task 2-1: Identify and Characterize Threat Sources of Concern**

1923 *Identify and characterize threat sources of concern, including capability, intent, and targeting*
 1924 *characteristics for adversarial threats and range of effects for non-adversarial threats.*

1925 Orvilia examined NIST SP 800-30 Revision 1’s Table D-2: Taxonomy of Threat Sources [9] and identified
 1926 the following threat sources of concern:

1927 **Table E-1 Threat Sources of Concern**

Identifier	Threat Source	Description	Characteristic
TS-1	Adversarial, Organization, Competitor	Orvilia’s competitors seek to exploit dependence on cyber resources, specifically the data entrusted by its customers to increase market share.	Capability, Intent, Targeting
TS-2	Adversarial, Nation-State	Nation-state actors stealing sensitive government data from unsecured devices and infrastructure	Capability, Intent, Targeting

1928 Orvilia produced the following table as output of Task 2-1 to provide relevant inputs to the risk tables. It
 1929 identifies the threat sources identified in NIST SP 800-30 Revision 1 with the associated risk rating of

1930 capability, intent, and targeting score (using the previously mentioned five-point scale: very low, low,
 1931 moderate, high, and very high).

1932 Orvilia’s assessment found that all threat events could be initiated by both threat sources
 1933 (Organization/Competitor and Nation-State).

1934 Capability refers to the level of expertise of the malicious actor. Intent refers to the malicious actor’s
 1935 goal. Targeting refers to the reconnaissance and selection methods performed by the malicious actor.

1936 **Table E-2 Threat Sources Qualitative Scale**

Identifier	Threat Events Relevant to Threat Sources	In Scope	Capability	Intent	Targeting
TS-1	All threat events (Threat Events 1-12)	Yes	High	High	High
TS-2	All threat events (Threat Events 1-12)	Yes	Very High	Very High	Very High

1937 **E.1.7 Task 2-2: Identify Potential Threat Events**

1938 *Identify potential threat events, relevance of the events, and the threat sources that could initiate the*
 1939 *events.*

1940 The threat events used for the example solution are described below. These threat events describe how
 1941 the mobile devices in Orvilia might be compromised by malicious activities. All of the threat events map
 1942 to both threat sources identified in Section E.1.6.

1943 Orvilia examined the sample tables in NIST SP 800-30 Revision 1—Tables E-1, E-2, E-3, E-4, and E-5—and
 1944 analyzed the sources of mobile threats identified in Task 1-4. Using this process, Orvilia leadership
 1945 identified the following threat events.

1946 **E.1.7.1 Threat Event 1—Unauthorized Access to sensitive Information via a Malicious or**
 1947 **Privacy-Intrusive Application**

1948 A mobile application can attempt to collect and exfiltrate any information to which it has been granted
 1949 access. This includes any information generated during use of the application (e.g., user input), user-
 1950 granted permissions (e.g., contacts, calendar, call logs, camera roll), and general device data available to
 1951 any application (e.g., International Mobile Equipment Identity, device make and model, serial number).
 1952 Further, if a malicious application exploits a vulnerability in other applications, the OS, or device

1953 firmware to achieve privilege escalation, it may gain unauthorized access to any data stored on or
1954 otherwise accessible through the device.

1955 *E.1.7.2 Threat Event 2—Theft of credentials Through an SMS or Email Phishing Campaign*

1956 Malicious actors may create fraudulent websites that mimic the appearance and behavior of legitimate
1957 ones and entice users to authenticate to them by distributing phishing messages over short message
1958 service (SMS) or email. Effective use of social engineering techniques such as impersonating an authority
1959 figure or creating a sense of urgency may compel users to forgo scrutiny of the message and proceed to
1960 authenticate to the fraudulent website; it then captures and stores the user’s credentials before
1961 (usually) forwarding them to the legitimate website to allay suspicion.

1962 *E.1.7.3 Threat Event 3—Malicious Applications Installed via URLs in SMS or Email* 1963 *Messages*

1964 Malicious actors may send users SMS or email messages that contain a uniform resource locator (URL)
1965 where a malicious application is hosted. Generally, such messages are crafted using social engineering
1966 techniques designed to dissuade recipients from scrutinizing the nature of the message, thereby
1967 increasing the likelihood they access the URL by using their mobile device. If the URL is accessed, the
1968 device will attempt to download and install the application. Effective use of social engineering by the
1969 attacker will further compel an otherwise suspicious user to grant any trust required by the developer
1970 and all permissions requested by the application. Granting the former facilitates installation of other
1971 malicious applications by the same developer, and granting the latter increases the potential for the
1972 application to do direct harm.

1973 *E.1.7.4 Threat Event 4—Confidentiality and Integrity Loss due to Exploitation of Known* 1974 *Vulnerability in the OS or Firmware*

1975 When malware successfully exploits a code execution vulnerability in the mobile OS or device drivers,
1976 the delivered code generally executes with elevated privileges and issues commands in the context of
1977 the root user or the OS kernel. This may be enough for some to accomplish their goal, but advanced
1978 malicious actors will usually attempt to install additional malicious tools and to establish a persistent
1979 presence. If successful, the attacker will be able to launch further attacks against the user, the device, or
1980 any other systems to which the device connects. As a result, any data stored on, generated by, or
1981 accessible to the device at that time—or in the future—may be compromised.

1982 *E.1.7.5 Threat Event 5—Violation of Privacy via Misuse of Device Sensors*

1983 Malicious actors with access (authorized or unauthorized) to device sensors (microphone, camera,
1984 gyroscope, Global Positioning System receiver, and radios) can use them to conduct surveillance. It may
1985 be directed at the user, as when tracking the device location, or it may be applied more generally, as
1986 when recording any nearby sounds. Captured sensor data, such as a recording of an executive meeting,

1987 may be immediately useful to a malicious actor. Alternatively, the data may be analyzed in isolation or in
 1988 combination with other data to yield sensitive information. For example, audio recordings of on-device
 1989 or proximate activity can be used to probabilistically determine user inputs to touchscreens and
 1990 keyboards—essentially turning the device into a remote keylogger.

1991 *E.1.7.6 Threat Event 6—Compromise of the Integrity of the Device or Its Network*
 1992 *Communications via Installation of Malicious EMM/MDM, Network, VPN Profiles,*
 1993 *or Certificates*

1994 Malicious actors who successfully install an EMM/mobile device management (MDM), network, or
 1995 virtual private network (VPN) profile or certificate onto a device will gain a measure of additional control
 1996 over the device or its communications. Presence of an EMM/MDM profile will allow an attacker to
 1997 misuse existing OS application programming interfaces to send the device a wide variety of commands.
 1998 This may allow a malicious actor to obtain device information, install or restrict applications, or remotely
 1999 locate, lock, or wipe the device. Malicious network profiles may allow a malicious actor to automatically
 2000 compel the device to connect to access points under their control to achieve a man-in-the-middle attack
 2001 on all outbound connections. Alternatively, VPN profiles assist in the undetected exfiltration of sensitive
 2002 data by encrypting it, thus hiding it from network scanning tools. Additionally, malicious certificates may
 2003 allow the malicious actor to compel the device to automatically trust connections to malicious web
 2004 servers, wireless access points, or installation of applications under their control.

2005 *E.1.7.7 Threat Event 7—Loss of Confidentiality of Sensitive Information via Eavesdropping*
 2006 *on Unencrypted Device Communications*

2007 Malicious actors can readily eavesdrop on communication over unencrypted, wireless networks such as
 2008 public Wi-Fi access points, which are commonly provided by coffee shops and hotels. While a device is
 2009 connected to such a network, an attacker would gain unauthorized access to any data sent or received
 2010 by the device for any session not already protected by encryption at either the transport or application
 2011 layers. Even if the transmitted data were encrypted, an attacker would be privy to the domains, internet
 2012 protocol addresses, and services (as indicated by port numbers) to which the device connects; such
 2013 information could be used in future watering hole attacks or man-in-the-middle attacks against the
 2014 device user. Additionally, visibility into network layer traffic enables a malicious actor to conduct side-
 2015 channel attacks against its encrypted messages, which can still result in a loss of confidentiality. Further,
 2016 eavesdropping on unencrypted messages during a handshake to establish an encrypted session with
 2017 another host or endpoint may facilitate attacks that ultimately compromise the security of the session.

2018 *E.1.7.8 Threat Event 8—Compromise of Device Integrity via Observed, Inferred, or Brute-*
 2019 *Forced Device Unlock Code*

2020 A malicious actor may be able to obtain a user's device unlock code by direct observation, side-channel
 2021 attacks, or brute-force attacks. Both the first and second can be attempted with at least proximity to the

2022 device; only the third technique requires physical access. However, side-channel attacks that infer the
2023 unlock code by detecting taps and swipes to the screen can be attempted by applications with access to
2024 any peripherals that detect sound or motion (e.g., microphone, gyroscope, or accelerometer). Once the
2025 device unlock code has been obtained, a malicious actor with physical access to the device will gain
2026 immediate access to any data or functionality not already protected by additional access control
2027 mechanisms. Additionally, if the user employs the device unlock code as a credential to any other
2028 systems, the malicious actor may further gain unauthorized access to those systems.

2029 *E.1.7.9 Threat Event 9—Unauthorized Access to Backend Services via Authentication or*
2030 *Credential Storage Vulnerabilities in Internally Developed Applications*

2031 If a malicious actor gains unauthorized access to a mobile device, the malicious actor also has access to
2032 the data and applications on that mobile device. The mobile device may contain an organization’s in-
2033 house applications and can subsequently gain access to sensitive data or backend services. This could
2034 result from weaknesses or vulnerabilities present in the authentication or credential storage
2035 mechanisms implemented within an in-house application.

2036 *E.1.7.10 Threat Event 10—Unauthorized Access of Enterprise Resources from an*
2037 *Unmanaged and Potentially Compromised Device*

2038 An employee who accesses enterprise resources from an unmanaged mobile device may expose the
2039 enterprise to vulnerabilities that may compromise enterprise data. Unmanaged devices do not benefit
2040 from security mechanisms deployed by the organization such as mobile threat defense, mobile threat
2041 intelligence, application vetting services, and mobile security policies. These unmanaged devices limit an
2042 organization’s visibility into the state of a mobile device, including if the device is compromised by a
2043 malicious actor. Therefore, users who violate security policies to gain unauthorized access to enterprise
2044 resources from such devices risk providing malicious actors with access to sensitive organizational data,
2045 services, and systems.

2046 *E.1.7.11 Threat Event 11—Loss of Organizational Data due to a Lost or Stolen Device*

2047 Due to the nature of the small form factor of mobile devices, they are easy to misplace or be stolen. A
2048 malicious actor who gains physical custody of a device with inadequate security controls may be able to
2049 gain unauthorized access to sensitive data or resources accessible to the device.

2050 *E.1.7.12 Threat Event 12—Loss of Confidentiality of Organizational Data due to Its*
2051 *Unauthorized Storage to Non-Organizationally Managed Services*

2052 If employees violate data management policies by using unmanaged services to store sensitive
2053 organizational data, the data will be placed outside organizational control, where the organization can
2054 no longer protect its confidentiality, integrity, or availability. Malicious actors who compromise the

2055 unauthorized service account or any system hosting that account may gain unauthorized access to the
 2056 data.

2057 Further, storage of sensitive data in an unmanaged service may subject the user or the organization to
 2058 prosecution for violation of any applicable laws (e.g., exportation of encryption) and may complicate
 2059 efforts by the organization to achieve remediation or recovery from any future losses, such as those
 2060 resulting from the public disclosure of trade secrets.

2061 **E.1.8 Task 2-3: Identify Vulnerabilities and Predisposing Conditions**

2062 *Identify vulnerabilities and predisposing conditions that affect the likelihood that threat events of*
 2063 *concern result in adverse impacts.*

2064 Drawing on the scenario described in Section 3.2.1 of NIST SP 800-30 Revision 1, there existed
 2065 vulnerabilities and predisposing conditions that increased the likelihood that identified threat events
 2066 would result in adverse impacts for Orvilia. Each vulnerability or predisposing condition is listed in the
 2067 table below along with the corresponding threat events.

2068 The methodology used to rate the level of pervasiveness was qualitative (i.e., subjective) and used a
 2069 five-point scale.

- 2070 ▪ Very High
- 2071 ▪ High
- 2072 ▪ Moderate
- 2073 ▪ Low
- 2074 ▪ Very Low

2075 **Table E-3 Identify Vulnerabilities and Predisposing Conditions**

Vulnerability ID	Vulnerability or Predisposing Condition	Resulting Threat Events	Pervasiveness
VULN-1	Email and other enterprise resources can be accessed from anywhere, and only username/password authentication is required.	TE-2, TE-10, TE-11	Very High
VULN-2	Public Wi-Fi networks are regularly used by employees for remote connectivity from their corporate mobile devices.	TE-7	Very High

Vulnerability ID	Vulnerability or Predisposing Condition	Resulting Threat Events	Pervasiveness
VULN-3	No EMM/MDM deployment exists to enforce and monitor compliance with security-relevant policies on corporate mobile devices.	TE-1, TE-3, TE-4, TE-5, TE-6, TE-7, TE-8, TE-9, TE-11, TE-12	Very High

2076 **Note 1:** Ratings of the level of pervasiveness were based on the qualitative scale found in Table F-5 of
 2077 Appendix F in NIST SP 800-30 Revision 1 [9].

2078 **Note 2:** Ratings of pervasiveness indicate that the vulnerabilities apply few (i.e., very low), some (i.e.,
 2079 low), many (i.e., moderate), most (i.e., high), or all (i.e., very high) organizational missions/business
 2080 functions and processes, or information systems.

2081 E.1.9 Task 2-4: Determine Likelihood of a Threat and the Likelihood of the Threat 2082 Having Adverse Impacts

2083 *Determine the likelihood that threat events of concern result in adverse impacts, considering (i) the*
 2084 *characteristics of the threat sources that could initiate the events; (ii) the vulnerabilities/predisposing*
 2085 *conditions identified; and (iii) the organizational susceptibility reflecting the*
 2086 *safeguards/countermeasures planned or implemented to impede such events.*

2087 In the interest of brevity, the threat events of concern identified in Task 2-2 were limited to those
 2088 presumed to have a foreseeably high likelihood of occurrence.

2089 The methodology used to identify the likelihood of threats of concern was qualitative (i.e., subjective)
 2090 and used the following five-point scale.

- 2091 ▪ Very High
- 2092 ▪ High
- 2093 ▪ Moderate
- 2094 ▪ Low
- 2095 ▪ Very Low

2096 Table E-4 Likelihood of Threat Events of Concern

Threat ID	Likelihood of Threat Event Initiation	Likelihood of Threat Event Resulting in Adverse Impacts	Overall Likelihood
TE-1	High	Very High	Very High
TE-2	Very High	High	Very High
TE-3	High	High	High
TE-4	Moderate	Very High	High
TE-5	High	Very High	Very High
TE-6	Moderate	High	Moderate
TE-7	High	High	High
TE-8	Moderate	High	High
TE-9	Moderate	High	Very High
TE-10	High	Very High	Very High
TE-11	Very High	Very High	Very High
TE-12	High	High	High

2097 **Note 1:** For the Likelihood of Threat Event Initiation, the ratings translate as follows: Moderate =
 2098 malicious actor is somewhat likely to initiate; High = malicious actor is highly likely to initiate; Very high =
 2099 malicious actor is almost certain to initiate.

2100 **Note 2:** For the Likelihood of Threat Event Resulting in Adverse Impacts, the ratings translate as follows:
 2101 Moderate = if the threat is initiated, it is somewhat likely to have adverse impacts; High = if the threat is
 2102 initiated, it is highly likely to have adverse impacts; Very high = if the threat is initiated, it is almost
 2103 certain to have adverse impacts.

2104 **Note 3:** Overall likelihood was calculated based on the qualitative scale found in Table G-3 of Appendix
 2105 G in NIST SP 800-30 Revision 1 [9]. It is derived from both the Likelihood of Threat Event Initiation and

2106 Likelihood of Threat Event Resulting in Adverse Impacts. Because these scales are not true interval
 2107 scales, the combined overall ratings do not always reflect a strict mathematical average of the two
 2108 ratings.

2109 **E.1.10 Task 2-5: Determine the Extent of Adverse Impacts**

2110 *Determine the adverse impacts from threat events of concern considering (i) the characteristics of the*
 2111 *threat sources that could initiate the events; (ii) the vulnerabilities/predisposing conditions identified;*
 2112 *and (iii) the susceptibility reflecting the safeguards/countermeasures planned or implemented to impede*
 2113 *such events.*

2114 Threat events with a high potential for adverse impacts were then identified in our specific scenario.

2115 The methodology used to determine the extent of adverse impacts was qualitative (i.e., subjective) and
 2116 used the following five-point scale.

- 2117 ▪ Very High
- 2118 ▪ High
- 2119 ▪ Moderate
- 2120 ▪ Low
- 2121 ▪ Very Low

2122 **Table E-5 Potential Adverse Impacts**

Threat ID	Type of Impact	Impact Affected Asset	Maximum Impact
TE-1	Harm to Operations, Assets, Individuals	Inability, or limited ability, to perform missions/business functions in the future Damage to or loss of information systems or networks	High
TE-2	Harm to Operations, Other Organizations	Inability, or limited ability, to perform missions/business functions in the future	High
TE-3	Harm to Operations, Assets	Inability, or limited ability, to perform missions/business functions in the future	High

Threat ID	Type of Impact	Impact Affected Asset	Maximum Impact
		Damage to or loss of information systems or networks	
TE-4	Harm to Operations, Assets	Inability, or limited ability, to perform missions/business functions in the future Damage to or loss of information systems or networks	High
TE-5	Harm to Operations, Assets, Individuals	Inability, or limited ability, to perform missions/business functions in the future Damage to or loss of information systems or networks Loss of personally identifiable information	High
TE-6	Harm to Operations, Assets, Other Organizations	Inability, or limited ability, to perform missions/business functions in the future Damage to or loss of information systems or networks Damage to reputation (and hence future or potential trust relationships)	Very High
TE-7	Harm to Operations, Assets	Inability, or limited ability, to perform missions/business functions in the future Damage to or loss of information systems or networks	High
TE-8	Harm to Operations, Assets	Inability, or limited ability, to perform missions/business functions in the future Damage to or loss of information systems or networks	High
TE-9	Harm to Operations, Assets	Inability, or limited ability, to perform missions/business functions in the future	High

Threat ID	Type of Impact	Impact Affected Asset	Maximum Impact
		Damage to or loss of information systems or networks	
TE-10	Harm to Operations, Assets	Inability, or limited ability, to perform missions/business functions in the future Damage to or loss of information systems or networks	High
TE-11	Harm to Operations, Assets, Individuals	Inability, or limited ability, to perform missions/business functions in the future Damage to or loss of information systems or networks Damage to reputation (and hence future or potential trust relationships) Loss of personally identifiable information	High
TE-12	Harm to Operations, Assets, Other Organizations, Individuals	Inability, or limited ability, to perform missions/business functions in the future Damage to or loss of information systems or networks Loss of personally identifiable information Damage to reputation (and hence future or potential trust relationships)	High

2123 **Note 1:** Ratings of maximum impact were based on the qualitative scale found in Appendix H, Table H-3
 2124 in NIST SP 800-30 Revision 1 [9].

2125 **Note 2:** Ratings of maximum impact indicate the threat event could be expected to have negligible (i.e.,
 2126 very low risk), limited (i.e., low), serious (i.e., moderate), severe or catastrophic (i.e., high), or multiple
 2127 severe or catastrophic effects (i.e., very high).

2128 **Note 3:** For specific examples of types of impact, see Appendix H of NIST SP 800-30, Revision 1 [9].

2129 E.1.11 Task 2-6: Determine Risk to Organization

2130 *Determine the risk to the organization from threat events of concern considering (i) the impact that*
 2131 *would result from the events; and (ii) the likelihood of the events occurring.*

2132 In the interest of brevity, the threat events of concern identified in Task 2-2 were limited to those
 2133 presumed to have a foreseeably high likelihood of occurrence and high potential for adverse impact in
 2134 Orvilia's specific scenario.

2135 **Threat Source Characteristics**

2136 This table summarizes the risk assessment findings.

2137 The methodology used to identify risk to organization was qualitative (i.e., subjective) and used the
 2138 following five-point scale.

- 2139 ▪ Very High
- 2140 ▪ High
- 2141 ▪ Moderate
- 2142 ▪ Low
- 2143 ▪ Very Low

2144 **Table E-6 Summary of Risk Assessment Findings**

Threat Event	Vulnerabilities, Predisposing Conditions	Overall Likelihood	Level of Impact	Risk
TE-1: Unauthorized access to sensitive information via a malicious or privacy-intrusive application	VULN-3	Very High	High	High
TE-2: Theft of credentials through an SMS or email phishing campaign	VULN-1	Very High	High	High
TE-3: Malicious applications installed via URLs in SMS or email messages	VULN-3	High	High	High
TE-4: Confidentiality and integrity loss due to exploitation of known vulnerability in the OS or firmware	VULN-3	High	High	High

Threat Event	Vulnerabilities, Predisposing Conditions	Overall Likelihood	Level of Impact	Risk
TE-5: Violation of privacy via misuse of device sensors	VULN-3	Very High	High	High
TE-6: Compromise of the integrity of the device or its network communications via installation of malicious EMM/MDM, network, VPN profiles, or certificates	VULN-3	Moderate	Very High	High
TE-7: Loss of confidentiality of sensitive information via eavesdropping on unencrypted device communications	VULN-2	High	High	High
TE-8: Compromise of device integrity via observed, inferred, or brute-forced device unlock code	VULN-3	High	High	High
TE-9: Unauthorized access to backend services via authentication or credential storage vulnerabilities in internally developed applications	VULN-3	Very High	High	High
TE-10: Unauthorized access of enterprise resources from an unmanaged and potentially compromised device	VULN-1	Very High	High	High
TE-11: Loss of organizational data due to a lost or stolen device	VULN-3	Very High	High	High
TE-12: Loss of confidentiality of organizational data due to its unauthorized storage in non-organizationally managed services	VULN-3	High	High	High

2145 **Note 1:** Risk is stated in qualitative terms based on the scale in Table I-2 of Appendix I in NIST SP 800-30
 2146 Revision 1 [9].

2147 **Note 2:** The risk rating itself is derived from both the overall likelihood and level of impact using Table I-
2148 2 of Appendix I in NIST SP 800-30 Revision 1 [9]. Because these scales are not true interval scales, the
2149 combined overall risk ratings from Table I-2 do not always reflect a strict mathematical average of these
2150 two variables. This is demonstrated in the table above in which levels of Moderate weigh more heavily
2151 than other ratings.

2152 **Note 3:** Ratings of risk relate to the probability and level of adverse effect on organizational operations,
2153 organizational assets, individuals, other organizations, or the nation. Per NIST SP 800-30 Revision 1,
2154 adverse effects (and the associated risks) range from negligible (i.e., very low risk), limited (i.e., low),
2155 serious (i.e., moderate), severe or catastrophic (i.e., high), to multiple severe or catastrophic effects (i.e.,
2156 very high).

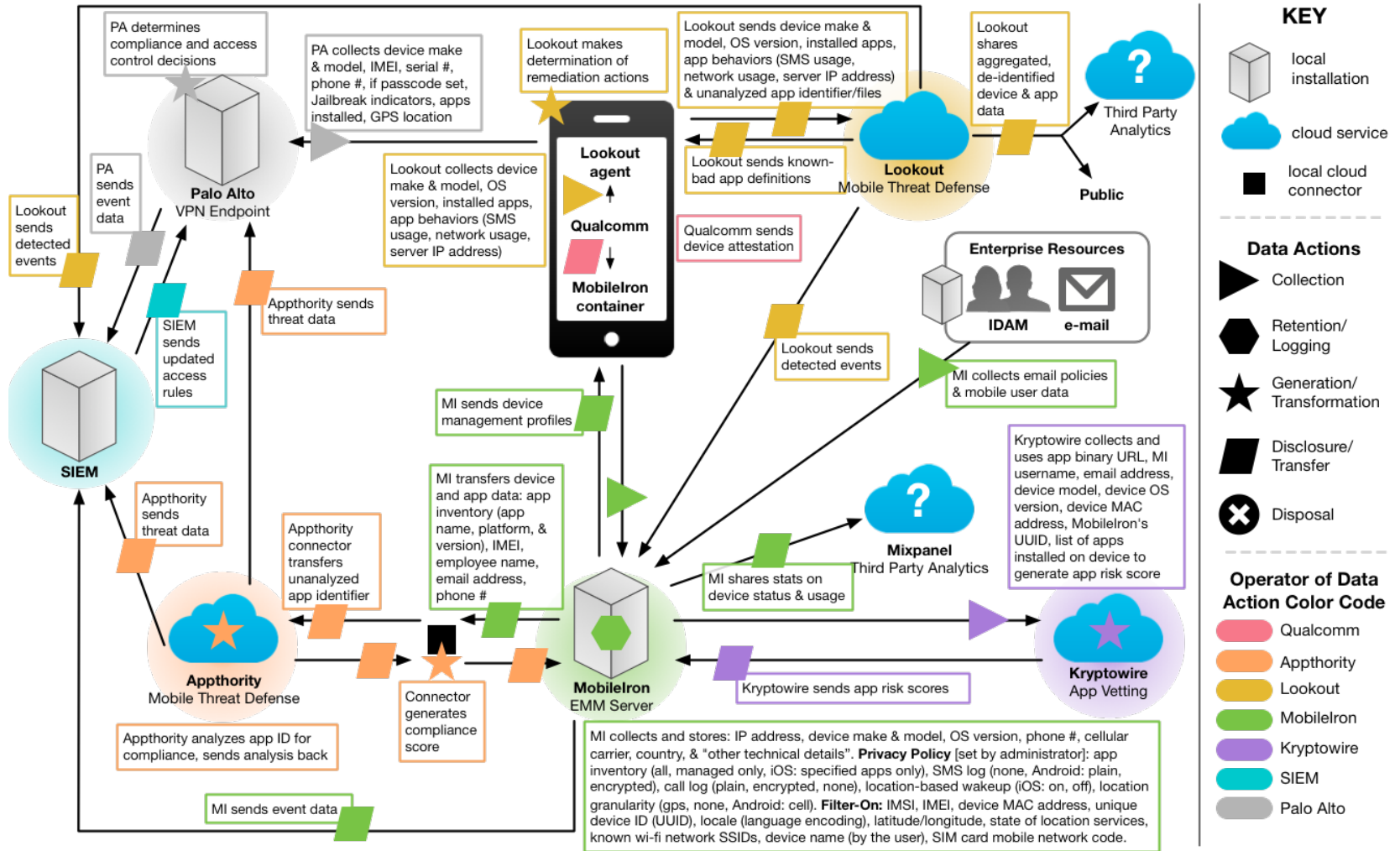
2157 **Appendix F Privacy Risk Assessment**

2158 This section describes the privacy risk assessment conducted on Orvilia’s enterprise security
2159 architecture. To perform the privacy risk assessment, the National Institute of Standards and Technology
2160 (NIST) Privacy Risk Assessment Methodology (PRAM) was used, a tool for analyzing, assessing, and
2161 prioritizing privacy risks to help organizations determine how to respond and select appropriate
2162 solutions. The PRAM can also serve as a useful communication tool to convey privacy risks within an
2163 organization. A blank version of the PRAM is available for download on NIST’s website [43].

2164 The PRAM uses the privacy risk model and privacy engineering objectives described in NIST Internal
2165 Report 8062, *An Introduction to Privacy Engineering and Risk Management in Federal Systems* [44], to
2166 analyze potential problematic data actions. Data actions are any system operations that process
2167 personally identifiable information (PII). Processing can include collection, retention, logging, analysis,
2168 generation, transformation or merging, disclosure, transfer, and disposal of PII. A problematic data
2169 action is one that could cause an adverse effect for individuals.

2170 The PRAM begins with framing the business objectives for the system, including the organizational
2171 needs served, and framing organizational privacy governance, including identification of privacy-related
2172 legal obligations and commitments to principles or other organizational policies. Next, create a data
2173 map to illustrate the data actions performed by the system and the PII processed by the data actions.
2174 These data actions, the PII being processed, and the contextual factors that describe the circumstances
2175 surrounding the system’s processing of PII serve as inputs to the risk analysis. Then, assess the
2176 probability that a data action will become problematic for individuals, assess the secondary costs
2177 absorbed by the organization from a data action creating a problem for individuals, and use likelihood
2178 and impact calculations to determine the total estimated risk per data action. Finally, list potential
2179 mitigating technical and policy controls for the identified risks. The output from the PRAM activities
2180 resulted in the information contained in Figure F-1.

2181 Figure F-1 PRAM Data Map for Orvilia's Enterprise Security Architecture



2182 As an output of the Orvilia PRAM, we identified three broad data actions with the potential to create
2183 problems for individuals and relevant mitigations. Some mitigations listed under a particular data action
2184 may provide privacy benefits to individuals beyond the scope of that data action. We also identified
2185 overarching training and support controls that can help mitigate risks associated with all three of these
2186 data actions.

2187 While a security information and event management (SIEM) capability was not used in the reference
2188 implementation, SIEMs, as discussed here, can be extremely beneficial in understanding the privacy
2189 implications of the mobile device security data being logged, aggregated, and stored.

2190 **F.1 Data Action 1: Blocking Access and Wiping Devices**

2191 Devices that might pose a risk to the organization’s security posture can be blocked from accessing
2192 enterprise resources or wiped and reset to factory setting defaults. Options are outlined in the following
2193 sections for how this might be accomplished.

2194 **F.1.1 Potential Problem for Individuals**

2195 In a corporate-owned personally-enabled or bring your own device environment, employees are likely to
2196 use their devices for both personal and work-related purposes. Therefore, in a system that features the
2197 capability to wipe a device entirely, there could be an issue of employees losing personal data—and
2198 employees may not even expect this possibility. A hypothetical example would be that an Orvilia
2199 employee stores pictures of their newborn child on their mobile device, but these photos are lost when
2200 their device is wiped after anomalous activity is detected.

2201 **F.1.2 Mitigations**

2202 **Block access instead of wiping devices.**

2203 As an alternative to wiping data entirely, devices can be blocked from accessing enterprise resources,
2204 for example, until an unapproved application is removed. This temporary blocking of access helps
2205 ensure an individual will not lose personal data through a full wipe of a device. Taking this approach may
2206 help bring the system’s capabilities into alignment with employees’ expectations about what can
2207 happen to their devices, especially if they are unaware that devices can be wiped by administrators—
2208 providing for greater *predictability* in the system.

- 2209
 - 2210 ▪ Related mitigation: If this approach is taken, remediation processes should also be established
2211 and communicated to employees. It is important to have a clear remediation process in place to
2212 help employees regain access to resources on their devices at the appropriate time. It is equally
2213 important to clearly convey this remediation process to employees. A remediation process
2214 provides greater manageability in the system supporting employees’ ability to access resources.
2215 If well communicated to employees, this also provides greater predictability, as employees will
know the steps involved in regaining access.

2216 Enable only selective wiping.

2217 An alternative mitigation option for wiping is to specify the information to be wiped. Performing a
2218 selective wipe is an option that only removes enterprise data from the device instead of being a full
2219 factory reset. When configured this way, a wipe preserves employees' personal configurations,
2220 applications, and data while removing only the corporate configurations, applications, and data. Within
2221 the example solution, this option is available for iOS devices.

2222 Advise employees to back up the personal data maintained on devices.

2223 If device wiping remains an option for administrators, encourage employees to perform regular backups
2224 of their personal data to ensure it remains accessible in case of a wipe.

2225 Limit staff with the ability to perform wipes or block access.

2226 Limit staff with the ability to perform a wipe to only those with that responsibility by using role-based
2227 access controls. This can help decrease the chances of accidentally removing employee data or blocking
2228 access to resources.

2229 F.2 Data Action 2: Employee Monitoring

2230 The assessed infrastructure offers Orvilva a number of security capabilities, including reliance on
2231 comprehensive monitoring capabilities, as noted in Section 4, Architecture. A significant amount of data
2232 relating to employees, their devices, and their activities is collected and analyzed by multiple parties.

2233 F.2.1 Potential Problem for Individuals

2234 Employees may not be aware that their interactions with the system are being monitored and may not
2235 want this monitoring to occur. Collection and analysis of information might enable Orvilva or other
2236 parties to craft a narrative about an employee based on their interactions with the system, which could
2237 lead to a power imbalance between Orvilva and the employee and loss of trust in the employer if the
2238 employee discovers unanticipated monitoring.

2239 F.2.2 Mitigations**2240 Limit staff with ability to review data about employees and their devices.**

2241 This may be achieved using role-based access controls and by developing organizational policies to limit
2242 how employee data can be used by staff with access to that data. Access can be limited to any
2243 dashboard in the system containing data about employees and their devices but is most sensitive within
2244 the mobile management dashboard, which is the hub for data about employees, their devices, and
2245 threats. Minimizing access to sensitive information can enhance *disassociability* for employees using the
2246 system.

2247 Limit or disable collection of specific data elements.

2248 Conduct a system-specific privacy risk assessment to determine what elements can be limited. Consider
2249 the configuration options for intrusive device features, such as location services, application inventory
2250 collection, and location-based wake-ups. When collecting application inventory data, ensure that
2251 information is gathered only from applications installed from the organization's corporate application
2252 store. While these administrative configurations may help provide for disassociability in the system,
2253 there are also some opportunities for employees to limit the data collected.

2254 Organizations may allow their employees to manage certain aspects and configurations of their device.
2255 For example, employees may be able to disable location services in their device OS to prevent collection
2256 of location data. Each of these controls contributes to reducing the number of attributes collected
2257 regarding employees and their mobile devices. This reduction of collected data limits administrators'
2258 ability to associate information with specific individuals.

2259 Dispose of PII.

2260 Disposal of PII after an appropriate retention period can help reduce the risk of entities building profiles
2261 of individuals. Disposal can also help bring the system's data processing into alignment with employees'
2262 expectations and reduce the security risk associated with storing a large volume of PII. Disposal may be
2263 particularly important for certain parties in the system that collect a larger volume of data or more
2264 sensitive data. Disposal may be achieved using a combination of policy and technical controls. Parties in
2265 the system may identify what happens to data, when, and how frequently.

2266 F.3 Data Action 3: Data Sharing Across Parties

2267 The infrastructure involves several parties that serve different purposes supporting Orvilia's security
2268 objectives. As a result, there is a significant flow of data about individuals and their devices occurring
2269 across various parties. This includes sharing device and application data publicly and with third-party
2270 analytics services, and includes sharing device status and usage with third-party analytics.

2271 F.3.1 Potential Problems for Individuals

2272 Data transmission about individuals and their devices among a variety of different parties could be
2273 confusing for employees who might not know who has access to different information about them. If
2274 administrators and co-workers know what colleague is conducting activity on his or her device that
2275 triggers security alerts, it could cause employee embarrassment or emotional distress. This information
2276 being revealed and associated with specific employees could also lead to stigmatization and even impact
2277 Orvilia upper management in their decision-making regarding the employee. Further, clear text
2278 transmissions could leave information vulnerable to attackers and the unanticipated release of
2279 employee information.

2280 F.3.2 Mitigations

2281 **Use de-identification techniques.**

2282 De-identification of data helps decrease the chances that a third party is aggregating information
2283 pertaining to one specific individual. While de-identification can help reduce privacy risk, there are
2284 residual risks of reidentification. De-identification techniques may be applied to aggregated data before
2285 sharing it with third-party analytics and publicly.

2286 **Use encryption.**

2287 Encryption decreases the chances of insecurity of information transmitted between parties.
2288 Organizations should keep this in mind when considering how their enterprise data is transmitted and
2289 stored. Mobile security systems share mobile device and application data with one another to optimize
2290 efficiency and leverage data to perform security functions. This data may include application inventory
2291 and employee name, email address, and phone number. Some systems offer multiple encryption
2292 options that allow an organization to choose the encryption level necessary for the type of data that is
2293 stored or transmitted.

2294 **Limit or disable access to data.**

2295 Conduct a system-specific privacy risk assessment to determine how access to data can be limited. Using
2296 access controls to limit staff access to compliance information, especially when associated with
2297 individuals, is important in preventing association of specific events with particular employees, which
2298 could cause embarrassment. Some mobile security systems offer options for restricting the amount of
2299 employee information that an administrator can access. These options may include hiding an
2300 employee's username and email address from the administrator console. Mobile application
2301 information may also include employee information. Organizations should consider how their mobile
2302 security systems hide application names, application binary analysis details, network names service set
2303 identifier, and network analysis details from administrators.

2304 **Limit or disable collection of specific data elements.**

2305 Conduct a system-specific privacy risk assessment to determine what elements can be limited.
2306 Identifying the employee information collected and determining what data elements are stored assist in
2307 assessing the privacy risk of mobile security systems. Organizations should consider the mobile security
2308 system's ability to limit or reduce collection and storage of employee information, such as username,
2309 email address, Global Positioning System location, and application data.

2310 **Use contracts to limit third-party data processing.**

2311 Establish contractual policies to limit data processing by third parties to only the processing that
2312 facilitates delivery of security services, and no data processing beyond those explicit purposes.

2313 **F.4 Mitigations Applicable Across Various Data Actions**

2314 Several mitigations provide benefits to employees pertaining to all three data actions identified in the
2315 privacy risk assessment. These training and support mitigations can help Orvilia appropriately inform
2316 employees about the system and its data processing.

2317 **Mitigations:**

2318 **Provide training to employees about the system, parties involved, data processing, and administrative**
2319 **actions that can be taken.**

2320 Training sessions can also highlight any privacy-preserving techniques used, such as for disclosures to
2321 third parties. Training should include confirmation from employees that they understand the actions
2322 that can be taken on their devices and the consequences—whether this involves blocking access or
2323 wiping data. Employees may also be informed of data retention periods and when their data will be
2324 disposed of. This can be more effective than simply sharing a privacy notice, which research has shown
2325 that individuals are unlikely to read.

2326 **Provide ongoing notifications or reminders about system activity.**

2327 This can be achieved using push notifications, similar to those pictured in screenshots in Appendix G,
2328 Threat Event 6, to help directly link administrative actions on devices to relevant threats and help
2329 employees understand why an action is being taken. Notifications of changes to policies can help
2330 increase system predictability by setting employee expectations appropriately with the way the system
2331 processes data and the resulting actions.

2332 **Provide a support point of contact.**

2333 By providing employees with a point of contact in the organization who can respond to inquiries and
2334 concerns regarding the system, employees can gain a better understanding of the system's processing of
2335 their data, which enhances predictability.

2336 **Appendix G Threat Event Test Information**

2337 Detailed information and screenshots for some of this practice guide’s threat events and their testing
2338 results are provided below.

2339 **G.1 Threat Event 1—Unauthorized Access to Sensitive Information via a** 2340 **Malicious or Privacy-Intrusive Application**

2341 A part of Threat Event 1’s testing conclusions is shown in the following screen capture, where the
2342 calendar access permission is being set to a risk score of 10. This allows MobileIron to automatically
2343 apply the mobile threat protection high-risk label to the device and quarantine the device until the
2344 privacy-intrusive application is removed.

2345 **Figure G-1 Setting a Custom Risk Level in Appthority**

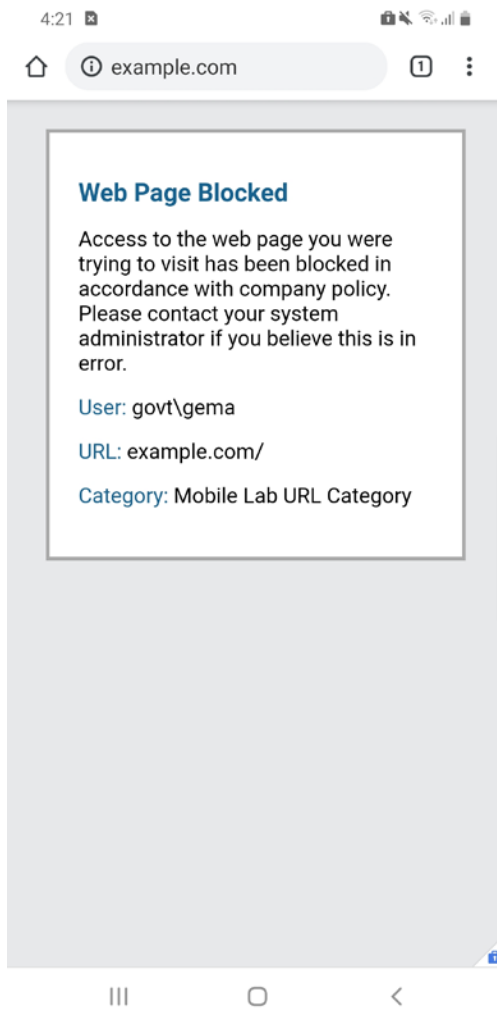
<input checked="" type="checkbox"/> Can Access Calendar	01/11/2019	Application	<input checked="" type="checkbox"/>	1	6	1	<div style="border: 1px solid #ccc; padding: 5px;"> <p>Active</p> <p>Default Risk Level</p> <p>Reset to Appthority Default</p> <p>✓ 10</p> <p>9</p> <p>8</p> <p>7</p> <p>6</p> <p>5</p> <p>4</p> <p>3</p> <p>2 (default)</p> <p>1</p> <p>0</p> </div>
<input checked="" type="checkbox"/> Requests Full Offline Access to Google Calendar API Using OAuth	03/22/2019	Application	<input checked="" type="checkbox"/>	0	0	0	
<input checked="" type="checkbox"/> Sends Calendar	01/11/2019	Application	<input checked="" type="checkbox"/>	0	0	0	
<input checked="" type="checkbox"/> Sends Calendar Unencrypted	01/11/2019	Application	<input checked="" type="checkbox"/>	0	0	1	

10 items per page

2346 **G.2 Threat Event 2—Theft of Credentials Through a Short Message Service** 2347 **(SMS) or Email Phishing Campaign**

2348 Threat Event 2’s outcome is shown in the following screen capture, where PAN-DB is blocking a website
2349 manually added to the malicious uniform resource locator (URL) database.

2350 **Figure G-2 PAN-DB Blocked Website**



2351 **G.3 Threat Event 3—Malicious Applications Installed via URLs in SMS or**
2352 **Email Messages**

2353 The following screenshots demonstrate enabling the Unknown Sources toggle and installing an
2354 application through a link in an email message.

Figure G-3 Lock Screen and Security

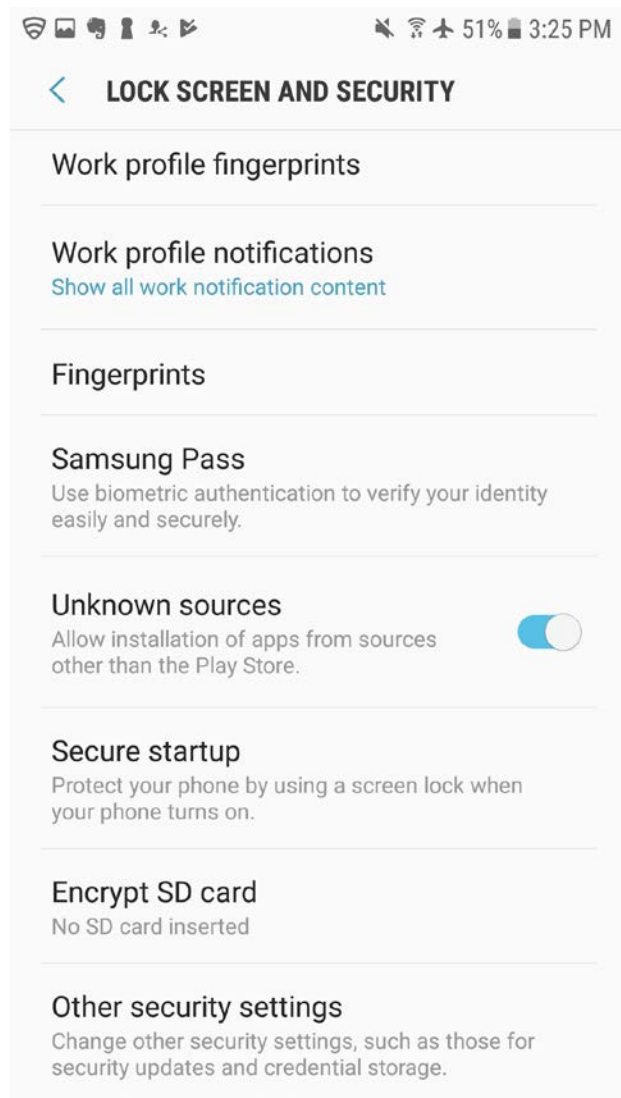
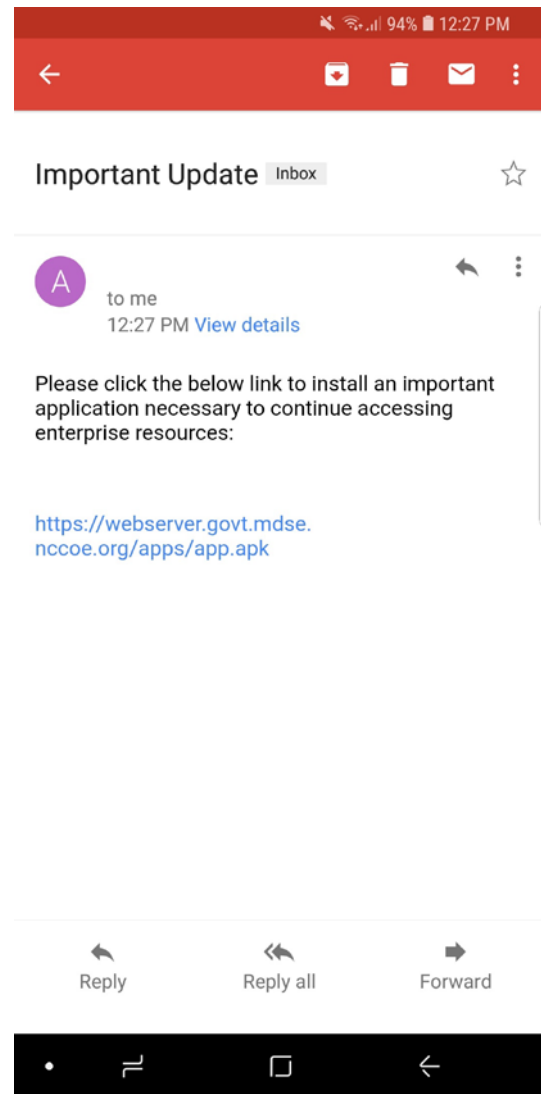


Figure G-4 Phishing Email on Android



2355 Figure G-5 depicts the iOS test activity of receiving an email containing a link to an application from a
2356 non-Apple App Store source.

Figure G-5 Phishing Email on iOS

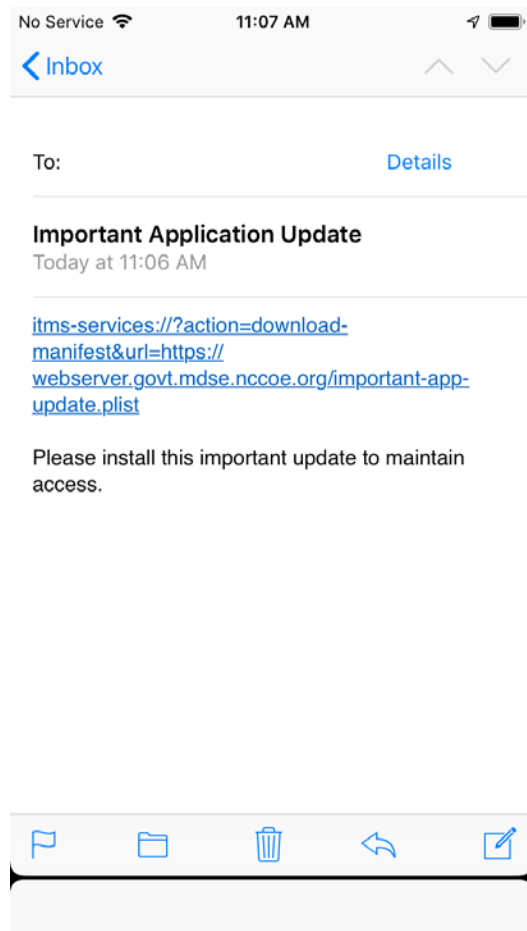
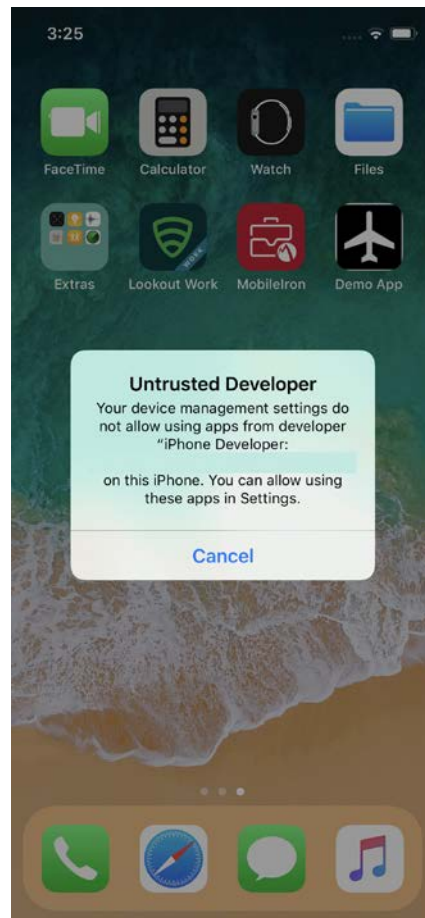


Figure G-6 Untrusted Developer Warning



2357 After the application is installed, an untrusted developer notice appears as shown in Figure G-6 when
2358 the user attempts to launch the application.

2359 Figure G-7 shows Lookout’s ability to detect application signing certificates that have been trusted on a
2360 device by the user to execute applications from sources other than Apple’s App Store.

2361 **Figure G-7 Application Signing Certificates**

Low Risk Configuration Issue

ISSUE STATUS	RISK	ISSUE TYPE	USER	DWELL TIME
Active	Low	Configuration	-	Days H M S 123 21:23:12

DEVICE DETAILS

iPhone X
[View device >](#)

CLASSIFICATION

Non-App Store Signer

FAMILY NAME

iPhone Developer: MITRE (XXXXXXXXXX)

CLASSIFICATION DESCRIPTION

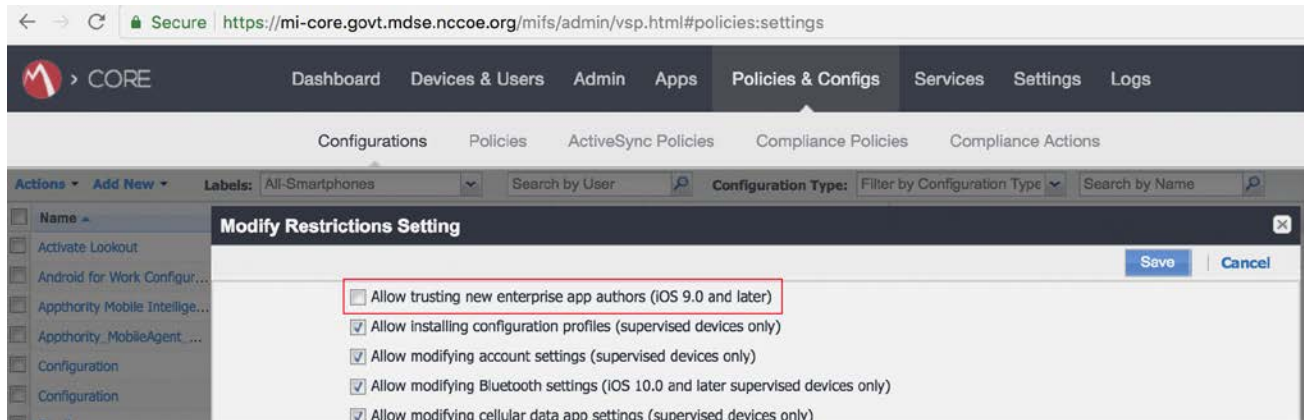
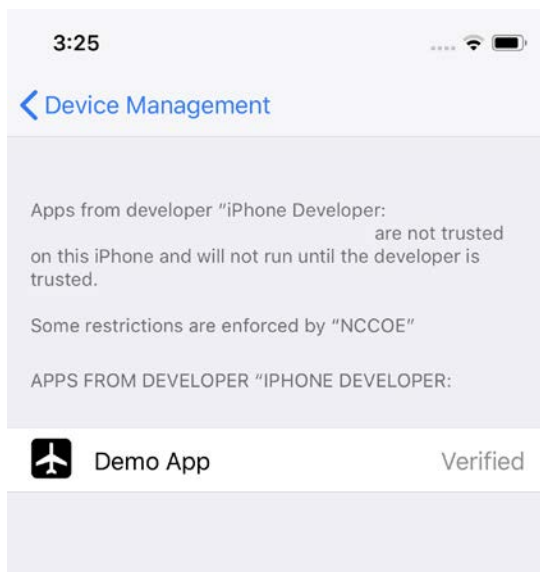
This device has explicitly trusted a developer in a way that allows this developer to install any number of apps on this device without going through the standard Apple App Store or beta approval process. Apps installed this way may possibly be harmful. This device may also be testing an app under development. If you believe this developer does not pose a risk to your organization, you may allow it to be trusted.

[Allow non-App Store signer](#)

Configuration Anomalies

ANOMALY	DESCRIPTION
Non-App Store Signer	-

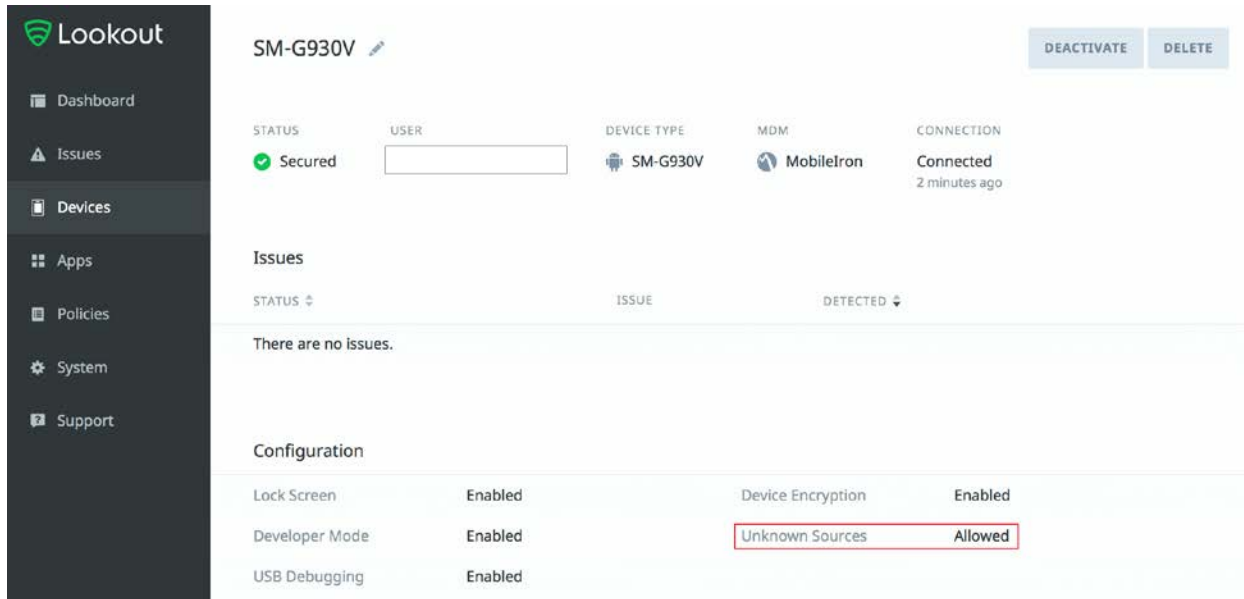
2362 The following screenshots depict an attempt to install and run the unauthorized demo application on an
2363 iOS device with the `allowEnterpriseAppTrust` policy restriction set to false by an Enterprise Mobility
2364 Management (EMM) system. The user is not able to trust the developer when the policy restriction is
2365 active, and hence the application will not run.

2366 **Figure G-8 Restriction Setting Modification Screen**2367 **Figure G-9 Unable to Trust Developer**2368 **Android Device Testing**

2369 On Android devices, applications cannot be installed from sources other than the Google Play Store
 2370 unless the Unknown Sources setting is enabled in the device's security settings. Lookout can identify
 2371 when the Unknown Sources setting has been enabled and can communicate this information to
 2372 MobileIron to enable automated response actions, such as blocking device access to enterprise
 2373 resources until the situation is resolved. However, even if Unknown Sources is disabled, it is possible
 2374 that the setting was previously enabled and that unauthorized applications were installed at that time.

2375 Figure G-10 shows Lookout's ability to detect Android devices with Unknown Sources enabled.

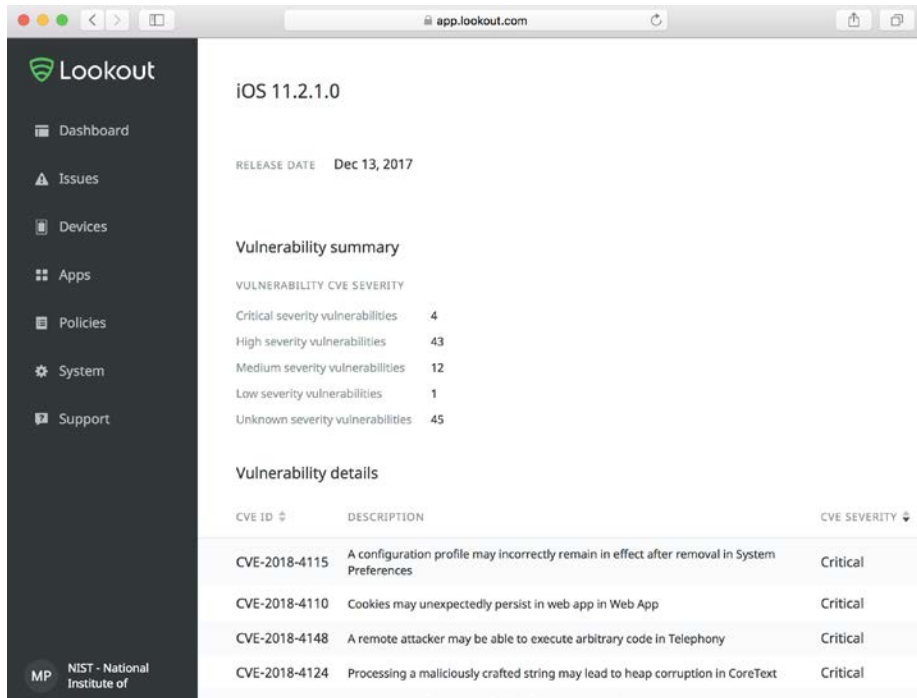
2376 **Figure G-10 Unknown Sources Detection**



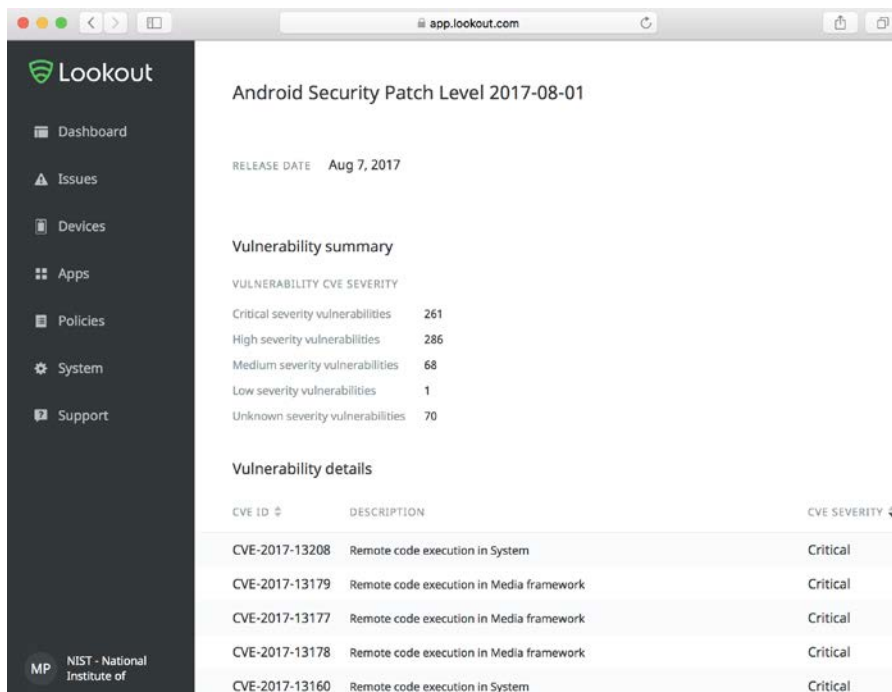
2377 **G.4 Threat Event 4—Confidentiality and Integrity Loss due to Exploitation**
2378 **of Known Vulnerability in the Operating System or Firmware**

2379 Figure G-11 demonstrates Lookout’s ability to identify known vulnerabilities to which unpatched iOS and
2380 Android devices are susceptible. Figure G-12 shows the patch level of the device.

2381 Figure G-11 Vulnerability Identification



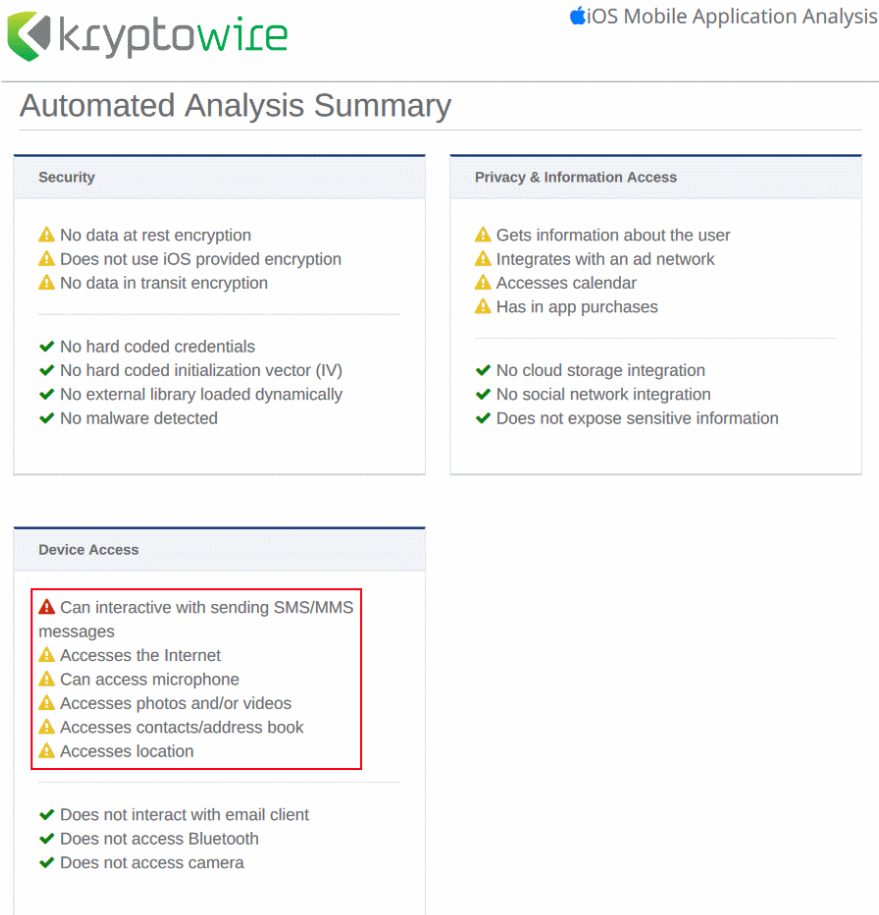
2382 Figure G-12 Patch Level Display



2383 **G.5 Threat Event 5—Violation of Privacy via Misuse of Device Sensors**

2384 The following screenshot depicts a Kryptowire application analysis report and the reported permissions
2385 that this application was requesting.

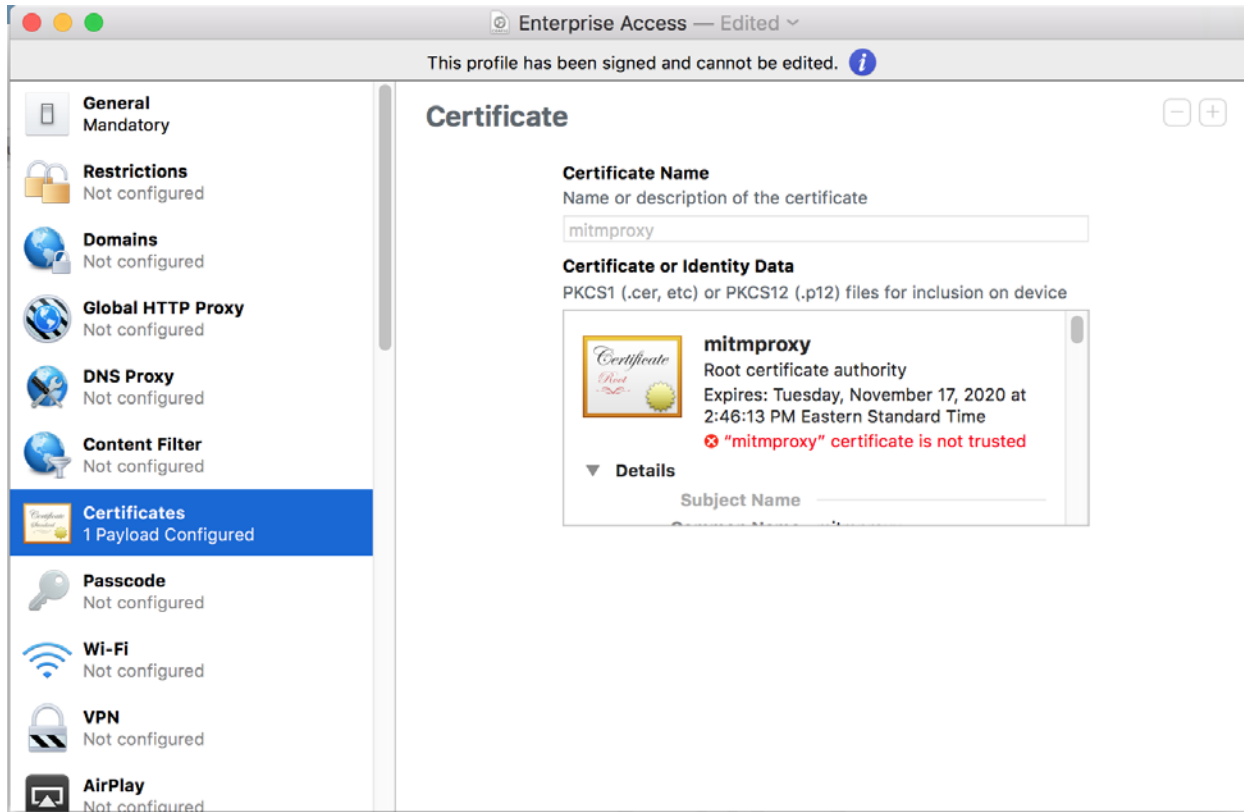
2386 **Figure G-13 Kryptowire Analysis Report**



2387 **G.6 Threat Event 6—Compromise of the Integrity of the Device or Its**
2388 **Network Communications via Installation of Malicious EMM/Mobile**
2389 **Device Management, Network, Virtual Private Network (VPN) Profiles,**
2390 **or Certificates**

2391 The configuration profile used for configuring and testing Threat Event 6 is shown in Figure G-14.

2392 Figure G-14 Configuration Profile Example



2393 Figure G-15 shows the email containing a malicious device configuration profile, and Figure G-16 shows
2394 the warning displayed to the user when attempting to mark the malicious certificate as a trusted root.

Figure G-15 Configuration Profile Phishing Email

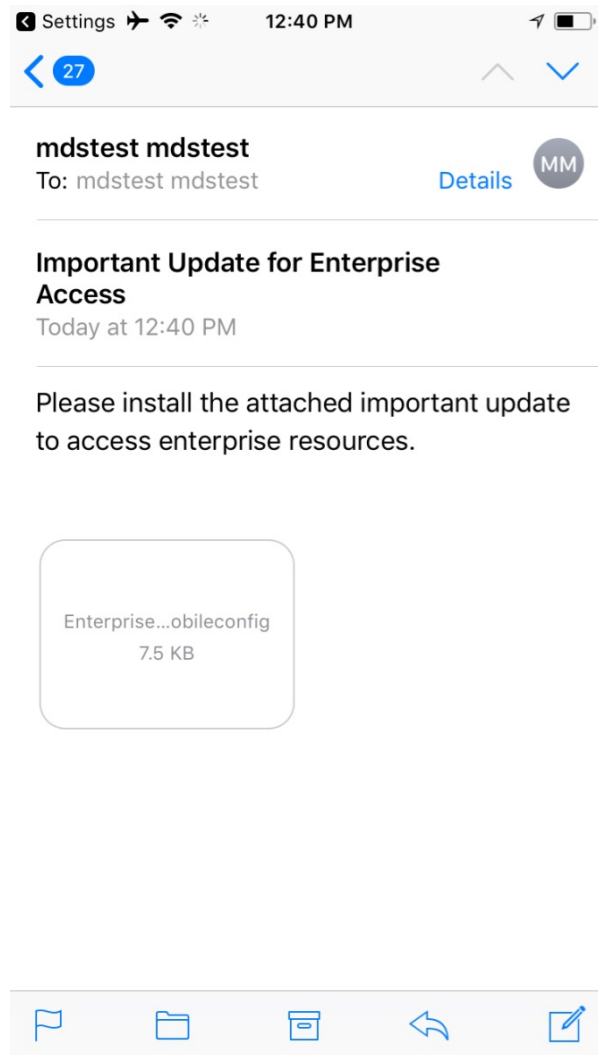
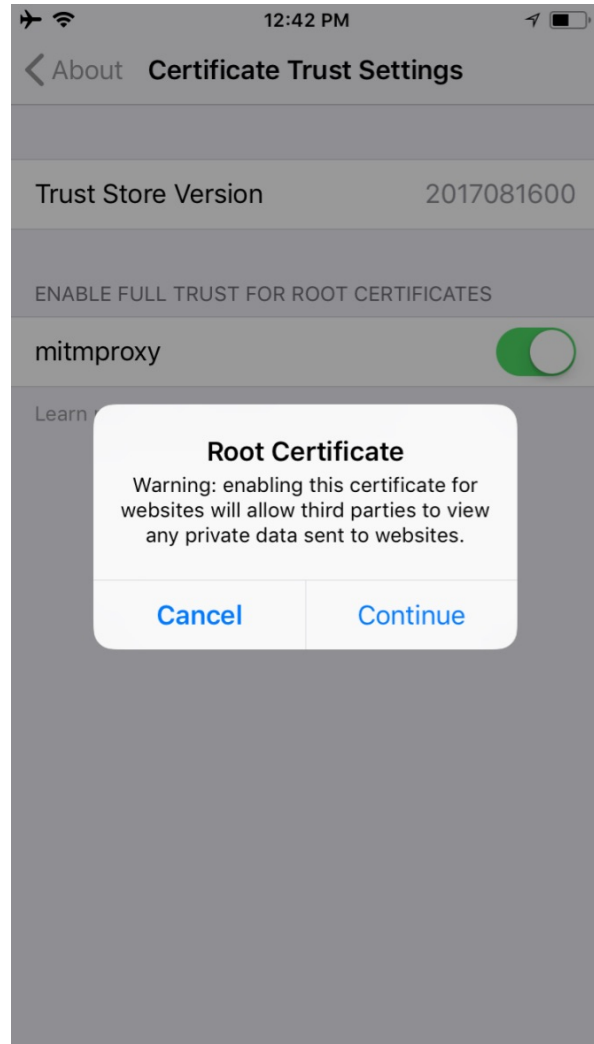
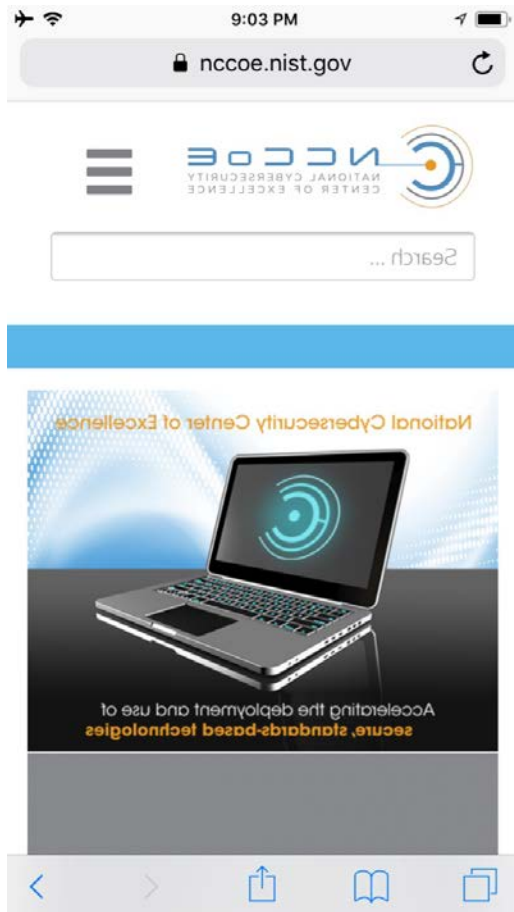


Figure G-16 Root Certificate Authority Enablement Warning



2395 **Figure G-17 Reversed Web Page**



2396 Browse to a hypertext transfer protocol secure (https) website from the mobile device and observe
2397 whether the content has been reversed. Figure G-17 illustrates that the man-in-the-middle attack on a
2398 Transport Layer Security-protected connection was successful.

2399 The following screenshots demonstrate a man-in-the-middle attack on Android.

Figure G-18 Certificate Phishing Email

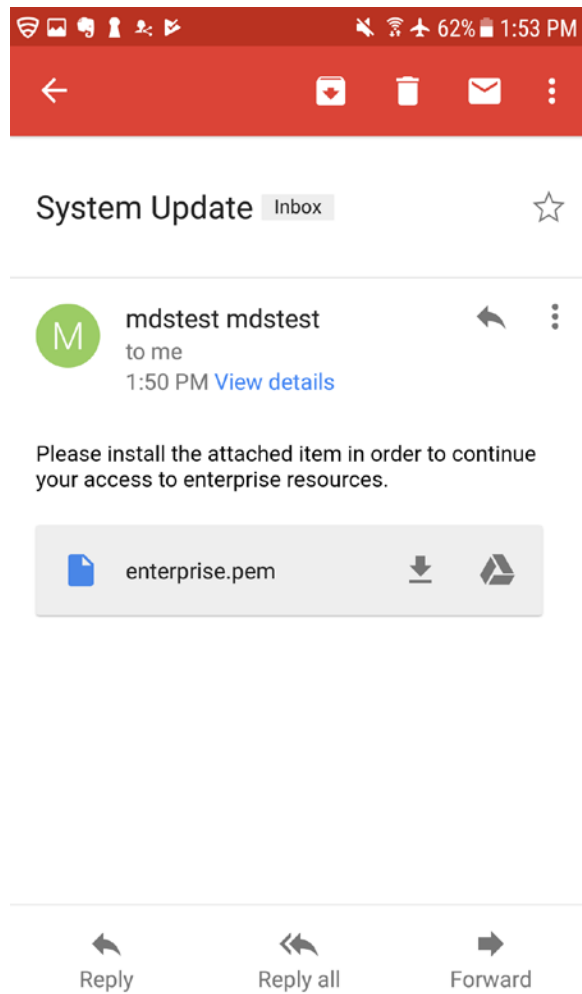
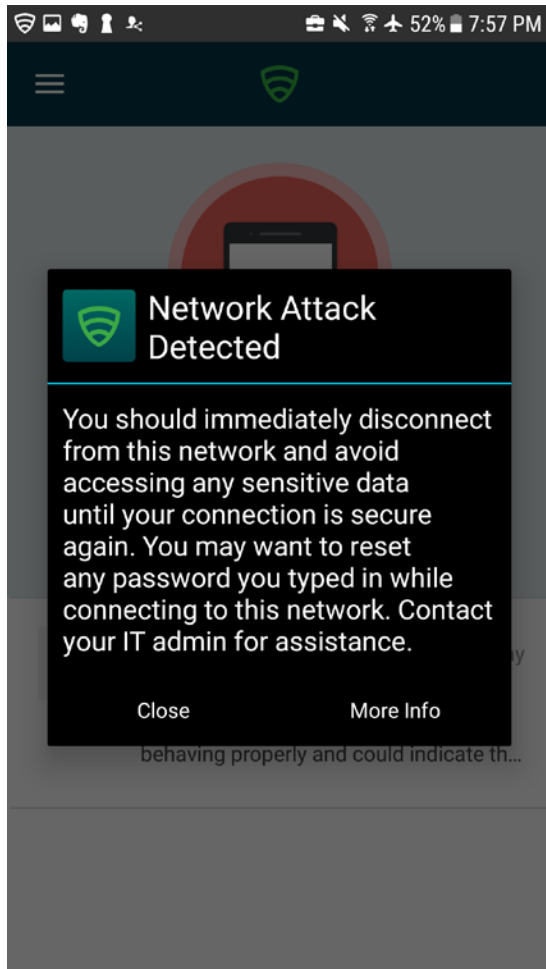


Figure G-19 Reversed Web Page



2400 Man-in-the-middle attack is detected by Lookout as shown in Figure G-20.

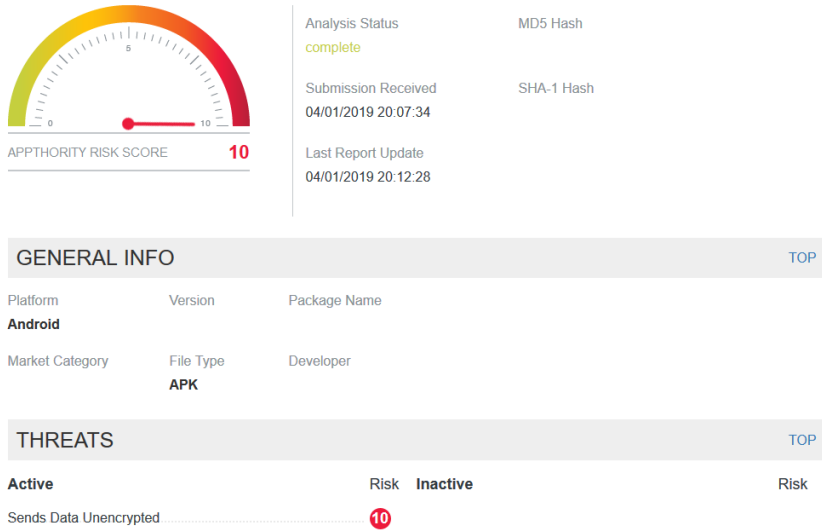
2401 **Figure G-20 Network Attack Detected**



2402 **G.7 Threat Event 7—Loss of Confidentiality of Sensitive Information via**
2403 **Eavesdropping on Unencrypted Device Communications**

2404 The following screenshot shows Appthority detecting an application sending data unencrypted.

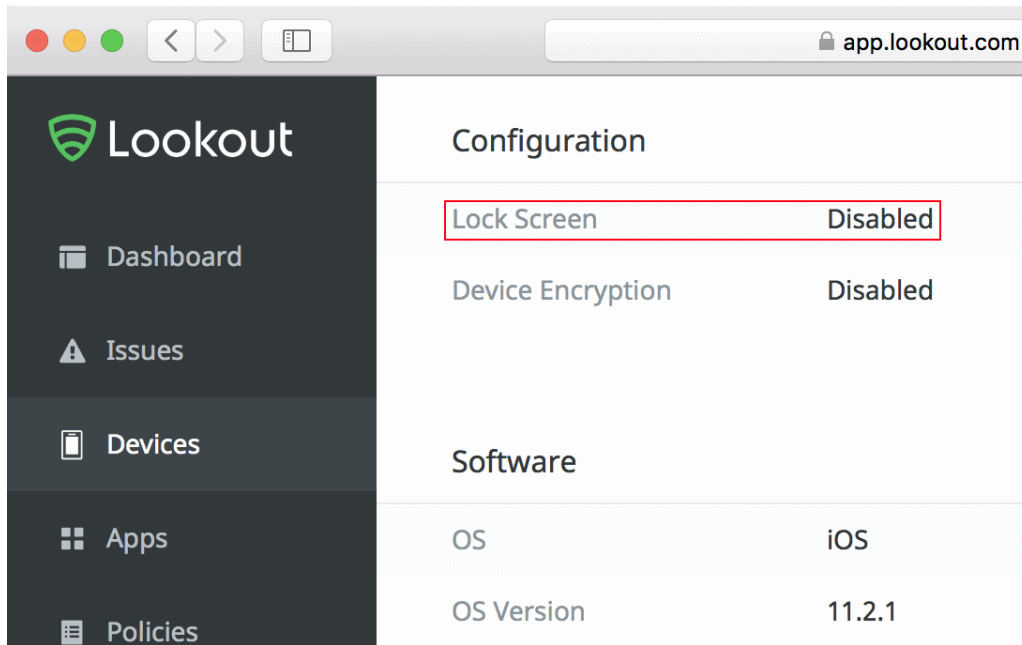
2405 **Figure G-21 Unencrypted Data Transfer**



2406 **G.8 Threat Event 8—Compromise of Device Integrity via Observed,**
2407 **Inferred, or Brute-Forced Device Unlock Code**

2408 MobileIron applies a policy to the devices to enforce a mandatory personal identification number and
2409 device-wipe capability. Lookout reports devices that have the lock screen disabled.

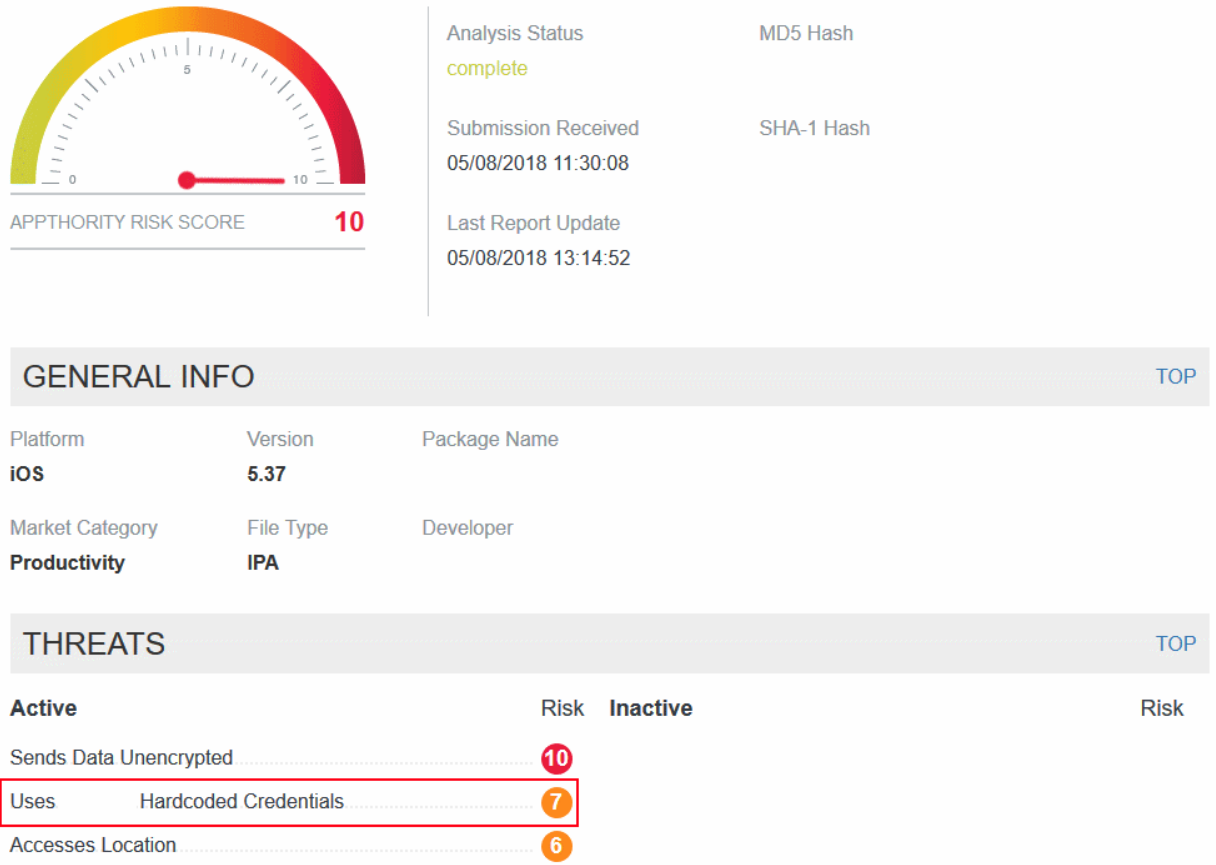
2410 Figure G-22 Lock Screen Disabled Detection Notice



2411 **G.9 Threat Event 9—Unauthorized Access to Backend Services via**
 2412 **Authentication or Credential Storage Vulnerabilities in Internally**
 2413 **Developed Applications**

2414 As shown in Figure G-23, Appthority recognized that an application used hard-coded credentials. The
 2415 application's use of hard-coded credentials could introduce vulnerabilities if the hard-coded credentials
 2416 were used for access to enterprise resources by unauthorized entities or for unauthorized actions.

2417 **Figure G-23 Hard-Coded Credentials**



2418 **G.10 Threat Event 10—Unauthorized Access of Enterprise Resources from**
 2419 **an Unmanaged and Potentially Compromised Device**

2420 The following two screenshots depict the inability to connect to the GlobalProtect VPN without the
 2421 proper client certificates, obtainable only through enrolling the device in MobileIron.

Figure G-24 No Certificates Found on Android

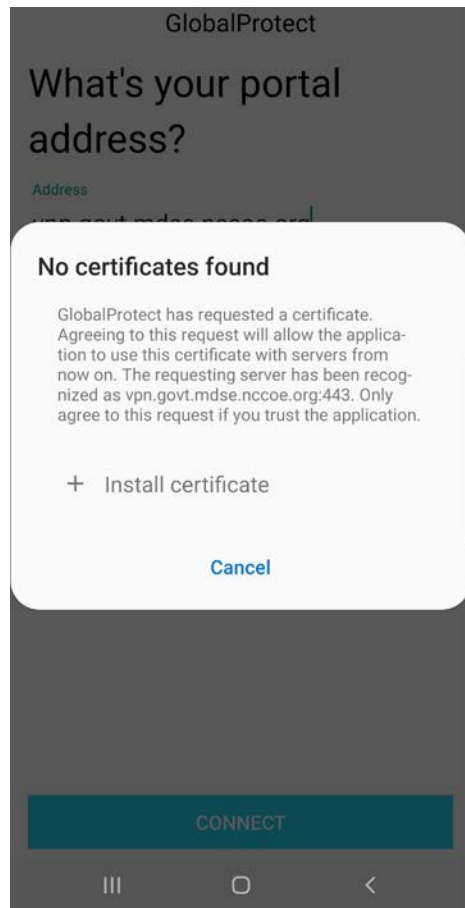
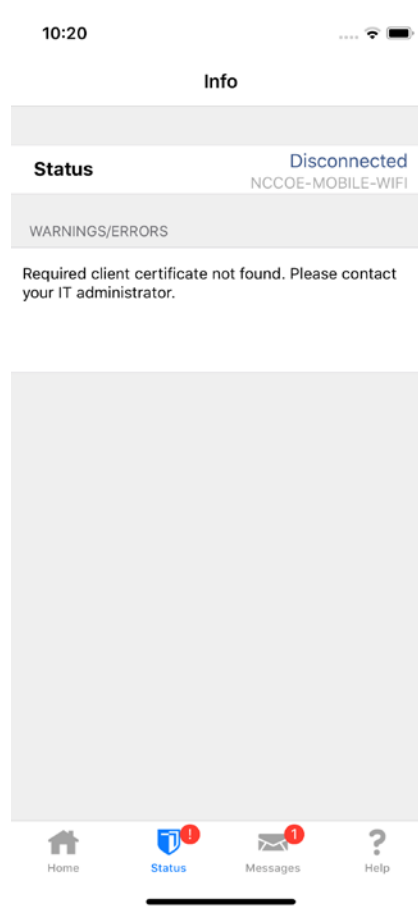


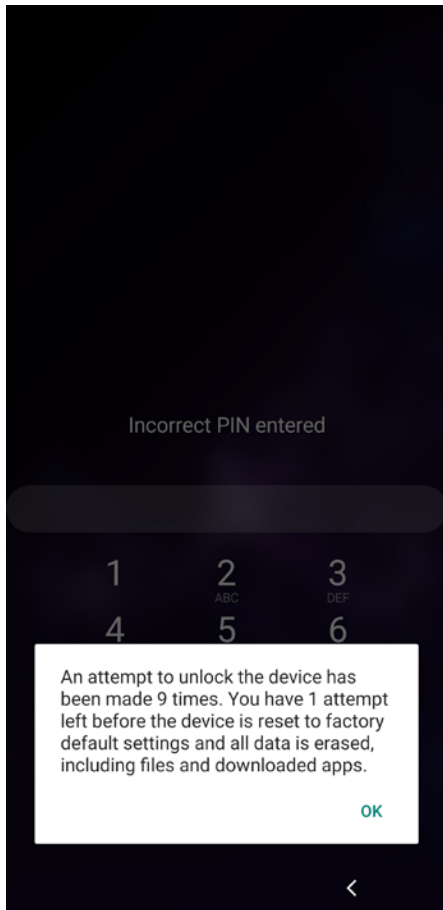
Figure G-25 No Certificates Found on iOS



2422 **G.11Threat Event 11—Loss of Organizational Data due to a Lost or Stolen**
 2423 **Device**

2424 This screenshot depicts the final warning before Android factory-resets the device. In the event the
 2425 device was stolen, all corporate data would be removed from the device after one more failed unlock
 2426 attempt, thwarting the malicious actor’s goal.

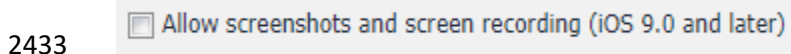
2427 **Figure G-26 Android Device Wipe Warning**



2428 **G.12 Threat Event 12—Loss of Confidentiality of Organizational Data due**
2429 **to Its Unauthorized Storage in Non-Organizationally Managed Services**

2430 The following screenshot shows one of the data loss prevention configuration options in MobileIron for
2431 iOS.

2432 **Figure G-27 Disallowing Screenshots and Screen Recording**



2434 **Appendix H Example Security Control Map**

2435 Table H-1 lists the technologies used in this project and provides a mapping among the generic
2436 application term, the specific product used, the security control(s) the product provides, and a mapping
2437 to the relevant National Institute of Standards and Technology (NIST) Special Publication (SP) 800-181,
2438 *National Initiative for Cybersecurity Education (NICE) Cybersecurity Workforce Framework Work Roles*.
2439 From left to right, the columns in the table describe:

- 2440 ▪ **Specific product used:** vendor product used by the example solution
- 2441 ▪ **How the component functions in the build:** capability the component provides in the example
2442 solution. This is mapped to the general mobile technology component term.
- 2443 ▪ **Applicable Cybersecurity Framework Subcategories:** applicable Cybersecurity Framework
2444 Subcategory(s) that the component is providing in the example solution
- 2445 ▪ **Applicable NIST controls:** the NIST SP 800-53 Revision 4 controls that the component provided
2446 in the example solution
- 2447 ▪ **ISO/IEC 27001:2013:** International Organization for Standardization (ISO), International
2448 Electrotechnical Commission (IEC) 27001:2013 mapping that the component provides in the
2449 example solution
- 2450 ▪ **CIS 6:** Center for Internet Security (CIS) version 6 controls mapping that the component provides
2451 in the example solution
- 2452 ▪ **NIST SP 800-181, NICE Framework Work Roles:** NICE Framework work role(s) that could be used
2453 to manage this component's use in the example solution. This mapping provides information on
2454 the workforce members who would be engaged in this part of the example solution's support.

2455 Table H-1 Example Solution’s Cybersecurity Standards and Best Practices Mapping

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
Mobile Threat Defense						
Appthority Cloud Service	Mobile Threat Intelligence	ID.RA-1—Asset vulnerabilities are identified and documented.	Security Assessment and Authorization CA-2, CA-7, CA-8 Risk Assessment RA-3, RA-5 System and Services Acquisition SA-5, SA-11 System and Information Integrity SI-2, SI-4, SI-5	A.12.6.1 Control of Technical vulnerabilities A.18.2.3 Technical Compliance Review	CSC 4 Continuous Vulnerability Assessment and Remediation	SP-RSK-002 Security Control Assessor SP-ARC-002 Security Architect OM-ANA-001 Systems Security Analyst PR-VAM-001 Vulnerability Assessment Analyst PR-CDA-001 Cyber Defense Analyst OV-MGT-001 Information Systems Security Manager

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
		ID.RA-3 - Threats, both internal and external, are identified and documented.	Risk Assessment RA-3 System and Information Integrity SI-5 Insider Threat Program PM-12, PM-16	Clause 6.1.2 Information Risk Assessment Process	CSC 4 Continuous Vulnerability Assessment and Remediation	SP-RSK-002 Security Control Assessor PR-CDA-001 Cyber Defense Analyst OV-SPP-001 Cyber Workforce Developer and Manager OV-TEA-001 Cyber Instructional Curriculum Developer AN-TWA-001 Threat/Warning Analyst PR-VAM-001 Vulnerability Assessment Analyst

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
						OV-MGT-001 Information Systems Security Manager
		DE.CM-4— Malicious code is detected.	System and Information Integrity SI-3, SI-8	A.12.2.1 Controls Against Malware	CSC 4 Continuous Vulnerability Assessment and Remediation CSC 7 Email and Web Browser Protections CSC 8 Malware Defenses CSC 12 Boundary Defense	PR-VAM-001 Vulnerability Assessment Analyst PR-CIR-001 Cyber Defense Incident Responder PR-CDA-001 Cyber Defense Analyst OM-NET-001 Network Operations Specialist
		DE.CM-5— Unauthorized mobile code is detected.	Mobile Code SC-18, SC-44 System and Information Integrity SI-4	A.12.5.1 Installation of Software on Operational Systems A.12.6.2 Restrictions on	CSC 7 Email and Web Browser Protections CSC 8 Malware Defenses	PR-CDA-001 Cyber Defense Analyst OM-NET-001

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
				Software Installation		Network Operations Specialist
Kryptowire Cloud Service	Application Vetting	ID.RA-1—Asset vulnerabilities are identified and documented.	Security Assessment and Authorization CA-2, CA-7, CA-8 Risk Assessment RA-3, RA-5 System and Services Acquisition SA-5, SA-11 System and Information Integrity SI-2, SI-4, SI-5	A.12.6.1 Control of Technical vulnerabilities A.18.2.3 Technical Compliance Review	CSC 4 Continuous Vulnerability Assessment and Remediation	SP-RSK-002 Security Control Assessor SP-ARC-002 Security Architect OM-ANA-001 Systems Security Analyst PR-VAM-001 Vulnerability Assessment Analyst PR-CDA-001 Cyber Defense Analyst OV-MGT-001 Information Systems Security Manager

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
		ID.RA-3— Threats, both internal and external, are identified and documented.	Risk Assessment RA-3 System and Information Integrity SI-5 Insider Threat Program PM-12, PM-16	Clause 6.1.2 Information Risk Assessment Process	CSC 4 Continuous Vulnerability Assessment and Remediation	SP-RSK-002 Security Control Assessor OM-ANA-001 Systems Security Analyst OV-SPP-001 Cyber Workforce Developer and Manager OV-TEA-001 Cyber Instructional Curriculum Developer

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
						AN-TWA-001 Threat/Warning Analyst PR-VAM-001 Vulnerability Assessment Analyst PR-CDA-001 Cyber Defense Analyst OV-MGT-001 Information Systems Security Manager
		DE.CM-4—Malicious code is detected.	System and Information Integrity SI-3, SI-8	A.12.2.1 Controls Against Malware	CSC 4 Continuous Vulnerability Assessment and Remediation CSC 7 Email and Web Browser Protections CSC 8 Malware Defenses CSC 12 Boundary Defense	PR-CIR-001 Cyber Defense Incident Responder PR-CDA-001 Cyber Defense Analyst PR-VAM-001 Vulnerability Assessment Analyst

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
						OM-NET-001 Network Operations Specialist
		DE.CM-5— Unauthorized mobile code is detected.	Mobile Code SC-18, SC-44 System and Information Integrity SI-4	A.12.5.1 Installation of Software on Operational Systems A.12.6.2 Restrictions on Software Installation	CSC 7 Email and Web Browser Protections CSC 8 Malware Defenses	PR-CDA-001 Cyber Defense Analyst OM-NET-001 Network Operations Specialist
Lookout Cloud Service/ Lookout Agent Version 5.10.0.142 (iOS), 5.9.0.420 (Android)	Mobile Threat Defense/Endpoint Security	PR.AC-5—Network integrity is protected (e.g., network segregation, network segmentation).	Access Control AC-4, AC-10 System and Communications Protection SC-7	A.13.1.1 Network Controls A.13.1.3 Segregation in Networks A.13.2.1 Information Transfer Policies and Procedures A.14.1.2 Securing	CSC 9 Imitation and Control of Network Ports, Protocols, and Services CSC 14 Controlled Access Based on the Need to Know CSC 15 Wireless Access Control	OM-ADM-001 System Administrator OV-SPP-002 Cyber Policy and Strategy Planner PR-CDA-001 Cyber Defense Analyst

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
				Application Services on Public Networks A.14.1.3 Protecting Application Services Transactions	CSC 18 Application Software Security	OM-NET-001 Network Operations Specialist
		PR.PT-4— Communications and control networks are protected.	Access Control AC-4, AC-17, AC-18 Contingency Planning Policy and Procedures CP-8 System and Communications Protection SC-7, SC-19, SC-20, SC-21, SC-22, SC-23, SC-24, SC-25, SC-29, SC-32, SC-36, SC-37, SC-38, SC-39, SC-40, SC-41, SC-43	A.13.1.1 Network Controls A.13.1.3 Segregation in Networks A.14.1.3 Protecting Application Services Transactions	CSC 8 Malware Defenses CSC 12 Boundary Defense CSC 15 Wireless Access Control	OM-ADM-001 System Administrator OV-SPP-002 Cyber Policy and Strategy Planner OV-MGT-002 Communications Security (COMSEC) Manager SP-ARC-0001 Enterprise Architect

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
						PR-CDA-001 Cyber Defense Analyst SP-ARC-002 Security Architect OM-NET-001 Network Operations Specialist
		DE.CM-5— Unauthorized mobile code is detected.	Mobile Code SC-18, SC-44 System and Information Integrity SI-4	A.12.5.1 Installation of Software on Operational Systems A.12.6.2 Restrictions on Software Installation	CSC 7 Email and Web Browser Protections CSC 8 Malware Defenses	PR-CDA-001 Cyber Defense Analyst OM-NET-001 Network Operations Specialist
Enterprise Mobility Management						
MobileIron Core Version 9.7.0.1	Enterprise Mobility Management	ID.AM-1— Physical devices and systems within the organization are inventoried.	Information System Component Inventory CM-8	A.8.1.1 Inventory of Assets	CSC 1 Inventory of Authorized and Unauthorized Devices	OM-STS-001 Technical Support Specialist OM-ADM-001

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
			Information System Inventory PM-5	A.8.1.2 Ownership of Assets		System Administrator
		PR.AC-1—Identities and credentials are issued, managed, verified, revoked, and audited for authorized devices, users, and processes.	Access Control AC-1, AC-2 Identification and Authentication IA-1, IA-2, IA-3, IA-4, IA-5, IA-6, IA-7, IA-8, IA-9, IA-10, IA-11	A.9.2.1 User Registration and De-Registration A.9.2.2 User Access Provisioning A.9.2.3 Management of Privileged Access Rights A.9.2.4 Management of Secret Authentication Information of Users A.9.2.6 Removal or Adjustment of Access Rights A.9.3.1 Use of Secret Authentication Information	CSC 1 Inventory of Authorized and Unauthorized Devices CSC 5 Controlled Use of Administrative Privileges CSC 15 Wireless Access Control CSC 16 Account Monitoring and Control	OV-SPP-002 Cyber Policy and Strategy Planner OM-ADM-001 System Administrator OV-MGT-002 Communications Security (COMSEC) Manager OM-STS-001 Technical Support Specialist OM-ANA-001 Systems Security Analyst PR-CDA-001

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
				A.9.4.2 Secure Log-On Procedures A.9.4.3 Password Management System		Cyber Defense Analyst
		PR.AC-6—Identities are proofed and bound to credentials and asserted in interactions.	Access Control AC-1, AC-2, AC-3, AC-16, AC-19, AC-24 Identification and Authentication IA-1, IA-2, IA-4, IA-5, IA-8 Physical and Environmental Protection PE-2	A.7.1.1 Screening A.9.2.1 User Registration and De-Registration	CSC 16 Account Monitoring and Control	OV-SPP-002 Cyber Policy and Strategy Planner OV-MGT-002 Communications Security (COMSEC) Manager OM-ADM-001

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
			Personnel Security PS-3			System Administrator
		PR.IP-1—A baseline configuration of information technology/industrial control systems is created and maintained, incorporating security principles (e.g., concept of least functionality).	Information System Component Inventory CM-2, CM-3, CM-4, CM-5, CM-6, CM-7, CM-9 System and Services Acquisition SA-10	A.12.1.2 Change Management A.12.5.1 Installation of Software on Operational Systems A.12.6.2 Restrictions on Software Installation A.14.2.2 System Change Control Procedures A.14.2.3 Technical Review of Applications After Operating	CSC 3 Secure Configurations for Hardware and Software on Mobile Devices, Laptops, Workstations, and Servers CSC 9 Limitation and Control of Network Ports, Protocols, and Services CSC 11 Secure Configurations for Network Devices Such as Firewalls, Routers, and Switches	SP-ARC-002 Security Architect OV-SPP-002 Cyber Policy and Strategy Planner SP-SYS-001 Information Systems Security Developer OM-ADM-001 System Administrator PR-VAM-001 Vulnerability Assessment Analyst

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
				Platform Changes A.14.2.4 Restrictions on Changes to Software Packages		OM-NET-001 Network Operations Specialist OV-MGT-001 Information Systems Security Manager OM-STS-001 Technical Support Specialist

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
<p>MobileIron Agent Version 11.0.1A (iOS), 10.2.1.1.3R (Android)</p>	<p>EMM/Endpoint Agent</p>	<p>PR.DS-6—Integrity-checking mechanisms are used to verify software, firmware, and information integrity.</p>	<p>System and Communications Protection SC-1 System and Information Integrity SI-7</p>	<p>A.12.2.1 Controls Against Malware A.12.5.1 Installation of Software on Operational Systems A.14.1.2 Securing Application Services on Public Networks A.14.1.3 Protecting Application Services Transactions A.14.2.4 Restrictions on Changes to Software Packages</p>	<p>CSC 2 Inventory of Authorized and Unauthorized Software CSC 3 Secure Configurations for Hardware and Software on Mobile Devices, Laptops, Workstations, and Servers</p>	<p>OV-SPP-002 Cyber Policy and Strategy Planner SP-ARC-0001 Enterprise Architect OV-MGT-001 Information Systems Security Manager OM-ADM-001 System Administrator OM-STS-001 Technical Support Specialist</p>
<p>Trusted Execution Environment</p>						

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
Qualcomm (Version is mobile device dependent)	Trusted Execution Environment	PR.DS-1— Data at rest is protected.	Media Downgrading MP-8 System and Communications Protection SC-12, SC-28	A.8.2.3 Handling of Assets	CSC 13 Data Protection CSC 14 Controlled Access Based on the Need to Know	OV-SPP-002 Cyber Policy and Strategy Planner PR-INF-001 Cyber Defense Infrastructure Support Specialist OV-LGA-002 Privacy Officer/Privacy Compliance Manager OV-MGT-002 COMSEC Manager OM-NET-001 Network Operations Specialist OM-ANA-001 Systems Security Analyst

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
		PR.DS-6—Integrity-checking mechanisms are used to verify software, firmware, and information integrity.	System and Communications Protection SC-16 System and Information Integrity SI-7	A.12.2.1 Controls Against Malware A.12.5.1 Installation of Software on Operational Systems A.14.1.2 Securing Application Services on Public Networks A.14.1.3 Protecting Application Services Transactions A.14.2.4 Restrictions on Changes to Software Packages	CSC 2 Inventory of Authorized and Unauthorized Software CSC 3 Secure Configurations for Hardware and Software on Mobile	OV-SPP-002 Cyber Policy and Strategy Planner PR-CDA-001 Cyber Defense Analyst SP-ARC-0001 Enterprise Architect OV-MGT-001 Information Systems Security Manager OM-STS-001 Technical Support Specialist OM-ADM-001 System Administrator

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
		PR.DS-8—Integrity-checking mechanisms are used to verify hardware integrity.	Developer Configuration Management SA-10 System and Information Integrity SI-7	A.11.2.4 Equipment Maintenance	Not applicable	OM-ADM-001 System Administrator SP-ARC-0001 Enterprise Architect
		DE.CM-4—Malicious code is detected.	System and Information Integrity SI-3, SI-8	A.12.2.1 Controls Against Malware	CSC 5 Controlled Use of Administrative Privileges CSC 7 Email and Web Browser Protections CSC 14 Controlled Access Based on the Need to Know CSC 16 Account Monitoring and Control	PR-CDA-001 Cyber Defense Analyst PR-INF-001 Cyber Defense Infrastructure Support Specialist PR-VAM-001 Vulnerability Assessment Analyst OM-NET-001 Network Operations Specialist PR-CDA-001 Cyber Defense Analyst

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
Virtual Private Network						
Palo Alto, PA-220 Version 8.1.1	Virtual Private Network	PR.AC-3—Remote access is managed.	Access Control AC-1, AC-17, AC-19, AC-20 System and Communications Protection SC-15	A.6.2.1 Mobile Device Policy A.6.2.2 Teleworking A.11.2.6 Security of Equipment and Assets Off-Premises A.13.1.1 Network Controls A.13.2.1 Information Transfer Policies and Procedures	CSC 12 Boundary Defense	OV-SPP-002 Cyber Policy and Strategy Planner OV-MGT-002 Communications Security (COMSEC) Manager OM-NET-001 Network Operations Specialist

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
		PR.AC-5—Network integrity is protected (e.g., network segregation, network segmentation).	Access Control AC-4, AC-10 System and Communications Protection SC-7	A.13.1.1 Network Controls A.13.1.3 Segregation in Networks A.13.2.1 Information Transfer Policies and Procedures A.14.1.2 Securing Application Services on Public Networks A.14.1.3 Protecting Application Services Transactions	CSC 9 Limitation and Control of Network Ports, Protocols, and Services CSC 14 Controlled Access Based on the Need to Know CSC 15 Wireless Access Control CSC 18 Application Software Security	PR-CDA-001 Cyber Defense Analyst OM-ADM-001 System Administrator OM-NET-001 Network Operations Specialist

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
		PR.AC-6—Identities are proofed and bound to credentials and asserted in interactions.	Access Control AC-1, AC-2, AC-3, AC-16, AC-19, AC-24 Identification and Authentication IA-1, IA-2, IA-4, IA-5, IA-8 Physical and Environmental Protection PE-2, PS-3	A.7.1.1 Screening A.9.2.1 User Registration and De-Registration	CSC 16 Account Monitoring and Control	OV-SPP-002 Cyber Policy and Strategy Planner OV-MGT-002 Communications Security (COMSEC) Manager OM-ADM-001 System Administrator
		PR.DS-2— Data in transit is protected.	System and Communications Protection SC-8, SC-11, SC-12	A.8.2.3 Handling of Assets A.13.1.1 Network Controls A.13.2.1 Information Transfer Policies and Procedures A.13.2.3 Electronic Messaging	CSC 13 Data Protection CSC 14 Controlled Access Based on the Need to Know	OV-SPP-002 Cyber Policy and Strategy Planner OV-MGT-002 Communications Security (COMSEC) Manager OV-LGA-002 Privacy Officer/Privacy Compliance Manager

Specific product used	How the component functions in the build	Applicable Cybersecurity Framework Version 1.1 Subcategories	Applicable NIST SP 800-53 Revision 4 Controls	ISO/IEC 27001:2013	CIS 6	NIST SP 800-181 NICE Framework Work Roles
				A.14.1.2 Securing Application Services on Public Networks A.14.1.3 Protecting Application Services Transactions		OM-NET-001 Network Operations Specialist
		PR.PT-4— Communications and control networks are protected.	Access Control AC-4, AC-17, AC-18 Contingency Planning CP-8 System and Communications Protection SC-7, SC-19, SC-20, SC-21, SC-22, SC-23, SC-24, SC-25, SC-29, SC-32, SC-36, SC-37, SC-38, SC-39, SC-40, SC-41, SC-43	A.13.1.1 Network Controls A.13.2.1 Information Transfer Policies and Procedures A.14.1.3 Protecting Application Services Transactions	CSC 8 Malware Defenses CSC 12 Boundary Defense CSC 15 Wireless Access Control	PR-INF-001 Cyber Defense Infrastructure Support Specialist OV-SPP-002 Cyber Policy and Strategy Planner PR-CDA-001 Cyber Defense Analyst OM-NET-001 Network Operations Specialist

Mobile Device Security

Corporate-Owned Personally-Enabled (COPE)

Volume C:
How-to Guides

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July 2019

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National Institute of Standards and Technology Special Publication 1800-21C Natl. Inst. Stand. Technol. Spec. Publ. 1800-21C, 169 pages, (July 2019), CODEN: NSPUE2

FEEDBACK

You can improve this guide by contributing feedback. As you review and adopt this solution for your own organization, we ask you and your colleagues to share your experience and advice with us.

Comments on this publication may be submitted to: mobile-nccoe@nist.gov.

Public comment period: July 22, 2019 through September 23, 2019

All comments are subject to release under the Freedom of Information Act.

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1 **NATIONAL CYBERSECURITY CENTER OF EXCELLENCE**

2 The National Cybersecurity Center of Excellence (NCCoE), a part of the National Institute of Standards
3 and Technology (NIST), is a collaborative hub where industry organizations, government agencies, and
4 academic institutions work together to address businesses' most pressing cybersecurity issues. This
5 public-private partnership enables the creation of practical cybersecurity solutions for specific
6 industries, as well as for broad, cross-sector technology challenges. Through consortia under
7 Cooperative Research and Development Agreements (CRADAs), including technology partners—from
8 Fortune 50 market leaders to smaller companies specializing in information technology security—the
9 NCCoE applies standards and best practices to develop modular, easily adaptable example cybersecurity
10 solutions using commercially available technology. The NCCoE documents these example solutions in
11 the NIST Special Publication 1800 series, which maps capabilities to the NIST Cybersecurity Framework
12 and details the steps needed for another entity to re-create the example solution. The NCCoE was
13 established in 2012 by NIST in partnership with the State of Maryland and Montgomery County,
14 Maryland.

15 To learn more about the NCCoE, visit <https://www.nccoe.nist.gov>. To learn more about NIST, visit
16 <https://www.nist.gov>.

17 **NIST CYBERSECURITY PRACTICE GUIDES**

18 NIST Cybersecurity Practice Guides (Special Publication 1800 series) target specific cybersecurity
19 challenges in the public and private sectors. They are practical, user-friendly guides that facilitate the
20 adoption of standards-based approaches to cybersecurity. They show members of the information
21 security community how to implement example solutions that help them align more easily with relevant
22 standards and best practices, and provide users with the materials lists, configuration files, and other
23 information they need to implement a similar approach.

24 The documents in this series describe example implementations of cybersecurity practices that
25 businesses and other organizations may voluntarily adopt. These documents do not describe regulations
26 or mandatory practices, nor do they carry statutory authority.

27 **ABSTRACT**

28 Mobile devices provide access to workplace data and resources that are vital for organizations to
29 accomplish their mission while providing employees the flexibility to perform their daily activities.
30 Securing these devices is essential to the continuity of business operations.

31 While mobile devices can increase organizations' efficiency and employee productivity, they can also
32 leave sensitive data vulnerable. Addressing such vulnerabilities requires mobile device management
33 tools to help secure access to the network and resources. These tools are different from those required
34 to secure the typical computer workstation.

35 To address the challenge of securing mobile devices while managing risks, the NCCoE at NIST built a
 36 reference architecture to show how various mobile security technologies can be integrated within an
 37 enterprise's network.

38 This NIST Cybersecurity Practice Guide demonstrates how organizations can use standards-based,
 39 commercially available products to help meet their mobile device security and privacy needs.

40 **KEYWORDS**

41 *Bring your own device; BYOD; corporate-owned personally-enabled; COPE; mobile device management;*
 42 *mobile device security, on-premise.*

43 **ACKNOWLEDGMENTS**

44 We are grateful to the following individuals for their generous contributions of expertise and time.

Name	Organization
Donna Dodson	NIST
Vincent Sritapan	Department of Homeland Security, Science and Technology Directorate
Jason Frazell	Appthority (acquired by Symantec)
Joe Middlyng	Appthority (acquired by Symantec)
Chris Gogoel	Kryptowire
Tom Karygiannis	Kryptowire
Tim LeMaster	Lookout
Victoria Mosby	Lookout
Michael Carr	MobileIron
Walter Holda	MobileIron
Farhan Saifudin	MobileIron

Name	Organization
Jeff Lamoureaux	Palo Alto Networks
Sean Morgan	Palo Alto Networks
Kabir Kasargod	Qualcomm
Viji Raveendran	Qualcomm
Lura Danley	The MITRE Corporation
Eileen Durkin	The MITRE Corporation
Sallie Edwards	The MITRE Corporation
Marisa Harriston	The MITRE Corporation
Nick Merlino	The MITRE Corporation
Doug Northrip	The MITRE Corporation
Titilayo Ogunyale	The MITRE Corporation
Oksana Slivina	The MITRE Corporation
Tracy Teter	The MITRE Corporation
Paul Ward	The MITRE Corporation

45 The Technology Partners/Collaborators who participated in this build submitted their capabilities in
46 response to a notice in the Federal Register. Respondents with relevant capabilities or product
47 components were invited to sign a Cooperative Research and Development Agreement (CRADA) with
48 NIST, allowing them to participate in a consortium to build this example solution. We worked with:

Technology Partner/Collaborator	Build Involvement
Appthority	Appthority Cloud Service, Mobile Threat Intelligence
Kryptowire	Kryptowire Cloud Service, Application Vetting
Lookout	Lookout Cloud Service/Lookout Agent Version 5.10.0.142 (iOS), 5.9.0.420 (Android), Mobile Threat Defense
MobileIron	MobileIron Core Version 9.7.0.1, MobileIron Agent Version 11.0.1A (iOS), 10.2.1.1.3R (Android), Enterprise Mobility Management
Palo Alto Networks	Palo Alto Networks PA-220
Qualcomm	Qualcomm Trusted Execution Environment (version is device dependent)

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292 1 Introduction

293 The following volumes of this guide show information technology (IT) professionals and security
294 engineers how we implemented this example solution. We cover all of the mobile device security
295 products employed in this reference design. We do not re-create the product manufacturers'
296 documentation, which is presumed to be widely available. Rather, these volumes show how we
297 incorporated the products together in our environment.

298 *Note: These are not comprehensive tutorials. There are many possible service and security configurations*
299 *for these products that are out of scope for this reference design.*

300 1.1 Practice Guide Structure

301 This National Institute of Standards and Technology (NIST) Cybersecurity Practice Guide demonstrates a
302 standards-based reference design and provides users with the information they need to replicate
303 addressing mobile device security (MDS) implementation challenges. This reference design is modular
304 and can be deployed in whole or in part.

305 This guide contains three volumes:

- 306 ▪ NIST SP 1800-21A: *Executive Summary*
- 307 ▪ NIST SP 1800-21B: *Approach, Architecture, and Security Characteristics* – what we built and why
- 308 ▪ NIST SP 1800-21C: *How-To Guides* – instructions for building the example solution (**you are**
309 **here**)

310 Depending on your role in your organization, you might use this guide in different ways:

311 **Business decision makers, including chief security and technology officers**, will be interested in the
312 *Executive Summary, NIST SP 1800-21A*, which describes the following topics:

- 313 ▪ challenges that enterprises face in securely deploying mobile devices within their organization
- 314 ▪ example solution built at the National Cybersecurity Center of Excellence (NCCoE)
- 315 ▪ benefits of adopting the example solution

316 **Technology or security program managers** who are concerned with how to identify, understand, assess,
317 and mitigate risk will be interested in *NIST SP 1800-21B*, which describes what we did and why. The
318 following sections will be of particular interest:

- 319 ▪ Section 3.4, Risk Assessment, describes the risk analysis we performed.
- 320 ▪ Section 4.3, Security Control Map, discusses the security mappings of this example solution to
321 cybersecurity standards and best practices.

322 You might share the *Executive Summary, NIST SP 1800-21A*, with your leadership team members to help
323 them understand the importance of adopting standards-based solutions when addressing MDS
324 implementation challenges.

325 **IT professionals** who want to implement an approach like this will find this whole practice guide useful.
326 You can use this How-To portion of the guide, *NIST SP 1800-21C*, to replicate all or parts of the build
327 created in our lab. This How-To portion of the guide provides specific product installation, configuration,
328 and integration instructions for implementing the example solution. We do not recreate the product
329 manufacturers' documentation, which is generally widely available. Rather, we show how we
330 incorporated the products together in our environment to create an example solution.

331 This guide assumes that IT professionals have experience implementing security products within the
332 enterprise. While we have used a suite of commercial products to address this challenge, this guide does
333 not endorse these particular products. Your organization can adopt this solution or one that adheres to
334 these guidelines in whole, or you can use this guide as a starting point for tailoring and implementing
335 parts of this guide's example solution for on-premises mobile device security management. Your
336 organization's security experts should identify the products that will best integrate with your existing
337 tools and IT system infrastructure. We hope that you will seek products that are congruent with
338 applicable standards and best practices. Section 3.6, Technologies, lists the products that we used and
339 maps them to the cybersecurity controls provided by this reference solution.

340 A NIST Cybersecurity Practice Guide does not describe "the" solution, but a possible solution. This is a
341 draft guide. We seek feedback on its contents and welcome your input. Comments, suggestions, and
342 success stories will improve subsequent versions of this guide. Please contribute your thoughts to
343 mobile-nccoe@nist.gov.

344 **1.2 Build Overview**

345 When a business is on the go, mobile devices can serve as a temporary workstation replacement. They
346 provide convenience of use, portability, and functionality. However, in many ways, mobile devices are
347 different from the common computer workstation, and alternative management tools are required to
348 secure their interactions with the enterprise. To address this security challenge, the NCCoE worked with
349 its Community of Interest and build team partners and developed a real-world scenario for mobile
350 deployment within an enterprise. The scenario presents a range of security challenges that an enterprise
351 may experience when deploying mobile devices.

352 The lab environment used in developing this solution includes the architectural components,
353 functionality, and standard best practices, which are described in Volume B. The build team partners
354 provided the security technologies used to deploy the architecture components and functionality. The
355 standard best practices are applied to the security technologies to ensure the appropriate security
356 controls are put in place to meet the challenges presented in the devised scenario.

357 This section of the guide documents the build process and discusses the specific configurations used to
 358 develop a secure mobile deployment.

359 *Note:* Android for Work has been re-branded as Android Enterprise. At the time of writing this
 360 document, it was named Android for Work.

361 1.3 Typographic Conventions

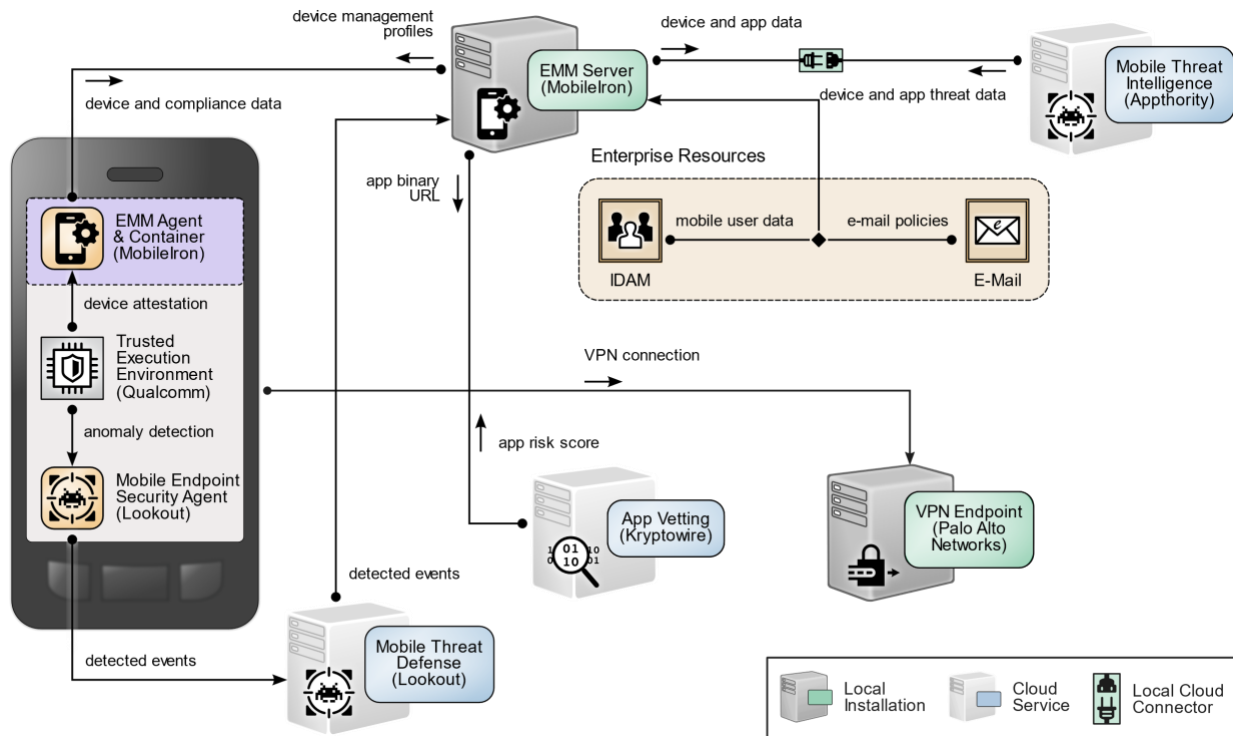
362 The following table presents typographic conventions used in this volume.

363 Table 1-1 Typographic Conventions

Typeface/Symbol	Meaning	Example
<i>Italics</i>	file names and path names; references to documents that are not hyperlinks; new terms; and placeholders	For detailed definitions of terms, see the <i>NCCoE Glossary</i> .
Bold	names of menus, options, command buttons, and fields	Choose File > Edit .
Monospace	command-line input, onscreen computer output, sample code examples, and status codes	<code>mkdir</code>
Monospace Bold	command-line user input contrasted with computer output	<code>service sshd start</code>
blue text	link to other parts of the document, a web URL, or an email address	All publications from NIST's NCCoE are available at https://www.nccoe.nist.gov .

364 1.4 Logical Architecture Summary

365 The following graphic illustrates the main components of this example implementation and provides a
 366 simplified view of how they interact.

367 **Figure 1-1 Logical Architecture Summary**368 **2 Product Installation Guides**

369 This section of the practice guide contains detailed instructions for installing and configuring key
 370 products used for the architecture illustrated below.

371 In our lab environment, the example solution was logically separated by a virtual local area network
 372 (VLAN) wherein each VLAN represented a separate mock enterprise environment. The network
 373 perimeter for this example implementation was enforced by a Palo Alto Networks virtual private
 374 network (VPN)/firewall appliance. It maintains three zones: one each for the internet/wide area network
 375 (WAN), a demilitarized zone (DMZ), and the organizational local area network (LAN).

376 **2.1 Appthority Mobile Threat Detection**

377 Appthority contributed a test instance of its Mobile Threat Detection service. Contact Appthority
 378 (Symantec) (<https://www.symantec.com/>) to establish an instance for your organization.

379 2.2 Kryptowire EMM+S

380 Kryptowire contributed a test instance of its EMM+S application-vetting service. Contact Kryptowire
381 (<https://www.kryptowire.com/mobile-app-security/>) to establish an instance for your organization.

382 2.3 Lookout Mobile Endpoint Security

383 Lookout contributed a test instance of its Mobile Endpoint Security (MES) service. Contact Lookout
384 (<https://www.lookout.com/products/mobile-endpoint-security>) to establish an instance for your
385 organization.

386 2.4 MobileIron Core

387 MobileIron Core is the central product in the MobileIron suite. The following sections describe the steps
388 for installation, configuration, and integration with Active Directory (AD).

389 2.4.1 Installation of MobileIron Core and Stand-Alone Sentry

390 Follow the steps below to install MobileIron Core:

- 391 1. Obtain a copy of the *On-Premise Installation Guide for MobileIron Core, Sentry, and*
392 *Enterprise Connector* from the MobileIron support portal.
- 393 2. Follow the MobileIron Core predeployment and installation steps in Chapter 1 of the *On-*
394 *Premise Installation Guide for MobileIron Core, Sentry, and Enterprise Connector* for the
395 version of MobileIron being deployed in your environment. In our lab implementation, we
396 deployed MobileIron Core 9.5.0.0 as a Virtual Core running on VMware 6.0. Post-
397 installation, we performed an upgrade to MobileIron Core 9.7.0.1 following guidance
398 provided in *CoreConnectorReleaseNotes9701_Rev12Apr2018*. Direct installations to
399 MobileIron Core 9.7.0.1 will experience slightly different results, as some added features in
400 this version are not used with earlier versions of configuration files.

401 2.4.2 General MobileIron Core Setup

402 The following steps are necessary for mobile device administrators or users to register devices with
403 MobileIron.

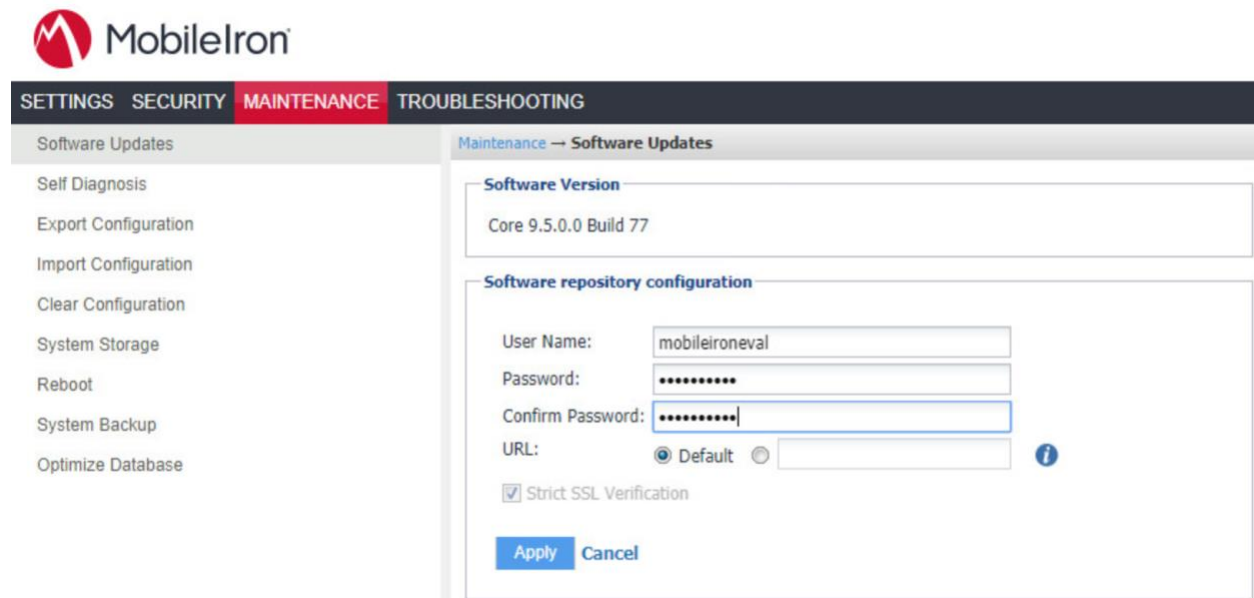
- 404 1. Obtain a copy of *MobileIron Core Device Management Guide for iOS Devices* from the
405 MobileIron support portal.
- 406 2. Complete all instructions provided in Chapter 1, Setup Tasks.

407 2.4.3 Upgrade MobileIron Core

408 The following steps were used to upgrade our instance of MobileIron Core from 9.5.0.0 to 9.7.0.1. Note
 409 there was no direct upgrade path between these two versions; our selected upgrade path was 9.5.0.0 >
 410 9.5.0.1 > 9.7.0.1.

- 411 1. Obtain upgrade credentials from MobileIron Support.
- 412 2. In **MobileIron Core System Manager**, navigate to **Maintenance > Software Updates**.
- 413 3. In the **Software repository configuration** section:
 - 414 a. In the **User Name** field, enter the username provided by MobileIron Support.
 - 415 b. In the **Password** field, enter the password provided by MobileIron Support.
 - 416 c. In the **Confirm Password** field, reenter the password provided by MobileIron Support.
 - 417 d. Select **Apply**.

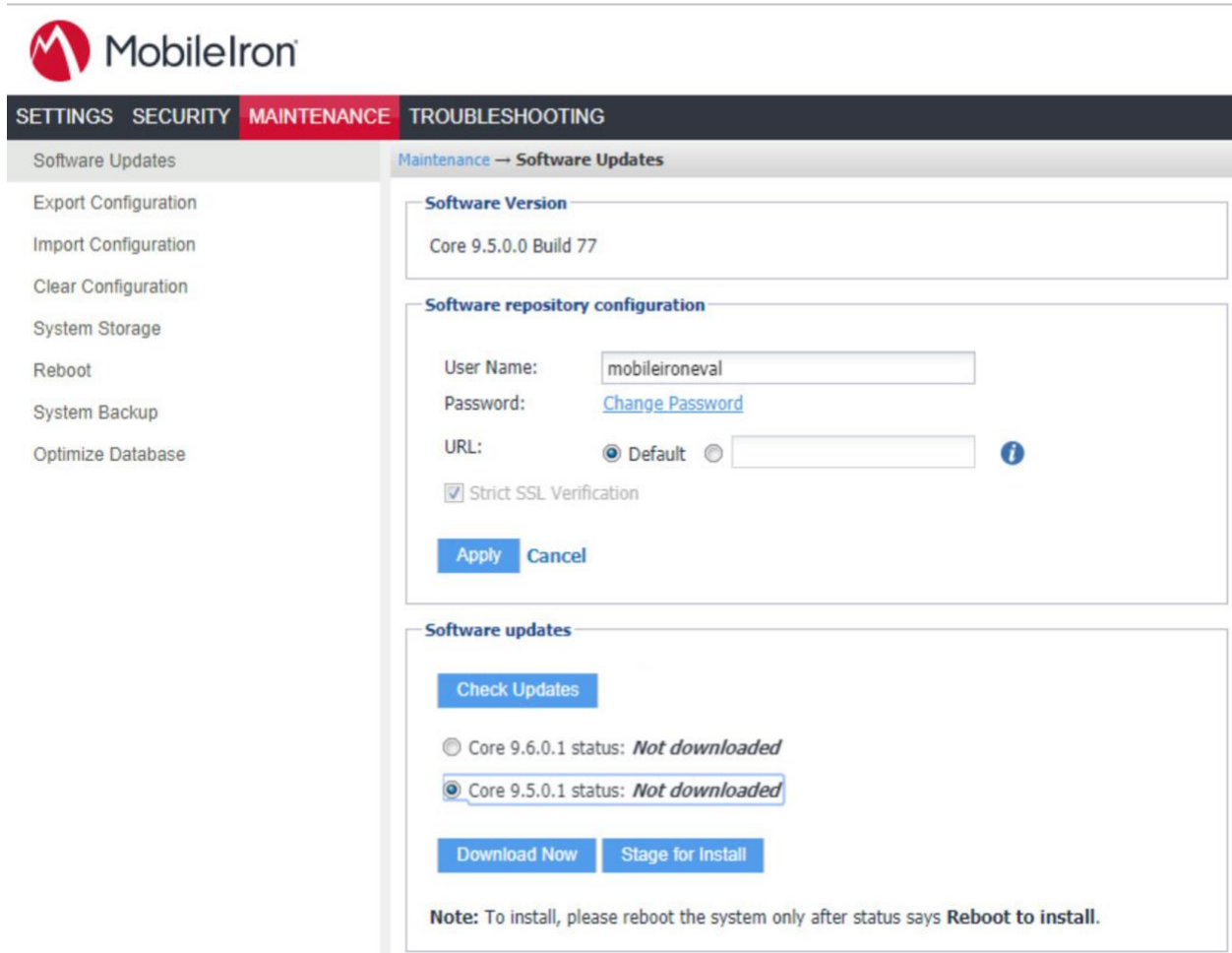
418 Figure 2-1 MobileIron Repository Configuration



- 419 4. In the **Software Updates** section:
 - 420 a. Select **Check Updates**; after a few seconds, the available upgrade path options will
 421 appear.
 - 422 b. Select the **Core 9.5.0.1 status: Not Downloaded** option.

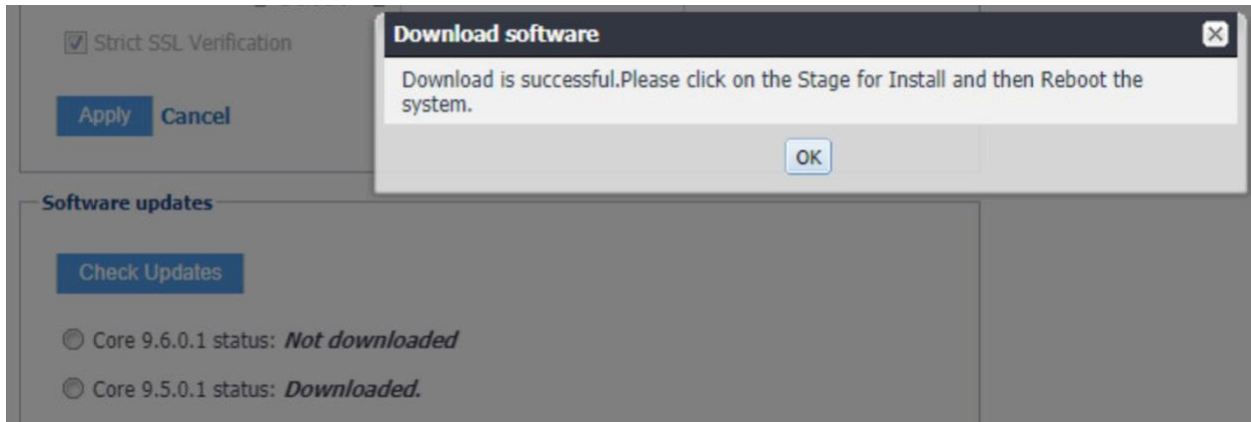
423 c. Select **Download Now**. After a delay, the Software Download dialogue will appear.

424 Figure 2-2 MobileIron Core Version



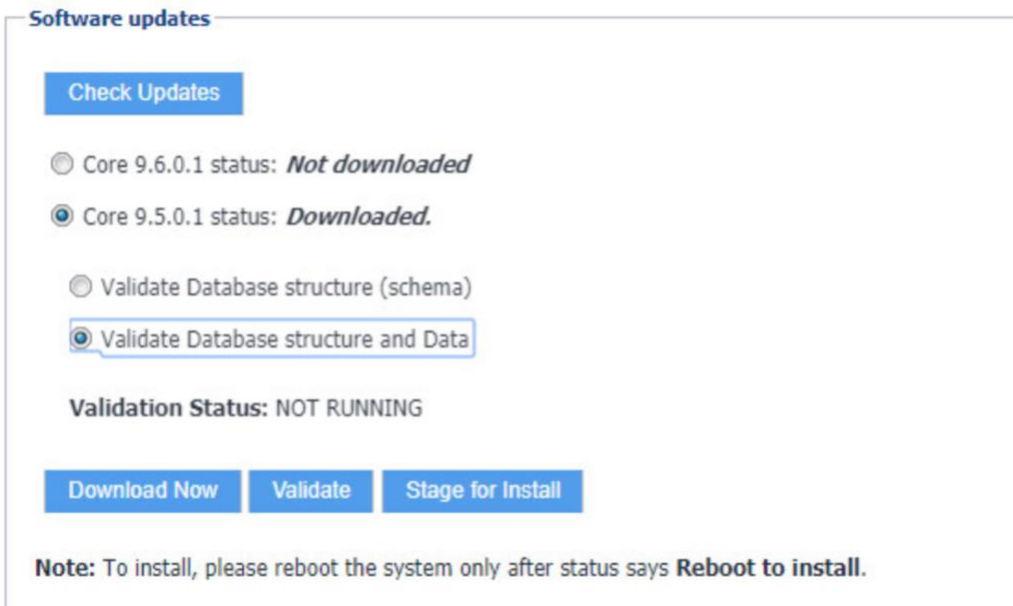
425 5. In the **Download Software** dialogue, select **OK**.

426 Figure 2-3 MobileIron Download Status



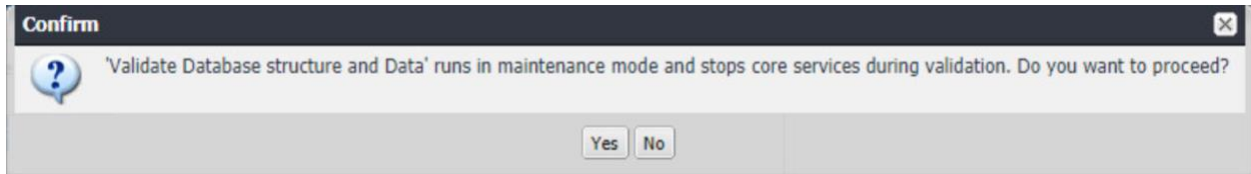
- 427 6. In the **Software updates** section:
- 428 a. Select the **Core 9.5.0.1 status: Downloaded** option.
- 429 b. Select the **Validate Database Structure and Data** option.
- 430 c. Select **Validate**.

431 Figure 2-4 Validating Database Data



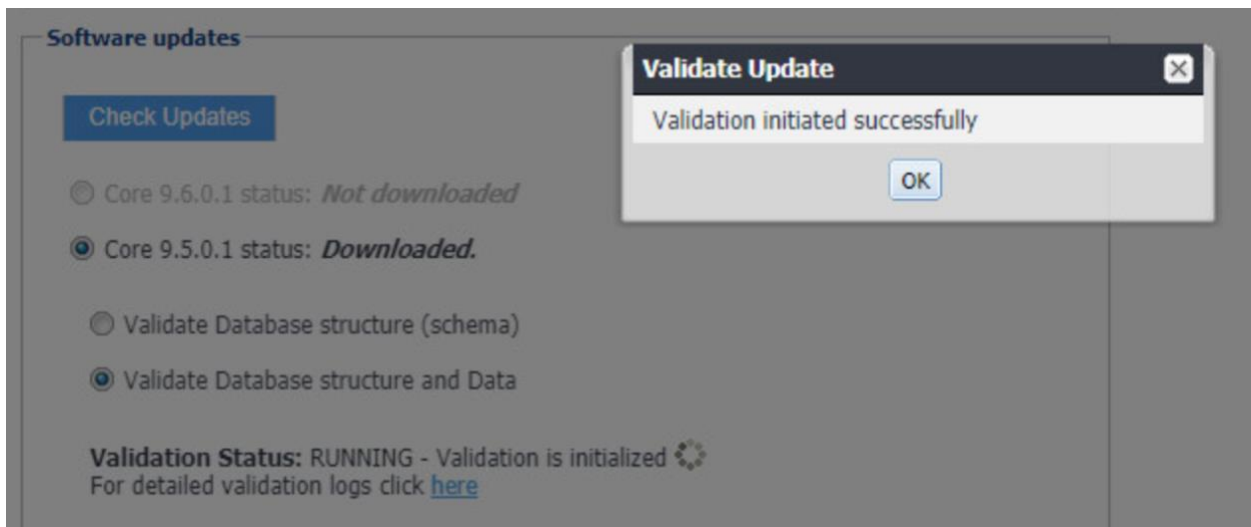
- 432 7. In the **Confirm** dialogue, select **Yes** to validate database structure and data.

433 Figure 2-5 Validating Database Data Confirmation



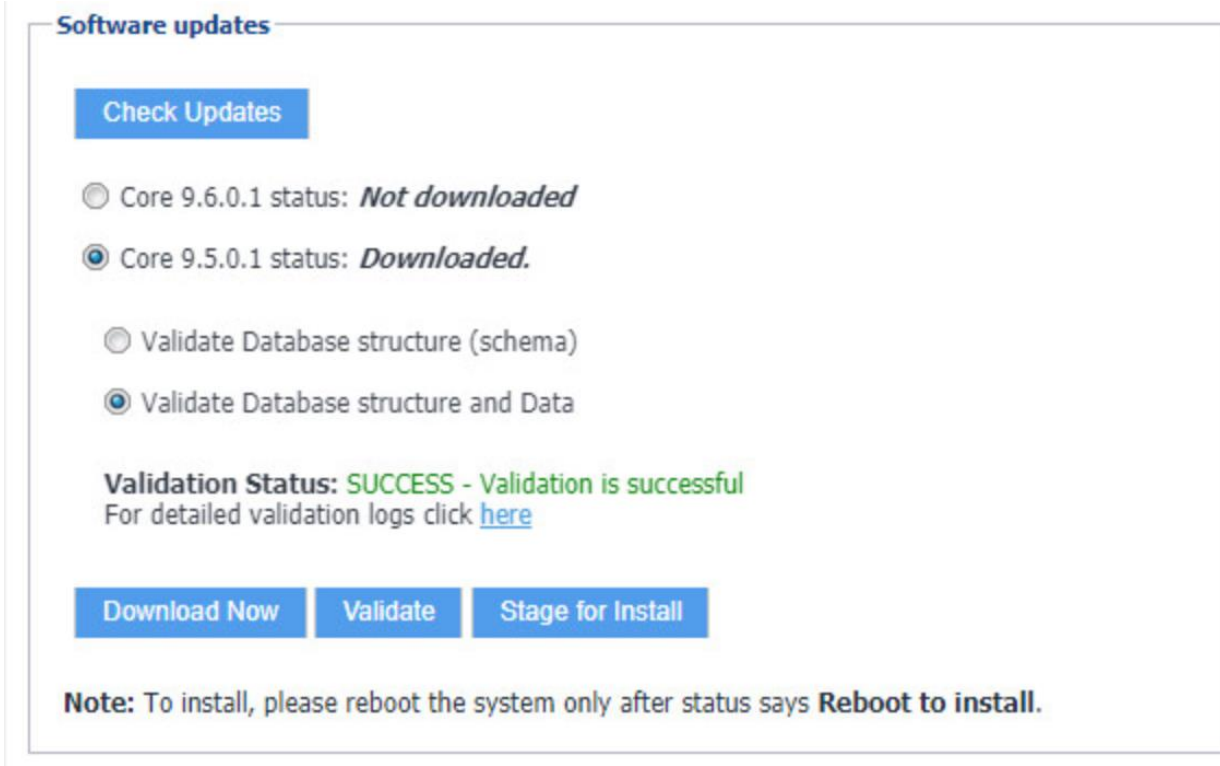
434 8. In the **Validate Update** dialogue, select **OK**.

435 Figure 2-6 Database Data Validation Initiation Confirmation



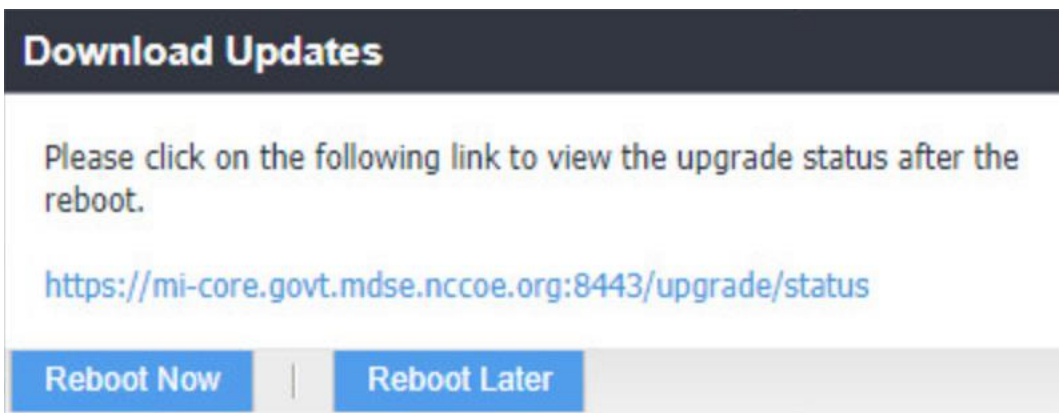
436 9. In the **Software updates** section, select **Stage for Install**; the **Download Updates** dialogue
437 will appear.

438 Figure 2-7 Database Data Validation Status



439 10. In the **Download Updates** dialogue, select **Reboot Now**; a series of dialogues will appear.

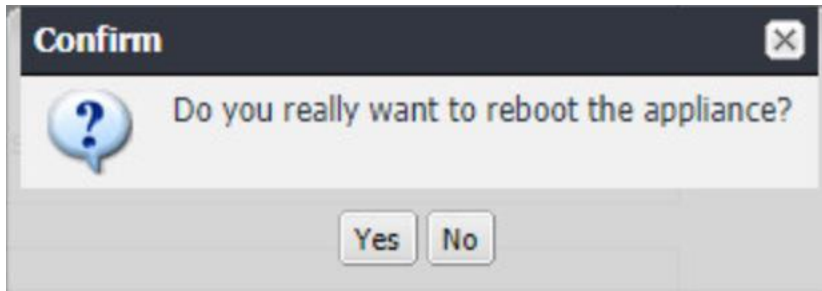
440 Figure 2-8 Software Updates Reboot Prompt



441 11. In the **Confirm** dialogues:

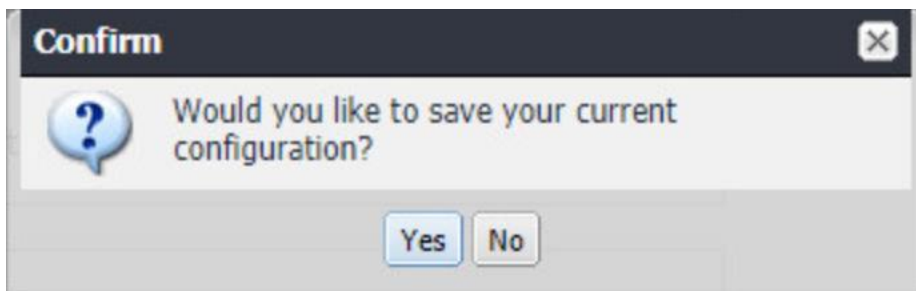
442 a. Select **Yes** to confirm reboot of the appliance.

443 Figure 2-9 Software Update Reboot Confirmation



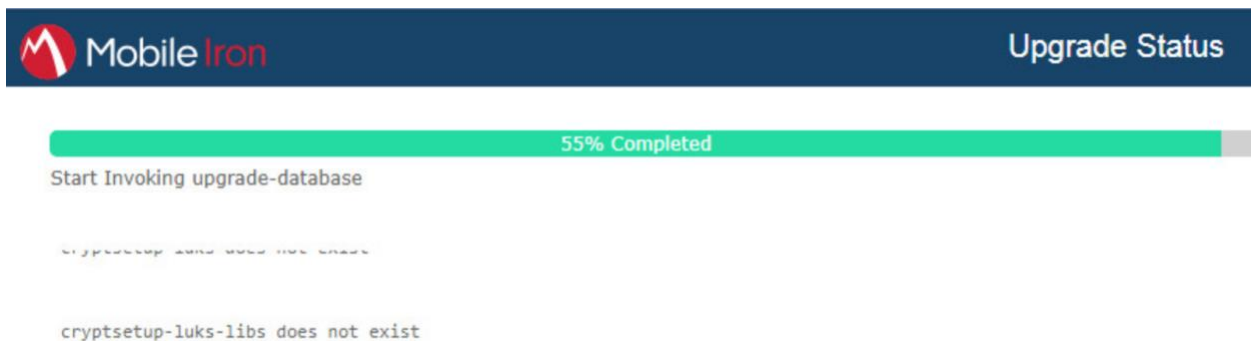
444 b. Select **Yes** to confirm saving the current configuration.

445 Figure 2-10 Reboot Configuration Save Prompt



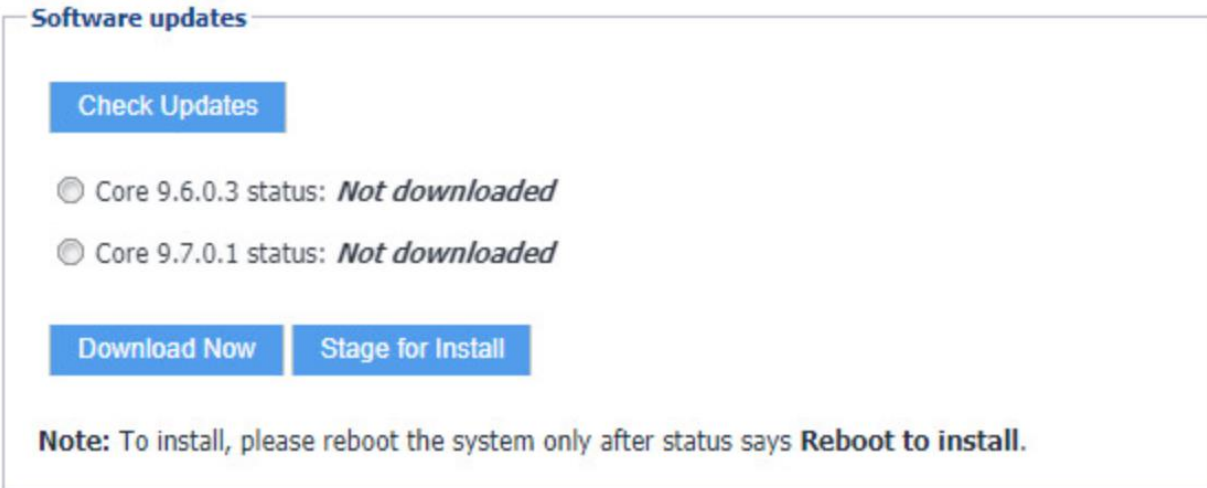
446 12. The Upgrade Status website hosted by Core will automatically open.

447 Figure 2-11 Upgrade Status



448 13. Once the upgrade is complete, **System Manager > Maintenance > Software Updates >**
449 **Software Updates** now shows the capability to upgrade to 9.7.0.1.

450 Figure 2-12 Ability to Upgrade to 9.7.0.1



- 451 14. Repeat **Steps 4b** through **11** above, replacing 9.5.0.1 with **9.7.0.1** during **Steps 4b** and **6**;
452 this will complete the upgrade path from MobileIron Core 9.5.0.0 to 9.7.0.1.

453 2.4.4 Integration with Microsoft Active Directory

454 In our implementation, we chose to integrate MobileIron Core with Active Directory using lightweight
455 directory access protocol (LDAP). This is optional. General instructions for this process are covered in the
456 *Configuring LDAP Servers* section in Chapter 2 of *On-Premise Installation Guide for MobileIron Core,*
457 *Sentry, and Enterprise Connector*. The configuration details used during our completion of selected steps
458 (retaining the original numbering) from that guide are given below:

- 459 1. From Step 4 in the MobileIron guide, in the **New LDAP Server** dialogue:
460 a. Directory Connection:

461 Figure 2-13 LDAP Settings

The screenshot shows a 'New LDAP Setting' dialog box with the following fields and options:

- Directory Connection**
- Directory URL: ldap://192.168.7.10
- Directory Failover URL: ldap(s)://<IP or Hostname>:[port]
- Directory UserID: mi-ldap-sync
- Change Password (link)
- Search Results Timeout: 30 Seconds
- Chase Referrals: Enable Disable
- Admin State: Enable Disable
- Directory Type: Active Directory Domino Other
- Domain: govt.mds.local

462 b. Directory Configuration—OUs:

463 Figure 2-14 LDAP OUs

The screenshot shows a 'New LDAP Setting' dialog box with the following fields:

- Directory Configuration - OUs**
- OU Base DN: dc=govt,dc=mds,dc=local
- OU Search Filter: (!(objectClass=organizationalUnit)(objectClass=container))

464 c. Directory Configuration—Users:

465 Figure 2-15 LDAP User Configuration

The screenshot shows a 'New LDAP Setting' dialog box with a dark header and a close button. The title is 'Directory Configuration - Users'. It contains several input fields for LDAP user configuration:

User Base DN:	dc=govt,dc=mds,dc=local
Search Filter:	(&(objectClass=user)(objectClass=person))
Search Scope:	All Levels
First Name:	givenName
Last Name:	sn
User ID:	sAMAccountName
Email:	mail
Display Name:	displayName
Distinguished Name:	distinguishedName
User Principal Name:	userPrincipalName
Locale:	c

466 d. Directory Configuration—Groups:

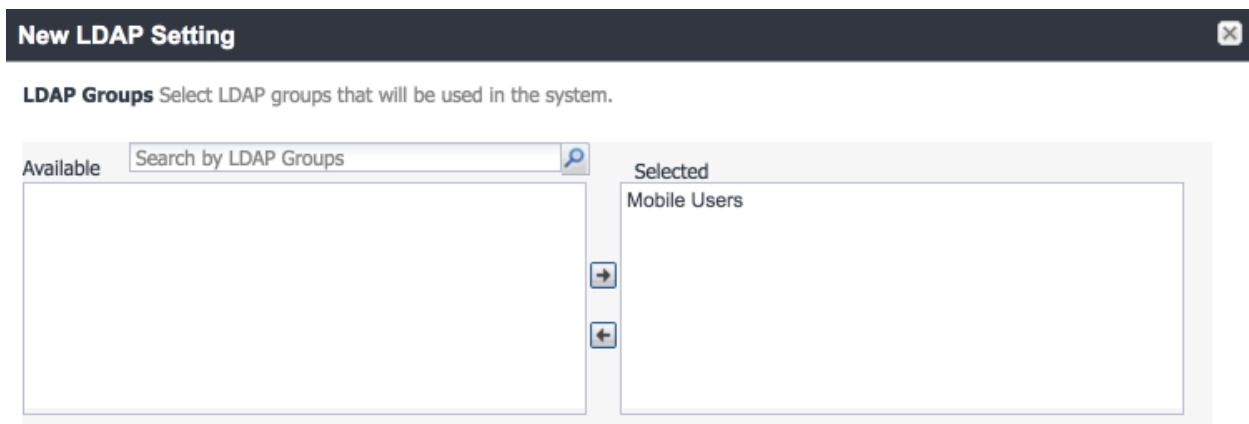
467 Figure 2-16 LDAP Group Configuration

The screenshot shows a 'New LDAP Setting' dialog box with a dark header and a close button. The title is 'Directory Configuration - Groups'. It contains several input fields for LDAP group configuration:

User Group Base DN:	dc=govt,dc=mds,dc=local
Search Filter:	(objectClass=group)
Search Scope :	All Levels
User Group Name:	cn
Membership Attribute:	member
Member Of Attribute:	memberOf
Custom Attribute-1:	
Custom Attribute-2:	
Custom Attribute-3:	
Custom Attribute-4:	

- 468 e. LDAP Groups:
- 469 i. As a preparatory step, we used Active Directory Users and Computers to create
470 a new security group for mobile-authorized users on the Domain Controller for
471 the *govt.mds.local* domain. In our example, this group is named **Mobile Users**.
- 472 ii. In the search bar, enter the name of the LDAP group for mobile-authorized
473 users.
- 474 iii. Select the **magnifying glass** button; the group name should be added to the
475 **Available** list.
- 476 iv. In the **Available** list box:
- 477 1) Select the **Mobile Users** list item.
- 478 2) Select the **right-arrow** button; the Mobile Users list item should move to
479 the **Selected** list box.
- 480 v. In the **Selected** list:
- 481 1) Select the default **Users** group list item.
- 482 2) Select the **left-arrow** button; the Users list item should move to the
483 **Available** list box.

484 Figure 2-17 Selected LDAP Group



- 485 f. Custom Settings: Custom settings were not specified.
- 486 g. Advanced Options: Advanced options were configured as shown in Figure 2-18.

487 Figure 2-18 LDAP Advanced Options

The screenshot shows a dialog box titled "New LDAP Setting" with a close button (X) in the top right corner. Below the title bar, there are two empty input fields. The main content area is titled "Advanced Options" and is checked. It contains the following settings:

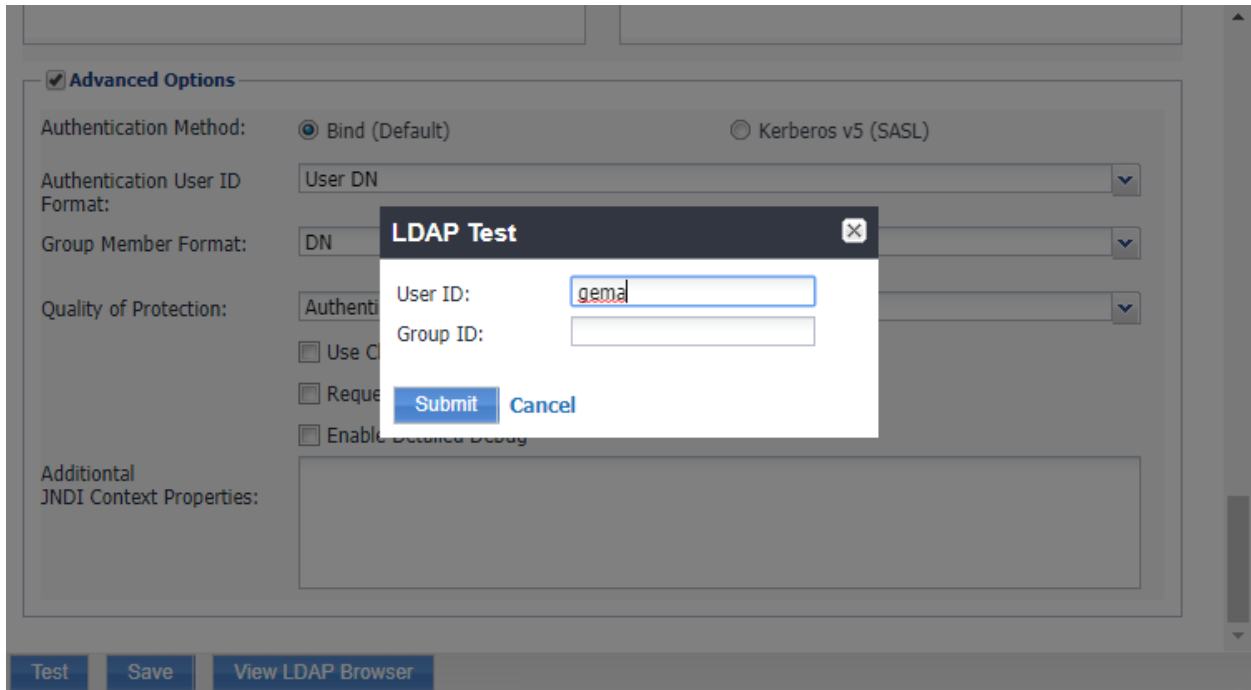
- Authentication Method:** Radio buttons for "Bind (Default)" (selected) and "Kerberos v5 (SASL)".
- Authentication User ID Format:** A dropdown menu with "User DN" selected.
- Group Member Format:** A dropdown menu with "DN" selected.
- Quality of Protection:** A dropdown menu with "Authentication only" selected.
- Use Client TLS Certificate:** An unchecked checkbox.
- Request Mutual Authentication:** An unchecked checkbox.
- Enable Detailed Debug:** An unchecked checkbox.
- Additional JNDI Context Properties:** A large empty text area.

At the bottom of the dialog, there are three buttons: "Test", "Save", and "View LDAP Browser".

488 **Note:** In our lab environment, we did not enable stronger Quality of Protection or enable the Use of
 489 Client Transport Layer Security Certificate or Request Mutual Authentication features. However, we
 490 recommend that implementers consider using those additional mechanisms to secure communication
 491 with the LDAP server.

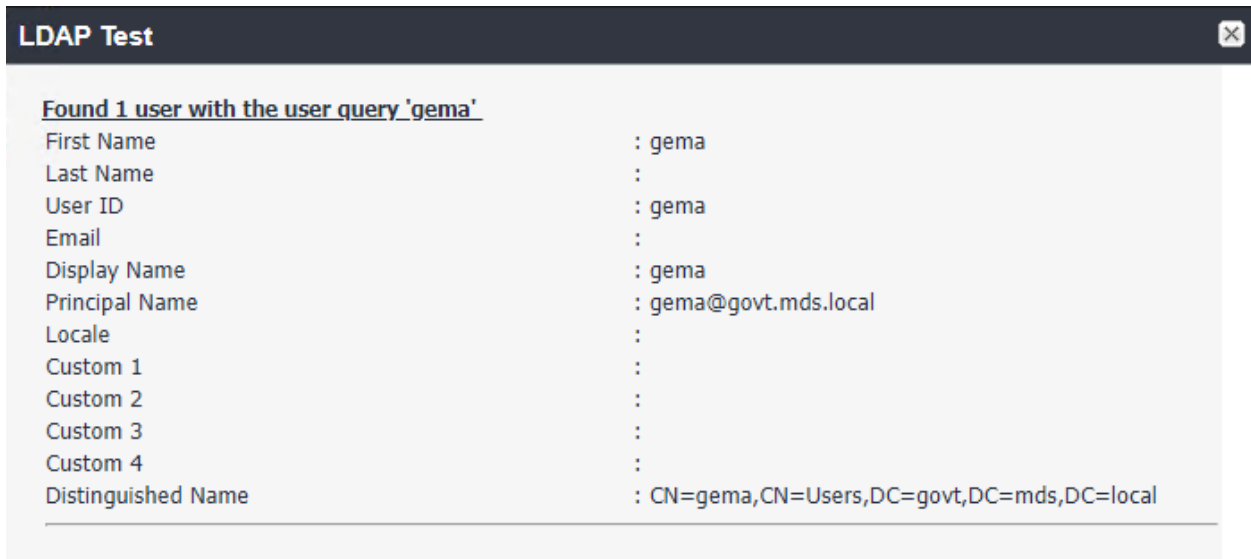
- 492 2. From **Steps 19** through **21** from the MobileIron guide, we tested that MobileIron can
 493 successfully query LDAP for Derived Personal Identity Verification Credential (DPC) Users.
- 494 a. In the **New LDAP Setting** dialogue, click the **Test** button to open the **LDAP Test** dialogue.
- 495 b. In the **LDAP Test** dialogue, enter a **User ID** for a member of the DPC Users group, then
 496 click the **Submit** button. A member of the Mobile Users group in our environment is
 497 **gema**.

498 Figure 2-19 Testing LDAP Configuration



499 c. The **LDAP Test** dialogue indicates the query was successful:

500 Figure 2-20 LDAP Test Result



501 2.4.5 Create a Mobile Users Label

502 MobileIron uses labels to link policies and device configurations with users and mobile devices. Creating
 503 a unique label for each category of authorized mobile user allows mobile device administrators to apply
 504 a consistent set of controls applicable to users with a common mobile use case. Our limited usage
 505 scenario only required a single MobileIron label to be created.

- 506 1. In the **MobileIron Core Admin Portal**, navigate to **Devices & Users > Labels**.
- 507 2. Select **Add Label**.

508 **Figure 2-21 MobileIron Device Labels**

	NAME	DESCRIPTION	TYPE	CRITERIA	SPACE	VIEW DE...
<input type="checkbox"/>	AFW	Android for Work - enter...	Filter	("common.platform" = "android" and "android.afw_cap...	Global	10
<input type="checkbox"/>	All-Smartphones	Label for all devices irre...	Filter	"common.retired"=false	Global	16

- 509 3. In the **Name** field, enter a unique name for this label (**Mobile Users** in this example).
- 510 4. In the **Description** field, enter a meaningful description to help others identify its purpose.
- 511 5. Under the **Criteria** section:
 - 512 a. In the blank rule:
 - 513 i. In the **Field** drop-down menu, select **User > LDAP > Groups > Name**.
 - 514 ii. In the **Value** drop-down menu, select the Active Directory group created to
 515 support mobile user policies (named **Mobile User** in this example).
 - 516 b. Select the **plus sign icon** to add a blank rule.
 - 517 c. In the newly created blank rule:
 - 518 i. In the **Field** drop-down menu, select **Common > Platform**.
 - 519 ii. In the **Value** drop-down menu, select **Android**.

520 Figure 2-22 Adding a Device Label

Add Label [X]

Name:

Description:

Type: Manual Filter

Criteria

of the following rules are true

Name Equals + -

Platform Equals + -

- 521 d. The list of matching devices will appear below the specified criteria.
- 522 e. Select **Save**.

523 Figure 2-23 Device Label Matches

Exclude retired devices from search results

3 matching devices

DISPLAY NAME	CURRENT PHONE NUMBER	MODEL	STATUS
sallie	1234567890		Pending
jason	PDA		Pending
gema	PDA		Pending

- 524 6. Navigate to **Devices & Users > Labels** to confirm the label was successfully created.

525 Figure 2-24 MobileIron Label List

	NAME	DESCRIPTION	TYPE	CRITERIA	SPACE	VIEW DE...
<input type="checkbox"/>	macOS	Label for all macOS De...	Filter	"common.platform"="macOS" AND "common.retired"=...	Global	0
<input type="checkbox"/>	Mobile Users	Label for users authoriz...	Filter	("user.idap.groups.name" = "Mobile Users" AND "com...	Global	3
<input type="checkbox"/>	MTP - Deactivated	Device lifecycle: deactiv...	Manual		Global	0

526 2.5 Integration of Palo Alto Networks GlobalProtect with MobileIron

527 The following steps detail how to integrate MobileIron Core, Microsoft Certificate Authority (CA), and
 528 Palo Alto Networks GlobalProtect to allow mobile users to authenticate to the GlobalProtect gateway
 529 using user-aware device certificates issued to mobile devices by Microsoft CA during enrollment with
 530 MobileIron Core.

531 2.5.1 MobileIron Configuration

532 The following steps create the MobileIron Core configurations necessary to support integration with
 533 Palo Alto GlobalProtect and Microsoft CA.

534 2.5.1.1 Create Simple Certificate Enrollment Protocol (SCEP) Configuration

- 535 1. In the **MobileIron Admin Portal**, navigate to **Policies & Configs > Configurations**.
- 536 2. Select **Add New > Certificate Enrollment > SCEP**; the **New SCEP Configuration Enrollment**
 537 **Setting** dialogue will open.
- 538 3. In the **New SCEP Certificate Enrollment Setting** dialogue:
 - 539 a. For the **Name** field, enter a unique name to identify this configuration.
 - 540 b. Enable the **Device Certificate** option.
 - 541 c. In the **URL** field, enter the URL where SCEP is hosted within your environment.
 - 542 d. In the **CA-Identifier (ID)** field, enter the subject name of the Microsoft CA that will issue
 543 the device certificates.
 - 544 e. In the **Subject** drop-down menu, select **\$DEVICE_IMEI\$**.

545 Figure 2-25 MobileIron SCEP Configuration

New SCEP Certificate Enrollment Setting

Name

Description

Centralized
 Decentralized

Store keys on core
 Proxy requests through Core

User Certificate
 Device Certificate

URL

CA-Identifier

Subject

Subject Common Name Type

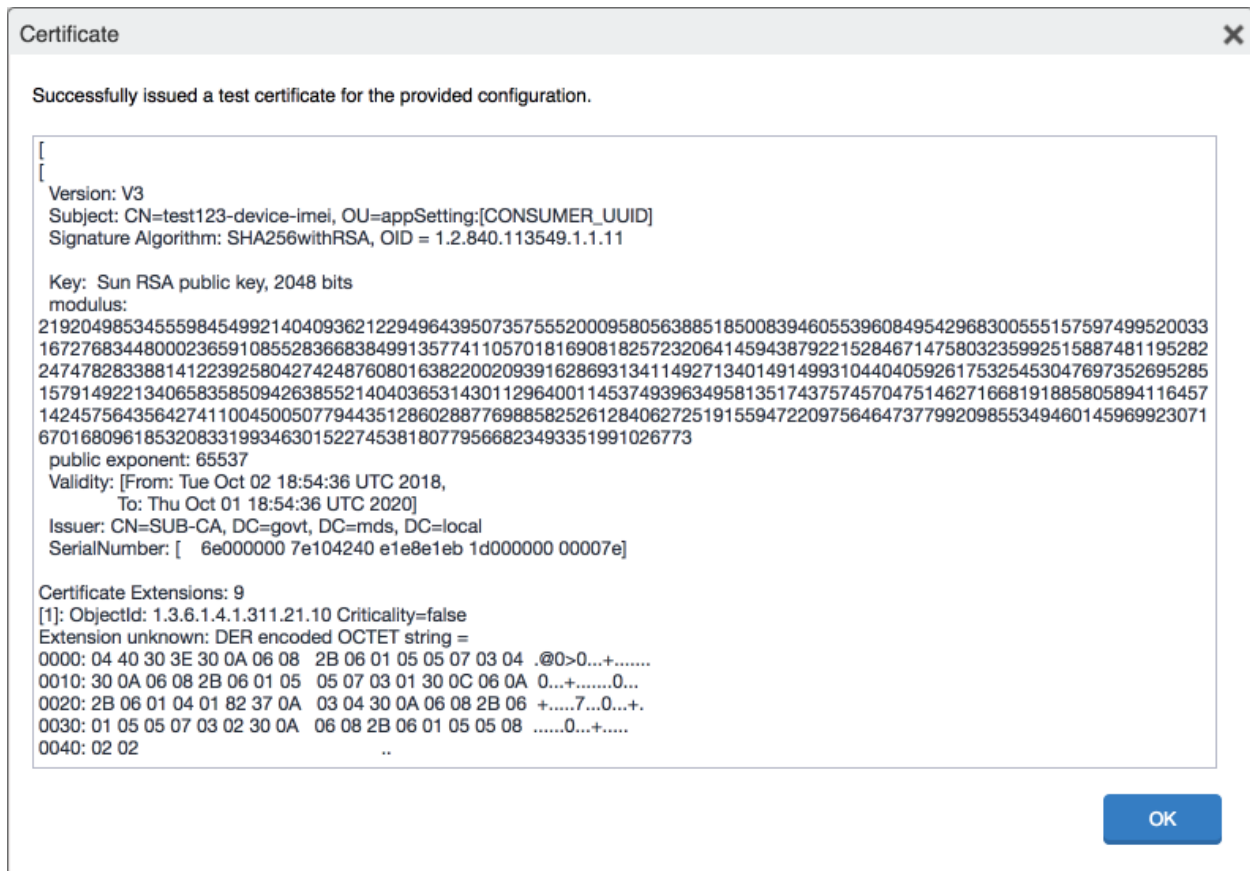
Key Usage Signing Encryption

Key Type

Key Length

- 546 f. In the **Fingerprint** field, enter the fingerprint of the Microsoft CA that will issue the
- 547 device certificates.
- 548 g. For the **Challenge Type** drop-down menu, select **Microsoft SCEP**.
- 549 h. Below the **Subject Alternative Names** list box, select **Add**; a new list item will appear.
- 550 i. For the new list item:
- 551 i. For the **Type** drop-down menu, select **NT Principal Name**.
- 552 ii. For the **Value** drop-down menu, select **\$USER_UPN\$**.
- 553 j. Select **Issue Test Certificate**; the **Certificate** dialogue should indicate success.
- 554 k. In the **Certificate** dialogue, select **OK**.

555 Figure 2-26 Test SCEP Certificate



556 4. Select **Save**.

557 Figure 2-27 Test SCEP Certificate Configuration

CSR Signature Algorithm ⓘ

Finger Print

Challenge Type

Challenge URL

User Name

Challenge [Change](#)

Subject Alternative Names		
TYPE	VALUE	ⓘ
NT Principal Name	\$USER_UPN\$	✕

ⓘ

558 **2.5.1.2 Create Palo Alto Networks GlobalProtect Configuration**

559 The GlobalProtect configuration instructs the mobile client to connect to use the provisioned device
 560 certificate and to automatically connect to the correct VPN URL; mobile users will not need to manually
 561 configure the application. The following steps will create the GlobalProtect configuration.

- 562 1. In the **MobileIron Admin Portal**, navigate to **Policies & Configs > Configurations**.
- 563 2. Select **Add New > VPN**; the **Add VPN Setting** dialogue will appear.
- 564 3. In the **Add VPN Setting** dialogue:
- 565 a. In the **Name** field, enter a unique name to identify this VPN setting.
- 566 b. In the **Connection Type** drop-down menu, select **Palo Alto Networks GlobalProtect**.
- 567 c. In the **Server** field, enter the fully qualified domain name (FQDN) of your Palo Alto
 568 Networks appliance; our sample implementation uses **vpn.govt.mdse.nccoe.org**.

- 569 d. For the **User Authentication** drop-down menu, select **certificate**.
- 570 e. For the **Identity Certificate** drop-down menu, select the SCEP enrollment profile created
- 571 in the previous section.
- 572 f. Select **Save**.

573 **Figure 2-28 MobileIron VPN Configuration**

Add VPN Setting [X]

Name: GlobalProtect VPN

Description: Allows devices to authenticate to the GlobalProtect VPN

Connection Type: Palo Alto Networks GlobalProtect [v] [i]

Server: vpn.govt.mdse.nccoe.org

Proxy: None [v] [i]

Username: \$USERID\$ [i]

User Authentication: Certificate [v]

Password: \$PASSWORD\$ [i]

Identity Certificate: Internal_Microsoft_CA [v]

VPN on Demand [i]

Per-app VPN: Yes No [i] **License Required**

▼ **Safari Domains (iOS7 and later; macOS 10.11 and later)**
 If the server ends with one of these domain names, the VPN is started automatically.

SAFARI DOMAIN	DESCRIPTION

Cancel Save

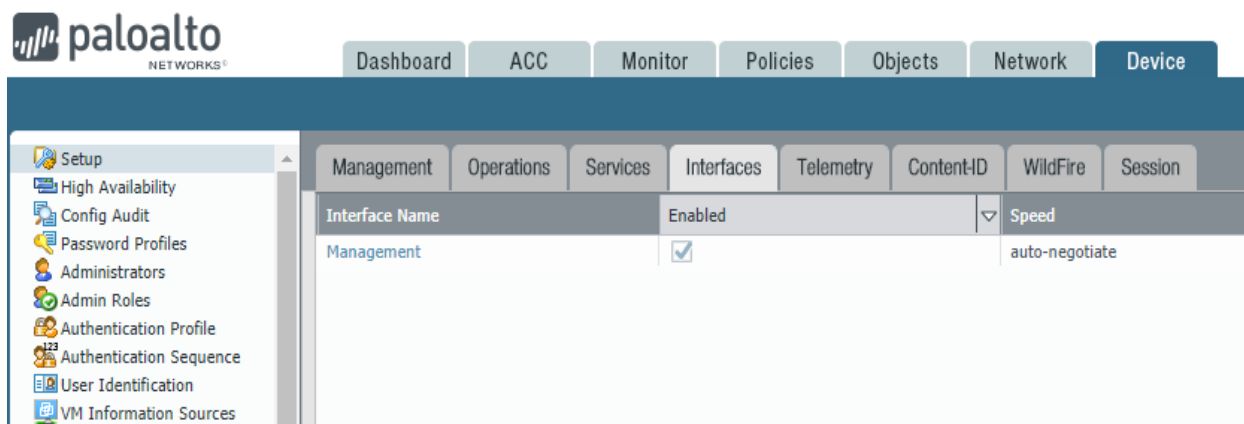
574 2.5.2 Basic Palo Alto Networks Configuration

575 During basic configuration, internet protocol (IP) addresses are assigned to the management interface,
 576 domain name system (DNS), and network time protocol (NTP). The management interface allows the
 577 administrator to configure and implement security rules through this interface.

578 **2.5.2.1 Configure Management Interface**

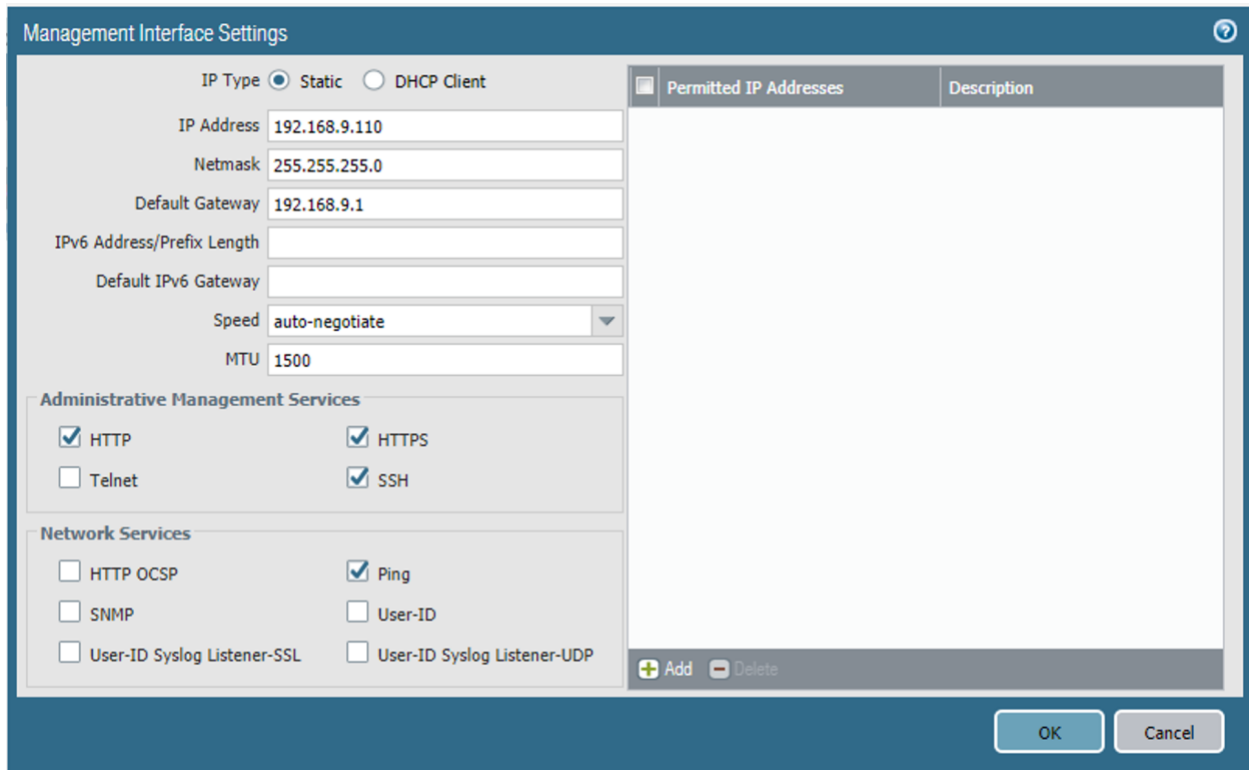
579 The following steps will configure the Palo Alto Networks appliance management interface.

- 580 1. In the Palo Alto Networks portal, navigate to **Device > Setup > Interfaces**.
- 581 2. On the Interfaces tab, enable the **Management** option; the Management Interface Setting
- 582 page will open.

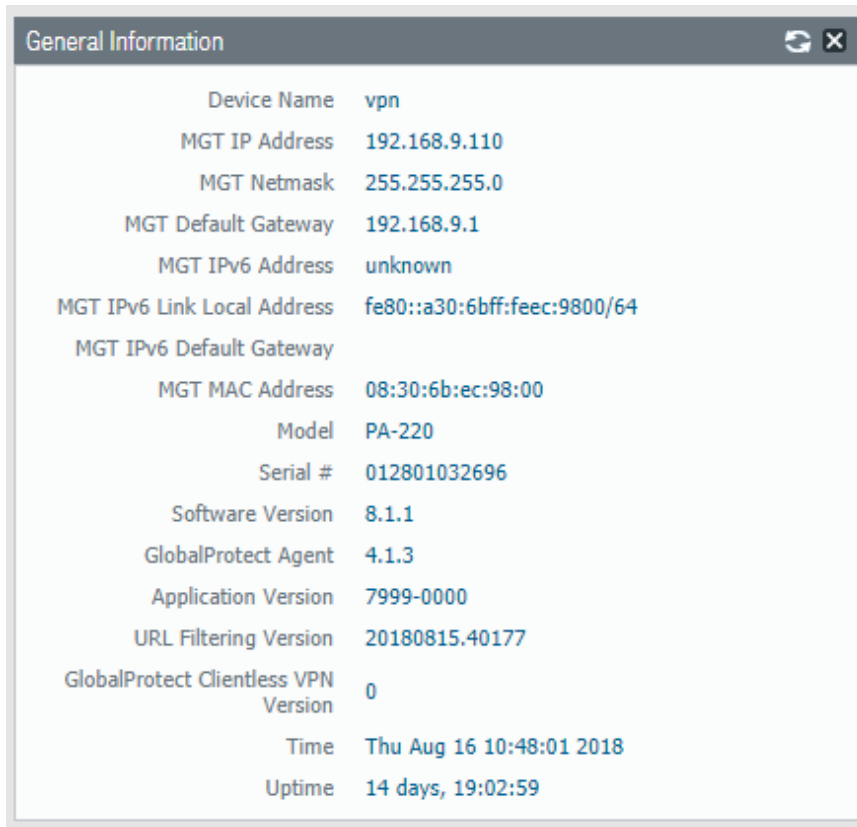
583 **Figure 2-29 Palo Alto Networks Management Interface Enabled**

- 584 3. On the Management Interface Setting screen:
- 585 a. In the **IP Address** field, enter the IP address for the Palo Alto Networks appliance.
- 586 b. In the **Netmask** field, enter the netmask for the network.
- 587 c. In the **Default Gateway** field, enter the IP address of the router that provides the
- 588 appliance with access to the internet.
- 589 d. Under **Administrative Management Services**: Enable the **Hypertext Transfer Protocol**
- 590 **(HTTP)**, **Hypertext Transfer Protocol Secure (HTTPS)**, **Secure Shell (SSH)**, and **Ping**
- 591 options.
- 592 e. Click **OK**.

593 Figure 2-30 Management Interface Configuration



- 594 4. To verify the configuration, navigate to **Palo Alto Networks Portal > Dashboard**; the
595 **General Information** section should reflect the appliance’s network configuration.

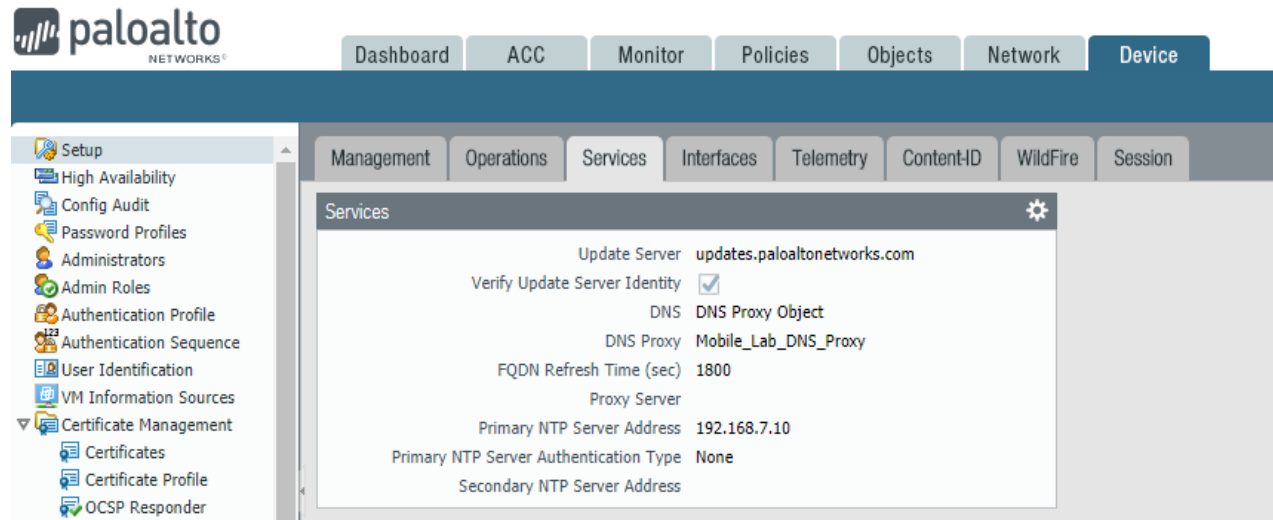
596 **Figure 2-31 Palo Alto Networks Firewall General Information**A screenshot of a web-based configuration window titled "General Information". The window has a dark header bar with a refresh icon and a close button. The main content area is white and displays a list of system parameters and their values in a key-value format. The parameters include device name, management IP and MAC addresses, model, serial number, software and application versions, and system time and uptime.

Device Name	vpn
MGT IP Address	192.168.9.110
MGT Netmask	255.255.255.0
MGT Default Gateway	192.168.9.1
MGT IPv6 Address	unknown
MGT IPv6 Link Local Address	fe80::a30:6bff:feec:9800/64
MGT IPv6 Default Gateway	
MGT MAC Address	08:30:6b:ec:98:00
Model	PA-220
Serial #	012801032696
Software Version	8.1.1
GlobalProtect Agent	4.1.3
Application Version	7999-0000
URL Filtering Version	20180815.40177
GlobalProtect Clientless VPN Version	0
Time	Thu Aug 16 10:48:01 2018
Uptime	14 days, 19:02:59

597 **2.5.2.2 Configure DNS and NTP**

- 598 1. In the **Palo Alto Networks Portal**, navigate to **Device > Setup > Services**.
- 599 2. In the **Services** tab, select the settings icon.

600 Figure 2-32 Palo Alto Networks Services Configuration



- 601 3. On the Services > Services tab:
- 602 a. For the **Primary DNS Server** field, enter the primary DNS server IP address.
- 603 b. For the **Secondary DNS Server** field, enter the secondary DNS server IP address, if
- 604 applicable.
- 605 4. Select the **NTP** tab.

606 Figure 2-33 DNS Configuration

The screenshot shows the 'Services' configuration window with the 'NTP' tab selected. The 'Update Server' field is set to 'updates.paloaltonetworks.com' and the 'Verify Update Server Identity' checkbox is checked. The 'DNS Settings' section has 'DNS Servers' selected, with 'Primary DNS Server' set to '10.5.1.1', 'Secondary DNS Server' set to '192.168.7.10', and 'FQDN Refresh Time (sec)' set to '1800'. The 'Proxy Server' section has empty fields for 'Server', 'Port' (with a range of [1 - 65535]), 'User', 'Password', and 'Confirm Password'. 'OK' and 'Cancel' buttons are at the bottom right.

- 607 5. On the **NTP** tab:
- 608 a. For the **Primary NTP Server > NTP Server Address** field, enter the IP address of the
- 609 primary NTP server to use.
- 610 b. For the **Secondary NTP Server > NTP Server Address** field, enter the IP address of the
- 611 backup NTP server to use, if applicable.
- 612 6. Select **OK**.

613 **Figure 2-34 NTP Configuration**

614 **2.5.3 Palo Alto Networks Interfaces and Zones Configuration**

615 Palo Alto Networks firewall model PA-220 has eight interfaces that can be configured as trusted (inside)
 616 or untrusted (outside) interfaces. This section describes creating a zone and assigning an interface to it.

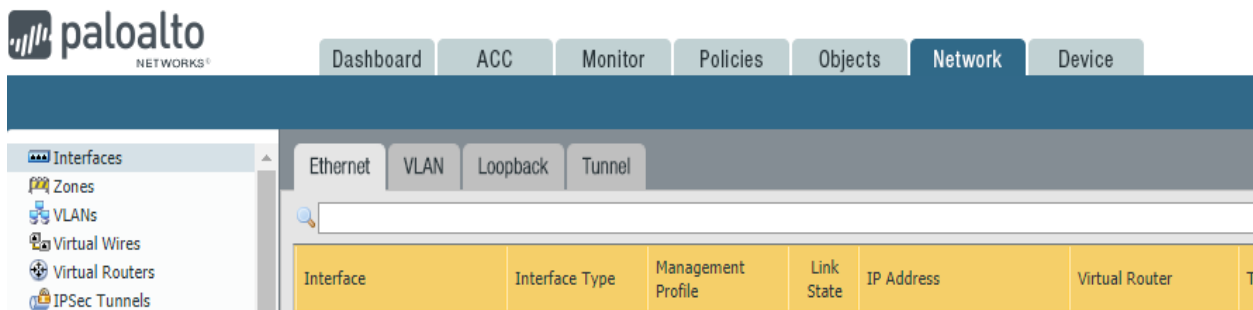
617 **2.5.3.1 Create Ethernet Interfaces and Addresses**

618 Our example implementation uses three interfaces:

- 619 ▪ LAN: Orvilia’s LAN, which hosts intranet web and mail services
- 620 ▪ DMZ: Orvilia’s DMZ network subnet, which hosts MobileIron Core and MobileIron Sentry
- 621 ▪ WAN: provides access to the internet and is the inbound interface for secure sockets layer (SSL)
- 622 ▪ VPN connections

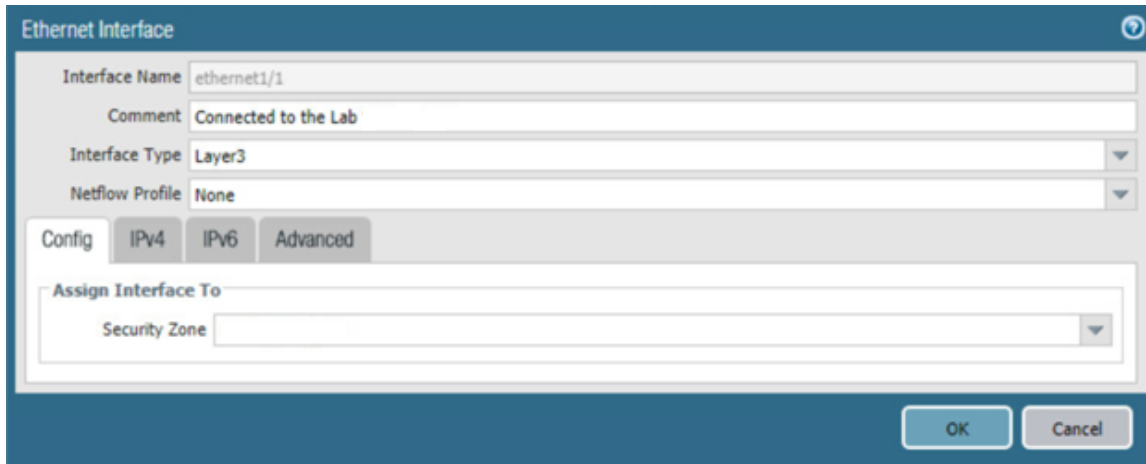
623 To create and configure Ethernet interfaces:

- 624 1. Navigate to **Palo Alto Networks Portal > Network > Ethernet > Interfaces > Ethernet.**

625 **Figure 2-35 Ethernet Interfaces**

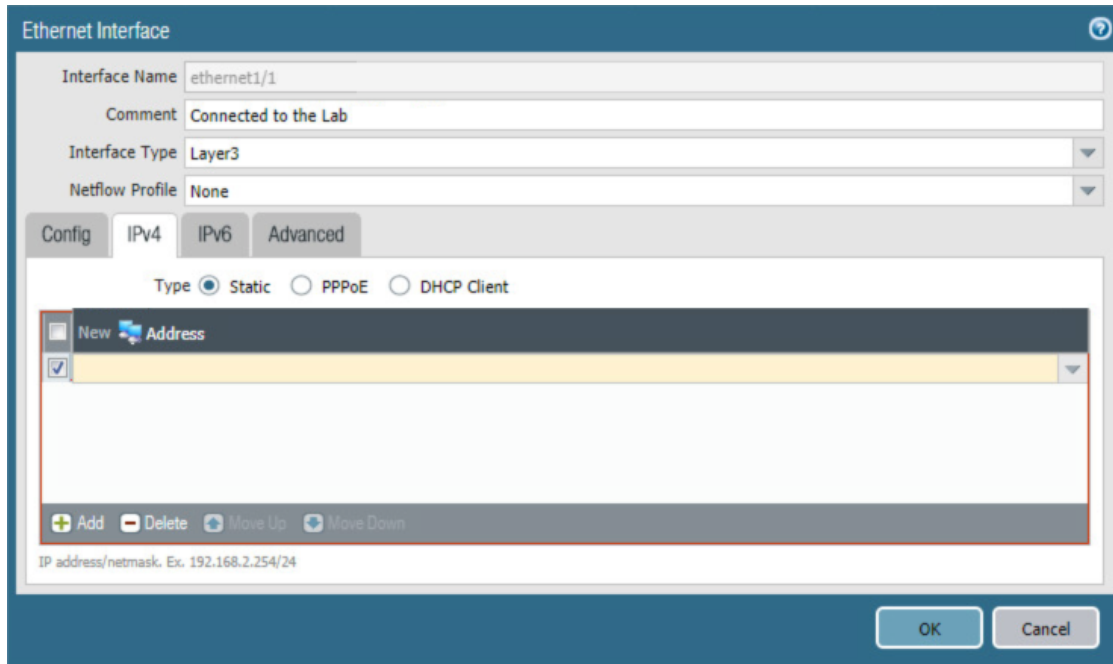
- 626 2. In the **Ethernet** tab, select the name of the interface to configure; the Ethernet Interface
627 dialogue will appear.
- 628 3. In the **Ethernet Interface** dialogue:
- 629 a. In the **Comment** field, enter a description for this interface.
- 630 b. For the **Interface Type** drop-down menu, select **Layer3**.

631 **Figure 2-36 Ethernet Interface Configuration**



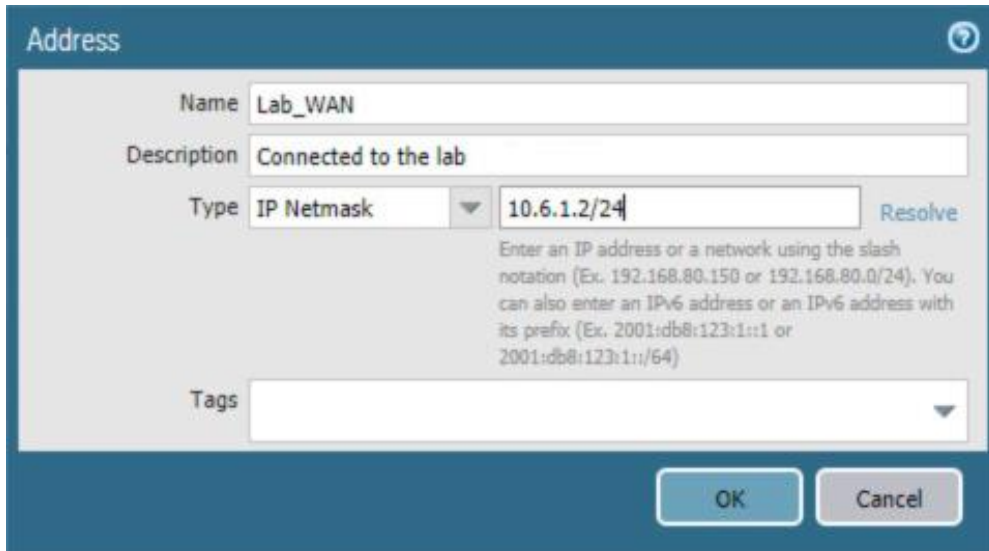
- 632 c. Select the **IPv4** tab.
- 633 d. On the **IPv4** tab:
- 634 i. In the **IP** list box, select **Add**; a blank list item will appear.
- 635 ii. In the blank list item, select **New Address**; the Address dialogue will appear.

636 Figure 2-37 WAN Interface IPv4 Configuration



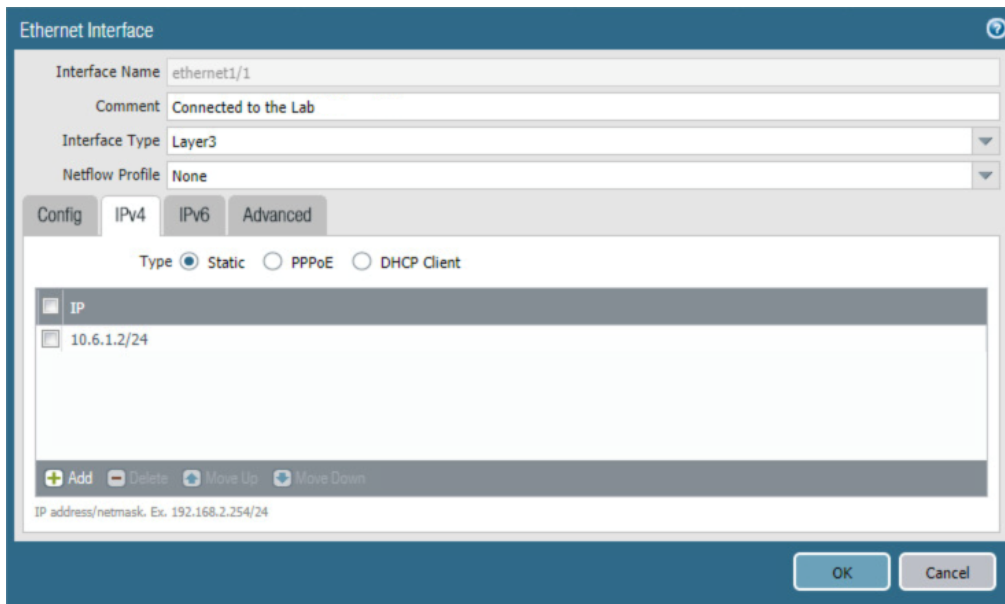
- 637 iii. In the **Address** dialogue:
- 638 1) For the **Name** field, enter a unique name to identify this address.
- 639 2) For the **Description** field, enter a meaningful description of the purpose of
- 640 this address.
- 641 3) In the unnamed field following the **Type** drop-down menu, enter the IPv4
- 642 address that this interface will use in **Classless Inter-Domain Routing**
- 643 notation. This example uses **10.6.1.2/24** for the WAN interface in our lab
- 644 environment.
- 645 4) Select **OK**.

646 Figure 2-38 WAN Interface IP Address Configuration



- 647 e. The address should now appear as an item in the IP list box; select **OK**; the Address
- 648 dialog will close.

649 Figure 2-39 Completed WAN Interface Configuration



- 650 4. Select **OK**.
- 651 5. Repeat **Steps 2** and **3** for each of the additional Ethernet/Layer3 interfaces.

652

2.5.3.2 Create Security Zones

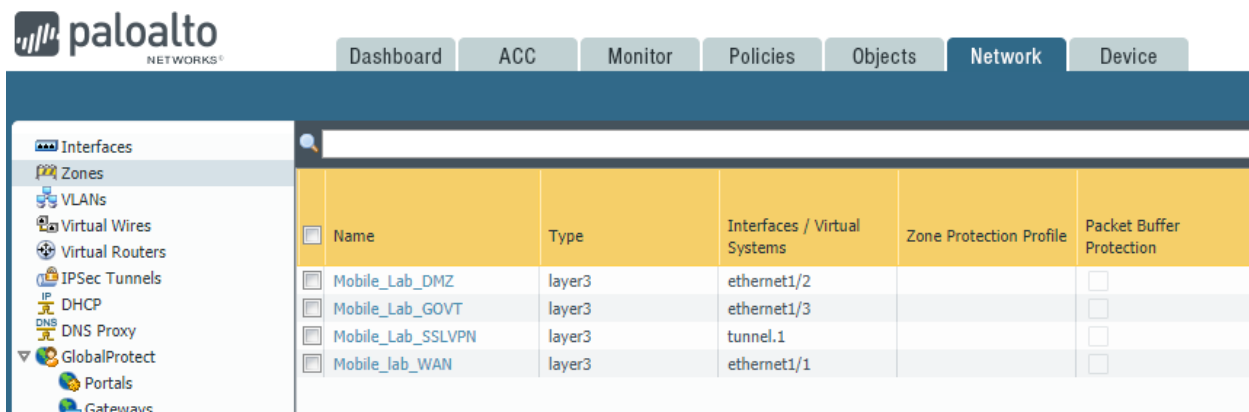
653 The PA Security Zone is a collection of single or multiple interfaces that have the same security rules. For
654 this setup, four different zones have been configured:

- 655 ▪ *Mobile_Lab_GOVT*: inside (trusted) interface connecting to the government (GOVT) segment
- 656 ▪ *Mobile_Lab_DMZ*: inside (trusted) interface connecting to the DMZ segment
- 657 ▪ *Mobile_Lab_WAN*: outside (untrusted) interface to permit trusted inbound connections (e.g.,
658 Lookout cloud service) from the untrusted internet and allow internet access to on-premises
659 devices
- 660 ▪ *Mobile_Lab_SSLVPN*: outside (untrusted) interface for VPN connections by trusted mobile
661 devices originating from untrusted networks (e.g., public Wi-Fi)

662 To configure each zone:

- 663 1. Navigate to **Palo Alto Networks Portal > Network > Zones**.

664 **Figure 2-40 Security Zone List**



Name	Type	Interfaces / Virtual Systems	Zone Protection Profile	Packet Buffer Protection
Mobile_Lab_DMZ	layer3	ethernet1/2		<input type="checkbox"/>
Mobile_Lab_GOVT	layer3	ethernet1/3		<input type="checkbox"/>
Mobile_Lab_SSLVPN	layer3	tunnel.1		<input type="checkbox"/>
Mobile_lab_WAN	layer3	ethernet1/1		<input type="checkbox"/>

- 665
- 666 2. In the **Zones** pane, select **Add**; the Zones page will open.
- 667 3. On the **Zones** page:
 - 668 a. For the **Name** field, provide a unique name for the zone.
 - 669 b. For the **Type** drop-down menu, select **Layer 3**.
 - 670 c. Under **Interfaces**, select **Add**; a blank drop-down menu will appear.
 - 671 d. In the drop-down menu, select the interface to assign to this zone; this example shows
672 selection of **ethernet 1/3**, which is associated with the LAN interface.

673 e. Select **OK**.

674 **Figure 2-41 LAN Security Zone Configuration**

675 f. Repeat **Step b** for each zone.

676 2.5.4 Configure Router

677 Palo Alto Networks uses a virtual router to emulate physical connectivity between interfaces in different
 678 zones. To permit systems to reach systems in other zones, the following steps will create a virtual router
 679 and add interfaces to it. The router also sets which of these interfaces will act as the local gateway to
 680 the internet.

- 681 1. In the **Palo Alto Networks Portal**, navigate to **Network > Virtual Routers**.
- 682 2. Below the details pane, select **Add**; the Virtual Router form will open.

- 683 3. In the **Virtual Router** form, on the **Router Settings** tab:
- 684 a. For the **Name** field, enter a unique name to identify this router.
- 685 b. On the **Router Settings > General** tab:
- 686 i. Under the **Interfaces** list box, select **Add**; a new list item will appear.
- 687 ii. In the new list item drop-down menu, select an existing interface.
- 688 iii. Repeat **Steps 3a** and **3b** to add all existing interfaces to this router.
- 689 4. Select the **Static Routes** tab.
- 690 5. On the **Static Routes > IPv4** tab:
- 691 a. Below the list box, select **Add**; the Virtual Router - Static Route - IPv4 form will open.
- 692 b. In the **Virtual Router—Static Route—IPv4** form:
- 693 i. For the **Name** field, enter a unique name to identify this route.
- 694 ii. For the **Destination** field, enter **0.0.0.0/0**.
- 695 iii. For the **Interface** drop-down menu, select the interface that provides access to
- 696 the internet.
- 697 iv. For the **Next Hop** drop-down menu, select **IP Address**.
- 698 v. In the field below **Next Hop**, enter the IP address of the gateway that provides
- 699 access to the internet.
- 700 vi. Select **OK**.

701 Figure 2-42 Virtual Router Configuration

Virtual Router - Static Route - IPv4

Name: Wan Default Route

Destination: 0.0.0.0/0

Interface: ethernet1/1

Next Hop: IP Address
10.6.1.1

Admin Distance: 10 - 240

Metric: 10

Route Table: Unicast

Path Monitoring

Failure Condition: Any All

Preemptive Hold Time (min): 2

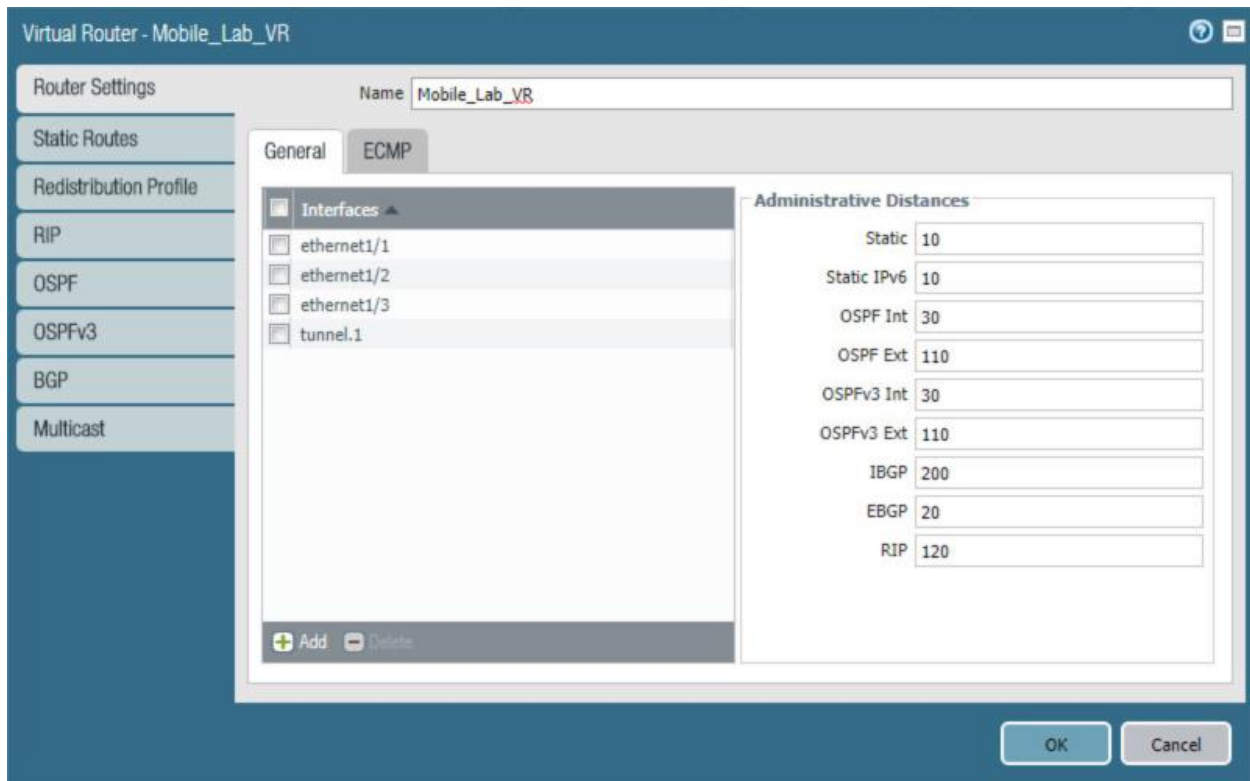
Name	Enable	Source IP	Destination IP	Ping Interval(sec)	Ping Count
------	--------	-----------	----------------	--------------------	------------

+ Add - Delete

OK Cancel

702 6. Select **OK**.

703 Figure 2-43 Virtual Router General Settings

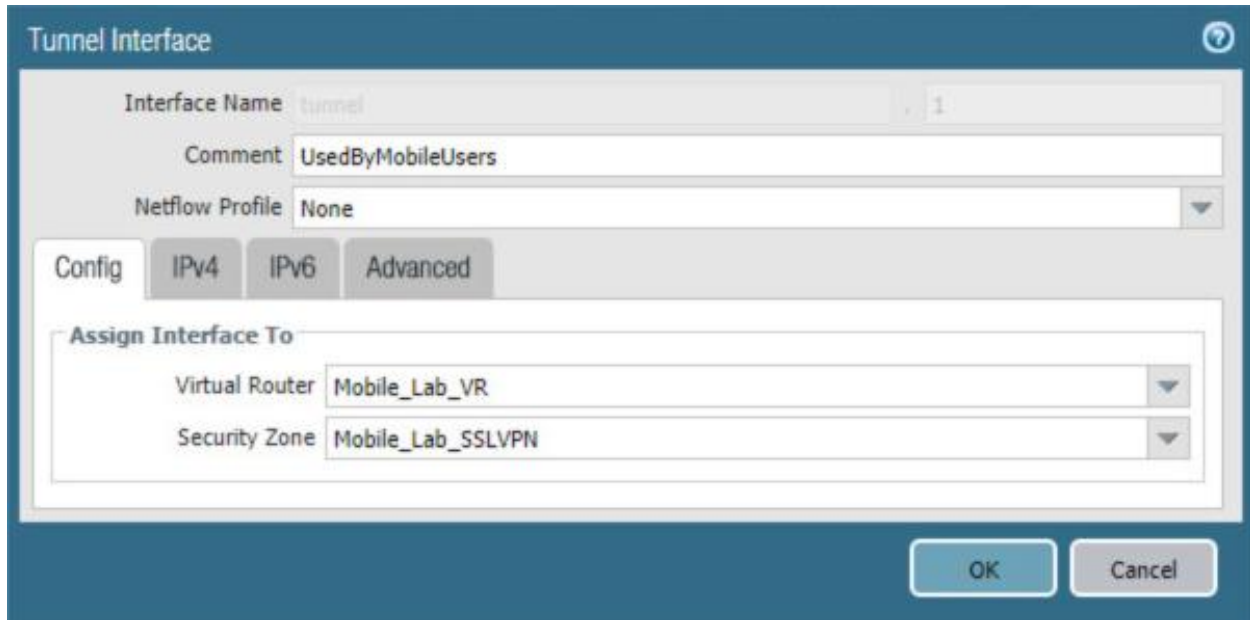
704

2.5.5 Configure Tunnel Interface

705 The SSL VPN uses a tunnel interface to secure traffic from the external zone to the internal zone where
 706 organizational resources available to mobile users are maintained. To configure the tunnel interface:

- 707 1. Navigate to **Palo Alto Networks Portal > Network > Ethernet > Interfaces > Tunnel.**
- 708 2. Below the details pane, select **Add**; the Tunnel Interface form will open.
- 709 3. In the **Tunnel Interface** form on the **Config** tab:
 - 710 a. In the **Assign Interface To** section:
 - 711 i. For the **Virtual Router** drop-down menu, select the virtual router created in the
 - 712 previous section.
 - 713 ii. For the **Security Zone** drop-down menu, select the security zone created for the
 - 714 SSL VPN.
 - 715 b. Select **OK**.

716 Figure 2-44 SSL VPN Tunnel Interface



717 2.5.6 Configure Applications and Security Policies

718 Security policies work similarly to firewall rules; they block or allow traffic between defined zones
719 identified by a source, destination, and application(s) (contextually, Palo Alto Networks' objects define
720 network protocols and ports). Palo Alto Networks has built-in applications for a large number of
721 standard and well-known protocols and ports (e.g., LDAP and Secure Shell), but we defined custom
722 applications for MobileIron-specific traffic.

723 2.5.6.1 Configure Applications

724 The following steps will create an application:

- 725 1. In the **Palo Alto Networks Portal**, navigate to **Objects > Applications**.

726 Figure 2-45 Application Categories

Category ▲	Subcategory ▲	Technology ▲
823 business-systems	51 audio-streaming	1041 browser-based
614 collaboration	22 auth-service	1107 client-server
445 general-internet	37 database	365 network-protocol
293 media	82 email	134 peer-to-peer
472 networking	64 encrypted-tunnel	
2 unknown	48 erp-crm	
	315 file-sharing	
	64 gaming	
	173 general-business	

- 727
- 728 2. On the **Applications** screen:
- 729 3. Select **Add**; the Application form will open.
- 730 4. On the **Application > Configuration** screen:
- 731 a. In the **General > Name** field, provide a unique name to identify this application.
- 732 b. In the **General > Description** field, enter a meaningful description of its purpose.
- 733 c. For the **Properties > Category** drop-down menu, select a category appropriate to your
- 734 environment; our sample implementation uses **networking**.
- 735 d. For the **Properties > Subcategory** drop-down menu, select a subcategory appropriate to
- 736 your environment; our sample implementation uses **infrastructure**.
- 737 e. For the **Properties > Technology** drop-down menu, select a technology appropriate to
- 738 your environment; our sample implementation uses **client-server**.
- 739 5. Select the **Advanced** tab.

740 Figure 2-46 MobileIron Core Palo Alto Networks Application Configuration

The screenshot shows the 'Application' configuration window in Palo Alto Networks. The window has three tabs: 'Configuration', 'Advanced', and 'Signatures'. The 'Configuration' tab is active. The 'General' section contains a 'Name' field with the value 'MobileIron9997' and a 'Description' field with the text 'Allows mobile devices to check-in with MobileIron Core'. The 'Properties' section includes dropdown menus for 'Category' (networking), 'Subcategory' (infrastructure), 'Technology' (client-server), 'Parent App' (None), and 'Risk' (1). The 'Characteristics' section has several checkboxes, all of which are unchecked: 'Capable of File Transfer', 'Excessive Bandwidth Use', 'Tunnels Other Applications', 'Has Known Vulnerabilities', 'Used by Malware', 'Evasive', 'Pervasive', 'Prone to Misuse', and 'Continue scanning for other Applications'. At the bottom right, there are 'OK' and 'Cancel' buttons.

741

742

6. On the **Application > Advanced** screen:

743

a. Select **Defaults > Port**.

744

b. Under the Ports list box, select **Add**; a blank list item will appear.

745

c. In the blank list item, enter the port number used by the application; this example uses **9997**.

746

747

7. Select **OK**.

748 Figure 2-47 MobileIron Application Port Configuration

- 749 8. Repeat **Steps 2** through **7** with the following modifications to create an application for
 750 MobileIron Core system administration console:
- 751 a. **Configuration > General > Name is MobileIron8443.**
- 752 b. **Configuration > Default > Category is business-systems.**
- 753 c. **Configuration > Default > Subcategory is management.**
- 754 d. **Advanced > Defaults > Ports > entry_1 is 8443.**

755 2.5.6.2 *Configure Security Policies*

756 Security policies allow or explicitly deny communication within, between, or (externally) to or from Palo
 757 Alto Networks zones. For this sample implementation, several security policies were created to support
 758 communication by other components of the architecture. The first subsection covers the steps to create
 759 a given security policy. The second subsection provides a table illustrating the security policies we used;
 760 these policies would need to be adapted to host names and IP addresses specific to your network
 761 infrastructure.

762 2.5.6.2.1 Create Security Policies

763 To create a security policy:

- 764 1. In the **Palo Alto Networks Portal**, navigate to **Policies > Security**.
- 765 2. Select **Add**; the **Security Policy Rule** form will open.
- 766 3. In the **Security Policy Rule** form:
 - 767 a. In the **Name** field, enter a unique name for this security rule.
 - 768 b. For the **Rule Type** drop-down menu, select the scope of the rule.

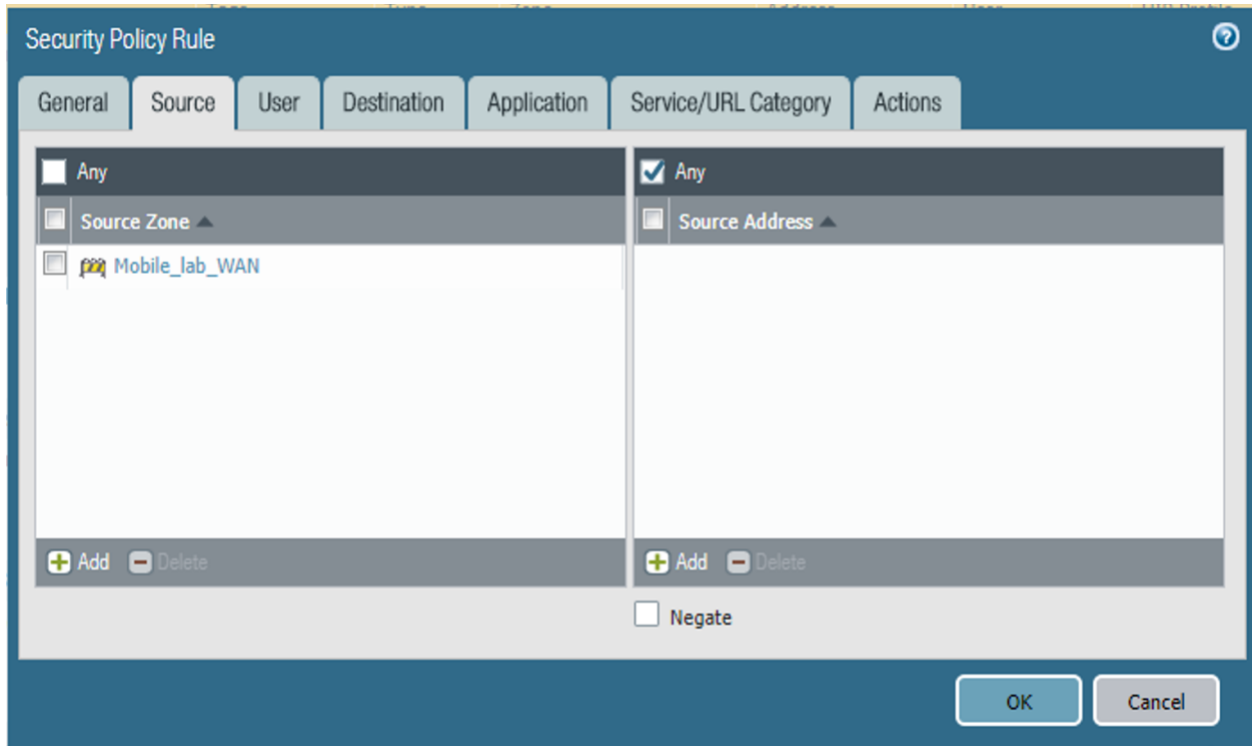
769 Figure 2-48 DMZ Access to MobileIron Firewall Rule Configuration

The screenshot shows the 'Security Policy Rule' configuration window. The 'General' tab is active. The 'Name' field contains 'DMZAccessVirtualIPCore'. The 'Rule Type' dropdown is set to 'universal (default)'. The 'Description' field is empty. The 'Tags' dropdown is also empty. The 'OK' and 'Cancel' buttons are visible at the bottom right.

- 770 4. Select the **Source** tab.
- 771 5. On the **Source** tab:
 - 772 a. If the security rule applies to a specific source zone:
 - 773 i. Under the **Source Zone** list box, select **Add**; a new entry will appear in the list box.
 - 774 ii. For the new list item, select the source zone for this rule.
 - 775 b. If the rule applies to only specific source IP addresses:

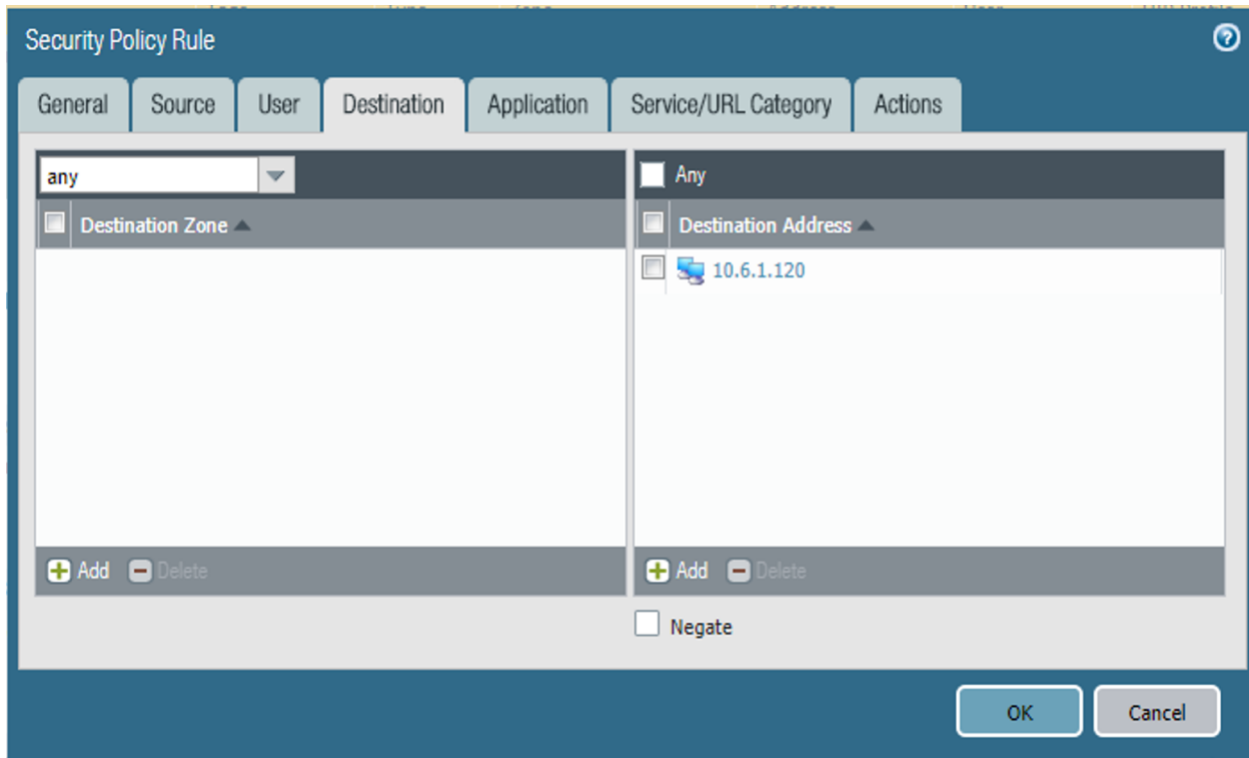
- 776 i. Under the **Source Address** list box, select **Add**; a new list item will appear.
- 777 ii. For the new list item, select the source address for this rule.

778 **Figure 2-49 DMZ Access to MobileIron Security Rule Source Zone Configuration**



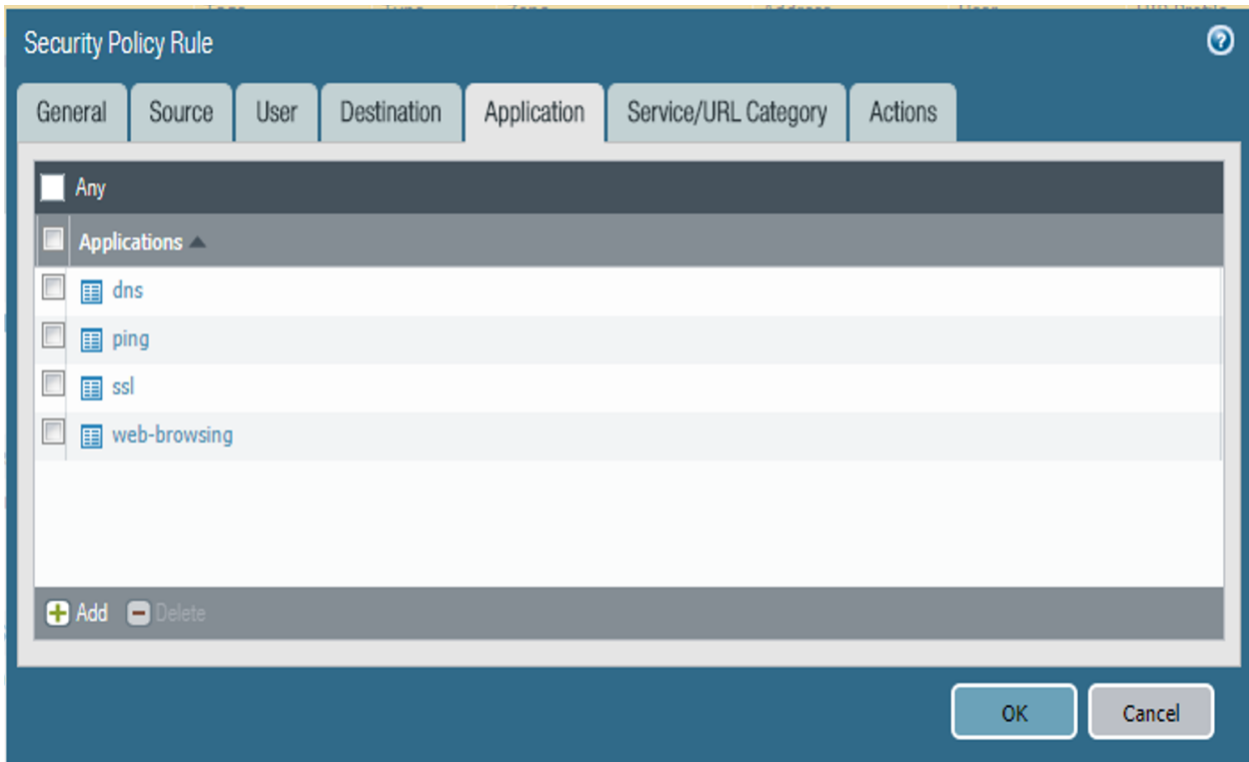
- 779 6. Select the **Destination** tab.
- 780 7. On the **Destination** tab:
- 781 a. If the security rule applies to a specific destination zone:
- 782 i. Under the **Destination Zone** list box, select **Add**; a new destination list item will
- 783 appear.
- 784 ii. For the new **Source Zone** list item, select the destination zone for this rule.
- 785 b. If the rule applies to only specific destination IP addresses:
- 786 i. Under the **Destination Address** list box, select **Add**; a new list item will appear.
- 787 ii. For the new list item, select the destination address for this rule.

788 Figure 2-50 DMZ Access to MobileIron Security Rule Destination Address Configuration



- 789 8. Select the **Application** tab.
- 790 9. On the **Application** tab:
- 791 a. Under the **Applications** list box, select **Add**; a new list item will appear.
- 792 b. For the new **Applications** list item, select the application representing the protocol and
- 793 port combination of the traffic to control.
- 794 c. Repeat **Steps 9a** and **9b** for each application involving the same source and destination
- 795 that would also have its traffic allowed or explicitly blocked (if otherwise allowed by a
- 796 more permissive security rule).

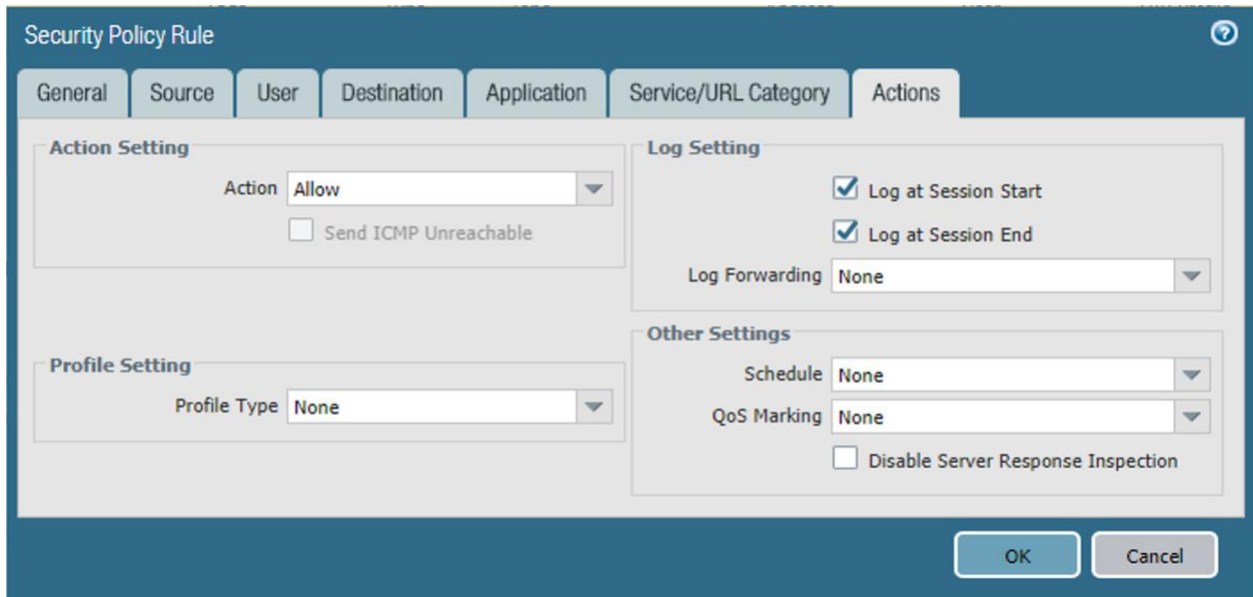
797 **Figure 2-51 DMZ Access to MobileIron Security Rule Application Protocol Configuration**



798 10. Select the **Actions** tab.

799 11. On the **Actions** tab: Unless explicitly blocking traffic permitted by a more permissive
800 security rule, ensure that the **Action Setting > Action** drop-down menu is set to **Allow**.

801 Figure 2-52 DMZ Access to MobileIron Security Rule Action Configuration



802 12. Select **OK**.

803 [2.5.6.2.2 Implemented Security Policies](#)

804 The implemented security policies are provided in Table 2-1, Table 2-2, and Table 2-3. Configuration
 805 options that aren't shown were left as their default values.

806 **Table 2-1 Implemented Security Policies**

Name	Tags	Type	Source Zone	Source Address
DMZAccessVirtualIPCore	none	universal	Mobile_lab_WAN	any
CoretoAppleSrvs	none	universal	Mobile_Lab_DMZ	MI_Core
AdminAccessToMI	none	interzone	Mobile_Lab_GOVT	MDS.govt.admin
AppthorityConnectorAccessToMI-Core	none	interzone	Mobile_Lab_GOVT	govt.appthority
MICoreObtainDeviceCERT	none	interzone	Mobile_Lab_DMZ	MI_Core
MICoreAccessDNS	none	interzone	Mobile_Lab_DMZ	MI_Core
MICoreRelaySMSNotifications	none	interzone	Mobile_Lab_DMZ	MI_Core
MICoreSyncLDAP	none	interzone	Mobile_Lab_DMZ	MI_Core

807 Table 2-2 Implemented Security Policies

Name	Source User	Source Host Information Protocol Profile	Destination Zone	Destination Address
DMZAccessVirtualIPCore	any	any	any	10.6.1.120
CoretoAppleSrvs	any	any	any	17.0.0.0/8
AdminAccessToMI	any	any	Mobile_Lab_DMZ	MI_Core;MI_Sentry
AppthorityConnectorAccessToMI-Core	any	any	Mobile_Lab_DMZ	MI_Core
MICoreObtainDeviceCERT	any	any	Mobile_Lab_GOVT	SCEP_server
MICoreAccessDNS	any	any	Mobile_Lab_GOVT	DNS_Server
MICoreRelaySMSNotifications	any	any	Mobile_Lab_GOVT	SMTP_Relay
MICoreSyncLDAP	any	any	Mobile_Lab_GOVT	LDAP_Server

808 Table 2-3 Implemented Security Policies

Name	Application	Service	Action	Profile	Options
DMZAccessVirtualIPCore	dns;ping;ssl;web-browsing	any	allow	none	none
CoretoAppleSrvs	any	any	allow	none	none
AdminAccessToMI	AdminAccessMI;ssh;ssl	any	allow	none	none
AppthorityConnectorAccessToMI-Core	AdminAccessMI;ssl;web-browsing	any	allow	none	none
MICoreObtainDeviceCERT	scep;web-browsing	application-default	allow	none	none
MICoreAccessDNS	dns	application-default	allow	none	none
MICoreRelaySMSNotifications	smtp	application-default	allow	none	none
MICoreSyncLDAP	ldap	application-default	allow	none	none

809

2.5.7 Network Address Translation (NAT)

810 To allow communication with external networks over the internet, the appliance also needs to be
811 configured with NAT rules. To configure NAT:

- 812 1. In the **Palo Alto Networks Portal**, navigate to **Policies > NAT**.
- 813 2. Below the details pane, select **Add**; the **NAT Policy Rule** form will open.
- 814 3. In the **NAT Policy Rule** form, on the **General** tab:
- 815 a. In the **Name** field, provide a unique name for this NAT policy rule.
- 816 b. Ensure the **NAT Type** drop-down menu is set to **ipv4**.

817 **Figure 2-53 Outbound NAT Rule**

The screenshot shows the 'NAT Policy Rule' configuration window. It has a dark blue header with the title 'NAT Policy Rule' and a help icon. Below the header are three tabs: 'General', 'Original Packet', and 'Translated Packet'. The 'General' tab is active. The form contains the following fields:

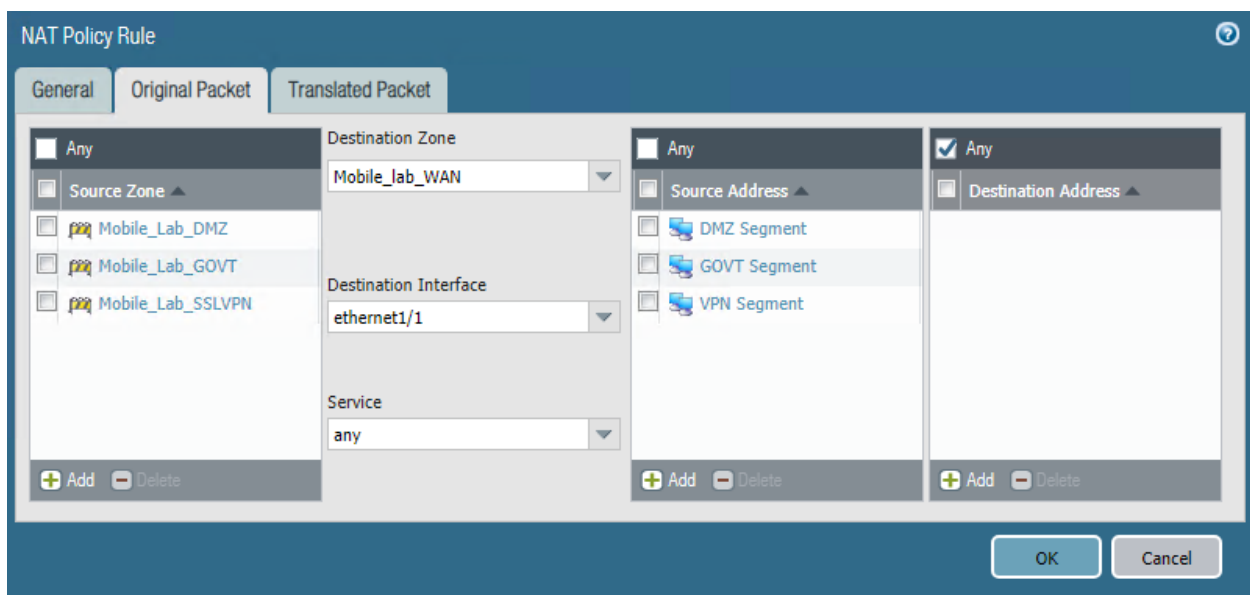
- Name:** A text input field containing 'GOVT to Outside'.
- Description:** A larger text input field that is currently empty.
- Tags:** A dropdown menu that is currently empty.
- NAT Type:** A dropdown menu set to 'ipv4'.

At the bottom right of the form are two buttons: 'OK' and 'Cancel'.

- 818 4. Select the **Original Packet** tab.
- 819 5. On the **Original Packet** tab:
- 820 a. Under the **Source Zone** list box, select **Add**; a new Source Zone list item will appear.
- 821 b. For the new **Source Zone** list item, select the zone that represents your LAN subnet; in
- 822 this sample implementation, that is **Mobile_Lab_GOVT**.
- 823 c. Repeat **Steps 5a** and **5b** to add the zone that represents your DMZ; in this sample
- 824 implementation, that is **Mobile_Lab_DMZ**.
- 825 d. Repeat **Steps 5a** and **5b** to add the zone that represents your SSL VPN; in this sample
- 826 implementation, that is **Mobile_Lab_SSLVPN**.
- 827 e. For the **Destination Zone** drop-down menu, select the zone that represents the
- 828 internet; in this sample implementation, that is **Mobile_lab_WAN**.
- 829 f. For the **Destination Interface**, select the adapter that is physically connected to the
- 830 same subnet as your internet gateway; in this sample implementation, that is
- 831 **ethernet1/1**.

- 832 g. Under the **Source Address** list box, select **Add**; a new Source Address list item will
833 appear.
- 834 h. For the new **Source Address** list item, select the address that represents the subnet (IP
835 address range) for the LAN.
- 836 i. Repeat **Steps 5f** and **5g** to add the address representing the DMZ subnet.
- 837 j. Repeat **Steps 5f** and **5g** to add the address representing the SSL VPN subnet.

838 **Figure 2-54 Outbound NAT Original Packet Configuration**



- 839
- 840 6. Select the **Translated Packet** tab.
- 841 7. On the **Translated Packet** tab, under **Source Address Translation**:
- 842 a. For the **Translation Type** drop-down menu, select **Dynamic IP and Port**.
- 843 b. For the **Address Type** drop-down menu, select **Interface Address**.
- 844 c. For the **Interface** drop-down menu, select the same interface selected in **Step 5e**.
- 845 d. For the **IP Address** drop-down menu, select the IPv4 address on the same subnet as
846 your internet gateway.

847 **Figure 2-55 Outbound NAT Translated Packet Configuration**

The screenshot shows the 'NAT Policy Rule' configuration window with the 'Translated Packet' tab selected. It contains two main sections: 'Source Address Translation' and 'Destination Address Translation'. The 'Source Address Translation' section has the following settings: Translation Type (Dynamic IP And Port), Address Type (Interface Address), Interface (ethernet1/1), and IP Address (10.6.1.2/24). The 'Destination Address Translation' section has Translation Type (None). At the bottom right, there are 'OK' and 'Cancel' buttons.

848

849 8. Select **OK**.850

2.5.8 Configure SSL VPN

851 The SSL VPN enables remote mobile device users to create an encrypted connection to the enterprise
 852 from unencrypted networks (e.g., public Wi-Fi hot spots).

853

2.5.8.1 Configure End-User Authentication

854 The following steps establish the integrations and configurations related to mobile user identification
 855 and authentication.

856

2.5.8.1.1 Configured Server Profile

857 The following steps integrate this appliance with Microsoft Active Directory Domain Services to manage
 858 mobile user permissions via AD groups and roles.

- 859 1. In the **Palo Alto Networks Portal**, navigate to **Devices > Server Profiles > LDAP**.
- 860 2. Below the details pane, select **Add**; the **LDAP Server Profile** form will open.
- 861 3. In the **LDAP Server Profile** form:
 - 862 a. In the **Profile Name** field, enter a unique name to identify this profile.
 - 863 b. Under the **Service List** box, select **Add**; a new **Server List** item will appear.
 - 864 c. In the new **Service List** item:
 - 865 i. In the **Name** column, enter a name to identify the server.
 - 866 ii. In the **LDAP Server** column, enter the IP address of the LDAP server.

- 867 iii. The value in the **Port** column defaults to 389; change this if your LDAP server
868 communicates over a different port number.
- 869 iv. Repeat **Steps 3ci** through **3ciii** for each LDAP server that you intend to use.
- 870 d. Under **Server Settings**:
- 871 i. In the **Type** drop-down menu, select **active-directory**.
- 872 ii. In the **Base DN** drop-down menu, select the DN for your Active Directory domain
873 users who will use the SSL VPN.
- 874 iii. In the **Bind DN** field, enter the Active Directory domain user account that will
875 authenticate to LDAP to perform queries.
- 876 iv. In the **Password** field, enter the password for the Active Directory user account
877 specified in the previous step.
- 878 v. In the **Confirm Password** field, reenter the password entered in the previous step.
- 879 4. Select **OK**.

880 **Figure 2-56 LDAP Profile**

LDAP Server Profile

Profile Name

Administrator Use Only

Server List

Name	LDAP Server	Port
AD	192.168.7.10	389

Enter the IP address or FQDN of the LDAP server

Server Settings

Type

Base DN

Bind DN

Password

Confirm Password

Bind Timeout

Search Timeout

Retry Interval

Require SSL/TLS secured connection

Verify Server Certificate for SSL sessions

881 **2.5.8.2 Configure Authentication Profile**

- 882 1. In the **Palo Alto Networks Portal**, navigate to **Device > Authentication Profile**.
- 883 2. Under the details pane, select **Add**; the **Authentication Profile** form will open.
- 884 3. In the **Authentication Profile** form:
- 885 a. In the **Name** field, provide a unique name to identify this authentication profile.
- 886 b. On the **Authentication** tab:
- 887 i. For the **Type** drop-down menu, select **LDAP**.
- 888 ii. For the **Server Profile** drop-down menu, select the name of the LDAP Server
- 889 Profile created in the previous section.
- 890 iii. For the **Login Attribute** field, enter **userPrincipalName**.
- 891 iv. For the **User Domain**, enter the name of your enterprise domain; our sample
- 892 implementation uses **govt**.

893 Figure 2-57 Authentication Profile

Authentication Profile

Name: Mobile_Lab_Auth-Profile

Authentication Factors Advanced

Type: LDAP

Server Profile: Mobile_Lab_LDAP-Profile

Login Attribute: userPrincipalName

Password Expiry Warning: 7
Number of days prior to warning a user about password expiry.

User Domain: govt

Username Modifier: %USERINPUT%

Single Sign On

Kerberos Realm: [Empty]

Kerberos Keytab: Click "Import" to configure this field X Import

OK Cancel

- 894 c. Select the **Advanced** tab.
- 895 d. On the **Advanced** tab:
- 896 i. Under the **Allow List** box, select **Add**; this will create a new list item.
- 897 ii. In the new list item, select the Active Directory group for your mobile users.
- 898 iii. Repeat **Steps 3di** and **3dii** for any additional groups that should authenticate to
- 899 the SSL VPN.
- 900 e. Select **OK**.

901 Figure 2-58 Advanced Authentication Profile Settings

Authentication Profile

Name: Mobile_Lab_Auth-Profile

Authentication Factors Advanced

Allow List

- Allow List ▲
- cn=domain admins,cn=users,dc=govt,dc=mds,dc=local
- cn=mobile users,cn=users,dc=govt,dc=mds,dc=local

+ Add - Delete

Account Lockout

Failed Attempts: 0

Lockout Time (min): 0

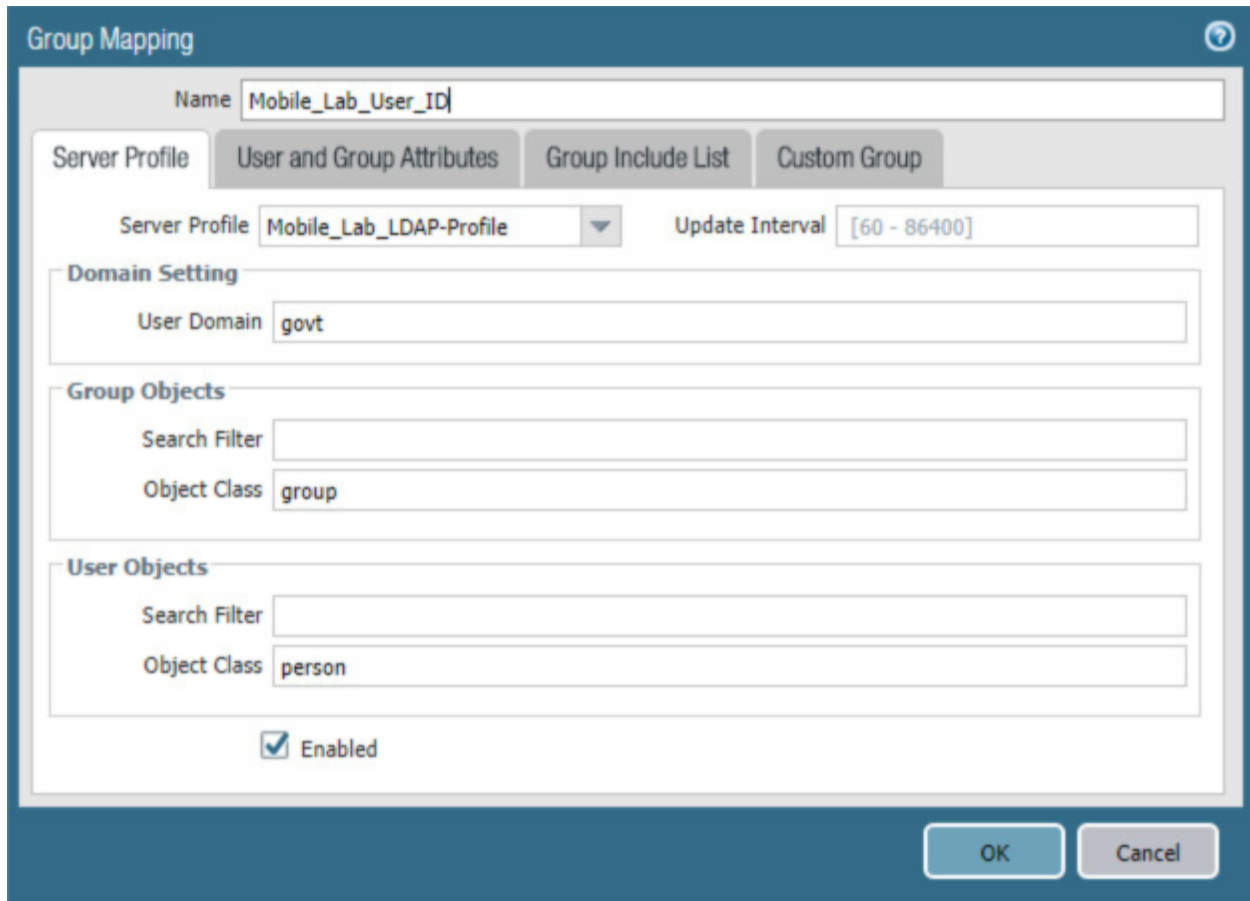
OK Cancel

902 **2.5.8.3 Configure User Identification**

- 903 1. In the **Palo Alto Networks Portal**, navigate to **Device & User Identification**.
- 904 2. In the details pane, select the **Group Mapping Settings** tab.
- 905 3. Below the details pane, select **Add** the **Group Mapping** form will open.
- 906 4. In the **Group Mapping** form:
- 907 a. In the **Name** field, enter a unique name to identify this group mapping.
- 908 b. In the **Server Profile** tab:

- 909 i. For the **Server Profile** drop-down menu, select the LDAP Server Profile created
- 910 previously.
- 911 ii. For **Domain Setting > User Domain**, enter the name of your Active Directory
- 912 domain; this sample implementation uses **govt**.

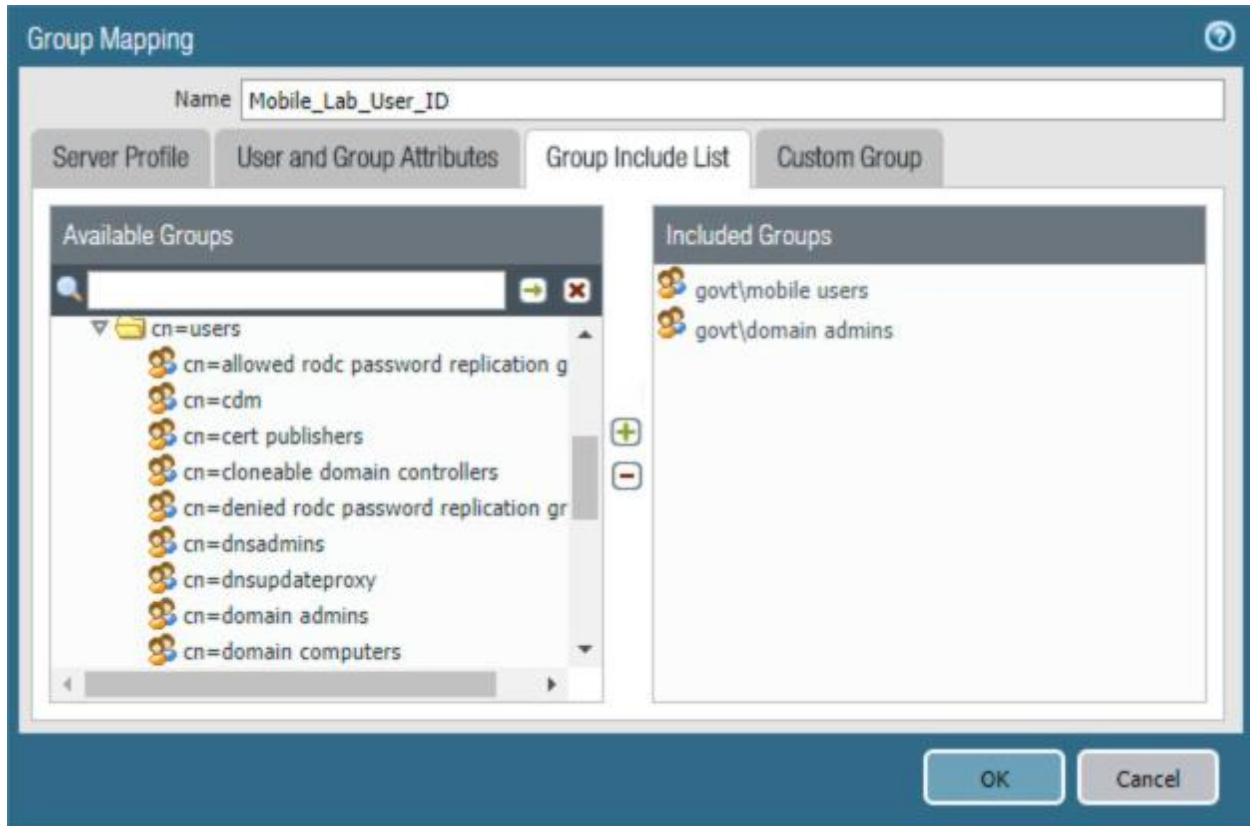
913 **Figure 2-59 LDAP Group Mapping**



- 914 c. Select the **Group Includes List** tab.
- 915 d. On the **Group Includes List** tab:
 - 916 i. In the **Available Groups** list box, expand the Active Directory domain to reveal
 - 917 configured user groups.
 - 918 ii. For each Active Directory group to be included in this User Identification
 - 919 configuration:
 - 920 1) Select the **Active Directory** group.

921 2) Select the **plus icon** to transfer the group to the **Included Groups** list box.

922 Figure 2-60 LDAP Group Include List

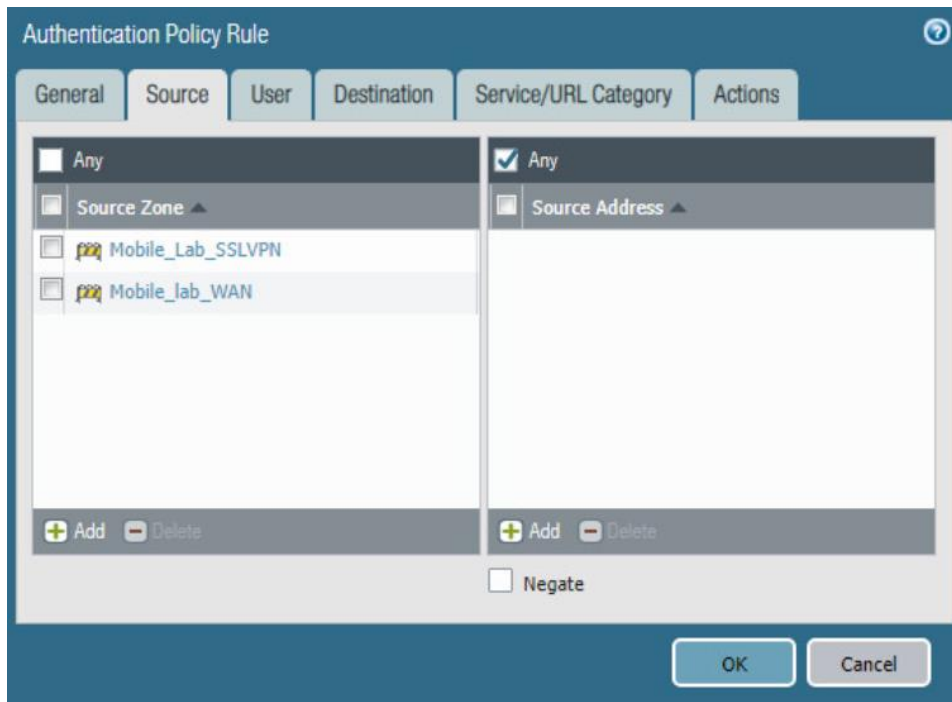


923 5. Select **OK**.

924 2.5.8.4 *Configure Authentication Policy Rule*

- 925 1. Navigate to **Policies > Authentication**.
- 926 2. Click **Add**.
- 927 3. Give the policy a name. In this implementation, **Mobile_Lab_Auth_Rule** was used.
- 928 4. Click **Source**.
- 929 5. Under Source Zone, click **Add**. Select the **SSL VPN** zone.
- 930 6. Under Source Zone, click **Add**. Select the **WAN** zone.

931 Figure 2-61 Authentication Policy Source Zones



932

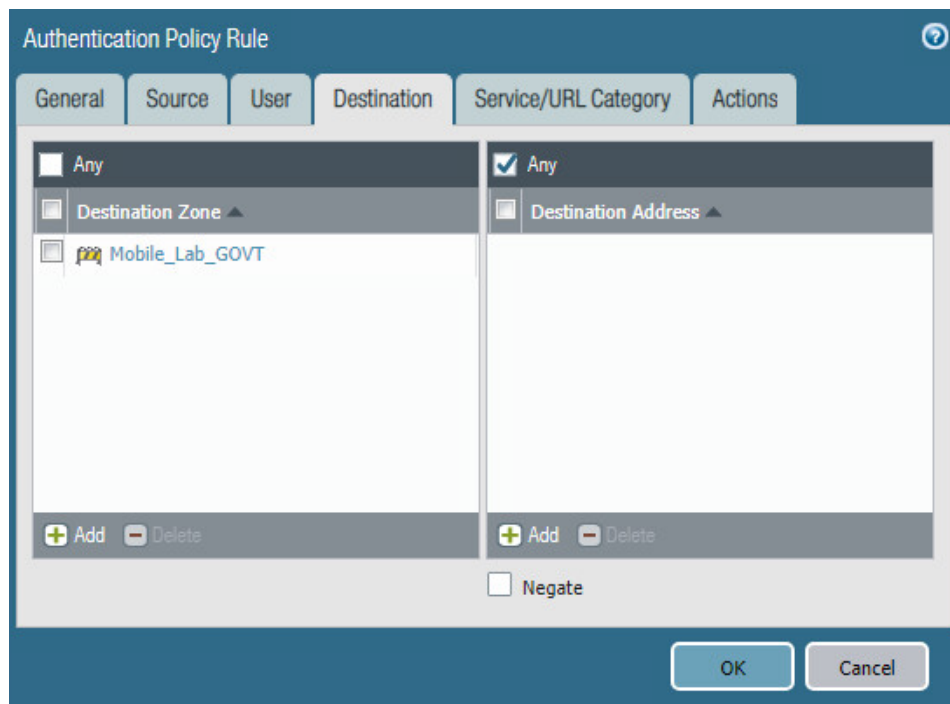
933

934

935

7. Click **Destination**.
8. Under Destination Zone, click **Add**.
9. Select the **LAN** zone.

936 Figure 2-62 Authentication Policy Destination Zones



- 937 10. Click **Service/URL Category**.
- 938 11. Under service, click **Add**.
- 939 12. Select **service-http**.
- 940 13. Under service, click **Add**.
- 941 14. Select **service-https**.
- 942 15. Click **Actions**.
- 943 16. Next to Authentication Enforcement, select **default-web-form**.
- 944 17. Leave Timeout and Log Settings as their default values.

945 **Figure 2-63 Authentication Profile Actions**

The screenshot shows the 'Authentication Policy Rule' configuration window with the 'Actions' tab selected. The 'Authentication Enforcement' dropdown is set to 'default-web-form'. The 'Timeout (min)' field is set to '60'. Under 'Log Settings', the 'Log Authentication Timeouts' checkbox is unchecked. The 'Log Forwarding' dropdown is set to 'None'. At the bottom right, there are 'OK' and 'Cancel' buttons.

946 18. Click **OK** and commit the changes.

947 2.5.9 Import Certificates

948 Certificates need to be imported into the appliance to configure certificate profiles that will affect how
 949 they are used in supporting communication with other systems. In particular, device certificates issued
 950 to mobile devices will be used to identify and authenticate mobile users.

951 **Note:** The certificate private keys must be password-protected to import them into the firewall.

- 952 1. In the **Palo Alto Networks Portal**, navigate to **Device > Certificate Management >**
 953 **Certificates**.
- 954 2. Under the details pane, select **Import**; the **Import Certificate** form will open.
- 955 3. In the **Import Certificate** form:
 - 956 a. For the **Certificate Type**, select **Local**.
 - 957 b. For the **Certificate Name** field, enter a unique name to identify this certificate.
 - 958 c. Next to the **Certificate File** field, Select **Browse...** to specify the full path to the file
 959 containing the certificate.
 - 960 d. For the **File Format** drop-down menu, select the certificate encoding appropriate to the
 961 certificate file; this example assumes the certificate and private key are in separate files,
 962 and select **PEM**. Note: The certificate's private key must be password-protected to
 963 import it into Palo Alto Networks appliances.

- 964 e. If the certificate identifies the Palo Alto Networks appliance:
- 965 i. Enable the **Import private key** checkbox.
- 966 ii. Next to **Key File**, select **Browse...** to specify the full path to the file containing the
- 967 private key for the uploaded certificate.
- 968 iii. For the **Passphrase** field, enter the pass phrase protecting the private key.
- 969 iv. For the **Confirm Passphrase** field, re-enter the pass phrase protecting the private
- 970 key.

971 Figure 2-64 Import MobileIron Certificate

The screenshot shows the 'Import Certificate' dialog box with the following fields and options:

- Certificate Type:** Local (selected), SCEP
- Certificate Name:** vpn.govt.mdse.nccoe.org
- Certificate File:** C:\fakepath\cert_vpn.govt.mdse.nccoe.org.crt (with a 'Browse...' button)
- File Format:** Base64 Encoded Certificate (PEM) (dropdown menu)
- Private key resides on Hardware Security Module
- Import private key
- Key File:** C:\fakepath\mi-sentry.govt.mdse.nccoe.org.key (with a 'Browse...' button)
- Passphrase:** [masked with dots]
- Confirm Passphrase:** [masked with dots]
- Buttons:** OK, Cancel

- 972 f. Select **OK**.
- 973 4. Repeat **Step 3** for each certificate to import into the Palo Alto Networks appliance. This will
- 974 include all certificates that the appliance will use to identify itself or authenticate to remote
- 975 systems, all certificates in the chain of trust for each such certificate, and any chain-of-trust
- 976 certificates supporting identity verification for remote systems to which this appliance will

977 require certificate-based identification and authentication. This sample implementation
978 uses certificates for the following systems:

- 979 ▪ server certificate for this appliance issued by DigiCert
- 980 ▪ DigiCert root CA certificate
- 981 ▪ DigiCert subordinate CA certificate
- 982 ▪ Microsoft CA enterprise root certificate
- 983 ▪ Microsoft CA enterprise subordinate CA certificate

984 2.5.10 Configure Certificate Profile

- 985 1. In the **Palo Alto Networks Portal**, navigate to **Device > Certificate Management >**
986 **Certificate Profile**.
- 987 2. Under the details pane, select **Add**; the **Certificate Profile** form will open.
- 988 3. In the **Certificate Profile** form:
 - 989 a. In the **Name** field, enter a unique name to identify this certificate profile.
 - 990 b. In the **Username Field** drop-down menu, select **Subject Alt**.
 - 991 c. Select the **Principal Name** option.
 - 992 d. In the **User Domain** field, enter the Active Directory domain name for your enterprise;
993 this sample implementation uses **govt**.
 - 994 e. Under the **CA Certificate** list box, select **Add**; a secondary Certificate Profile form will
995 appear.
 - 996 f. In the secondary **Certificate Profile** form, in the **CA Certificate** drop-down menu, select
997 the Microsoft Active Directory Certificate Services root certificate uploaded in **Section**
998 **2.5.6**.
 - 999 g. Select **OK**.
 - 1000 h. Repeat **Step 3f** for each intermediary certificate in the trust chain between the root
1001 certificate and the subordinate CA certificate that issues certificates to mobile devices.
 - 1002 i. Select **OK**.

1003 Figure 2-65 Internal Root Certificate Profile

CA Certificate: Internal Root

Default OCSP URL:

OCSP Verify Certificate: None

OK Cancel

1004 4. Select **OK**.

1005 Figure 2-66 Certificate Profile

Name: Mobile_Lab_Cert_Profile

Username Field: Subject Alt Email Principal Name

User Domain: govt

CA Certificates	Name	Default OCSP URL	OCSP Verify Certificate
<input type="checkbox"/>	Internal Root		
<input type="checkbox"/>	Internal SubCA		

+ Add - Delete

Default OCSP URL (must start with http:// or https://)

Use CRL CRL Receive Timeout (sec) 5 Block session if certificate status is unknown

Use OCSP OCSP Receive Timeout (sec) 5 Block session if certificate status cannot be retrieved within timeout

OCSP takes precedence over CRL Certificate Status Timeout (sec) 5 Block session if the certificate was not issued to the authenticating device

Block sessions with expired certificates

OK Cancel

1006

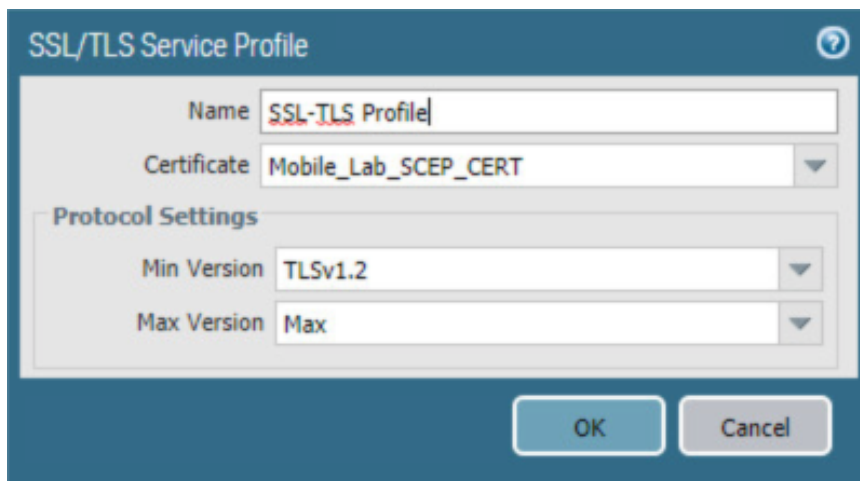
2.5.11 Configure SSL/TLS Service Profile

1007 The following steps will configure the SSL/TLS profile, which determines what certificates to trust when
 1008 mobile devices are connecting to the VPN and what certificate to use when establishing outbound
 1009 SSL/TLS connections.

- 1010 1. In the **Palo Alto Networks Portal**, navigate to **Device > Certificate Management > SSL/TLS**
 1011 **Service Profile**.

- 1012 2. Below the details pane, select **Add**; the **SSL/TLS Service Profile** form will open.
- 1013 3. In the **SSL/TLS Service Profile** form:
- 1014 a. In the **Name** field, enter a unique name to identify this service profile.
- 1015 b. For the **Certificate** drop-down menu, select the certificate to use for this SSL/TLS service
- 1016 profile; our sample implementation uses a client certificate obtained from a Microsoft
- 1017 enterprise CA via SCEP.
- 1018 c. For the **Min Version** drop-down menu, select **TLSv1.2**.
- 1019 d. Select **OK**.

1020 Figure 2-67 SSL/TLS Service Profile

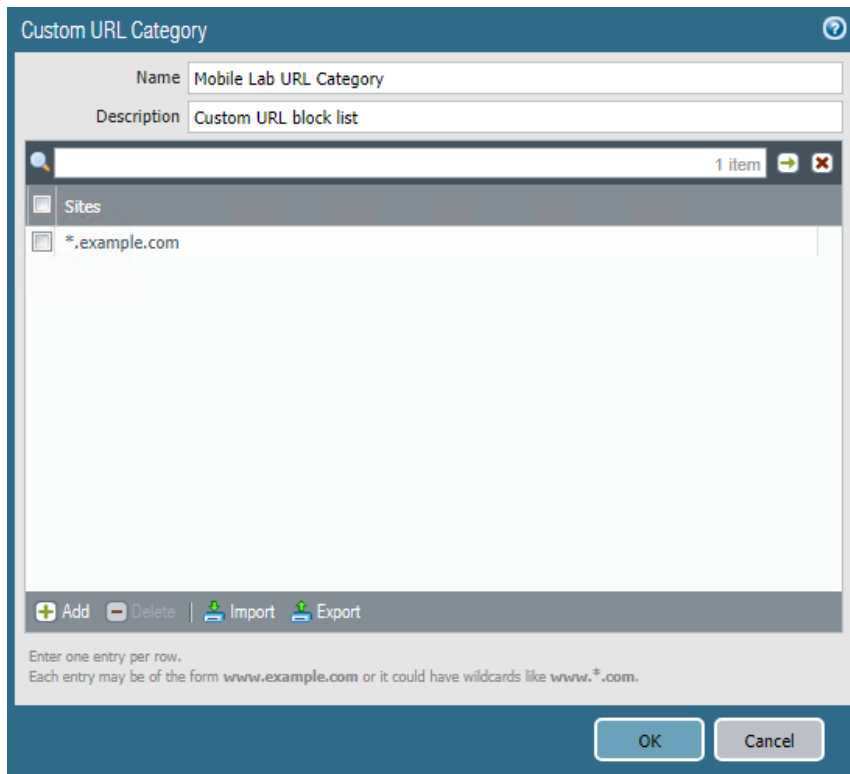
The image shows a screenshot of a web-based configuration form titled "SSL/TLS Service Profile". The form has a blue header bar with a question mark icon in the top right corner. Below the header, there are several input fields and dropdown menus. The "Name" field contains the text "SSL-TLS Profile". The "Certificate" dropdown menu is set to "Mobile_Lab_SCEP_CERT". Under a "Protocol Settings" section, the "Min Version" dropdown is set to "TLSv1.2" and the "Max Version" dropdown is set to "Max". At the bottom of the form, there are two buttons: "OK" and "Cancel".

- 1021 4. Repeat **Step 3** to add an identical SSL/TLS service profile for this appliance's server
- 1022 certificate issued through DigiCert.

1023 2.5.12 URL Filtering Configuration

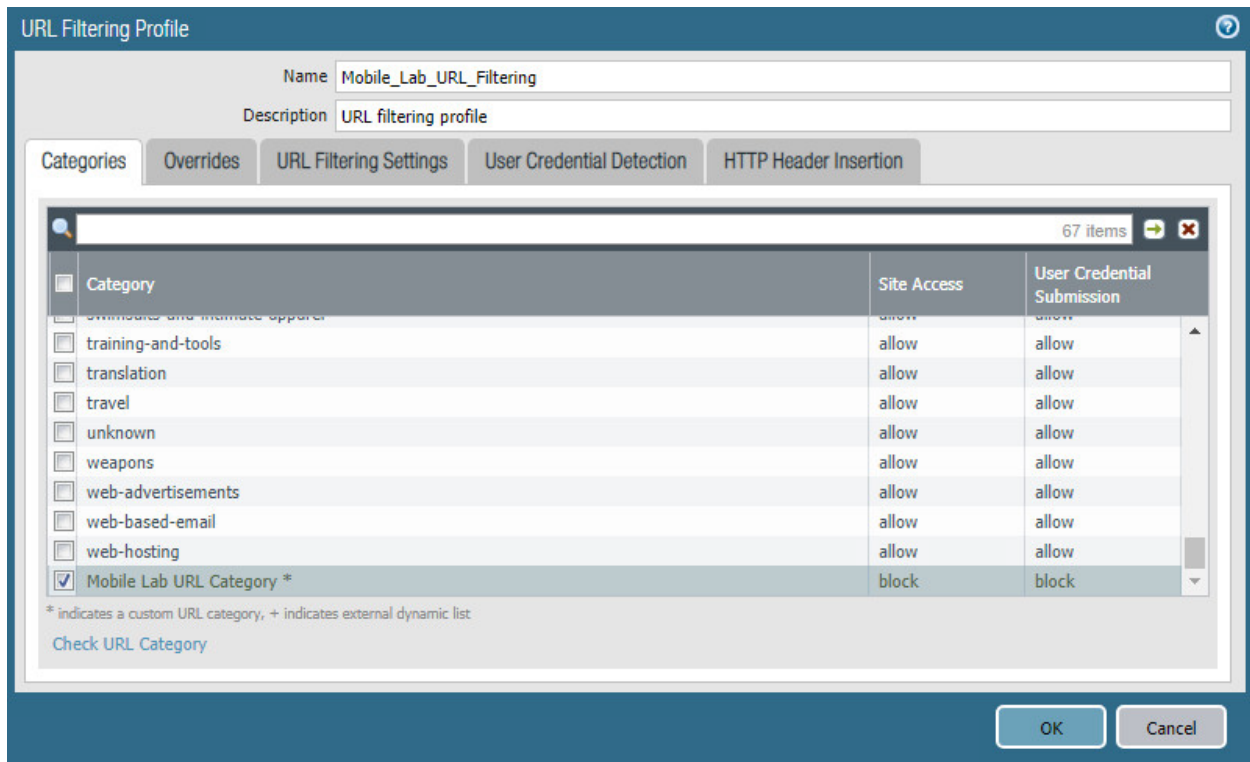
- 1024 1. Navigate to **Objects > Custom Objects > URL Category**.
- 1025 2. Click **Add**.
- 1026 3. Give the category a name and description.
- 1027 4. Add sites to be blocked. For this example, ***.example.com** was used.

1028 Figure 2-68 Custom URL Category



- 1029 5. Click **OK**.
- 1030 6. Navigate to **Objects > Security Profiles > URL Filtering**.
- 1031 7. Check the box next to default and click **Clone**.
- 1032 8. Select **default** from the window that appears.
- 1033 9. Click **OK**.
- 1034 10. Click the newly created profile, **default-1**.
- 1035 11. Give the policy a meaningful name and description.
- 1036 12. Scroll to the bottom of the list. The name of the created category will be last on the list.
- 1037 13. Click the option below **Site Access** and next to your created URL category.
- 1038 14. Set the Site Access option to **block**.

1039 Figure 2-69 URL Filtering Profile



- 1040 15. Click **OK**.
- 1041 16. Navigate to **Policies > Security**.
- 1042 17. Click the default outbound policy for the internal network (not VPN).
- 1043 18. Click **Actions**.
- 1044 19. Next to Profile Type, select **Profiles**.
- 1045 20. Next to URL Filtering, select the newly created profile.
- 1046 21. Click **OK**.
- 1047 22. Repeat **Steps 18** through **21** for the SSL VPN outbound traffic.

1048 Figure 2-70 URL Filtering Security Policy

Security Policy Rule

General Source User Destination Application Service/URL Category Actions

Action Setting

Action: Allow

Send ICMP Unreachable

Profile Setting

Profile Type: Profiles

Antivirus: None

Vulnerability Protection: None

Anti-Spyware: None

URL Filtering: Mobile_Lab_URL_Filtering

File Blocking: None

Data Filtering: None

WildFire Analysis: None

Log Setting

Log at Session Start

Log at Session End

Log Forwarding: None

Other Settings

Schedule: None

QoS Marking: None

Disable Server Response Inspection

OK Cancel

1049 23. Commit the changes.

1050 2.5.13 GlobalProtect Gateway and Portal Configuration

1051 The SSL VPN configuration requires creation of both a GlobalProtect gateway and a GlobalProtect portal,
 1052 the latter of which could be used to manage VPN connections across multiple gateways. In this sample
 1053 implementation, only a single gateway and portal are configured.

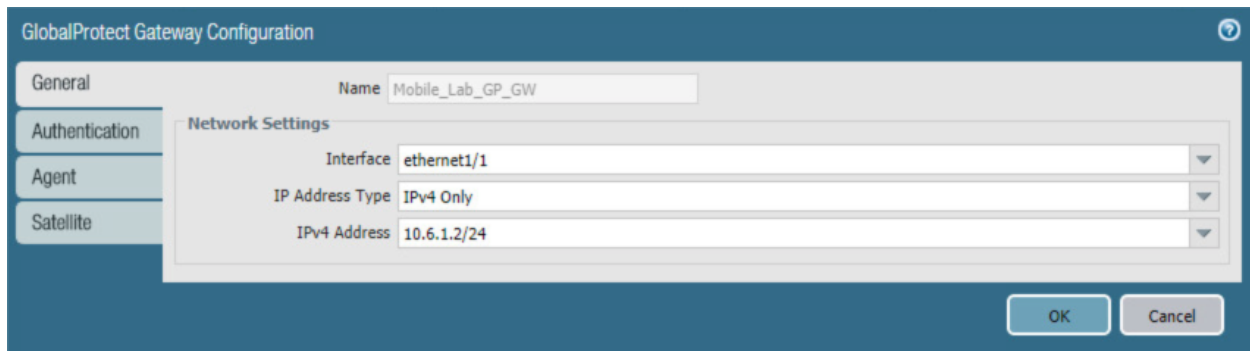
1054 2.5.13.1 Configure GlobalProtect Gateway

1055 The GlobalProtect gateway provides remote users with secure access to internal resources based on
 1056 their Microsoft AD group. To configure the GlobalProtect gateway:

- 1057 1. In the **Palo Alto Networks Portal**, navigate to **Network > GlobalProtect > Gateways**.
- 1058 2. Below the details pane, select **Add**; the **GlobalProtect Gateway Configuration** form will
 1059 open.

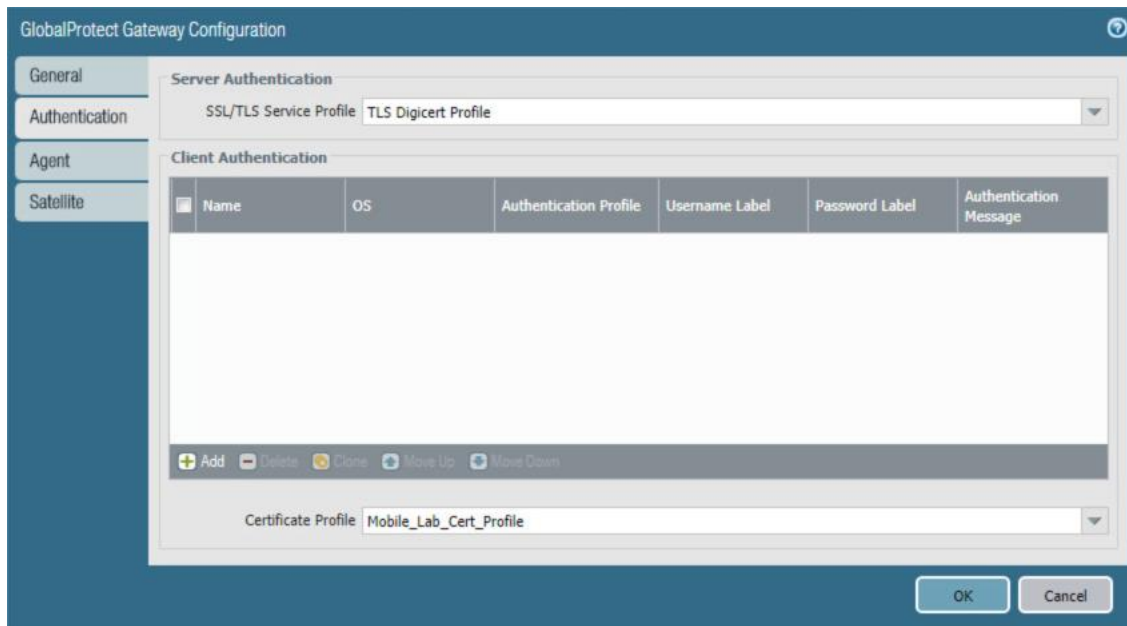
- 1060 3. In the **GlobalProtect Gateway Configuration** form, on the **General** tab:
- 1061 a. In the **Name** field, enter a unique name to identify this GlobalProtect Gateway.
- 1062 b. Under **Network Settings**:
- 1063 i. In the **Interface** drop-down menu, select the physical interface connected to the
- 1064 subnet on which the internet gateway device is located.
- 1065 ii. In the **IPv4 Address** drop-down menu, select the IP address associated with the
- 1066 physical interface specified in the previous step.

1067 **Figure 2-71 General GlobalProtect Gateway Configuration**

The image shows a screenshot of the 'GlobalProtect Gateway Configuration' dialog box. The 'General' tab is selected. The 'Name' field contains 'Mobile_Lab_GP_GW'. The 'Network Settings' section is expanded, showing three fields: 'Interface' set to 'ethernet1/1', 'IP Address Type' set to 'IPv4 Only', and 'IPv4 Address' set to '10.6.1.2/24'. At the bottom right, there are 'OK' and 'Cancel' buttons. The left sidebar shows other tabs: 'Authentication', 'Agent', and 'Satellite'.

- 1068 c. Select the **Authentication** tab.
- 1069 d. In the **Authentication** tab:
- 1070 i. For the **Server Authentication > SSL/TLS Service Profile** drop-down menu, select
- 1071 the TLS/SSL profile associated with the publicly trusted server certificate for this
- 1072 appliance.
- 1073 ii. For the **Client Authentication > Certificate Profile** drop-down menu, select the
- 1074 client TLS/SSL profile associated with the internally trusted client certificates
- 1075 issued to mobile devices.

1076 Figure 2-72 GlobalProtect Authentication Configuration



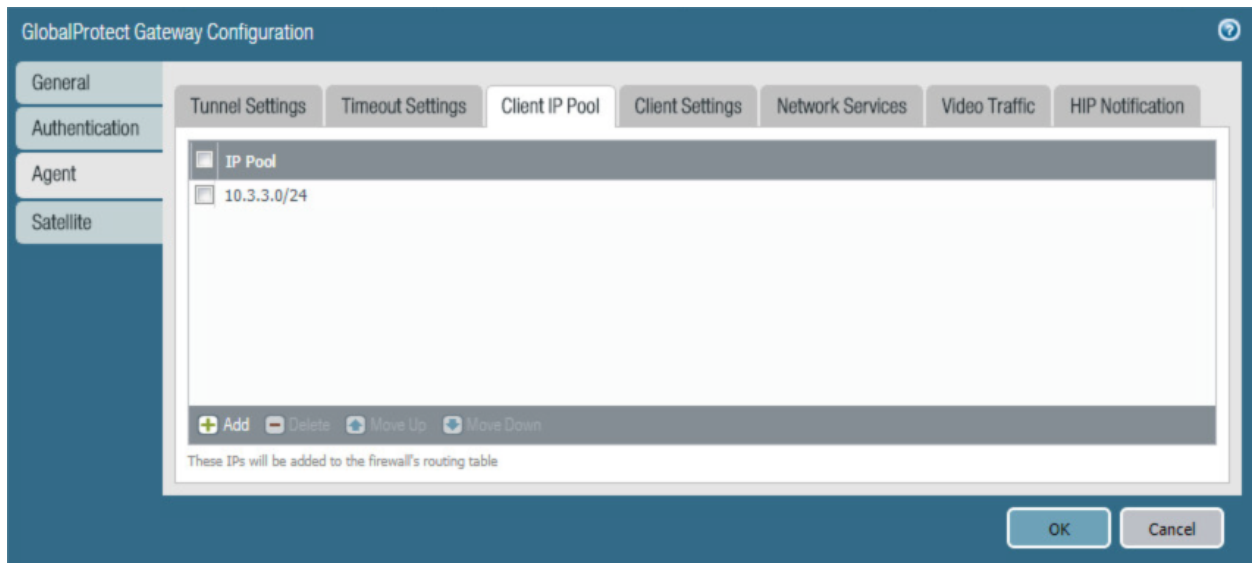
- 1077 e. Select the **Agent** tab.
- 1078 f. On the **Agent > Tunnel Settings** tab:
- 1079 i. Select the **Tunnel Mode** checkbox.
- 1080 ii. Select the **Enable IPSec** checkbox to disable IPSec.

1081 Figure 2-73 GlobalProtect Tunnel Configuration



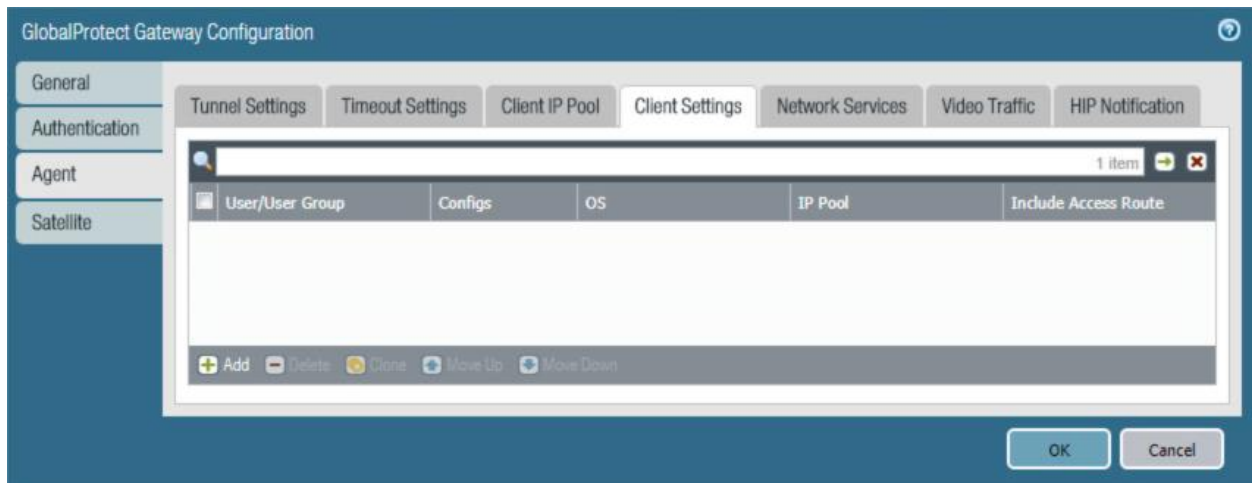
- 1082 g. Select the **Agent > Client IP Pool** tab.
- 1083 h. On the **Agent > Client IP Pool** tab:
- 1084 i. Below the **IP Pool** list box, select **Add**; a new list item will appear.
- 1085 ii. For the new **IP Pool** list item, enter the network address for the IP address pool
- 1086 from which connected devices will be allocated an IP address.

1087 Figure 2-74 VPN Client IP Pool



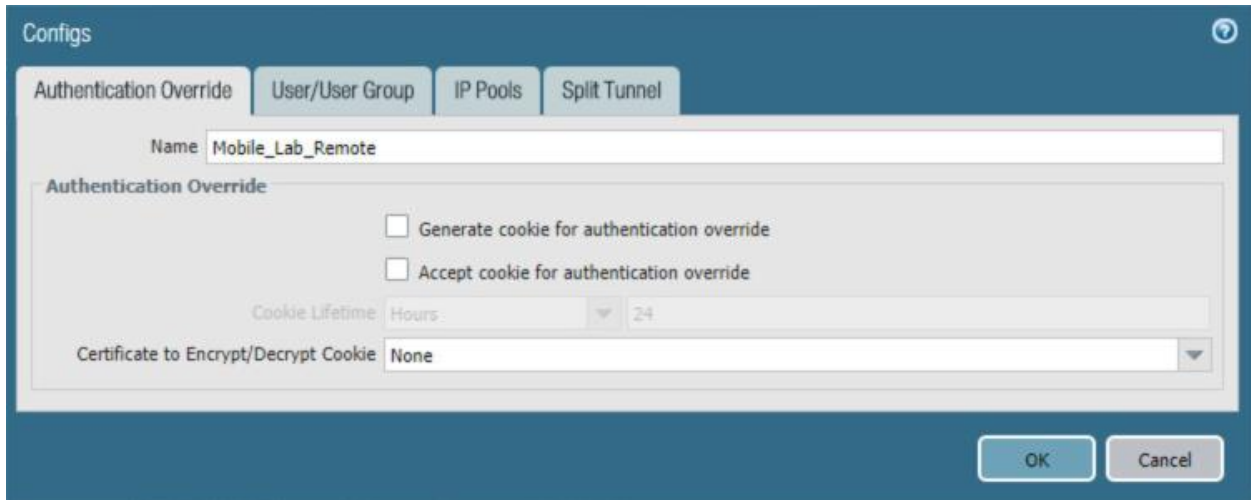
- 1088 i. Select the **Agent > Client Settings** tab.
- 1089 j. On the **Agent > Client Settings** tab:
 - 1090 i. Under the **Client Settings** list box, select **Add**; the **Configs** form will open.

1091 Figure 2-75 VPN Client Settings



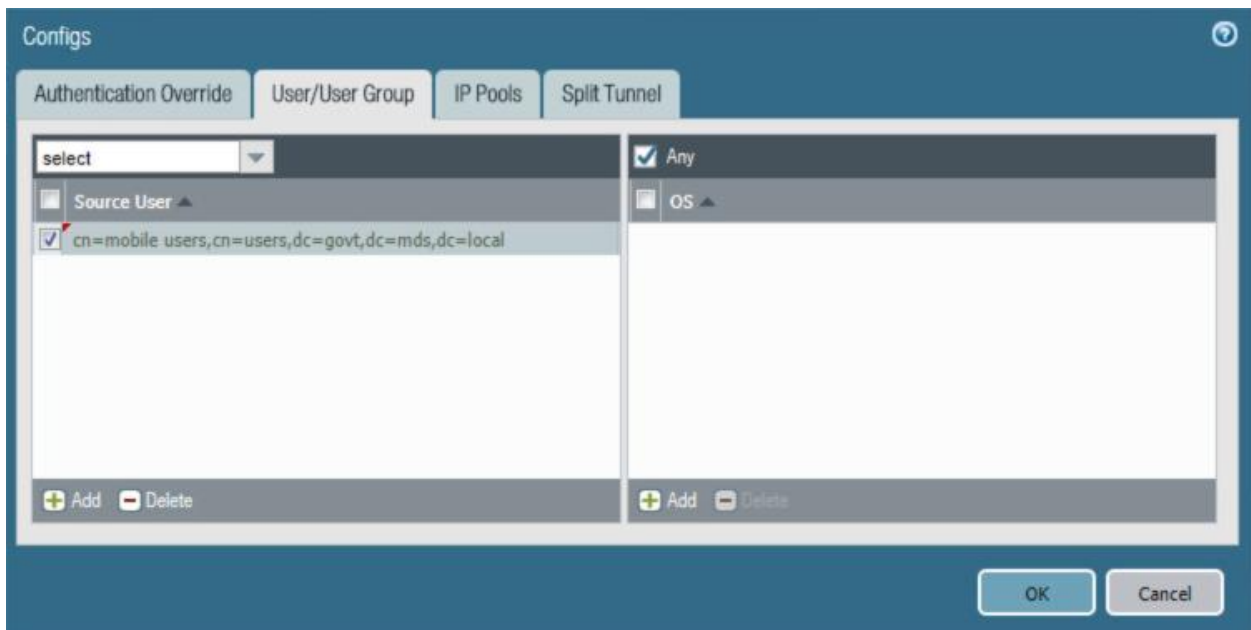
- 1092 ii. In the **Configs** form on the **Authorization Override** tab, enter a unique name to
- 1093 identify this client configuration.

1094 Figure 2-76 VPN Authentication Override Configuration



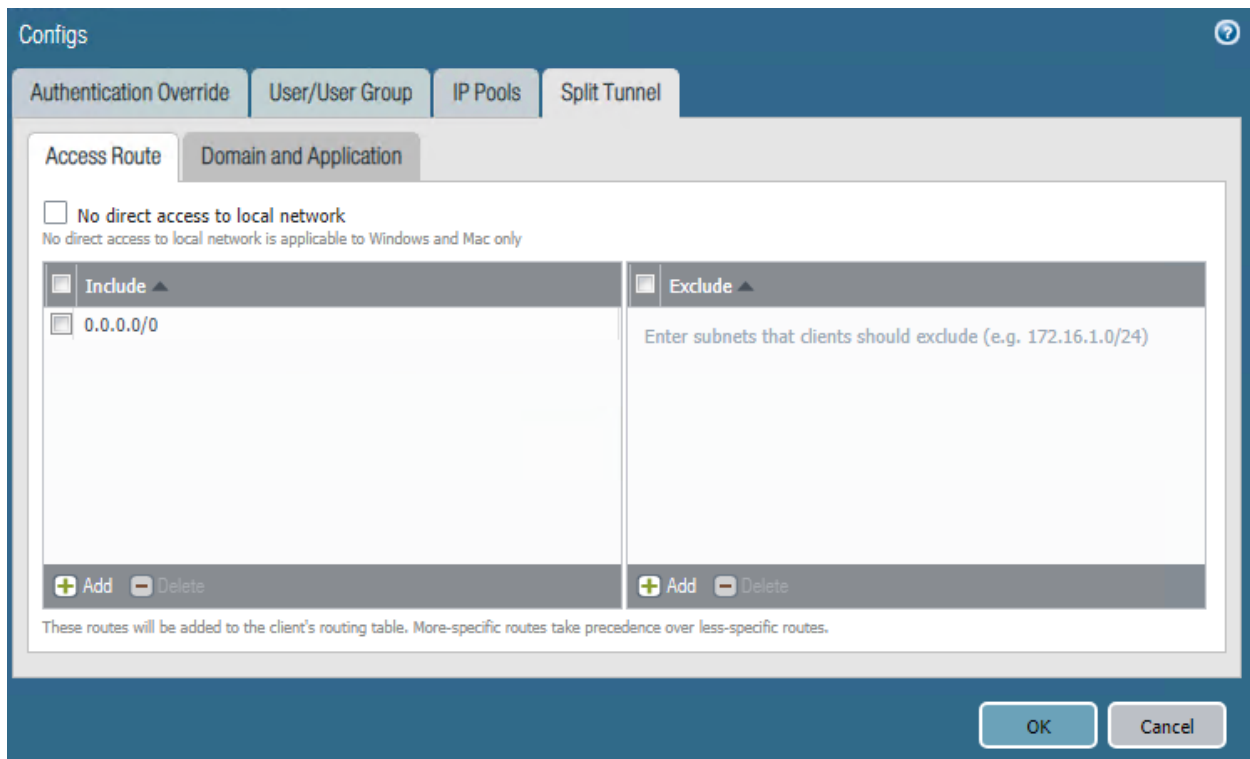
- 1095 iii. Select the **User/User Group** tab.
- 1096 iv. On the **User/User Group** tab:
 - 1097 1) Below the **Source User** list box, select **Add**; a new list item will appear.
 - 1098 2) In the **Source User** list item, select the Microsoft AD user group to grant
 - 1099 access to internal resources through this GlobalProtect gateway.

1100 Figure 2-77 VPN User Group Configuration



- 1101 v. Select the **Split Tunnel** tab.
- 1102 vi. On the **Split Tunnel** tab, on the **Access Route** tab:
- 1103 1) Under the **Include** list box, select **Add**; a new list item will appear.
- 1104 2) In the new **Include** list item, enter **0.0.0.0/0**. This enforces full tunneling.

1105 **Figure 2-78 VPN Split Tunnel Configuration**



- 1106 vii. Select **OK**.
- 1107 k. Select **OK**.

1108 *2.5.13.2 Configure GlobalProtect Portal*

- 1109 1. In the **Palo Alto Networks Portal**, navigate to **Network > GlobalProtect > Portal**.
- 1110 2. Below the details pane, select **Add**; the **GlobalProtect Portal Configuration** form will open.
- 1111 3. In the **GlobalProtect Portal Configuration** form, on the **General** tab:
- 1112 a. In the **Name** field, enter a unique name to identify this GlobalProtect portal.

1113 b. In the **Interface** drop-down menu, select the physical interface connected to the subnet
 1114 on which the internet gateway device is located.

1115 c. In the **IP Address Type** drop-down menu, select **IPv4 Only**.

1116 **Figure 2-79 GlobalProtect Portal Configuration**

1117 4. Select the **Authentication** tab.

1118 5. In the **Authentication** tab:

1119 a. For the **Server Authentication > SSL/TLS Service Profile** drop-down menu, select the
 1120 SSL/TLS service profile based on your third-party server certificate.

1121 b. For the **Certificate Profile** drop-down menu, select the client TLS/SSL profile associated
 1122 with the internally trusted client certificates issued to mobile devices.

1123 c. Click **Add**.

1124 d. Enter a profile name. In this example implementation, Client Authentication was used.

1125 e. For the **Authentication Profile** drop-down menu, select the previously created
 1126 authentication profile.

1127 f. Click **OK**.

1128 Figure 2-80 GlobalProtect Portal SSL/TLS Configuration

GlobalProtect Portal Configuration

General

Authentication

Agent

Clientless VPN

Satellite

Server Authentication

SSL/TLS Service Profile: TLS Digicert Profile

Client Authentication

<input type="checkbox"/>	Name	OS	Authentication Profile	Username Label	Password Label	Authentication Message
<input type="checkbox"/>	Authentication Profile	Any	Mobile_Lab_Auth-Profile	Username	Password	Enter login credentials

+ Add - Delete 🔄 Clone ↕ Move Up ↕ Move Down

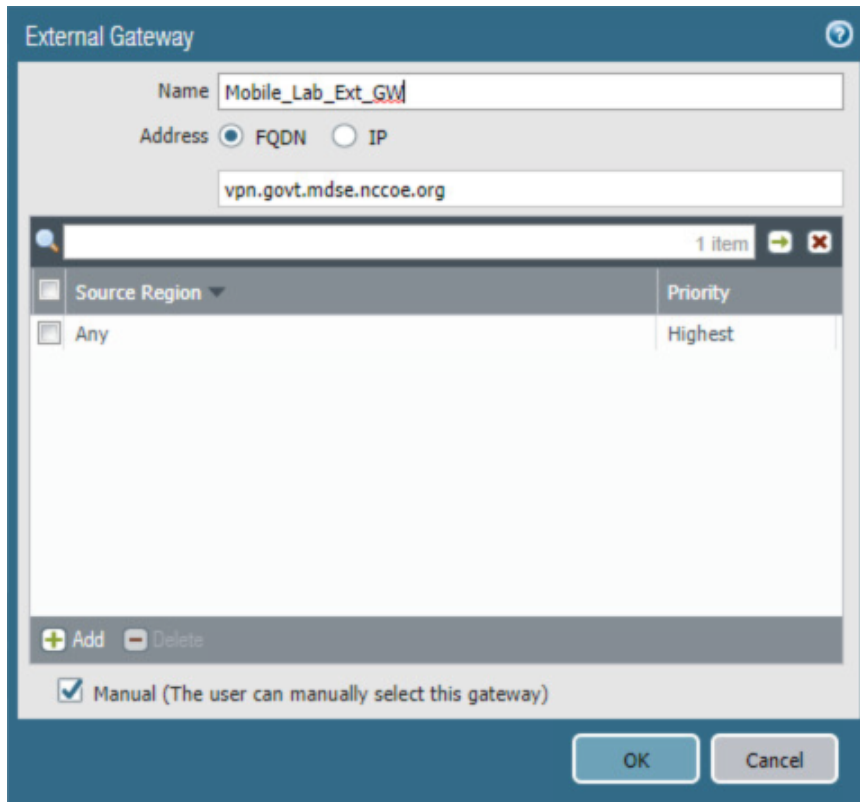
Certificate Profile: Mobile_Lab_Cert_Profile

OK Cancel

- 1129 6. Select the **Agent** tab.
- 1130 7. On the **Agent** tab:
- 1131 a. Below the **Agent** list box, select **Add**; the Configs form will open.
- 1132 b. In the **Configs** form:
- 1133 i. In the **Authentication** tab, below **Components that Require Dynamic Passwords**,
- 1134 check the box next to **Portal**.
- 1135 ii. In the **External** tab, under the **External Gateways** list box select **Add**; the **External**
- 1136 **Gateway** form will open.
- 1137 iii. In the External Gateway form:
- 1138 1) In the **Name** field, enter a unique name to identify this external gateway.
- 1139 2) For the **Address** option, enter the FQDN for this appliance; in this sample
- 1140 implementation, the FQDN is **vpn.govt.mdse.nccoe.org**.
- 1141 3) Below the **Source Region** list box, select **Add**; a new list item will appear.

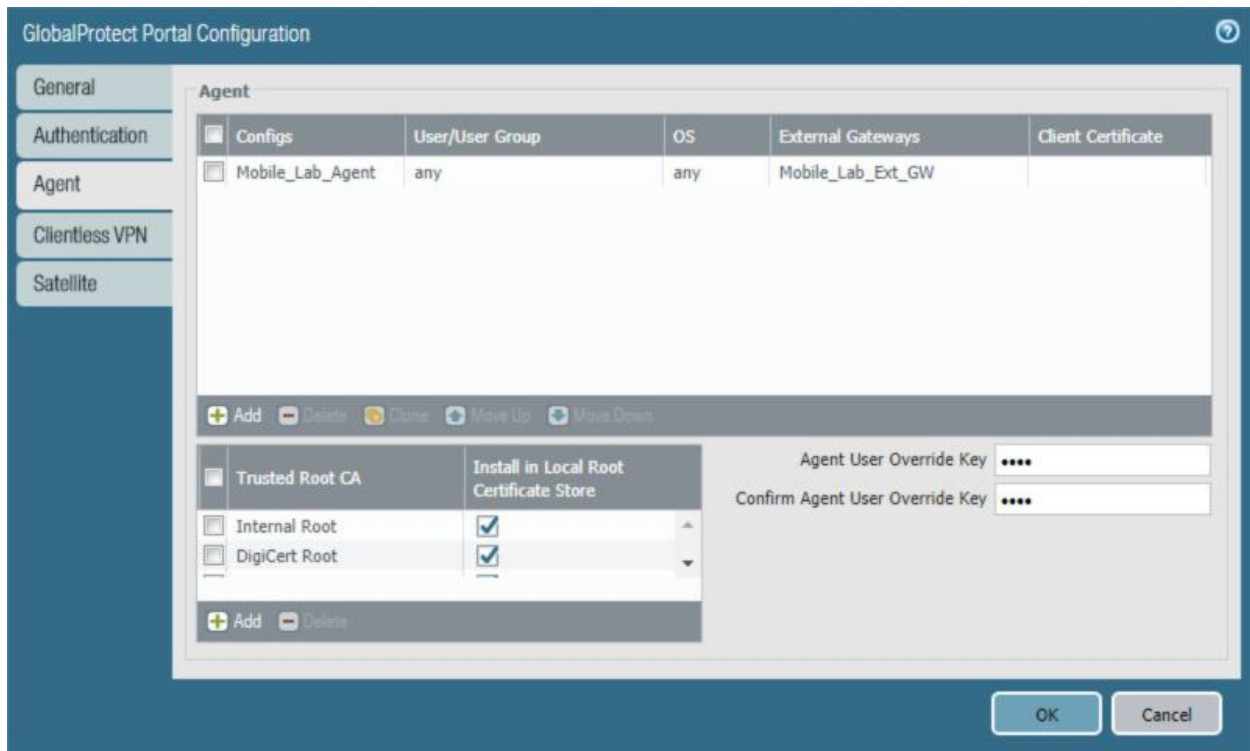
- 1142 4) In the new **Source Region** list item, select **Any**.
- 1143 5) Select the **Manual** checkbox.
- 1144 6) Select **OK**.

1145 **Figure 2-81 GlobalProtect External Gateway Configuration**



- 1146 iv. Below the **Trusted Root CA** list box, select **Add**; a new list item will appear.
- 1147 v. In the new **Trusted Root CA** list item, select your internal CA root certificate.
- 1148 vi. Repeat **Steps 7biii** and **7biv** to add each certificate in your internal or third-party
- 1149 certificate trust chains used when mobile devices contact the GlobalProtect
- 1150 portal.
- 1151 c. Click **App**. Ensure that Connect Method is set to **User-logon (Always On)**.

1152 Figure 2-82 GlobalProtect Portal Agent Configuration



1153 d. Select **OK**.

1154 2.5.14 Configure Automatic Threat and Application Updates

- 1155 1. In the **PAN-OS portal**, navigate to **Device > Dynamic Updates**.
- 1156 2. Click **Check Now** at the bottom of the page.
- 1157 3. Under Applications and Threats, click **Download** next to the last item in the list, with the
- 1158 latest Release Date. It will take a minute to download the updates.
- 1159 4. When the download completes, click **Done**.
- 1160 5. Click **Install** next to the downloaded update.
- 1161 6. Click **Continue Installation**.
- 1162 7. When installation completes, click **Close**.
- 1163 8. Next to Schedule, click the link with the date and time.

1164 **Figure 2-83 Schedule Link**

Version ▲	File Name	Features	Type
▼ Applications and Threats	Last checked: 2018/11/29 12:25:15 EST	Schedule:	Every Wednesday at 01:02 (Download only)

- 1165 9. Select the desired recurrence. For this implementation, Weekly was used.
- 1166 10. Select the desired day and time. For this implementation, Saturday at 23:45 was used.
- 1167 11. Next to Action, select **download-and-install**.

1168 **Figure 2-84 Threat Update Schedule**

Applications and Threats Update Schedule

Recurrence: Weekly

Day: saturday

Time: 23:45

Action: download-and-install

Disable new apps in content update

Threshold (hours): [1 - 336]
A content update must be at least this many hours old for the action to be taken.

Allow Extra Time to Review New App-IDs

Set the amount of time the firewall waits before installing content updates that contain new App-IDs. You can use this wait period to assess and adjust your security policy based on the new App-IDs.

New App-ID Threshold (hours): [1 - 336]

OK Cancel

- 1169
- 1170 12. Click **OK**.
- 1171 13. Commit the changes.

1172 **2.6 Integration of Kryptowire EMM+S with MobileIron**

1173 Kryptowire's application vetting service uses the MobileIron application programming interface (API) to
 1174 regularly pull current device application inventory information from MobileIron Core. Updated analysis
 1175 results are displayed in the Kryptowire portal.

1176 2.6.1 Add MobileIron API Account for Kryptowire

1177 The following steps will create an administrative account that will grant Kryptowire the specific
1178 permissions it requires within MobileIron.

- 1179 1. In the **MobileIron Admin Portal**, navigate to **Devices & Users > Users**.
- 1180 2. On the **Users** page:
 - 1181 a. Select **Add > Add Local User**; the Add New User dialogue will open.

1182 **Figure 2-85 MobileIron Users**

	EDIT	NAME	USER ID	EMAIL	CREATION DATE	SOURCE	ROLES
		admin	admin		2017-08-31 5:45:...	Local	Change Device Ownership, L
		Appthority Connector	appthority	appthority@govt.mds.local	2017-10-30 5:41:...	Local	User Portal

- 1183 b. In the **Add New User** dialogue:
 - 1184 i. In the **User ID** field, enter the user identity that the Kryptowire cloud will
1185 authenticate under; our implementation uses a value of **kryptowire**.
 - 1186 ii. In the **First Name** field, enter a generic first name for **Kryptowire**.
 - 1187 iii. In the **Last Name** field, enter a generic last name for **Kryptowire**.
 - 1188 iv. In the **Display Name** field, optionally enter a displayed name for this user
1189 account.
 - 1190 v. In the **Password** field, provide the password that the **Kryptowire** identity will use
1191 to authenticate to MobileIron.
 - 1192 vi. In the **Confirm Password** field, enter the same password as in the preceding step.
 - 1193 vii. In the **Email** field, provide an email account for the **Kryptowire** identity; this could
1194 be used in configuring automatic notifications and should be an account under
1195 the control of your organization.
 - 1196 viii. Select **Save**

1197 Figure 2-86 Kryptowire API User Configuration

The screenshot shows a dialog box titled "Add New User" with a close button (X) in the top right corner. The dialog contains the following fields and values:

Field	Value
User ID	kryptowire
First Name	Kryptowire
Last Name	Cloud
Display Name	Kryptowire 2 MobileIron API
Password
Confirm Password
Email	kryptowire@mds.local

At the bottom right of the dialog, there are two buttons: "Cancel" (text button) and "Save" (blue button).

- 1198 3. In the **MobileIron Admin Portal**, navigate to **Admin > Admins**.
- 1199 4. On the **Admins** page:
 - 1200 a. Enable the account you created for Kryptowire during **Step 2**.
 - 1201 b. Select **Actions > Assign to Space**; this will open the Assign to Space dialogue for the
 - 1202 Kryptowire account.

1203 Figure 2-87 MobileIron User List

<input type="checkbox"/>	NAME	USER ID	EMAIL	SOURCE	ROLES
<input type="checkbox"/>	admin	admin		Local	API, Add device, Apply and remove compliance policy labels, Apply
<input type="checkbox"/>	Appthority Connector	appthority	appthority@govt.mds.local	Local	API, Add device, Apply and remove compliance policy labels, Apply
<input checked="" type="checkbox"/>	Kryptowire 2 MobileIron...	kryptowire	kryptowire@govt.mds.local	Local	API, View dashboard, View device page, device details
<input type="checkbox"/>	Lookout Cloud	lookout	lookout@govt.mds.local	Local	API, Connector, Distribute app, View Audit logs, View apps and ibo

1204

1205

c. In the **Assign to Space** dialogue:

1206

i. In the **Select Space** drop-down menu, select **Global**.

1207 Figure 2-88 Kryptowire API User Space Assignment

1208

ii. Enable each of the following settings:

Admin Roles > Device Management > View device page, device details
Admin Roles > Device Management > View dashboard
Admin Roles > Privacy Control > View apps and ibooks in device details
Admin Roles > Privacy Control > View device IP and MAC address
Admin Roles > App Management > View app
Admin Roles > App Management > View app inventory
Other Roles > Common Services Provider (CSP)
Other Roles > API

1209

iii. Select **Save**.

1210 2.6.2 Contact Kryptowire to Create Inbound Connection

1211 Once the MobileIron API account has been created, contact Kryptowire customer support to integrate
 1212 your instance of MobileIron Core. Note that this will require creation of firewall rules that permit
 1213 inbound connections from IP addresses designated by Kryptowire to MobileIron Core on port 443. Once
 1214 the connection has been established, the Kryptowire portal will populate with information on devices
 1215 registered with MobileIron. The EMM (Enterprise Mobility Management) ID presented by Kryptowire
 1216 will be the same as the Universally Unique ID assigned to a device by MobileIron Core.

1217 **Figure 2-89 Kryptowire Device List**

Platform	Device	OS Version	User	Compliant	Email	MAC Address	MDM Identifier
	Pixel	8.1	mpeck	✓		ac:37:43:dc:0f:da	b04f418c-89ef-444a-8307-43f387b09797
	iPad Air 2	11.3.1	mike.peck	✓		a8:5b:78:15:45:39	cc598fa2-7110-4022-bb05-20771943f8c3
	Nexus 6	7.0	jean.luc	✓		f8:cf:c5:cd:48:29	d4511074-0297-4a64-949f-1f42bc6f6c29
	SM-G930V	7.0	mpeck	✓		2c:0e:3d:40:06:fa	eb195105-456e-4827-8aa0-f769d7b78d0f

1218 2.7 Integration of Lookout Mobile Endpoint Security with MobileIron

1219 Lookout's Mobile Endpoint Security cloud service uses the MobileIron API to pull mobile device details
 1220 and app inventory from MobileIron Core. Following analysis, Lookout uses the API to apply specific
 1221 labels to devices to categorize them by the severity of any issues detected. MobileIron can be
 1222 configured to automatically respond to the application of specific labels per built-in compliance actions.

1223 2.7.1 Add MobileIron API Account for Lookout

1224 The following steps will create an administrative account that will grant to Lookout the specific
 1225 permissions it requires within MobileIron.

- 1226 1. In the **MobileIron Admin Portal**, navigate to **Devices & Users > Users**.
- 1227 2. On the **Users** page:
 - 1228 a. Select **Add > Add Local User**; the Add New User dialogue will open.

1229 Figure 2-90 MobileIron User List

	E...	NAME	USER ID	EMAIL	CREATION DATE	SO...	ROLES
<input type="checkbox"/>	^	admin	admin		2017-08-31 5:45:19 AM	Local	Change Device
<input type="checkbox"/>	^	Administrator	Administrator		2018-07-27 9:14:22 AM	LDAP	
<input type="checkbox"/>	^	Appthority Connector	appthority	appthority@govt.mds.local	2017-10-30 5:41:49 AM	Local	User Portal

- 1230 b. In the **Add New User** dialogue:
- 1231 i. In the **User ID** field, enter the user identity the Lookout cloud will authenticate
- 1232 under. Our implementation uses a value of **lookout**.
- 1233 ii. In the **First Name** field, enter a generic first name for **Lookout**.
- 1234 iii. In the **Last Name** field, enter a generic last name for **Lookout**.
- 1235 iv. In the **Display Name** field, optionally enter a displayed name for this user
- 1236 account.
- 1237 v. In the **Password** field, provide the password the Lookout identity will use to
- 1238 authenticate to MobileIron.
- 1239 vi. In the **Confirm Password** field, enter the same password as in the preceding step.
- 1240 vii. In the **Email** field, provide an email account for the Lookout identity; since this
- 1241 may be used for alerts, it should be an account under the control of your
- 1242 organization.
- 1243 viii. Select **Save**.

1244 Figure 2-91 MobileIron Lookout User Configuration

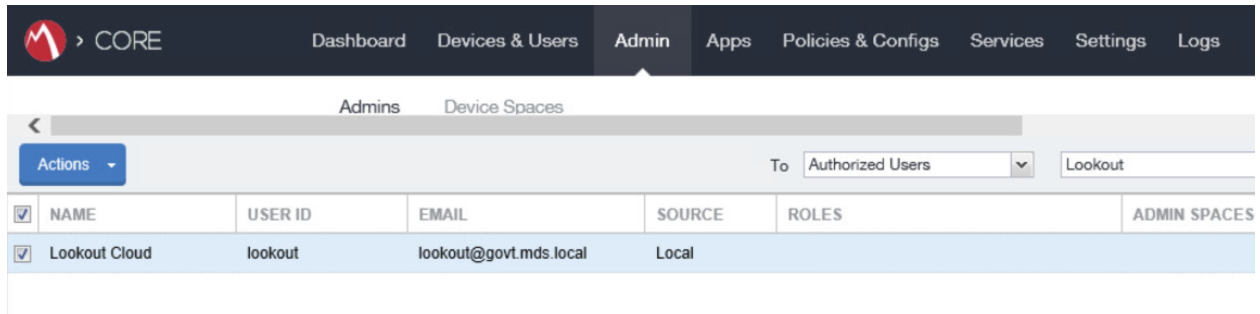
The screenshot shows a dialog box titled "Add New User" with a close button (X) in the top right corner. The dialog contains the following fields and values:

- User ID: lookout
- First Name: Lookout
- Last Name: Cloud
- Display Name: Lookout Cloud
- Password: masked with 8 dots
- Confirm Password: masked with 8 dots
- Email: lookout@govt.mds.local

At the bottom right of the dialog, there are two buttons: "Cancel" (text button) and "Save" (blue button).

- 1245 3. In the **MobileIron Admin Portal**, navigate to **Admin**.
- 1246 4. On the **Admin** page:
 - 1247 a. Enable the account you created for Lookout during **Step 2**.
 - 1248 b. Select **Actions > Assign to Space**; this will open the **Assign to Space** dialogue for the
 - 1249 Lookout account.

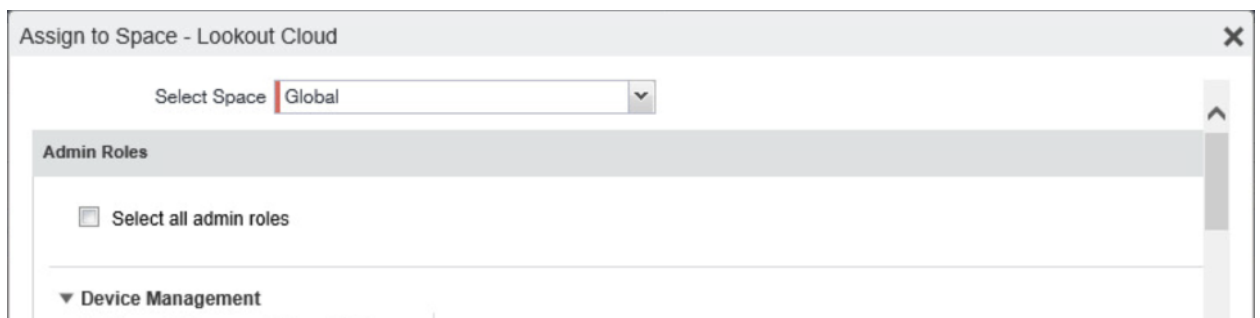
1250 Figure 2-92 Lookout MobileIron Admin Account



1251 c. In the **Assign to Space** dialogue:

1252 i. In the **Select Space** drop-down menu, select **Global**.

1253 Figure 2-93 Lookout Account Space Assignment



1254 ii. Enable each of the following settings:

Admin Roles > Device Management > View device page, device details
Admin Roles > Device Management > View dashboard
Admin Roles > Label Management > View Label
Admin Roles > Label Management > Manage Label
Admin Roles > Privacy Control > View apps and ibooks in device details
Admin Roles > Privacy Control > View device IP and MAC address
Admin Roles > App Management > Distribute app
Admin Roles > Logs and Event Management > View Audit logs
Admin Roles > Logs and Event Management > View events
Other Roles > CSP
Other Roles > Connector
Other Roles > API

1255 iii. Select **Save**.

1256

2.7.2 Add MobileIron Labels for Lookout

1257 Lookout will dynamically apply MobileIron labels to protected devices to communicate information
 1258 about their current state. The following steps will create a group of Lookout-specific labels.

- 1259 1. In the **MobileIron Admin Portal**, navigate to **Devices & Users > Labels**.
- 1260 2. On the **Labels** page:
 - 1261 a. Select **Add Label**; the **Add Label** dialogue will appear.

1262 **Figure 2-94 MobileIron Label List**

	NAME	DESCRIPTION	TYPE	CRITERIA
<input type="checkbox"/>	All-Smartphones	Label for all devices irrespective of OS	Filter	"common.retired"=false
<input type="checkbox"/>	Android	Label for all Android Phones.	Filter	"common.platform"="Android" AND "common.retired"=f
<input type="checkbox"/>	Company-Owned	Label for all Company owned smartphones.	Filter	"common.owner"="COMPANY" AND "common.retired"

- 1263 b. In the **Add Label** dialogue:
 - 1264 i. In the **Name** field, enter the name of the label. Note: future steps will use the
 1265 Label Names presented here but use of these names is optional.
 - 1266 ii. In the **Description** field, enter a brief description for this label.
 - 1267 iii. For the **Type** option, select **Manual**; this will hide all other form inputs.
 - 1268 iv. Select **Save**.

1269 Figure 2-95 MTP Low Risk Label Configuration

c. Complete **Step 3** for each label in the following table:

Label Name	Purpose
Lookout for Work	Device enrollment
MTP - Pending	Lifecycle management: devices with Lookout not yet activated
MTP - Secured	Lifecycle management: devices with Lookout activated
MTP - Threats Present	Lifecycle management: devices with threats detected by Lookout

MTP - Deactivated	Lifecycle management: devices with Lookout deactivated
MTP - Low Risk	Risk posture: devices with a low risk score in Lookout
MTP - Moderate Risk	Risk posture: devices with a moderate risk score in Lookout
MTP - High Risk	Risk posture: devices with a high risk score in Lookout

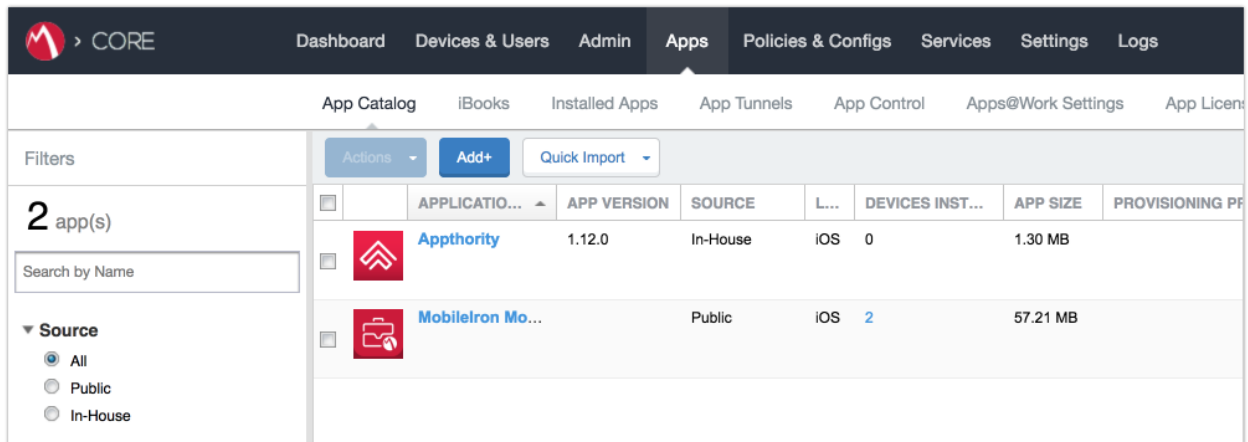
1270 **Note:** Administrators can choose to alter the label names to something more appropriate for their
1271 environment.

1272 2.7.3 Add Lookout for Work for Android to MobileIron App Catalog

1273 The following steps will add the Lookout for Work app for Android to MobileIron.

- 1274 1. In the **MobileIron Admin Portal**, navigate to **Apps > App Catalog**.
- 1275 2. On the **App Catalog** page, select **Add**; this will start the workflow to add a new app to the
1276 app catalog.

1277 **Figure 2-96 MobileIron App Catalog**

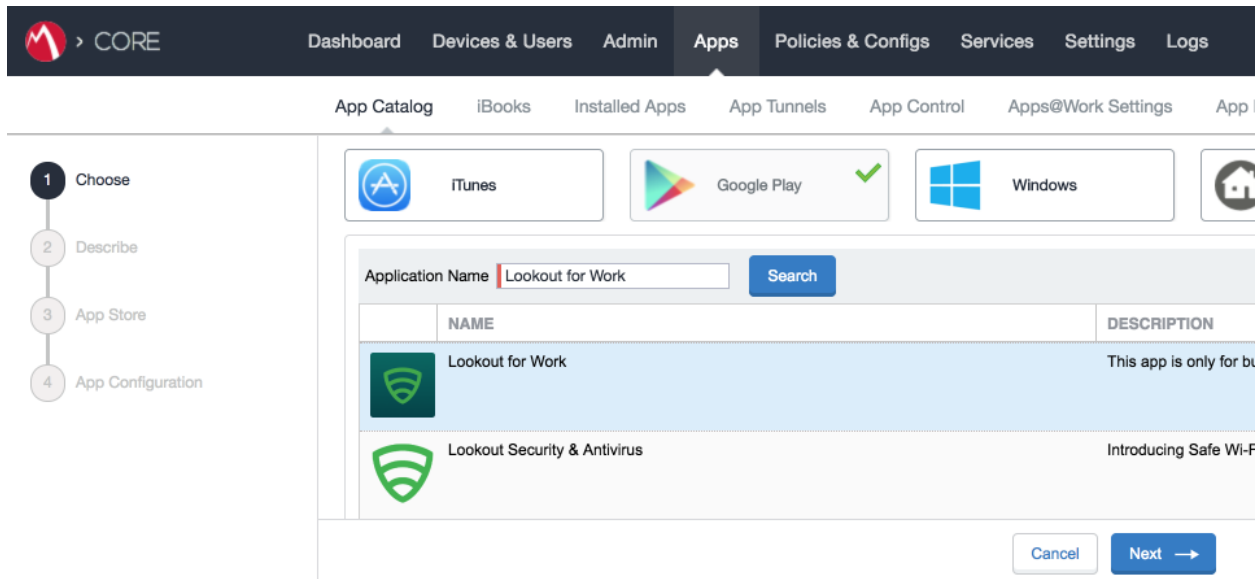


- 1278 3. On the **App Catalog > Choose** page:
 - 1279 a. Select **Google Play**; additional controls will be displayed.
 - 1280 b. In the **Application Name** field, enter **Lookout for Work**.
 - 1281 c. Select **Search**; search results will be displayed in the lower pane.

1282 d. In the list of search results, select the **Lookout for Work** app.

1283 e. Select **Next**.

1284 **Figure 2-97 Adding Lookout for Work to the MobileIron App Catalog**

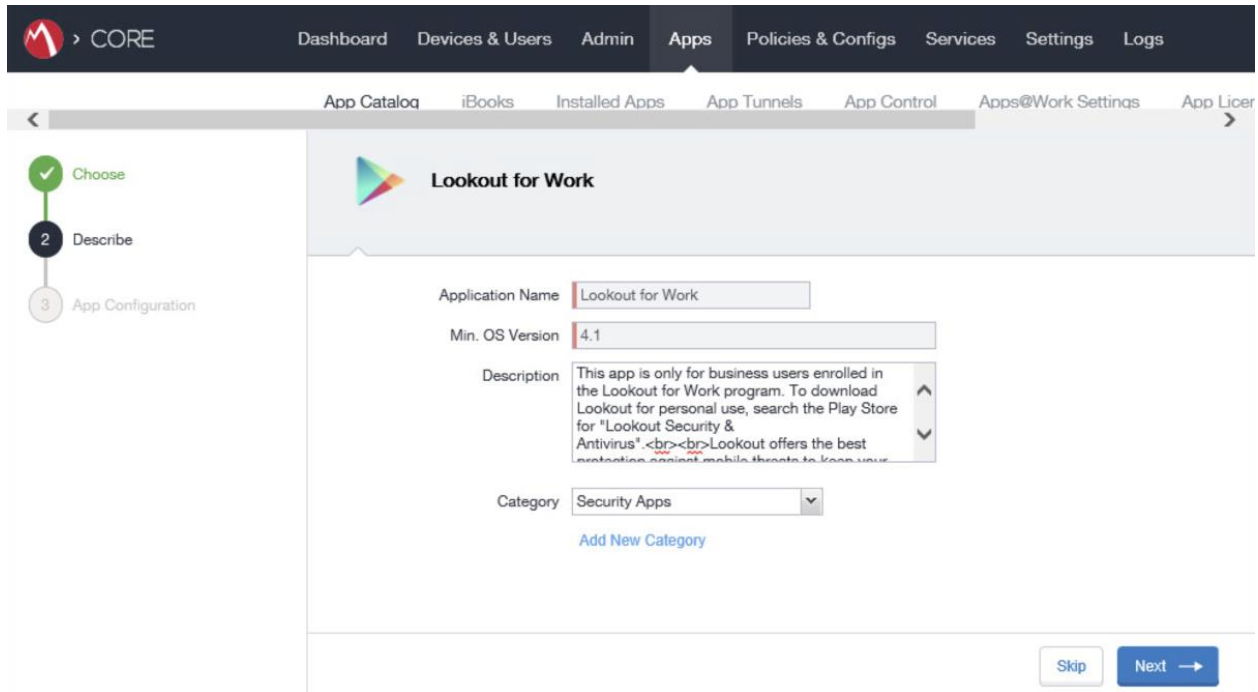


1285 4. On the **App Catalog > Describe** page:

1286 a. In **Category** drop-down menu, optionally assign the app to a category as appropriate to
1287 your MobileIron deployment strategy.

1288 b. Select **Next**.

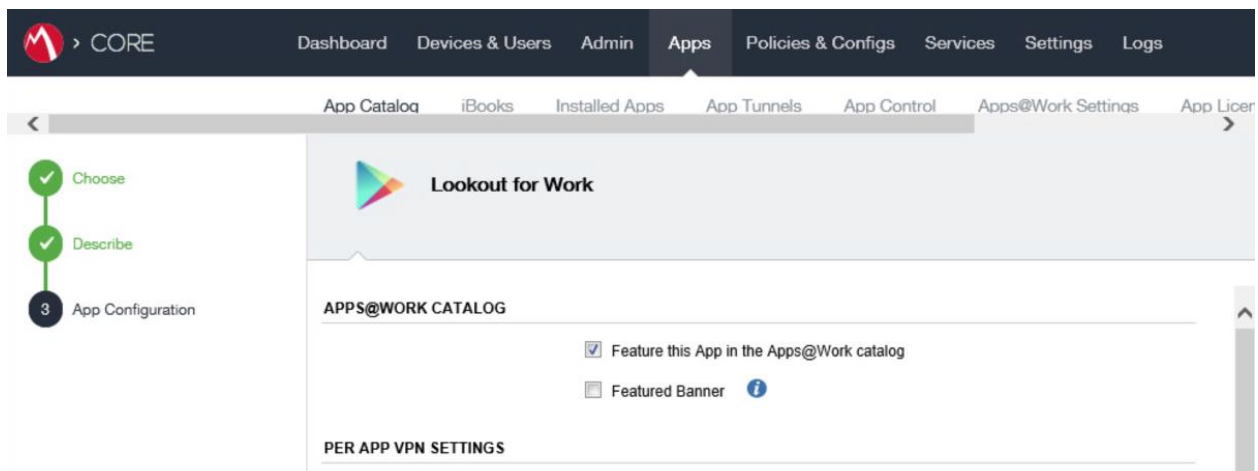
1289 Figure 2-98 Lookout for Work Application Configuration



1290 5. On the **App Catalog > App Configuration** page:

1291 a. In the **Apps@Work Catalog** section, Enable **Feature this App in the Apps@Work**
1292 **catalog**.

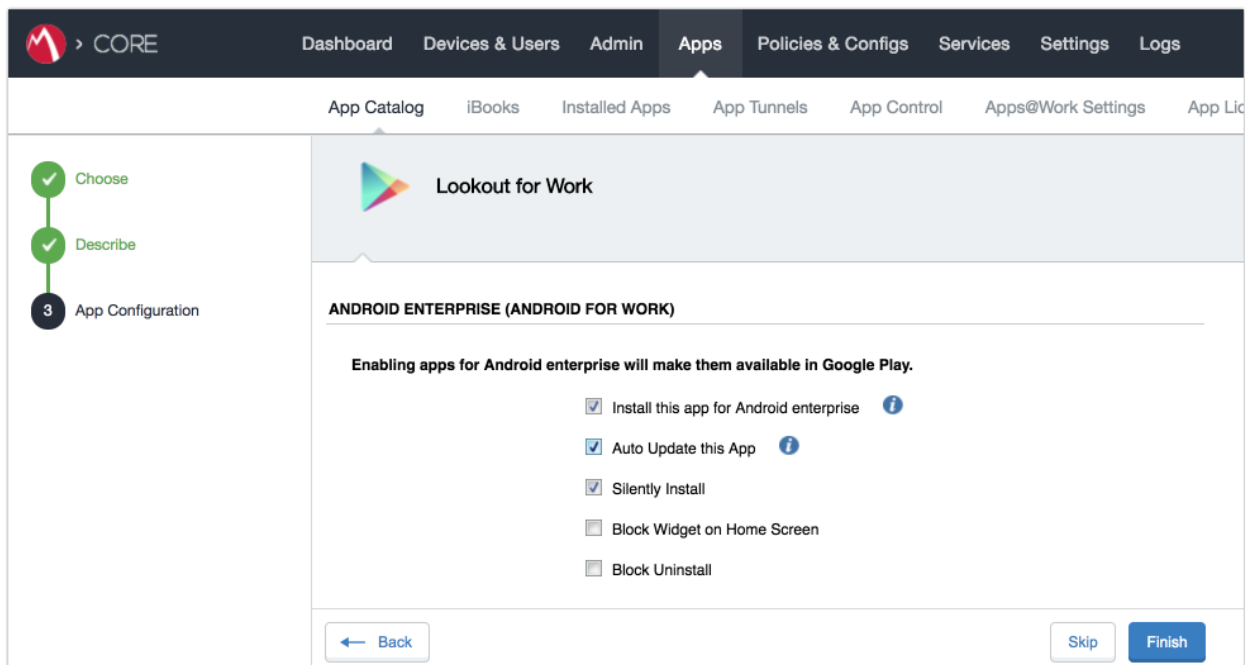
1293 Figure 2-99 Lookout for Work Application Configuration



1294 b. In the **Android Enterprise (Android for Work [AFW])** section:
1295

- 1296 i. Enable **Install this app for Android enterprise**; additional controls will be made
1297 visible.
- 1298 ii. Enable **Auto Update this App**.
- 1299 iii. Ensure **Silently Install** is enabled.
- 1300 c. Select **Finish**.

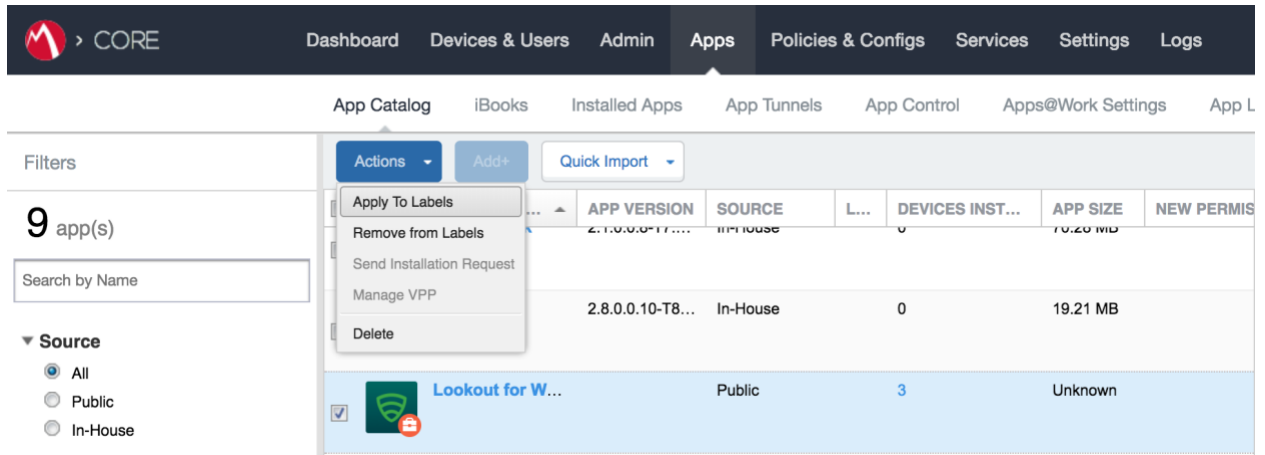
1301 **Figure 2-100 Lookout for Work AFW Configuration**



- 1302 6. The **Lookout for Work** app should now appear in the App Catalog with the AFW indicator.

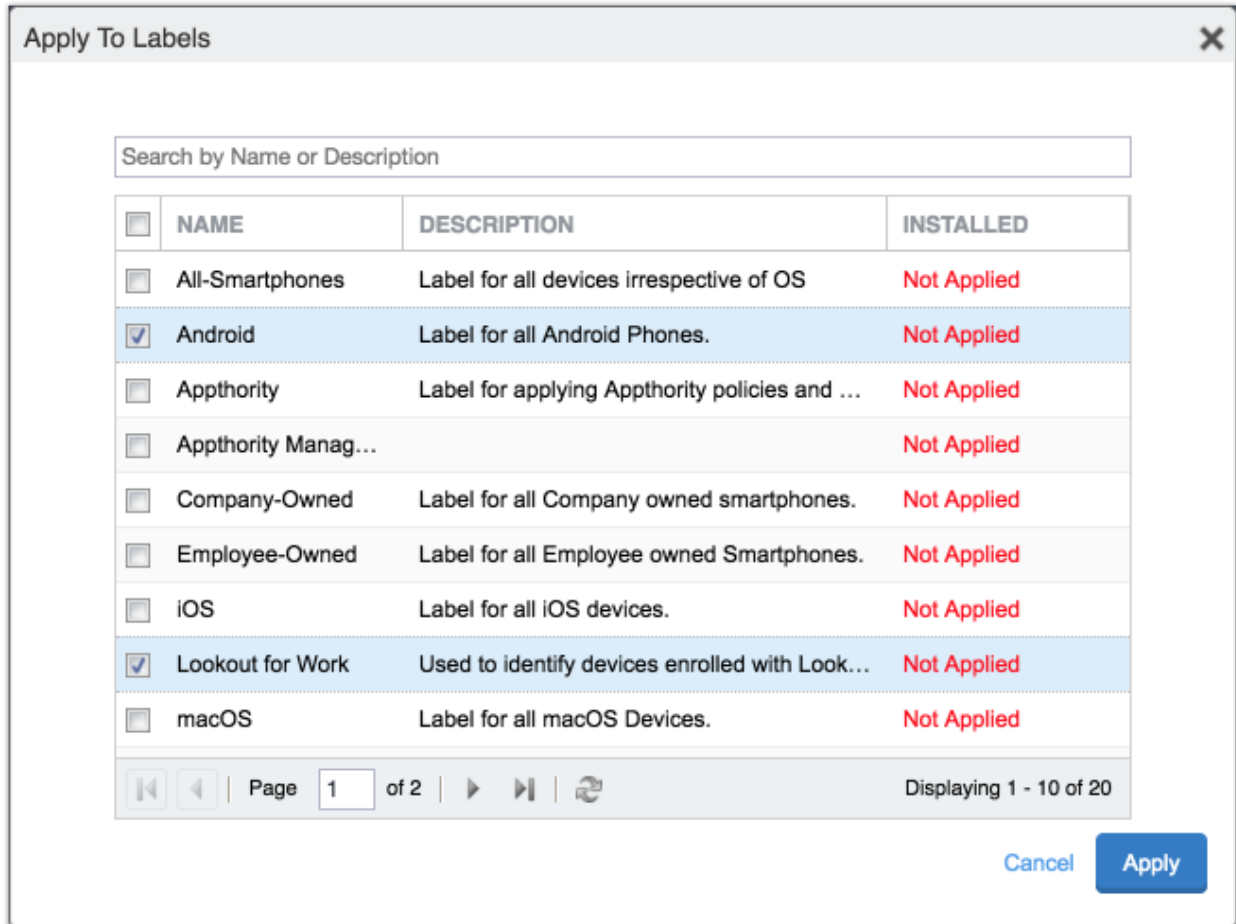
1303 2.7.4 Apply Labels to Lookout for Work for Android

- 1304 1. On the **App Catalog** page:
- 1305 a. Enable Lookout for Work.
- 1306 b. Select **Actions > Apply To Labels**; the Apply To Labels dialogue will appear.

1307 **Figure 2-101 Apply Lookout for Work to Android Devices**

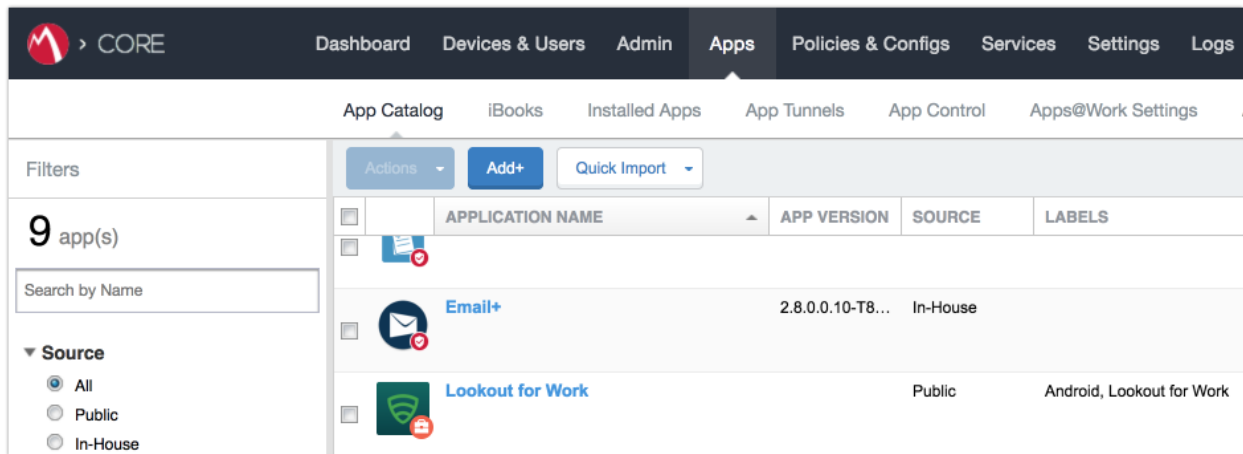
- 1308 c. In the **Apply To Labels** dialogue:
- 1309 i. Enable the **Lookout for Work** and **Android** labels, plus any other labels
- 1310 appropriate to your organization's mobile security policies.
- 1311 ii. Select **Apply**.

1312 Figure 2-102 Apply To Labels Dialogue



- 1313 d. The **Lookout for Work** app should now appear with the **Lookout for Work** and **Android**
 1314 labels applied.

1315 Figure 2-103 Lookout for Work with Applied Labels

1316

2.7.5 Add Lookout for Work app for iOS to MobileIron App Catalog

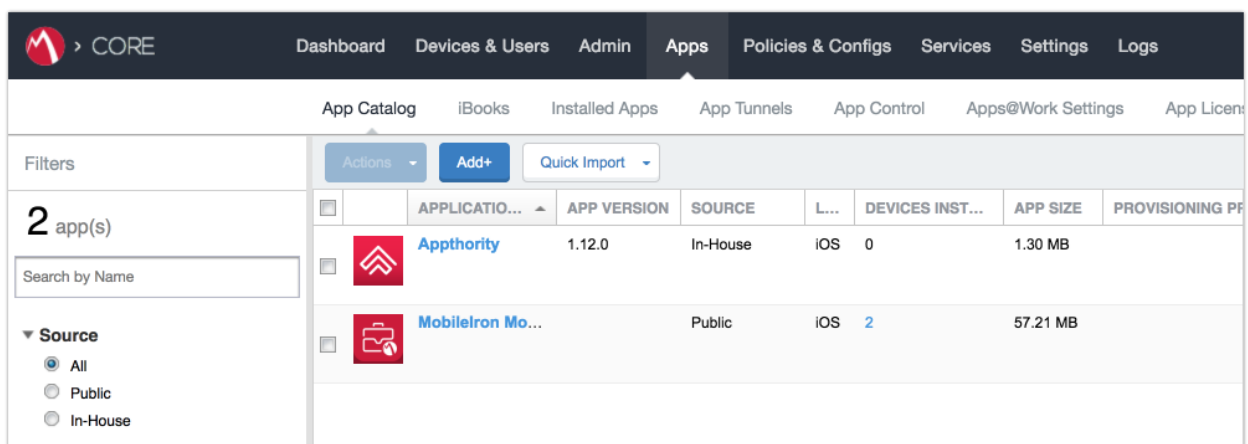
1317 The following steps will add the Lookout for Work app for iOS to MobileIron, apply appropriate
 1318 MobileIron labels, and create and upload a configuration file for one-touch activation of the app.

1319

2.7.5.1 Import Lookout for Work App

- 1320 1. In the **MobileIron Admin Portal**, navigate to **Apps > App Catalog**.
- 1321 2. On the **App Catalog** page, select **Add**; this will start the workflow to add a new app to the
 1322 app catalog.

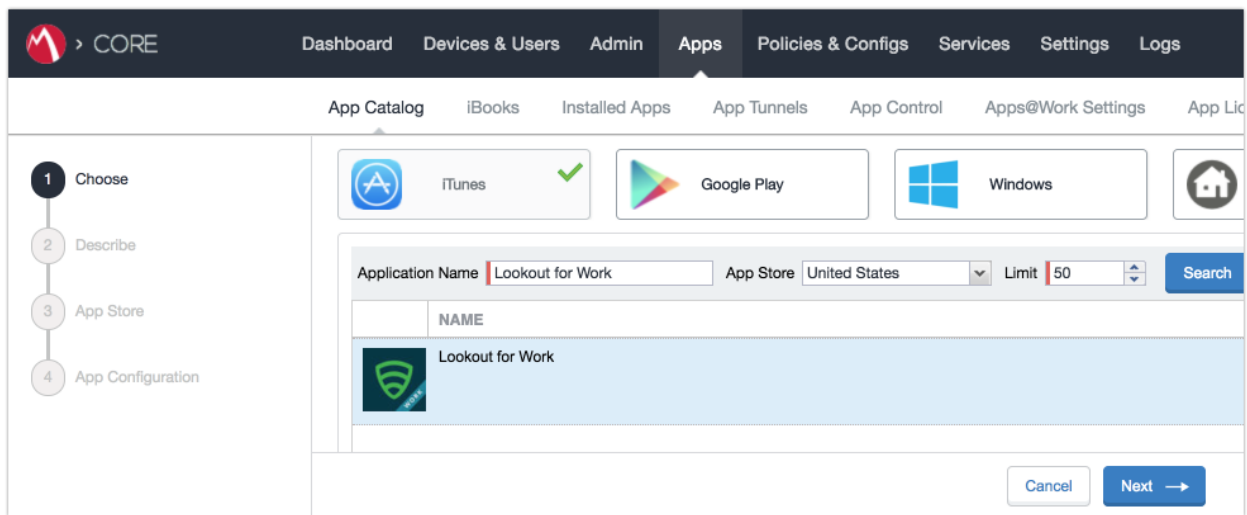
1323 Figure 2-104 MobileIron App Catalog



- 1324 3. On the **App Catalog > Choose** page:

- 1325 a. Select **iTunes**; additional controls will be displayed.
- 1326 b. In the **Application Name** field, enter **Lookout for Work**.
- 1327 c. Select **Search**; search results will be displayed in the lower pane.
- 1328 d. In the list of search results, select the **Lookout for Work** app.
- 1329 e. Select **Next**.

1330 **Figure 2-105 Lookout for Work Selected From iTunes**



- 1331 4. On the **App Catalog > Describe** page:
- 1332 a. In **Category** drop-down menu, optionally assign the app to a category as appropriate to
- 1333 your MobileIron deployment strategy.
- 1334 b. Select **Next**.

1335 Figure 2-106 Lookout for Work App Configuration

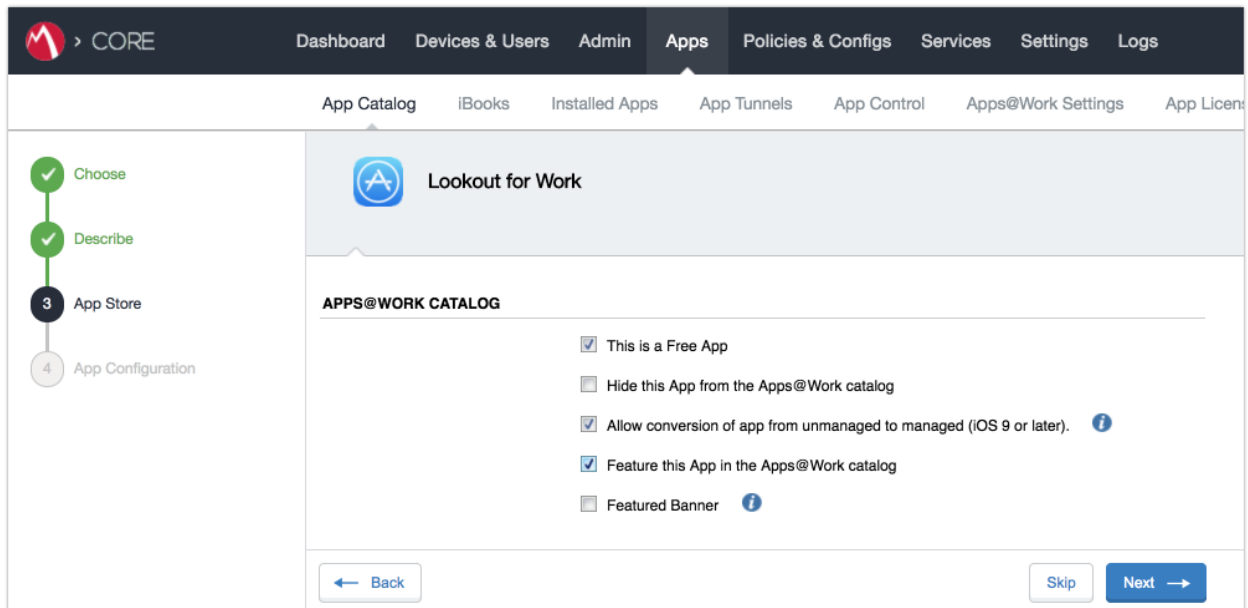
The screenshot shows the 'Lookout for Work' configuration page in the CORE system. The navigation bar includes 'Dashboard', 'Devices & Users', 'Admin', 'Apps', 'Policies & Configs', 'Services', 'Settings', and 'Logs'. The 'Apps' section is active, showing 'App Catalog', 'iBooks', 'Installed Apps', 'App Tunnels', 'App Control', 'Apps@Work Settings', and 'App Licen'. A sidebar on the left indicates the configuration steps: 1. Choose (completed), 2. Describe (current step), 3. App Store, and 4. App Configuration. The main content area is titled 'Lookout for Work' and contains the following fields:

- Application Name: Lookout for Work
- Min. OS Version: 9.0
- Developer: Lookout, Inc.
- Description: Lookout for Work is only for employers who have enrolled in the Lookout Enterprise program. Install Lookout for Work on your corporate device to make sure your device stays compliant with your company's corporate policies. If a device is found to be out of compliance, you can easily contact...
- iPad Only: No
- Category: Security Apps (dropdown menu)
- [Add New Category](#)

At the bottom right, there are 'Skip' and 'Next →' buttons.

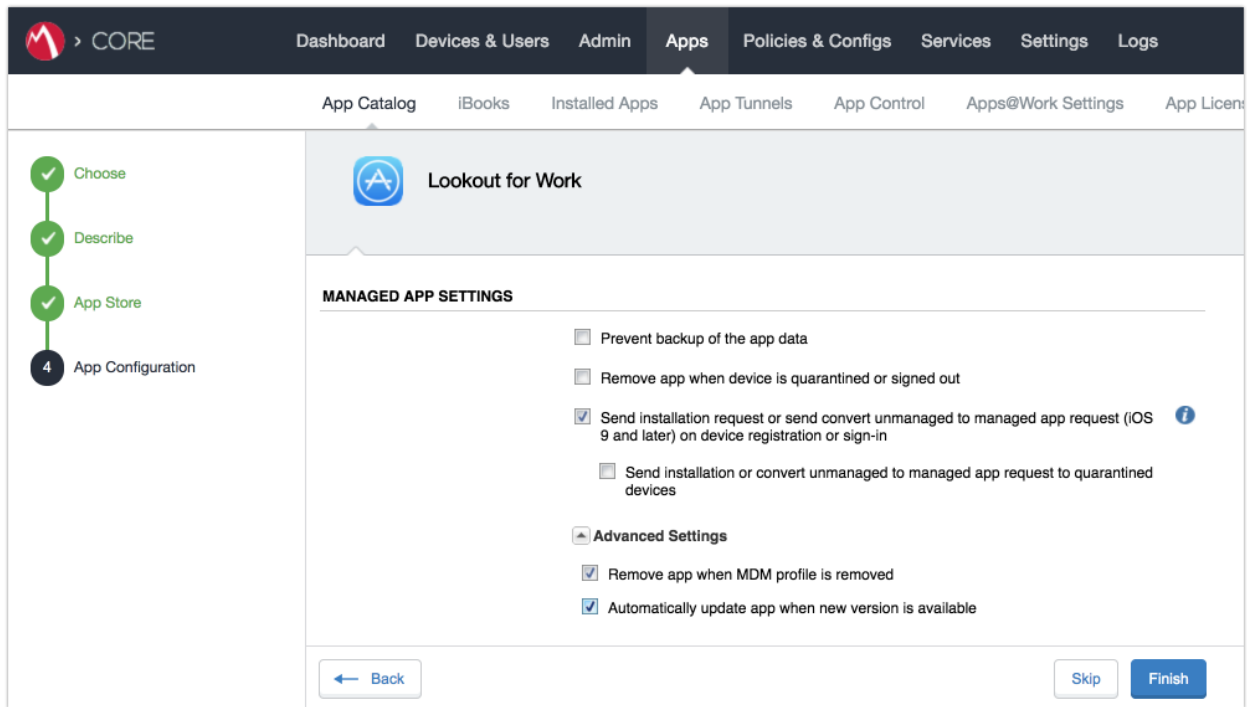
- 1336 5. On the **App Catalog > App Store** page:
- 1337 a. In the **Apps@Work Catalog** section:
- 1338 i. Enable **Allow conversion of app from unmanaged to managed (iOS 9 or later)**.
- 1339 ii. Enable **Feature this App in the Apps@Work catalog**.
- 1340 iii. Select **Next**.

1341 Figure 2-107 Lookout for Work App Configuration



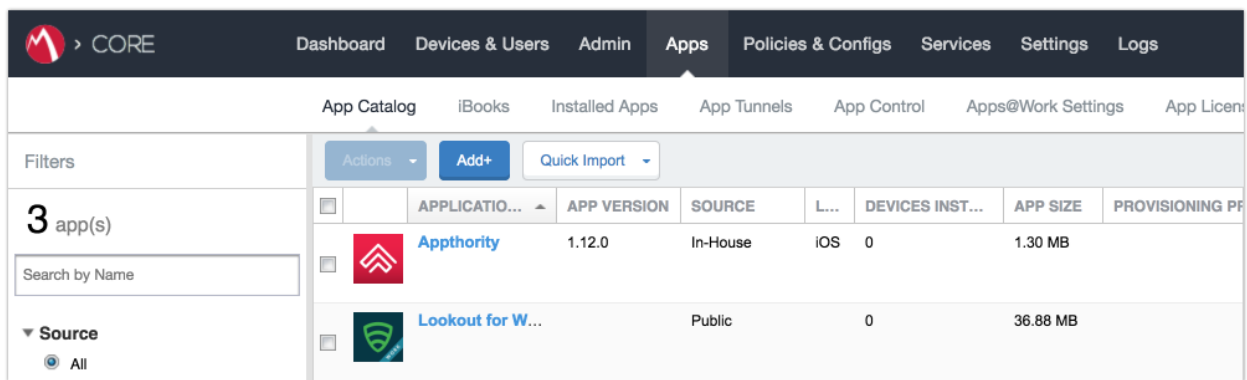
- 1342 b. In the **App Catalog > App Configuration** section:
- 1343 i. Enable **Send installation request or send convert unmanaged to managed app**
- 1344 request (iOS 9 and later) on device registration or sign-in.
- 1345 ii. Enable **Advanced Settings > Automatically update app when new version is**
- 1346 available.
- 1347 c. Select **Finish**.

1348 Figure 2-108 Lookout for Work Managed App Settings



1349 6. The **Lookout for Work** app should now appear in the App Catalog with AFW indicator.

1350 Figure 2-109 App Catalog With Lookout for Work



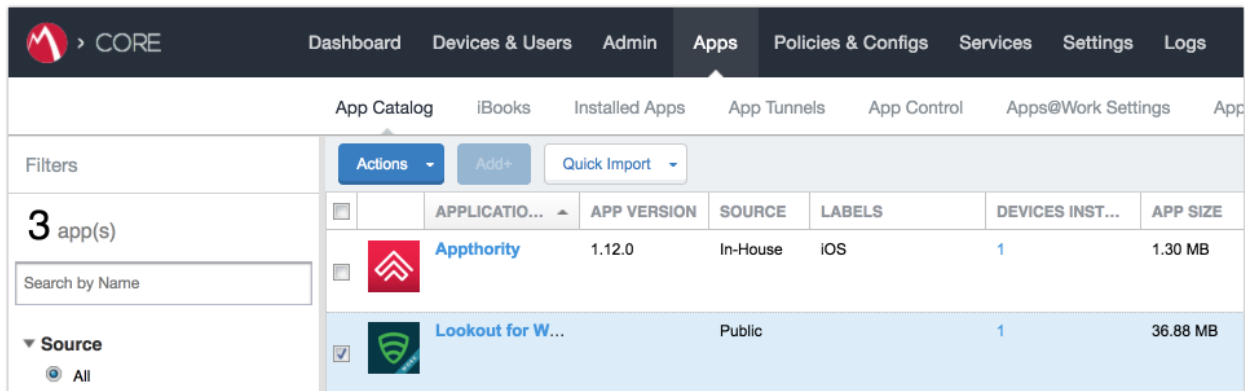
1351 **2.7.5.2 Apply MobileIron Labels to Lookout for Work App**



1352 1. On the **App Catalog** page:

1353 a. Enable Lookout for Work.

1354 b. Select **Actions > Apply To Labels**; the Apply To Labels dialogue will appear.

1355 **Figure 2-110 Lookout for Work Selected**



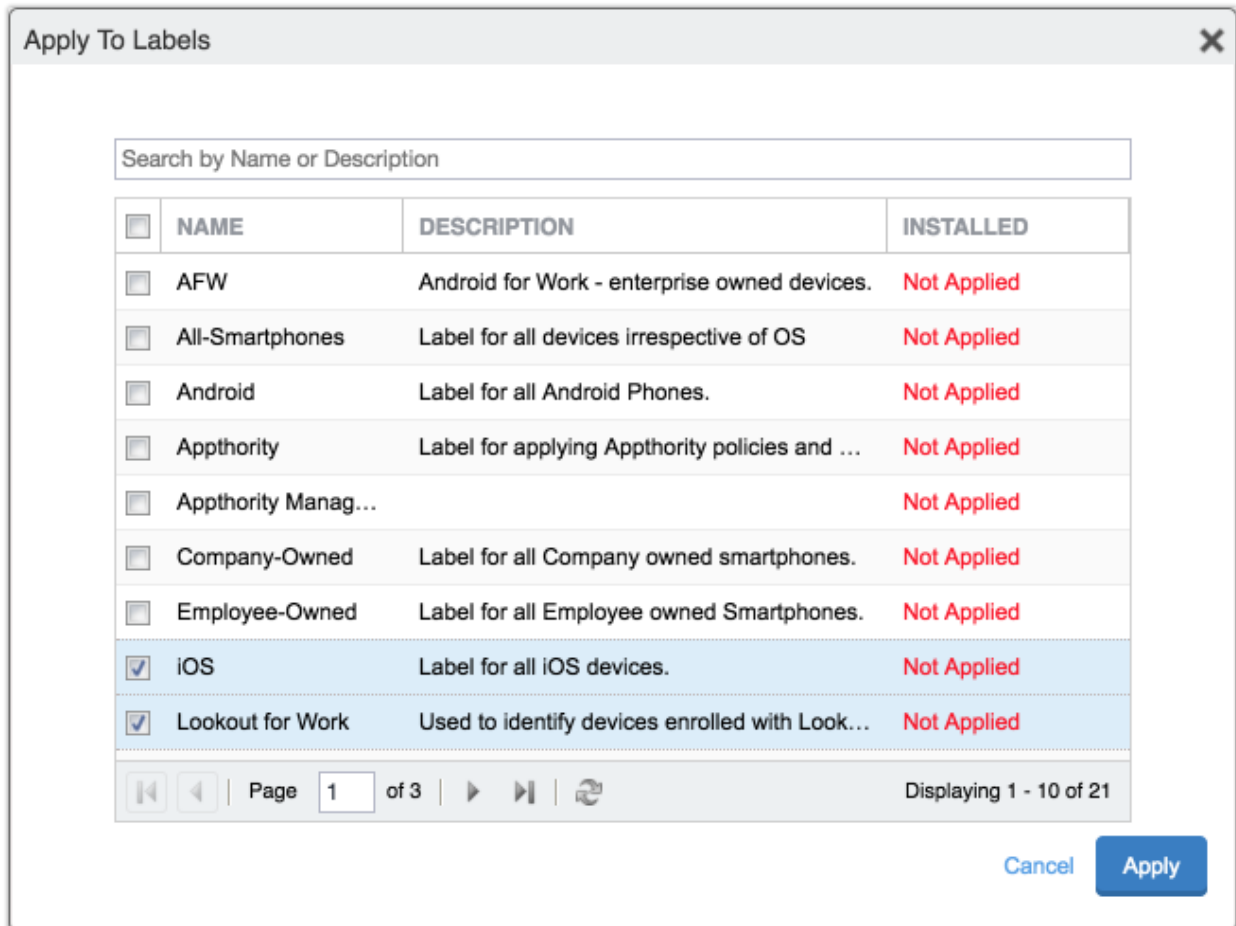
APPLICATION...	APP VERSION	SOURCE	LABELS	DEVICES INST...	APP SIZE
 Appthority	1.12.0	In-House	IOS	1	1.30 MB
 Lookout for W...		Public		1	36.88 MB

1356 c. In the **Apply To Labels** dialogue:

1357 i. Enable the **Lookout for Work** and **iOS** labels, plus any other labels appropriate to
1358 your organization's mobile security policies.

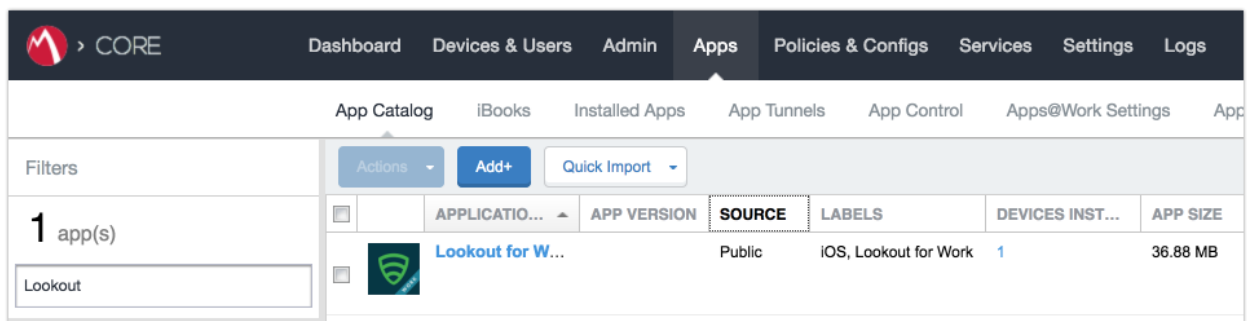
1359 ii. Select **Apply**.

1360 Figure 2-111 Apply To Labels Dialogue



- 1361
- 1362 d. The **Lookout for Work** app should now appear with the Lookout for Work and iOS labels
- 1363 applied.

1364 Figure 2-112 App Catalog With Lookout for Work



1365 [2.7.5.3 Create Managed App Configuration File for Lookout for Work](#)

1366 MobileIron can push a configuration file down to managed iOS devices to allow users easy activation of
1367 Lookout for Work. The following steps will create and upload the necessary file.

- 1368 1. Using a **plain text** editor, create the following text file by **replacing the asterisks on line 13**
1369 **with your organization's Global Enrollment Code.**

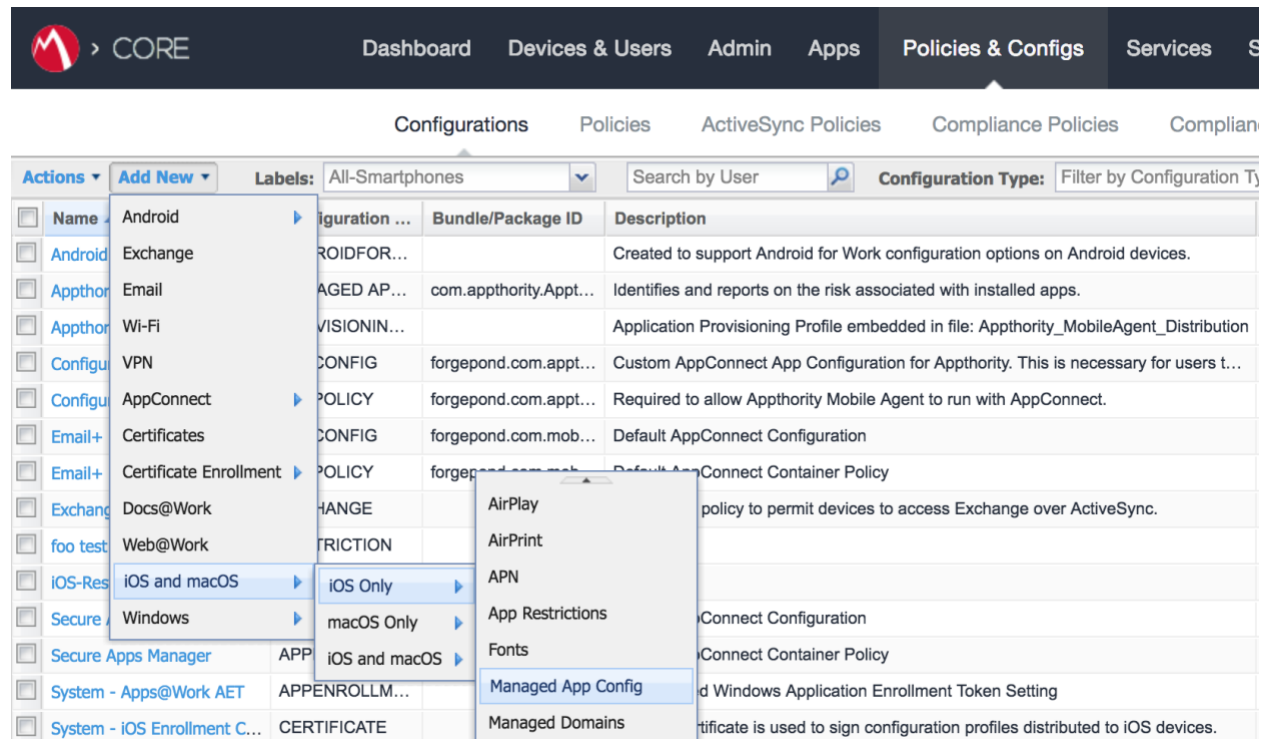
```
1370 <?xml version="1.0" encoding="UTF-8"?>
1371 <!DOCTYPE plist PUBLIC "-//Apple//DTD PLIST 1.0//EN"
1372 "https://www.apple.com/DTDs/PropertyList-1.0.dtd">
1373 <plist version="1.0">
1374   <dict>
1375     <key>MDM</key>
1376     <string>MOBILEIRON</string>
1377     <key>DEVICE_UDID</key>
1378     <string>$DEVICE_UDID$</string>
1379     <key>EMAIL</key>
1380     <string>$EMAIL$</string>
1381     <key>GLOBAL_ENROLLMENT_CODE</key>
1382     <string>*****</string>
1383   </dict>
1384 </plist>
```

- 1385 2. In the **MobileIron Admin Portal**, navigate to **Policies & Configs > Configurations**.

- 1386 3. On the **Configurations** Page:

- 1387 a. Select **Add New > iOS and OS X > iOS Only > Managed App Config**; the New Managed
1388 App Config Setting dialogue will open.

1389 Figure 2-113 Importing Managed Application Configuration



- 1390 b. In the **Managed App Config Setting** dialogue:
- 1391 i. In the **Name** field, provide a name for this configuration; our implementation
- 1392 used **Activate Lookout**.
- 1393 ii. In the **Description** field, provide the purpose for this configuration.
- 1394 iii. In the **BundleId** field, enter the bundle ID for Lookout at Work, which for our
- 1395 version was **com.lookout.work**.
- 1396 iv. Select **Choose File...** to upload the plist file created during **Step 1**.
- 1397 v. Select **Save**.

1398 Figure 2-114 plist Import Configuration

New Managed App Config Setting

Managed App Config allows you to specify a configuration dictionary to communicate with and configure third-party managed apps. It is supported only by iOS7 and later.

License Required: This feature requires a separate license. Prior to using this feature, ensure your organization has purchased the required licenses.

Name:

Description:

BundleId:

File:

|

1399 *2.7.5.4 Apply Labels to Managed App Configuration for Lookout for Work*

1400 The following steps will apply the managed app configuration created in the previous section to labels.

- 1401 1. In the **MobileIron Admin Portal**, navigate to **Policies & Configs > Configurations**.
- 1402 2. On the **Configurations** page:
- 1403 a. Enable the **Lookout Activation** managed app configuration created in the previous
- 1404 section.
- 1405 b. Select **Actions > Apply To Label**; the Apply To Label dialogue will open.

1406 Figure 2-115 Lookout Configuration Selected

Name	Configuration Type	Bundle/Package ID	Description	Configuration Details
<input checked="" type="checkbox"/> Activate Lookout	MANAGED APP CONFIG	com.lookout.work	Activates Lookout	View File
<input type="checkbox"/> Android for Work Configur...	ANDROIDFORWORK		Created to support	
<input type="checkbox"/> Appthority Mobile Intellige...	MANAGED APP CONFIG	com.appthority.Appt...	Identifies and repo	
<input type="checkbox"/> Appthority_MobileAgent_...	PROVISIONING_PROFILE		Application Provisi	

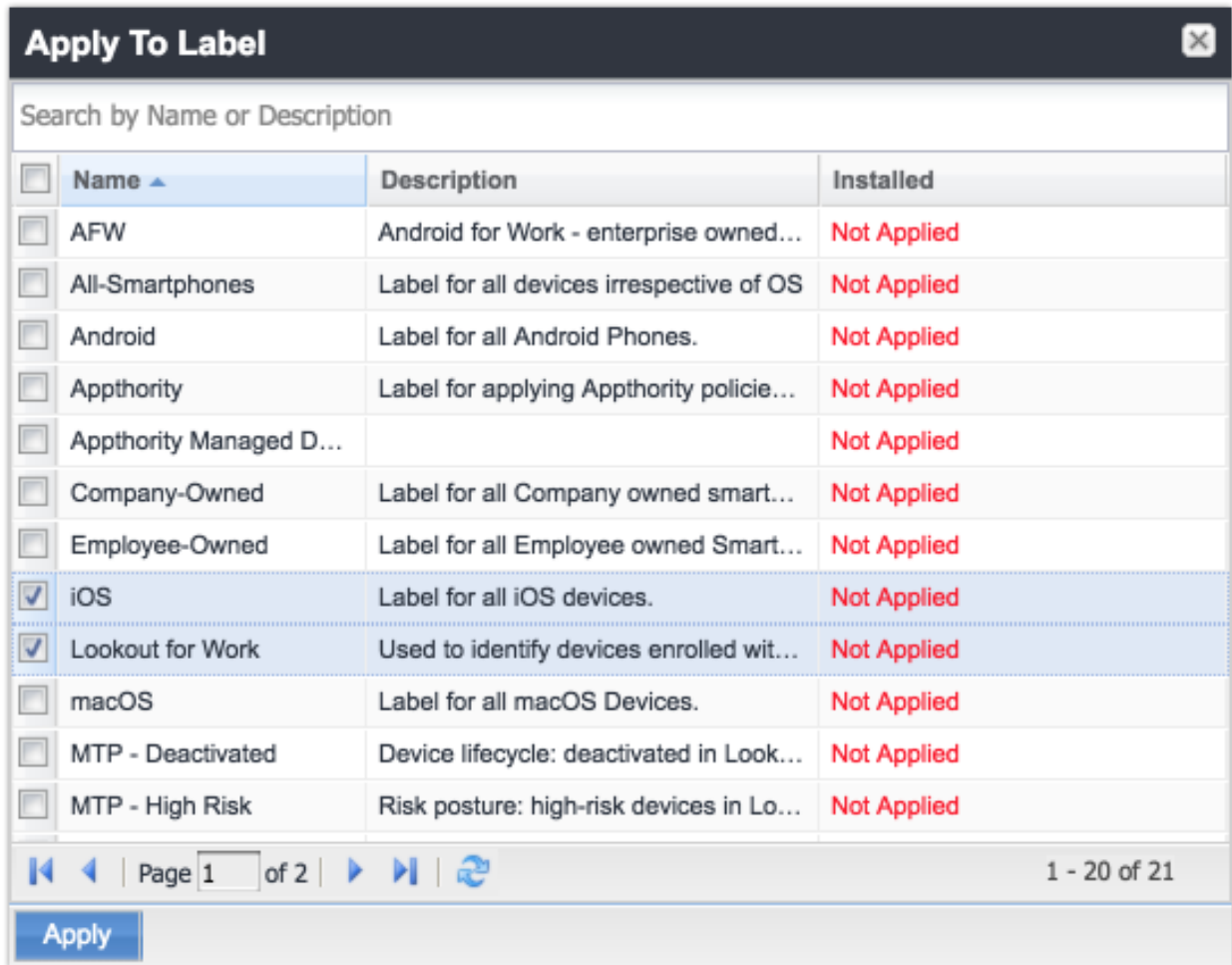
Activate Lookout
Activates Lookout for Work on iOS.

- 1407 c. In the **Apply To Label** dialogue:

1408 i. Enable the iOS and Lookout for Work labels.

1409 ii. Select **Apply**.

1410 Figure 2-116 Apply To Label Dialogue



1411 d. The system should now reflect the **Lookout for iOS** and **iOS** labels have been applied to
 1412 the **Activate Lookout** configuration.

1413 Figure 2-117 Lookout Configuration With Labels

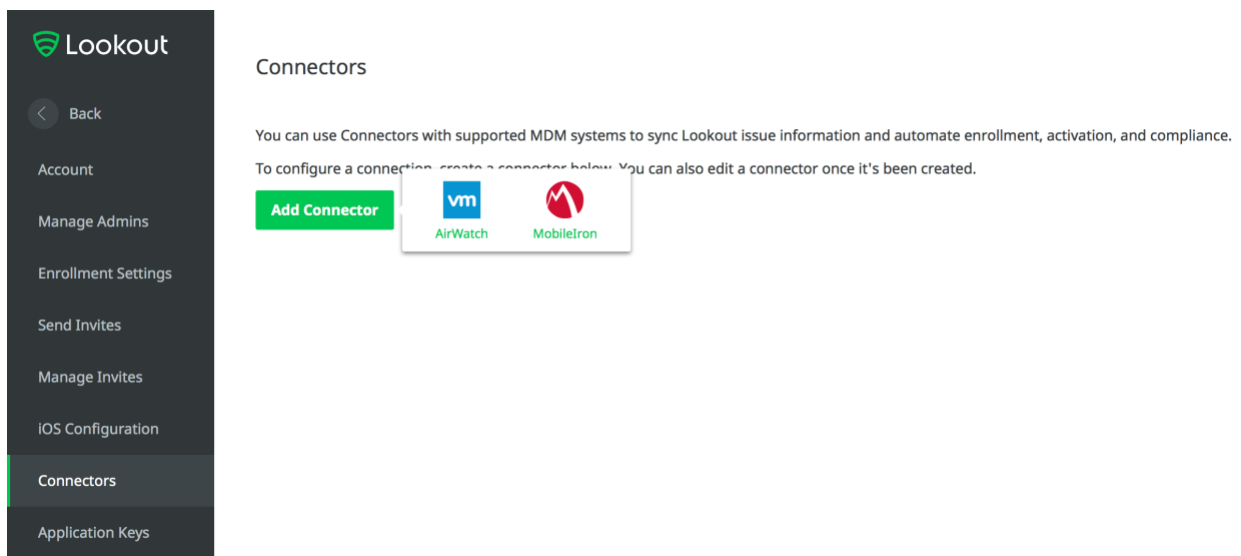
Name	Configuration Type	Bundle/Package ID	Description	# Phones	Labels
Activate Lookout	MANAGED APP CONFIG	com.lookout.work	Activates Lookout for Work on iOS.	3	Lookout for Work, iOS
Android for Work Configur...	ANDROIDFORWORK		Created to support Android for Work con...	7	Android
Appthority Mobile Intellige...	MANAGED APP CONFIG	com.appthority.Appt...	Identifies and reports on the risk associa...	3	iOS

1414 2.7.6 Add MDM Connector for MobileIron to Lookout MES

1415 The following instructions will connect Lookout with your MobileIron instance and associate Lookout
 1416 device states with the MobileIron labels created previously.

- 1417 1. Using the most-recent version of *MDM Service IP Whitelisting* available from the Lookout
 1418 support portal, configure your organization's firewalls to permit inbound connections from
 1419 the IP addresses provided on port 443 to your instance of MobileIron Core.
- 1420 2. In the **Lookout MES portal**, navigate to **Lookout > System > Connectors**.
- 1421 3. On the **Connectors** page:
 1422 a. Select **Add Connector > MobileIron**; this will open a new form.

1423 Figure 2-118 Add Lookout Connector Display



- 1424 b. In the **Connector Settings** section of the form:
- 1425 i. For the **MobileIron URL** field, enter the FQDN for your instance of MobileIron. In
1426 our example implementation, the URL was **mi-core.govt.mdse.nccoe.org**.
- 1427 ii. For the **Username** field, enter the User ID of the MobileIron admin account
1428 created in 2.7.1. In our example implementation, the **User ID** is **lookout**.
- 1429 iii. For the **Password** field, enter the password associated with that MobileIron
1430 admin account.
- 1431 iv. Select **Create Connector**; this will enable additional sections of the form.

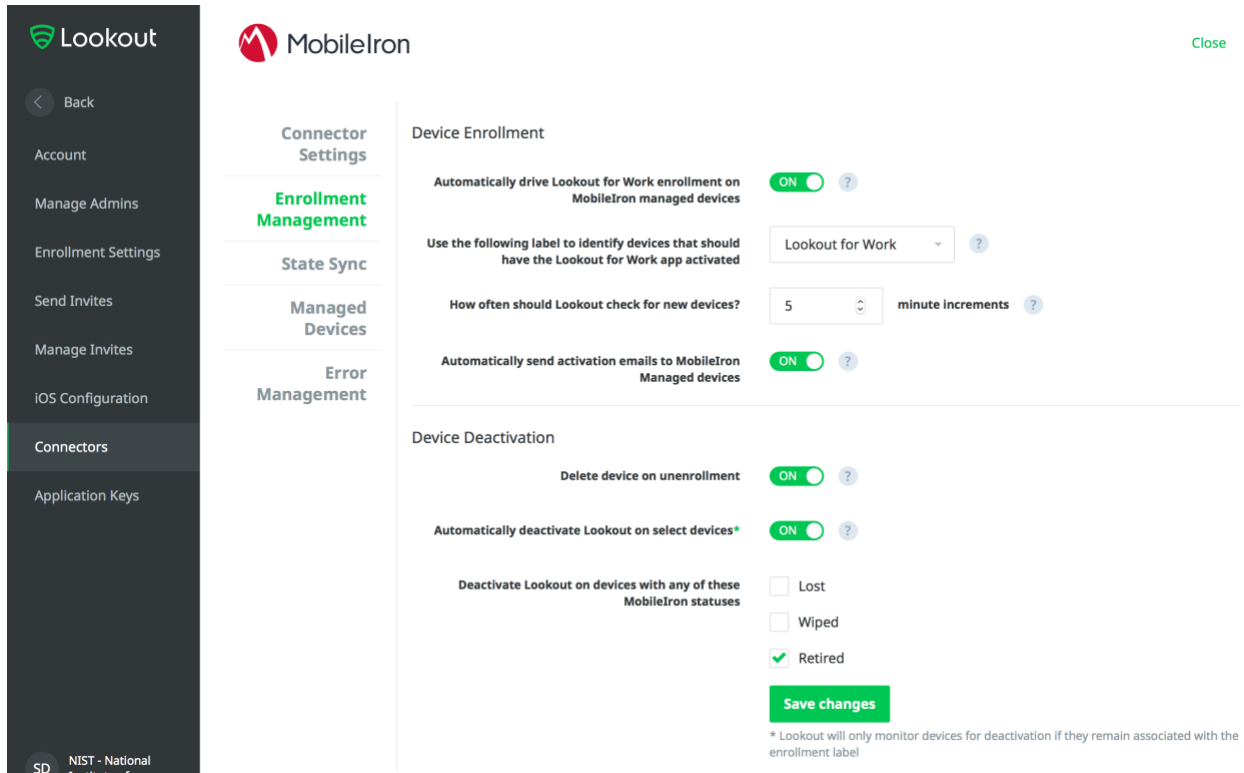
1432 **Figure 2-119 Connector Settings**

The screenshot displays the Lookout mobile application interface. On the left is a dark navigation menu with the Lookout logo at the top and a 'Back' button. Below the menu are several options: Account, Manage Admins, Enrollment Settings, Send Invites, Manage Invites, iOS Configuration, Connectors (highlighted in green), and Application Keys. The main content area features the MobileIron logo at the top left. Below it is a vertical list of menu items: Connector Settings (highlighted in green), Enrollment Management, State Sync, Managed Devices, and Error Management. The 'Connector Settings' form is the central focus, containing three input fields: 'MobileIron URL' with the value 'mi-core.govt.mdse.nccoe.org', 'Username' with the value 'lookout', and 'Password' with masked characters. Each field has a help icon (question mark) to its right. Below the fields is a green 'Create connector' button. A note below the URL field states: 'You may need to whitelist Lookout IP addresses to establish connectivity. [Learn more](#)'.

- 1433 c. In the **Enrollment Management** section of the form:
- 1434 i. Toggle **Device Enrollment > Automatically** drive Lookout for Work enrollment on
1435 MobileIron managed devices to **On**.
- 1436 ii. For the **Device Enrollment > Use the following label to identify devices that
1437 should have the Lookout for Work app activated** drop-down menu, select the
1438 **Lookout for Work** label.
- 1439 iii. Toggle **Device Enrollment > Automatically send activation emails to MobileIron
1440 managed devices** to **On**.

1441 iv. Select **Save Changes**.

1442 **Figure 2-120 Connector Enrollment Settings**



1443 d. In the **State Sync** section of the form:

1444 i. Toggle **State Sync > Synchronize Device Status to MobileIron** to **On**.

1445 ii. For each entry in the table below:

1446 1) Toggle the control to **On**.

1447 2) From the drop-down menu, select the **MobileIron Label** with the
 1448 associated Purpose from the table in **Section 2.6.2 Add MobileIron Labels**
 1449 **for Lookout**. We provide the Label Name we used for each Purpose in our
 1450 example implementation.

State	Purpose	Label Name
Devices that have not activated Lookout yet	Lifecycle management: devices with Lookout not yet activated	MTP - Pending

Devices with Lookout activated	Lifecycle management: devices with Lookout activated	MTP - Secured
Devices on which Lookout is deactivated	Lifecycle management: devices with Lookout deactivated	MTP - Deactivated
Devices with any issues present	Lifecycle management: devices with threats detected by Lookout	MTP - Threats Detected
Devices with Low Risk issues present	Risk posture: devices with a low risk score in Lookout	MTP - Low Risk
Devices with Medium Risk issues present	Risk posture: devices with a moderate risk score in Lookout	MTP - Moderate Risk
Devices with High Risk issues present	Risk posture: devices with a high risk score in Lookout	MTP - High Risk

1451 **Note:** Administrators can choose to alter the label names to something more appropriate for their
 1452 environment.

1453 iii. Select **Save Changes**.

1454 Figure 2-121 Connector Sync Settings

The screenshot displays the MobileIron Admin Portal interface for configuring Lookout connector sync settings. The left sidebar shows navigation options, with 'Connectors' selected. The main content area is titled 'Connector Sync Settings' and includes a 'State Sync' section. This section contains several settings, each with a dropdown menu and a toggle switch:

- Synchronize device status to MobileIron:** ON
- Device Lifecycle:**
 - Devices that have not activated Lookout yet: MTP - Pending (ON)
 - Devices with Lookout activated: MTP - Secured (ON)
 - Devices on which Lookout is deactivated: MTP - Deactivated (ON)
 - Devices that have lost connectivity with Lookout: Choose status tag... (OFF)
 - Devices with any issues present: MTP - Threats Present (ON)
- Risk Posture:**
 - Devices with Low Risk issues present: MTP - Low Risk (ON)
 - Devices with Medium Risk issues present: MTP - Moderate Risk (ON)
 - Devices with High Risk issues present: MTP - High Risk (ON)

A green 'Save changes' button is located at the bottom right of the settings area.

1455 2.7.7 Configure MobileIron Risk Response

1456 The following steps will allow MobileIron to generate responses to various device states as assigned to
 1457 devices by Lookout (e.g. MTP - High Risk).

1458 2.7.7.1 Add MobileIron App Control Rule

- 1459 1. In the **MobileIron Admin Portal**, navigate to **Apps > App Control**.
- 1460 2. Select **Add**; the Add App Control Rule dialogue will appear.
- 1461 3. In the **Add App Control Rule** dialogue:
 - 1462 a. In the **Name** field, enter **Threats Present Trigger**.

- 1463 b. Of the **Type** options, select **Required**.
- 1464 c. In the **App Identifier/Name** field enter **app does not exist**.
- 1465 d. In the **Device Platform** drop-down menu, select **All**.
- 1466 e. In the **Comment** field, optionally enter **Forces non-compliant state**.
- 1467 f. Select **Save**.

1468 **Figure 2-122 MobileIron App Control Rule**

Edit App Control Rule [Close]

Save | Cancel

Name: Threats Present Trigger

Type: Allowed Disallowed WIP Required (Required option is only applicable to Android, iOS and macOS)

When creating policies for

- Android, iOS or macOS, use "Name Equals/Identifier Equals/Name Contains/Identifier Contains"
- Windows Phone 8.1 or Windows 10 Mobile, only use "MS Store GUID Equals"
- Windows 10 Desktop, use "Publisher/PFN Equals" or "EXE/Win32 Equals"

Note: When using "EXE/Win32 Equals", you can choose either the publisher/application for signed apps or the direct path for unsigned apps.

Rule Entries:

App Identifier/Name	Device Platform	Comment	
App Identifier Equals [v]	app does not exist	All [v]	Forced non-compliant state [minus] [plus]

Save | Cancel

- 1469 4. The new app control rule should now appear on the **Apps > App Control** page.

1470 Figure 2-123 MobileIron App Control Rule

<input type="checkbox"/>	Edit	Name ▲	Type	Rule Entries	Used In Policy
<input type="checkbox"/>		Threats Present Trigger	Required	View Rule Entries	Not Used

1471

2.7.7.2 Add MobileIron Compliance Actions

1472 A Compliance Action defines what actions MobileIron will take when an App Control policy, like the one
 1473 created in the previous section, is violated by a managed mobile device. The following steps will create
 1474 and configure an example Compliance Action in response to the MTP - High Risk App Control rule. Note
 1475 that a single Compliance Action can be associated with multiple App Control rules if the same response
 1476 would be configured for each. Otherwise, a new Compliance Action should be created.

- 1477 1. In the **MobileIron Admin Portal**, navigate to **Policies & Configs > Compliance Actions**.
- 1478 2. Select **Add**; the **Add Compliance Action** dialogue will open.
- 1479 3. In the **Add Compliance Action** dialogue:
 - 1480 a. In the **Name** field, add a description of the compliance action; we recommend indicating
 1481 the kind of action taken. This example illustrates creating a compliance action that will
 1482 be associated with the **MTP - High Risk** label.
 - 1483 b. Select the **Enforce Compliance Actions Locally on Devices** check box.
 - 1484 c. Select the **Send a compliance notification or alert to the user** check box.
 - 1485 d. Select the **Block email access and AppConnect apps** check box.
 - 1486 e. Select the **Quarantine the device** check box.
 - 1487 f. Deselect the **Remove All Configurations** check box.
 - 1488 g. Select **Save**.

1489 Figure 2-124 MTP High Risk Compliance Action

Add Compliance Action ✕

Select the actions that will be performed when devices are out-of-compliance.

Name:

Enforce Compliance Actions Locally on Devices i

Tier 1


▼ **ALERT**

Send a compliance notification or alert to the user

▼ **BLOCK ACCESS**

Block email access and AppConnect apps i

▼ **QUARANTINE**

 For Android enterprise devices, all Android enterprise apps and functionality will be hidden except Downloads, Google settings, Google Play Store and Mobile@Work app.

Quarantine the device

Remove All Configurations

Remove iBooks content, managed apps, and block new app downloads

+

Cancel Save

1490

1491

2.7.7.3 Create MobileIron Security Policy for Lookout MES

1492 In addition to potentially defining other controls, such as password requirements, a Security Policy can
 1493 map a Compliance Action to an App Control rule, enabling MobileIron to execute the configured actions
 1494 whenever a device that applies the policy violates the App Control rule. The following steps will create a

1495 new Security Policy for Lookout MES High Risk devices using an existing policy as a baseline from which
 1496 to apply more stringent controls.

- 1497 1. In the **MobileIron Admin Portal**, navigate to **Policies & Configs > Policies**.
- 1498 2. On the **Policies** page:
 - 1499 a. Select the security policy to use as a baseline.
 - 1500 b. Select **More Actions > Save As**; this will open the **New Security Policy** dialogue.

1501 **Figure 2-125 Baseline Policy Selection**

Policy Name	Priority	Status	Descr...	Type	Last Modified	# Phones	Labels	Watch List
Default Lockdown...	LOCKDOWN	Active	Defaul...	LOCKDOWN	2008-01-01 3:00:00...	0		0
Default Sync Policy	SYNC	Active	Defaul...	SYNC	2008-01-01 3:00:00...	15		0
<input checked="" type="checkbox"/> DOD Policy	SECURITY - 3	Active	Mobil...	SECURITY	2018-06-11 2:52:57 ...	0		0

- 1503 c. In the **New Security Policy** dialogue:
 - 1504 i. In the **Name** field, rename the policy to **MTP - High Risk**.
 - 1505 ii. In the **Priority** drop-down menu, select the security policy this policy will be
 1506 prioritized in relation to; in this example, it is higher than the **MTP Medium Risk**
 1507 policy. **Note:** for ease of setting priority, it is recommended to add new security
 1508 policies in ascending order (lowest to highest priority).

1509 **Figure 2-126 MTP High Risk Policy**

New Security Policy

Name:

Status: Active Inactive

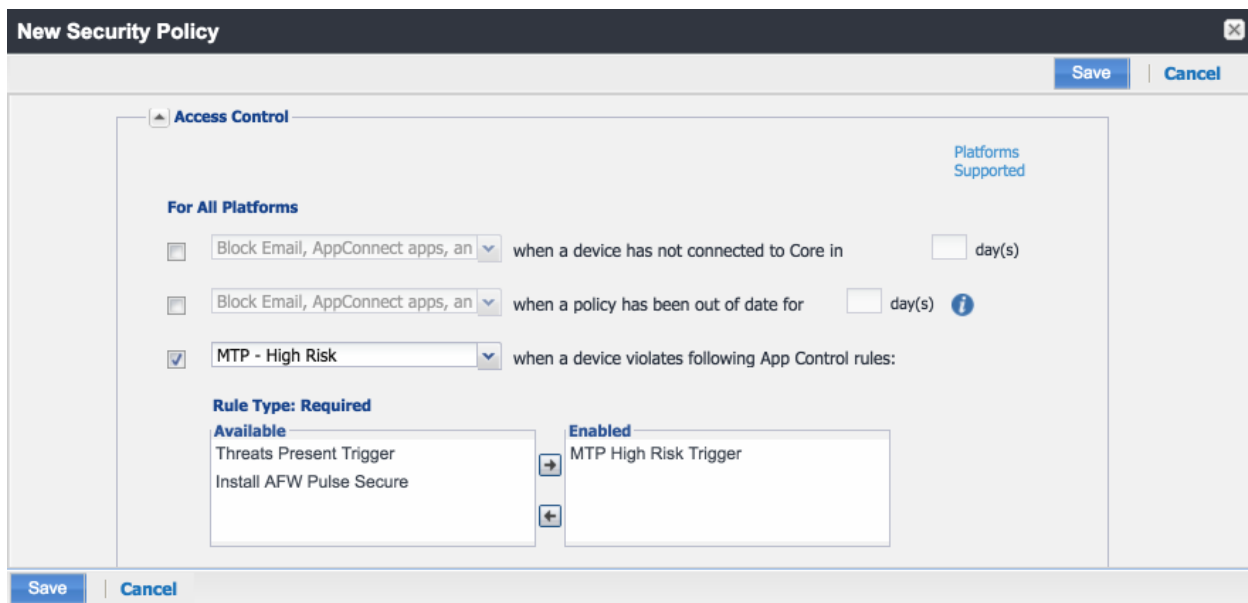
Priority: Higher than Lower than ▼

Description:

- 1511 iii. Under **Access Control > For All Platforms** section:

- 1512 1. For the **when a device violates the following app control rules** drop-down
 1513 menu, select the **MTP - High Risk** compliance action.
 1514 2. In the **Available** list of app control rules, highlight **MTP High Risk Trigger**.
 1515 3. Select the **right arrow** to move MTP High Risk Trigger item into the **Enabled**
 1516 **List**.
 1517 iv. Select **Save**.

1518 **Figure 2-127 Security Policy Trigger**



1519

1520 *2.7.7.4 Apply Lookout MES Label to MobileIron Security Policy*

1521 The following steps will apply the MTP - High Risk label to the security policy created in the previous
 1522 section. As a result, once the Lookout cloud service applies the label to any device with a detected high-
 1523 risk threat and such a device checks in with MobileIron, the security policy will automatically be applied
 1524 to it (provided it is of higher priority than the policy currently applied). In turn that will cause the MTP
 1525 High Risk Trigger App Control policy to be violated and the MTP - High Risk Compliance Action to be
 1526 taken. Once Lookout detects that the threat has been resolved, the Lookout service will remove the
 1527 MTP - High Risk label and on device check-in, MobileIron will then apply the next-lower-priority security
 1528 policy.

- 1529 1. In the **MobileIron Admin Portal**, navigate to **Policies & Configs > Policies**.
 1530 2. On the **Policies** page:
 1531 a. Select the check box in the **MTP High Risk** security policy item.
 1532 b. Select More **Actions > Apply to Label**; the Apply to Label dialogue will open.

1533 Figure 2-128 Policy List

Policy Name	Priority	Status	Descr...	Type	Last Modified	# Phones	Labels	Watch List
Appthority Android	APPCONNECT - 1	Active	Allows...	APPCONNECT	2017-11-16 12:26:0...	11	Android, Appthority	1
MTP High Risk	SECURITY - 1	Active	Applic...	SECURITY	2018-06-12 11:20:2...	0	MTP - High Risk	0

1534

1535

c. In the **Apply to Label** dialogue:

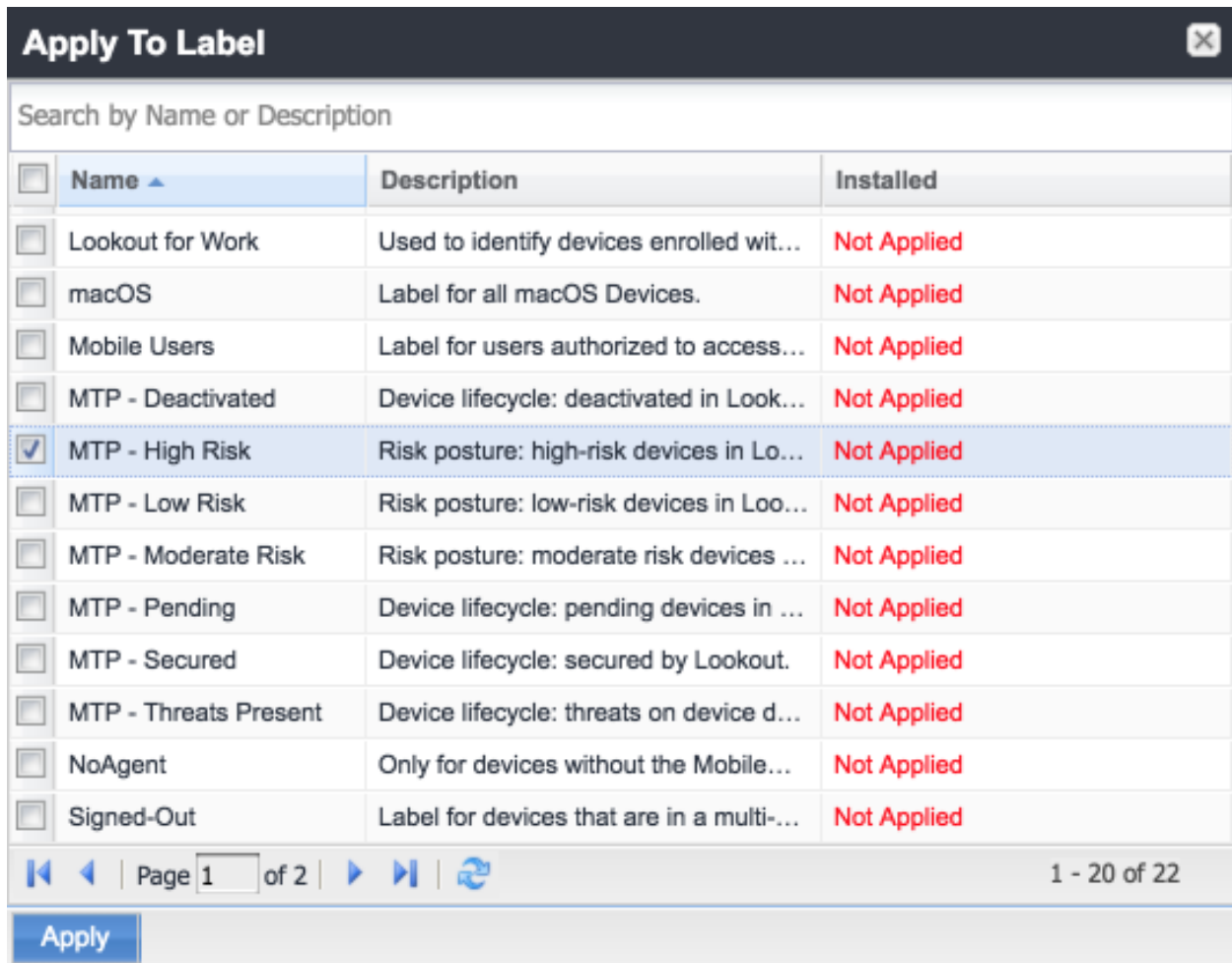
1536

i. Select the check box for the **MTP - High Risk** item.

1537

ii. Select **Apply**.

1538 Figure 2-129 Apply To Label Dialogue



1539

1540 2.8 Integration of Appthority Mobile Threat Detection with MobileIron

1541 Appthority provides an on-premises connector for MobileIron that runs as a Docker container on RedHat
 1542 Linux. The connector uses the MobileIron API to obtain information on managed devices and their
 1543 installed apps, which is then synchronized with the cloud service instance to obtain app and device risk
 1544 scores, which are assigned to devices using custom attributes. The following sections provide the steps
 1545 to create a MobileIron API account and deploy and configure the Appthority connector.

1546 2.8.1 Create MobileIron API Account for Appthority Connector

1547 The following steps will create an administrative account that will grant Appthority the specific
 1548 permissions it requires within MobileIron.

- 1549 1. In the **MobileIron Admin Portal**, navigate to **Devices & Users > Users**.
- 1550 2. On the **Users** page:
- 1551 a. Select **Add > Add Local User**; the **Add New User** dialogue will open.
- 1552 b. In the **Add New User** dialogue:
- 1553 i. In the **User ID** field, enter the **user identity** the Appthority connector will
- 1554 authenticate under. Our implementation uses a value of **Appthority**.
- 1555 ii. In the **First Name** field, enter a generic first name for **Appthority**.
- 1556 iii. In the **Last Name** field, enter a generic last name for **Appthority**.
- 1557 iv. In the **Display Name** field, optionally enter a displayed name for this user
- 1558 account.
- 1559 v. In the **Password** field, provide the password the **Appthority** identity will use to
- 1560 authenticate to MobileIron.
- 1561 vi. In the **Confirm Password** field, enter the same password as in the preceding step.
- 1562 vii. In the **Email** field, provide an email account for the **Appthority** identity; this
- 1563 should be an account under the control of your organization.
- 1564 viii. Select **Save**.

1565 Figure 2-130 Appthority User Settings

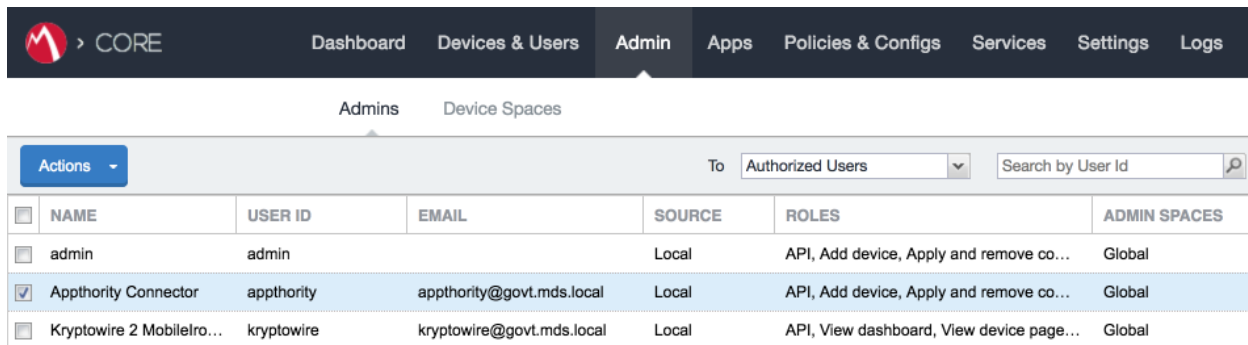
The screenshot shows a dialog box titled "Add New User" with a close button (X) in the top right corner. The dialog contains the following fields and values:

Field	Value
User ID	appthority
First Name	Appthority
Last Name	Connector
Display Name	Appthority Connector
Password
Confirm Password
Email	appthority@mds.local

At the bottom right of the dialog, there are two buttons: "Cancel" (text button) and "Save" (blue button).

- 1566
- 1567
- 1568
- 1569
- 1570
- 1571
1. In the **MobileIron Admin** Portal, navigate to **Admin**.
 2. On the **Admin** page:
 - a. Enable the account you created for **Appthority** during **Step 2**.
 - b. Select **Actions > Assign to Space**; this will open the **Assign to Space** dialogue for the **Appthority** account.

1572 Figure 2-131 Appthority Connector User

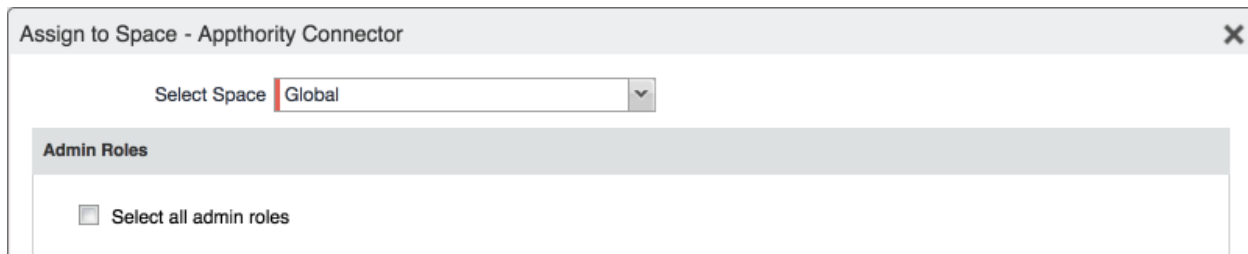


<input type="checkbox"/>	NAME	USER ID	EMAIL	SOURCE	ROLES	ADMIN SPACES
<input type="checkbox"/>	admin	admin		Local	API, Add device, Apply and remove co...	Global
<input checked="" type="checkbox"/>	Appthority Connector	appthority	appthority@govt.mds.local	Local	API, Add device, Apply and remove co...	Global
<input type="checkbox"/>	Kryptowire 2 Mobilelro...	kryptowire	kryptowire@govt.mds.local	Local	API, View dashboard, View device page...	Global

1573

1574 c. In the **Assign to Space** dialogue:1575 i. In the **Select Space** drop-down menu, select **Global**.

1576 Figure 2-132 Appthority Connector Space Assignment



Assign to Space - Appthority Connector

Select Space: Global

Admin Roles

Select all admin roles

1577

1578 ii. **Enable** each of the following settings:

Device Management > View device page, device details
Privacy Control > View apps and ibooks in device details
App Management > Apply and remove application label
Other Roles > API

1579 iii. Select **Save**.1580

2.8.2 Deploy Appthority Connector Open Virtualization Appliance

1581 One deployment option for the Appthority connector is a pre-built RedHat virtual machine distributed as
 1582 an Open Virtualization Appliance (OVA). We imported the OVA into our virtual lab environment
 1583 following guidance provided in *Connector On-Premises: Virtual Machine Setup* available from the
 1584 Appthority support portal: <https://support.appthority.com/>.

1585 2.8.3 Run the Enterprise Mobility Management Connector Deployment Script

1586 Once the Appthority docker container is running, the setup script will configure it to use the MobileIron
 1587 API account created previously. Detailed instructions on using the script are available on the Appthority
 1588 support portal at [https://help-](https://help-mtp.appthority.com/SetUp/EMM/EMM_Script/RunEMMDeployScript.html)
 1589 [mtp.appthority.com/SetUp/EMM/EMM_Script/RunEMMDeployScript.html](https://help-mtp.appthority.com/SetUp/EMM/EMM_Script/RunEMMDeployScript.html). The first two steps ask for
 1590 Appthority-supplied credentials necessary to verify your subscription and to link the connector with the
 1591 correct instance of their cloud service. In the third step you will provide details to integrate with your
 1592 on-premises instance of MobileIron core. Our results from completing the third step are shown below.

- 1593 1. **Obtain** a copy of *Run the EMM Connector Deployment Script* from the Appthority support
 1594 portal at [https://help-](https://help-mtp.appthority.com/SetUp/EMM/EMM_Script/RunEMMDeployScript.html)
 1595 [mtp.appthority.com/SetUp/EMM/EMM_Script/RunEMMDeployScript.html](https://help-mtp.appthority.com/SetUp/EMM/EMM_Script/RunEMMDeployScript.html) (authentication
 1596 to the portal is required).
- 1597 2. **Execute** the script. The third step in the script involves providing settings to enable the
 1598 Appthority Connector to communicate with MobileIron Core. The results of our completion
 1599 of that step are provided below as a reference.

1600 Figure 2-133 Appthority Connector CLI Configuration

```

Selection: 3

Configure EMM
-----
Select EMM Provider:

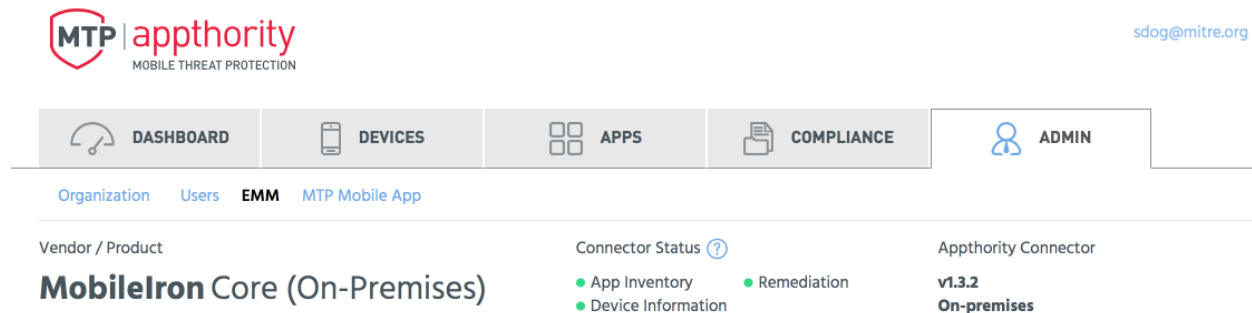
[A] - AirWatch 9.X
[M] - MobileIron Core 9.X
[MC] - MobileIron Cloud

EMM Provider:           M
EMM Provider Selected: mobileiron
Is MobileIron Core On-Premise? (y/n): y
EMM URL:                 mi-core.govt.mdse.nccoe.org
Is the EMM User a Domain Account (y/n)? n
EMM Username:           appthority
EMM Password:
Is there a Proxy (y/n)? n
Set EMM API Timeout (y/n)? n

[Okay]
  
```

- 1601
- 1602
- 1603 3. Once the script has been completed, verify successful synchronization with the Appthority
 1604 cloud service by accessing the Appthority MTP portal and navigating to **Admin > EMM** and
 1605 viewing items under **Connector Status**.

1606 Figure 2-134 Appthority EMM Connector Status



1607

1608 2.9 Registering Devices with MobileIron Core

1609 In this scenario, the employee manages their own personal apps, data, and many device functions. The
 1610 organization manages work-related apps and data, and has control over specific device functions, such
 1611 as requiring a complex device unlock PIN or being able to remotely wipe a lost device. The mechanisms
 1612 to achieve similar security characteristics between iOS and Android devices differ.

1613 2.9.1 Supervising and Registering iOS Devices

1614 Many MDM-based security controls are only applicable to iOS devices that are running in Supervised
 1615 Mode. The following steps outline how to place an iOS device into this mode, and then register with
 1616 MobileIron Core.

1617 2.9.1.1 Resetting the iOS Device

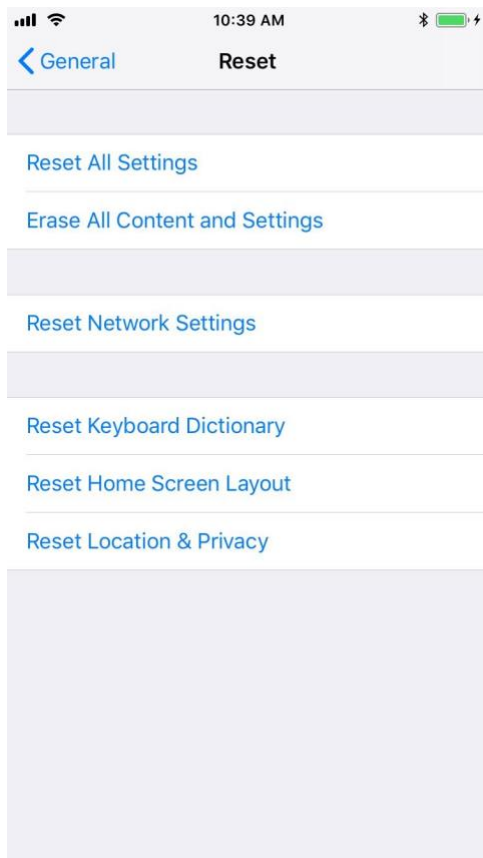
1618 Before a device can be placed into Supervised Mode, it must be in a factory-reset state with the
 1619 Activation Lock on the device removed. If Activation Lock is in-place, Configurator 2 will be unable to
 1620 place the device into Supervised Mode.

1621 [2.9.1.1.1 Reset an Unsupervised Device Using Settings App](#)

1622 If a device is not already in Supervised Mode, it is recommended to have the current device user
1623 manually reset and activate the device to factory settings using the following steps:

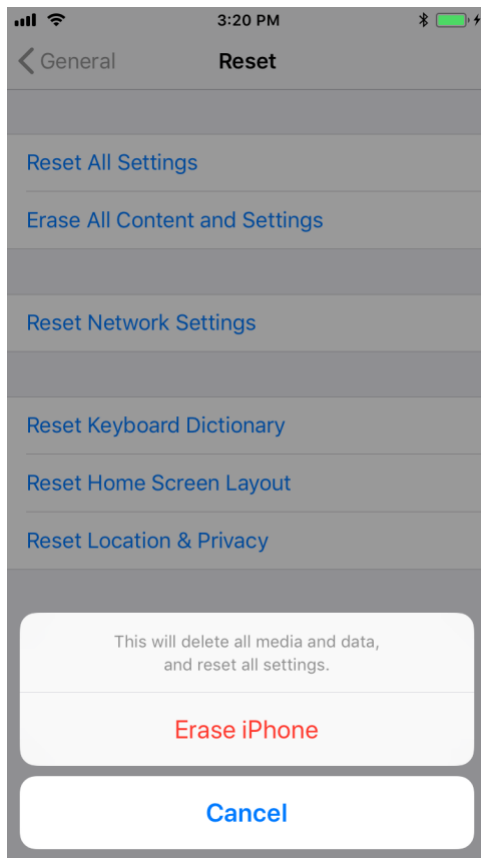
- 1624 1. Navigate to **Settings > General > Reset**.
- 1625 2. Select **Erase All Content and Settings**.

1626 **Figure 2-135 iOS Reset Screen**

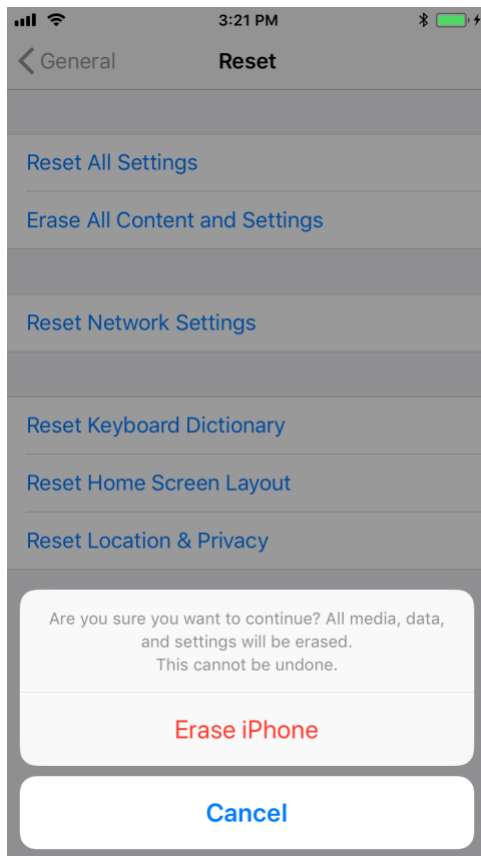


- 1627
- 1628 1. At the warning that this will delete all media and data and reset all settings, select **Erase**
1629 **iPhone**.

1630 **Figure 2-136 Erase iPhone Confirmation**



- 1631
- 1632 1. At the warning that all media, data, and settings will be irreversibly erased, select **Erase**
- 1633 **iPhone**. Once the reset process is complete, the device will reboot and need to be
- 1634 activated.

1635 **Figure 2-137 Erase iPhone Final Confirmation**

1636

1637

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1640

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1643

1644

1645

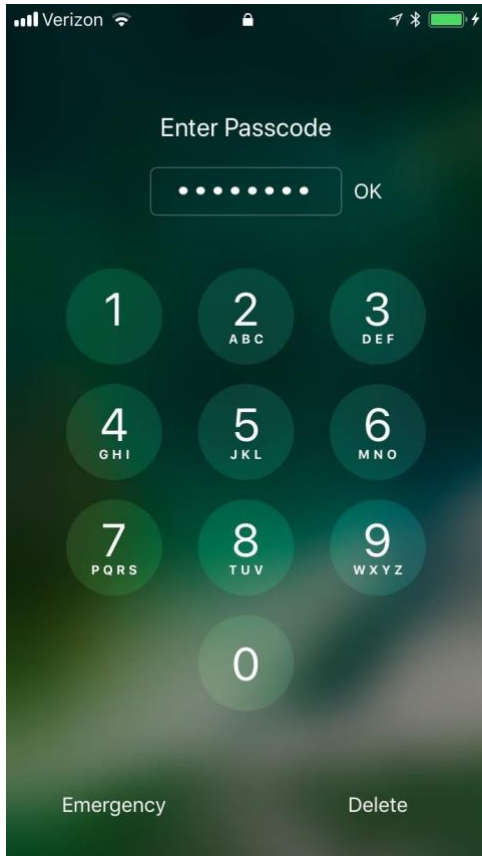
1646

1. Once the device displays the **Hello** screen, press the **Home key**.
2. At the **Select Your Language** screen, select **English**.
3. At the **Select Your Country or Region** screen, select **United States**.
4. At the **Quick Start** screen select **Set up Manually**.
5. At the **Choose a Wi-Fi Network** screen, select the **Service Set Identifier (SSID)** for the network and authenticate to your on-premises SSID Wi-Fi network; the device should indicate it is being activated. **Note:** you may need to attempt activation again if there is a delay in the device establishing connectivity to the internet.
6. **Stop** at the **Data & Privacy** screen. At this point, the device should be placed into **Supervised Mode** using **Configurator 2**.

1647 2.9.1.1.2 Reset a Supervised Device Using Configurator 2

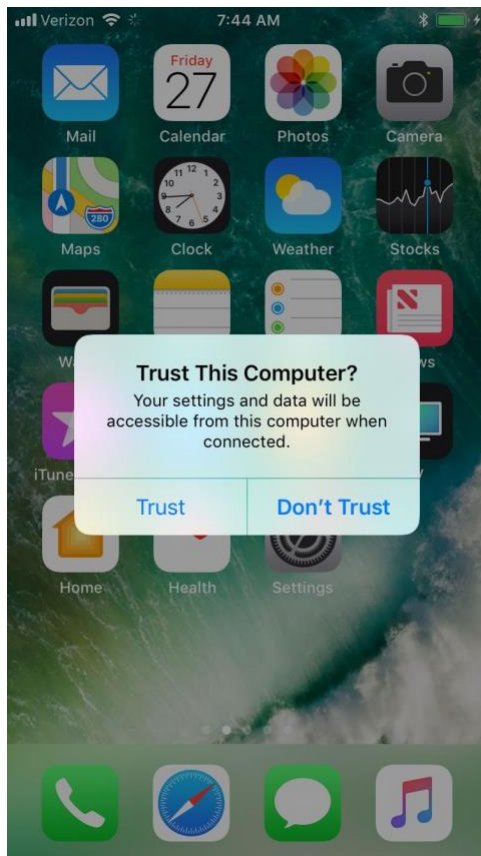
- 1648 1. **Connect** the iOS device with the system running **Configurator 2** over **Universal Serial Bus**
1649 **(USB)**.
- 1650 2. On the device at the **Enter Passcode** screen (if locked), enter the **device unlock passcode**.

1651 **Figure 2-138 Entering iOS Passcode**



- 1652
- 1653 3. At the **Trust this Computer?** dialogue, select **Trust**. Note that this step, along with step that
1654 follows, is only encountered the first time a device is paired with a given system.

1655 **Figure 2-139 iOS Trust Computer Confirmation**



1656

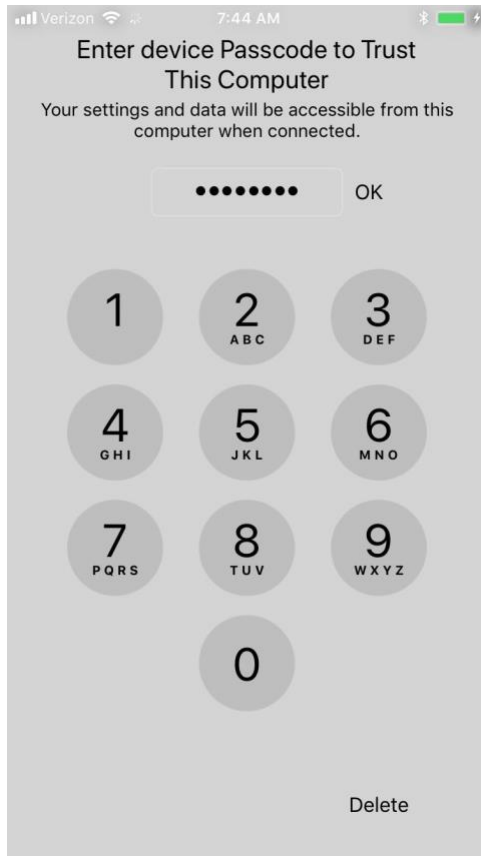
1657

1658

1659

4. At the **Enter Device Passcode to Trust This Computer** screen:
 - a. **Enter** the device unlock passcode.
 - b. Select **OK**.

1660 **Figure 2-140 Entering Passcode to Trust Computer**



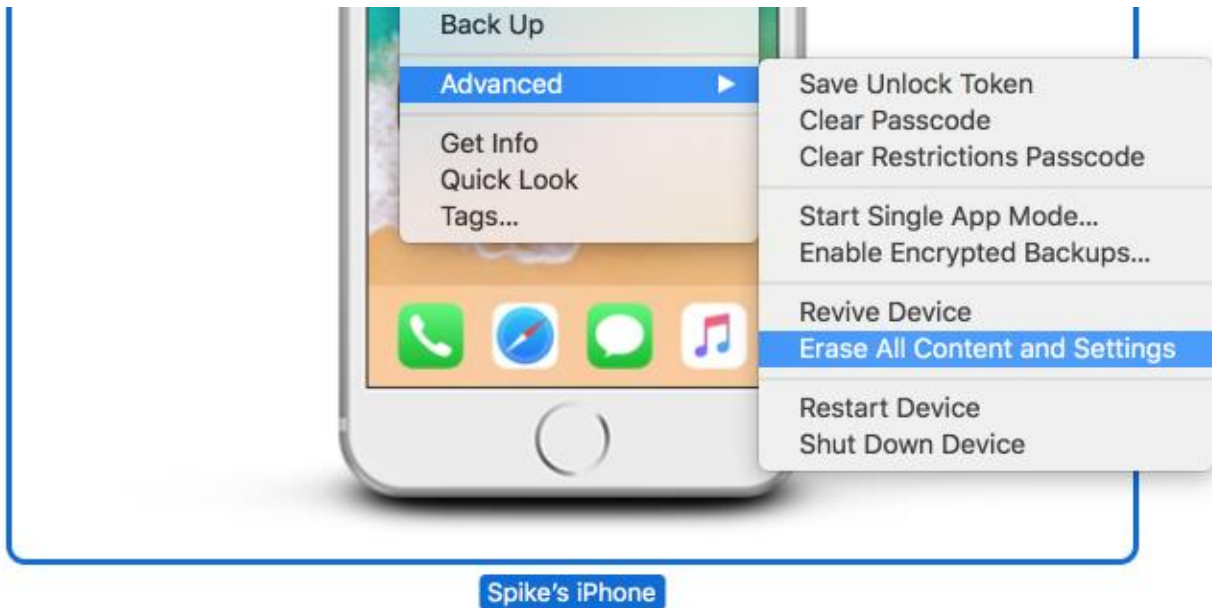
1661

1662

1663

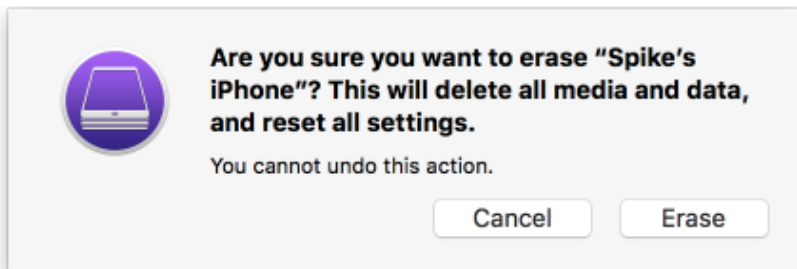
5. In **Configurator 2**, select the **representation** of the connected device.
6. From the **context** menu, select **Advanced > Erase All Content and Settings**.

1664 Figure 2-141 Resetting iPhone in Configurator 2



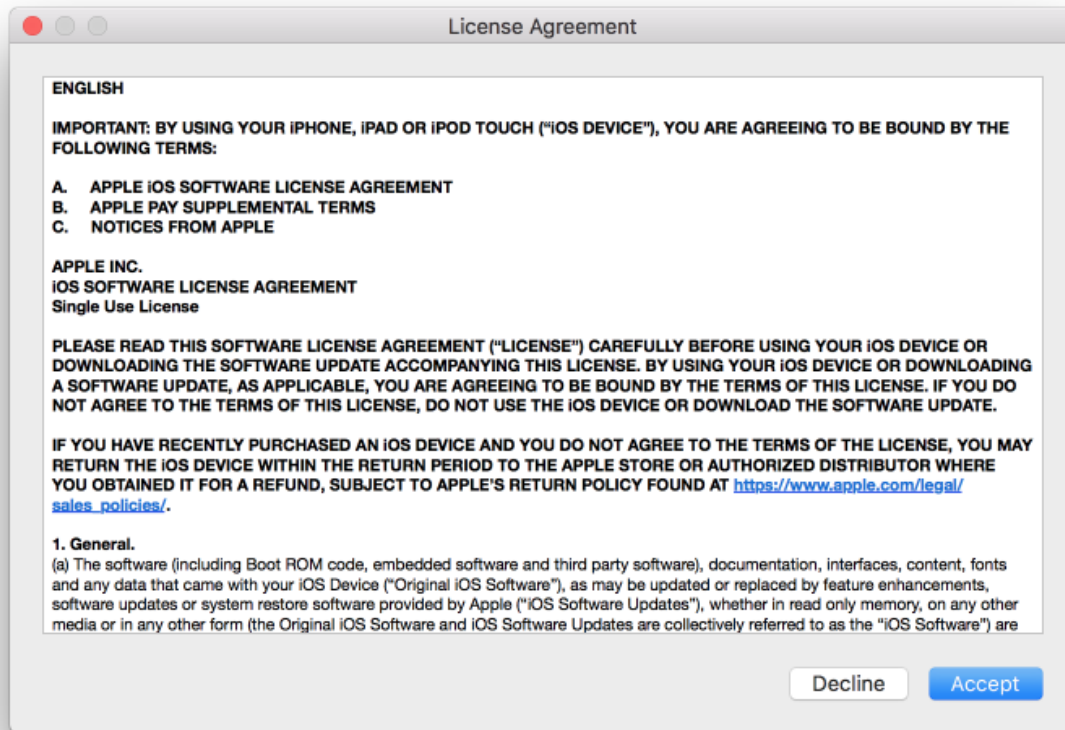
- 1665
- 1666 7. At the **Are you sure you want to erase "<device name>"**? dialogue, select **Erase**.

1667 Figure 2-142 Configurator 2 Erase Confirmation



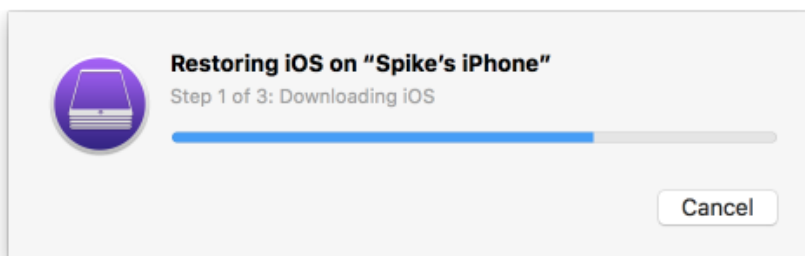
- 1668
- 1669 8. At the **License Agreement** screen:
- 1670 a. **Review** the license agreement.
- 1671 b. Select **Accept** to agree to the license and continue using the software.

1672 Figure 2-143 Configurator 2 License Agreement



- 1673
- 1674 9. **Configurator 2** will take several minutes to restore the device to factory default settings.
- 1675 **Configurator 2** will also activate the device following restoration.

1676 Figure 2-144 Restoring iPhone

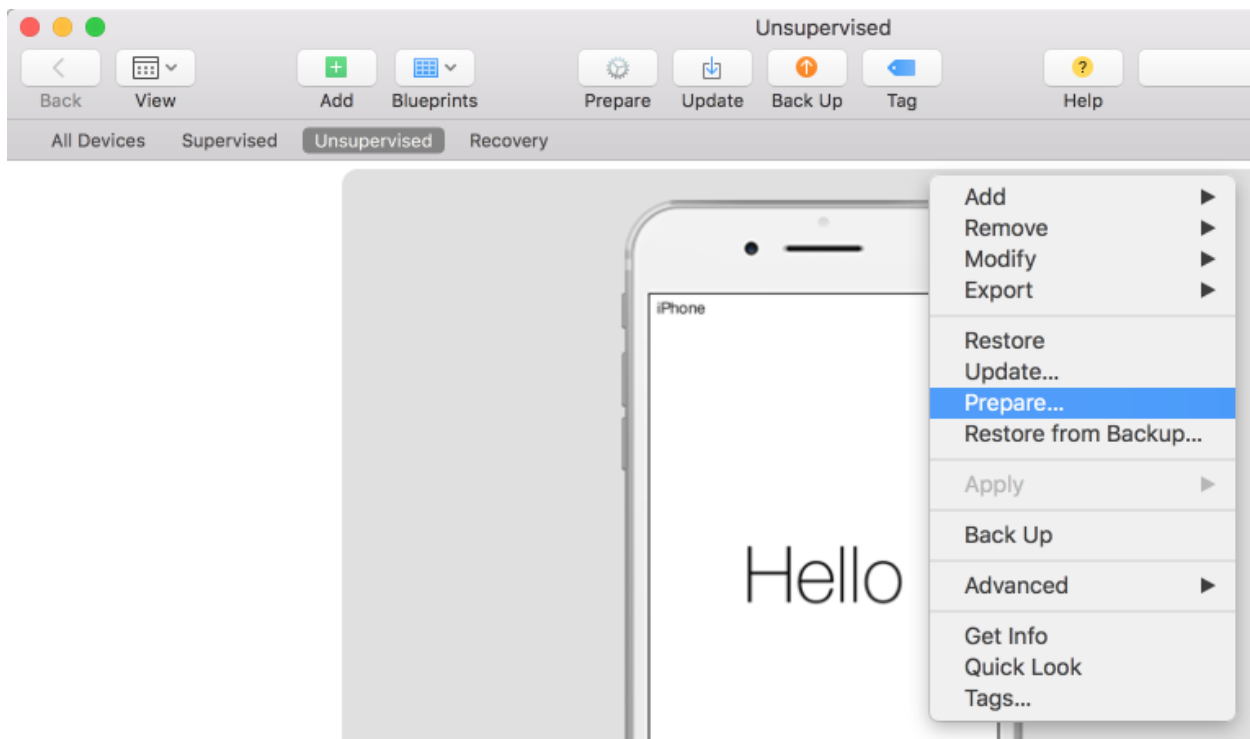


1677

1678 **2.9.1.2** *Placing an iOS Device into Supervised Mode*

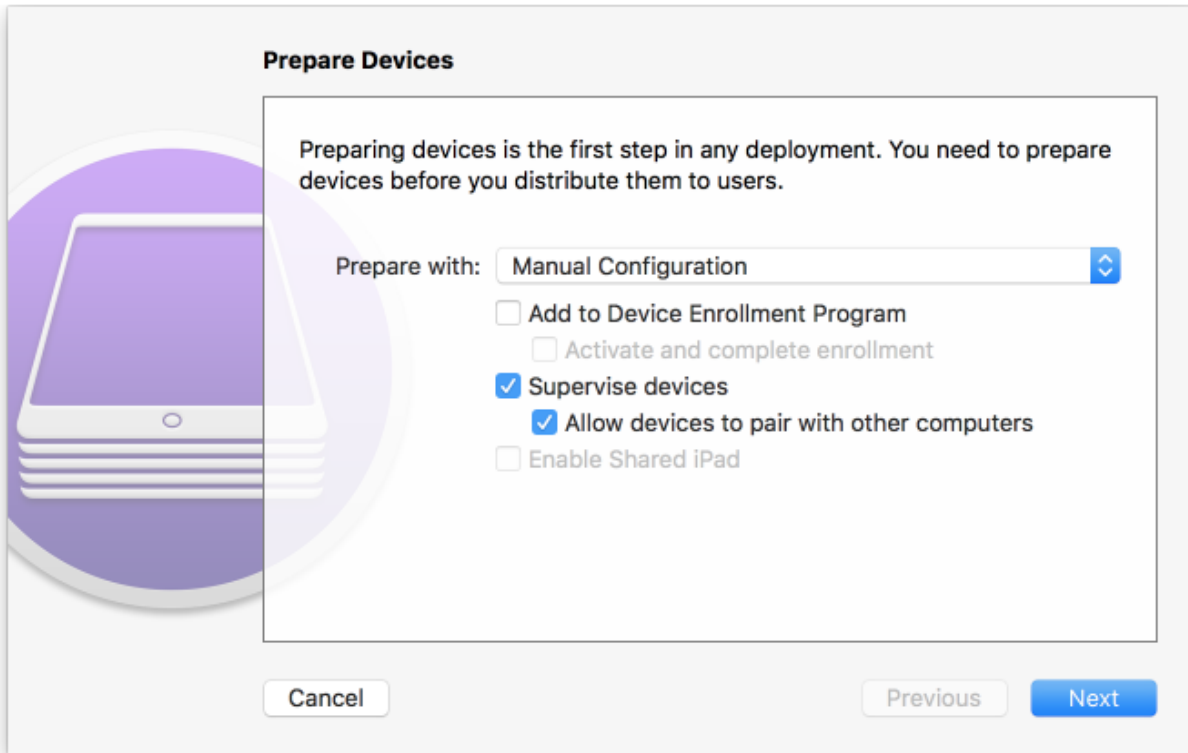
1679 iOS devices that have been factory reset and subsequently activated (the Activation Lock has been
1680 removed) can be placed into Supervised Mode using software available from Apple, Configurator 2, by
1681 the following steps:

- 1682 1. **Pair** the target iOS device with the system running Configurator 2 over USB.
- 1683 2. Navigate to **Configurator 2 > Unsupervised**; a representation of the connected device
1684 should appear.
- 1685 3. On the **All Devices** tab:
 - 1686 a. **Select** the representation of the paired device.
 - 1687 b. From the **context** menu, select **Prepare**; a wizard will open to guide the process.

1688 **Figure 2-145 Prepare Option in Configuration 2**

- 1689 4. For the **Prepare Devices** step:
 - 1690 a. **Enable** Supervise Devices.
 - 1691 b. Select **Next**.
 - 1692

1693 Figure 2-146 Device Preparation Options



1694

1695

5. For the **Enroll in MDM Server** step:

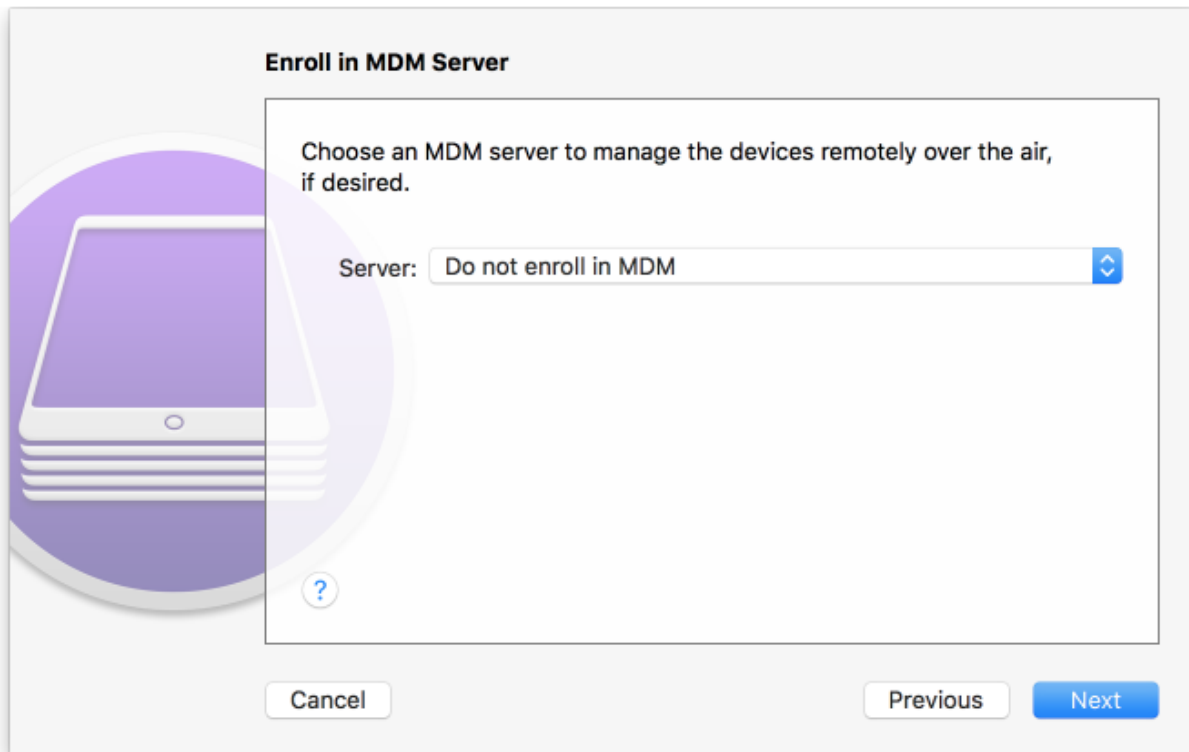
1696

a. Ensure the **Server** drop-down menu has **Do not enroll in MDM** selected.

1697

b. Select **Next**.

1698 Figure 2-147 Preparation MDM Server Selection

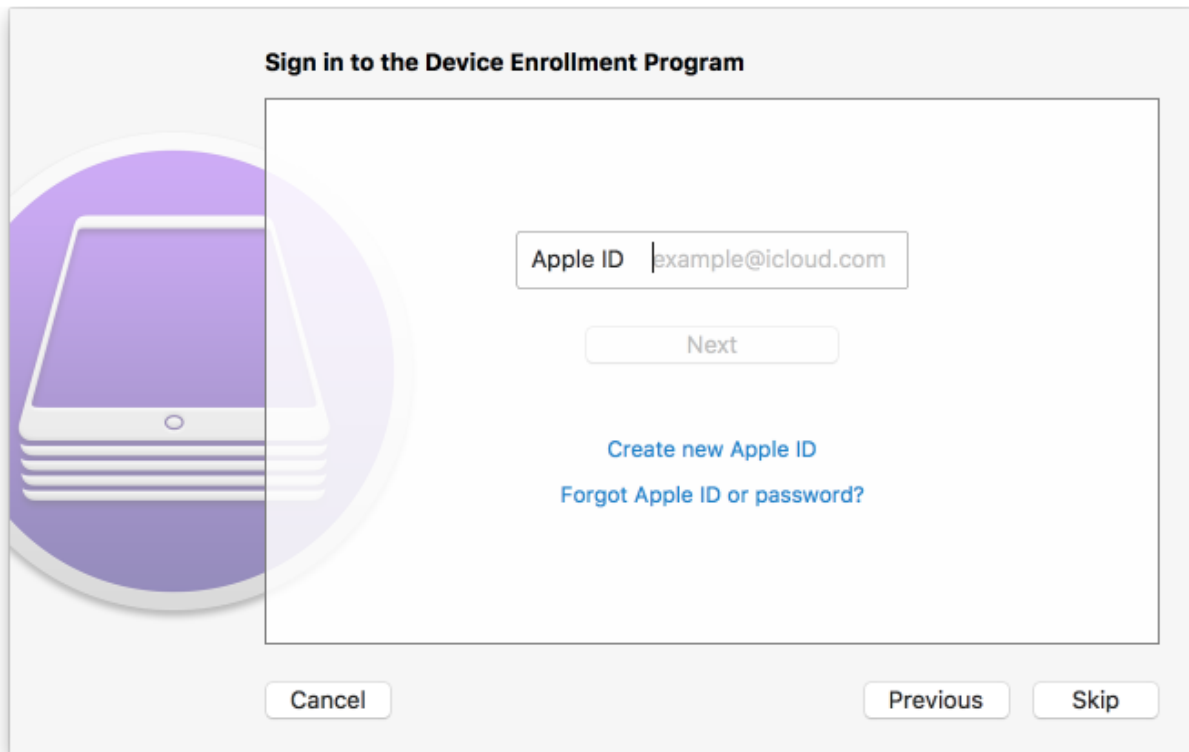


1699

1700

6. For the **Sign into the Device Enrollment Program** step, select **Skip**.

1701 Figure 2-148 Signing into Apple Account



1702

1703

7. For the **Assign to Organization** step:

1704

a. If you have previously created your organization, select **Next** and continue with **Step 9**.

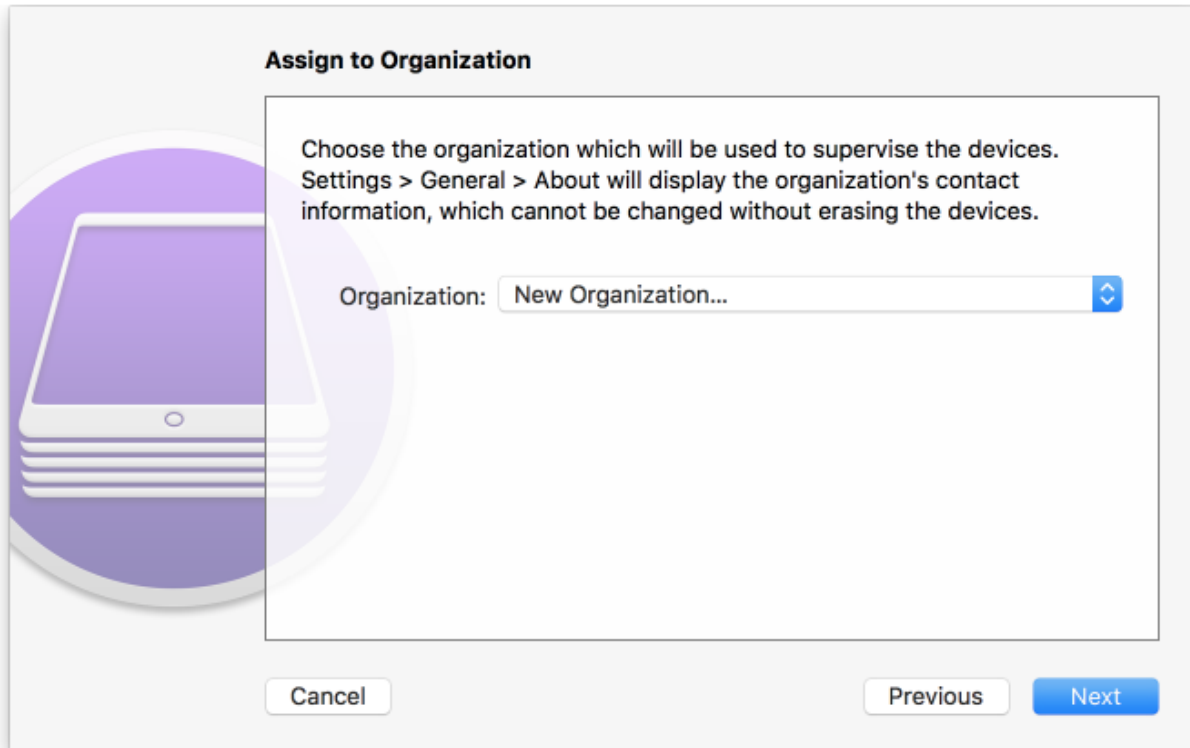
1705

b. If you have not created your organization, from the **Organization** drop-down menu,

1706

select **New Organization...**

1707 Figure 2-149 Organization Assignment Dialogue



1708

1709

8. At the **Create an Organization** screen:

1710

a. In the **Name** field, enter the name of your organization.

1711

b. In the **Phone** field, enter an appropriate support number for your mobility program.

1712

c. In the **Email** field, enter an appropriate support email for your mobility program.

1713

d. In the **Address** field, enter the address for your organization.

1714

e. Select **Next**.

1715 Figure 2-150 Creating an Organization

Create an Organization

Enter information about the organization.

Name: NCCoE MDSE Lab

Phone: [REDACTED]

Email: mobile-nccoe@nist.gov

Address: 9700 Great Seneca Hwy, Rockville, MD 20850

Cancel Previous Next

1716

1717

1718

9. If your organization has established a digital identity for placing devices into **Supervised Mode**:

1719

1720

- a. Continue with **Step 10. Note:** that the same digital identity must be used for any given device.

1721

- b. Otherwise, continue with **Step 14**.

1722

10. In the **Create an Organization** screen:

1723

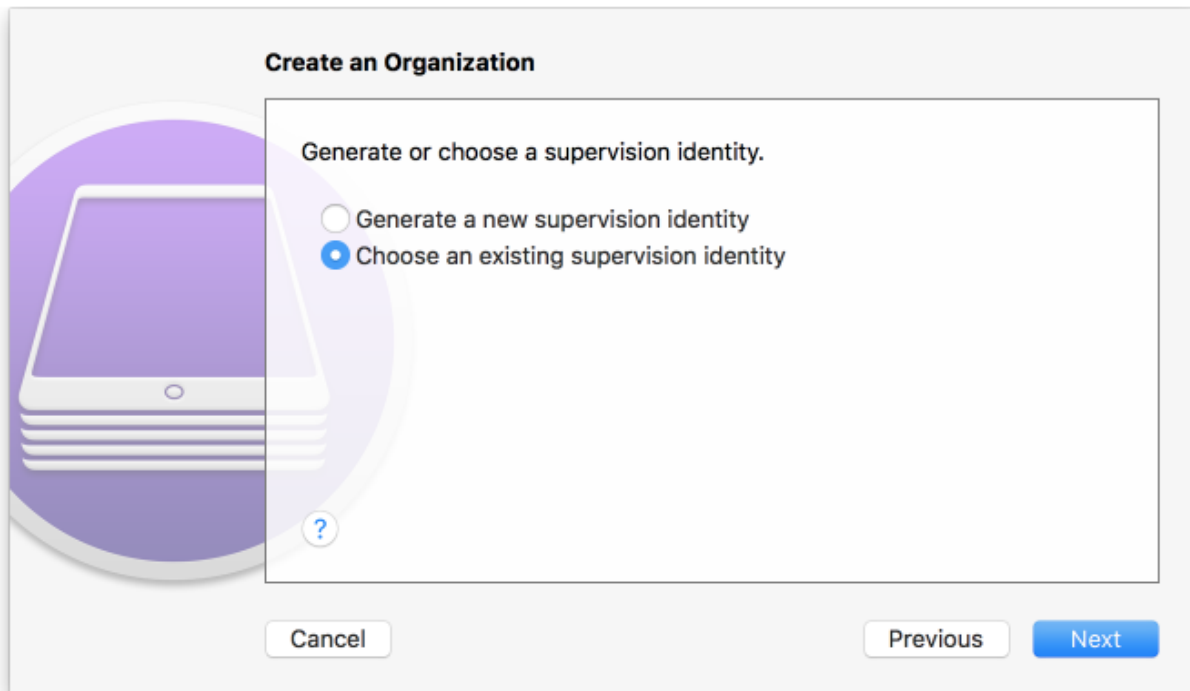
1724

- a. For the **Generate or choose a supervision identity** option, select **Choose an existing supervision identity**.

1725

- b. Select **Next**.

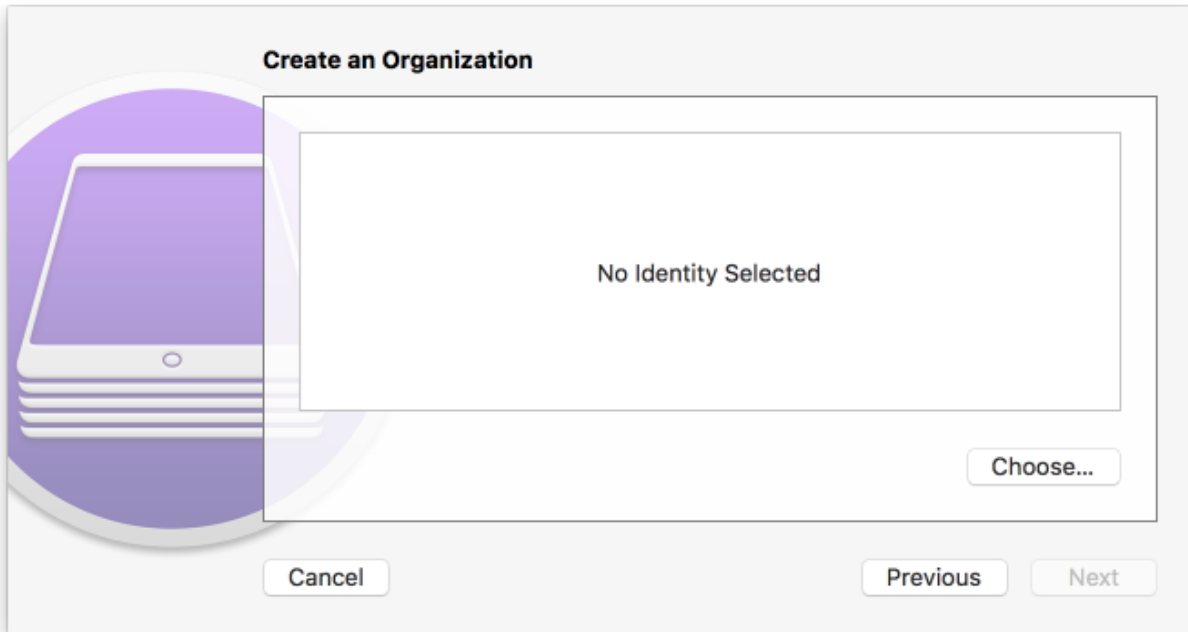
1726 Figure 2-151 Supervisory Identity Configuration



1727

1728 11. Select **Choose...**

1729 Figure 2-152 Organization Selection



1730

1731

12. At the **Choose a supervising identity for the organization** dialogue:

1732

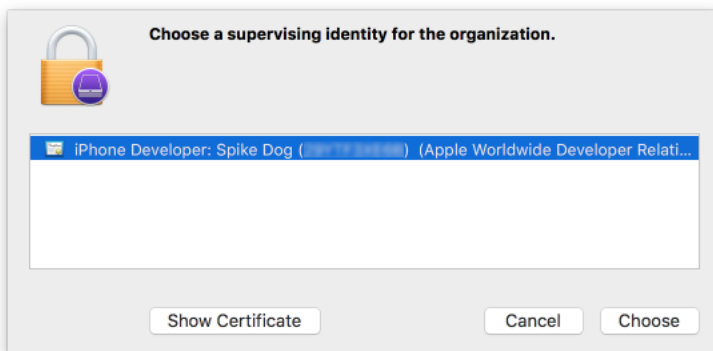
a. **Select** the digital certificate from the list of those available to the system.

1733

b. Select **Choose**.

1734

Figure 2-153 Supervising Identity Selection

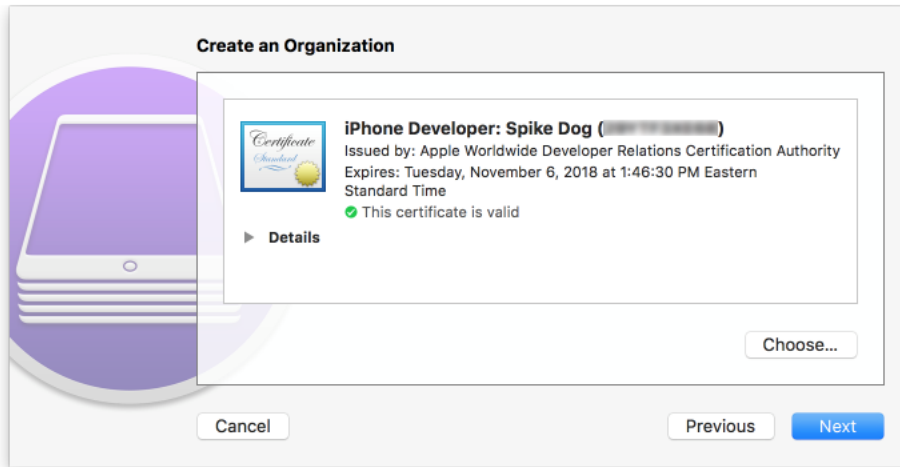


1735

1736

13. At the **Create an Organization** screen, select **Next**.

1737 **Figure 2-154 Selected Organization**



1738

1739

14. In the **Create an Organization** screen:

1740

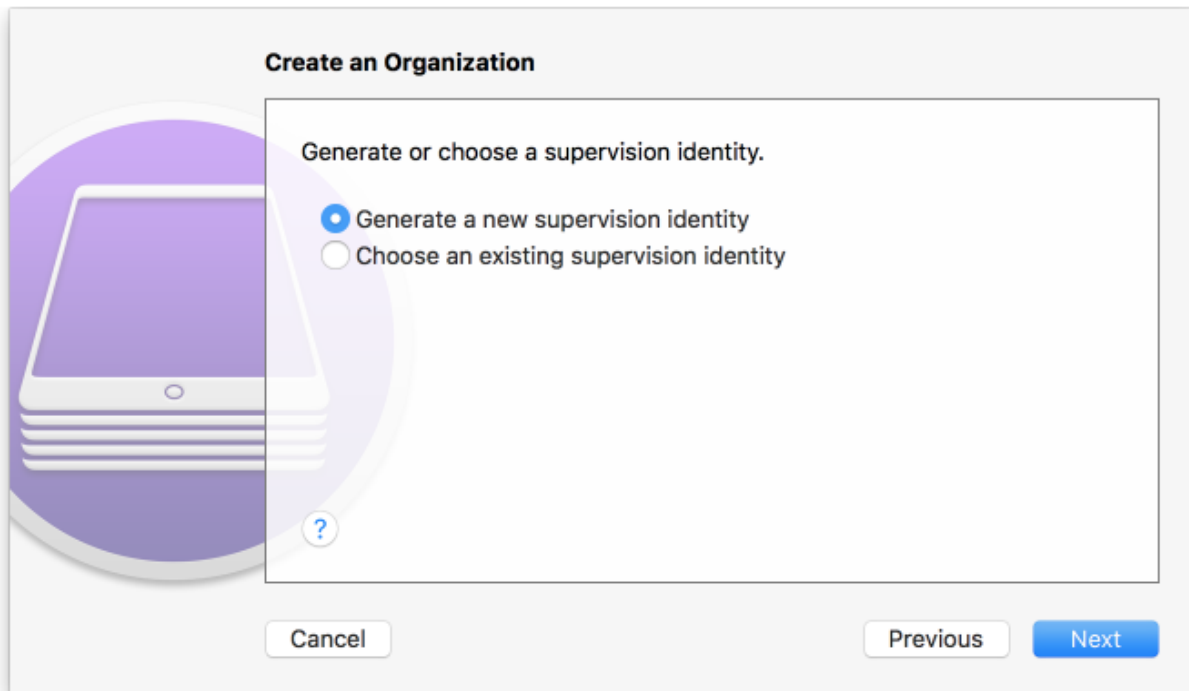
a. For the **Generate or choose a supervision identity option**, select **Generate a new supervision identity**.

1741

1742

b. Select **Next**.

1743 Figure 2-155 Create an Organization Supervision Identity Configuration



1744

1745

15. For the **Configure iOS Setup Assistant** step:

1746

a. Ensure the **Setup Assistant** drop-down menu shows **Show only some steps** selected; additional options will appear.

1747

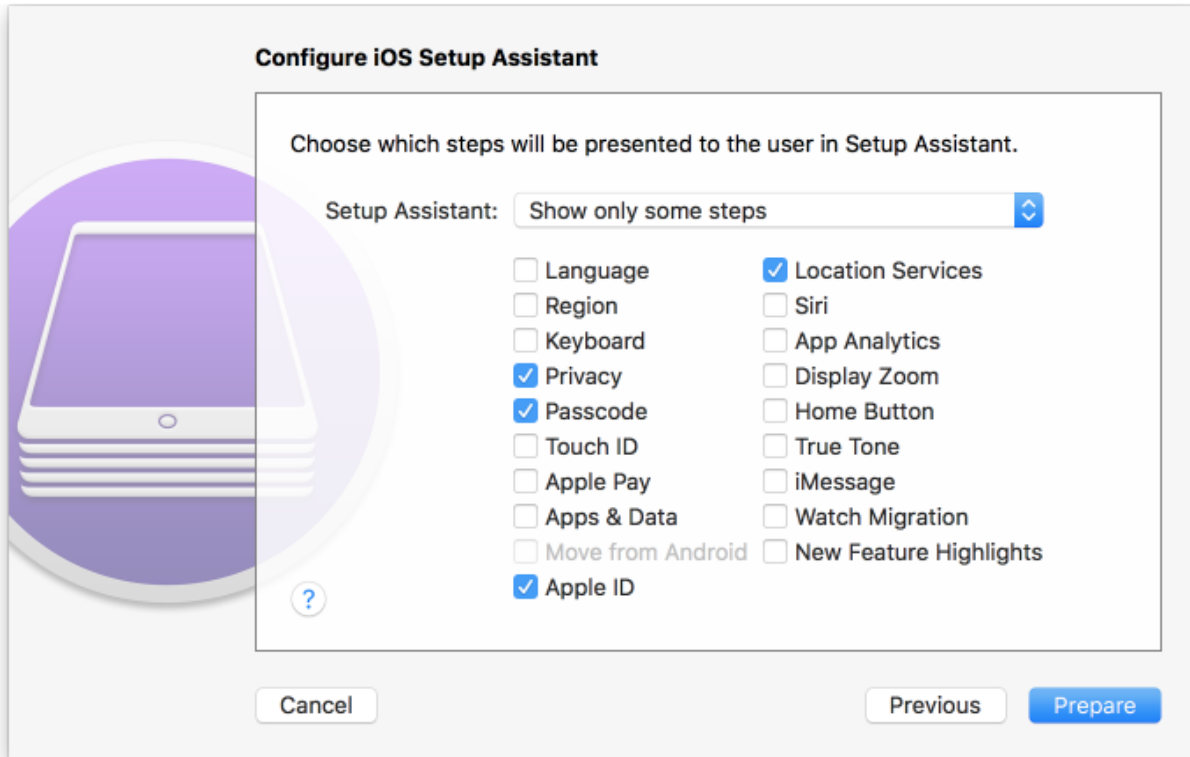
1748

b. Enable each of the **Privacy**, **Passcode**, **Apple ID**, and **Location Services** check-boxes.

1749

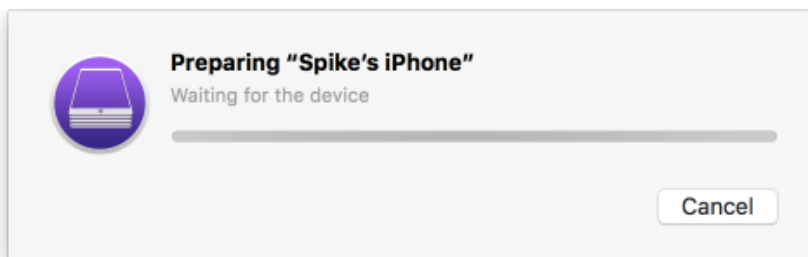
c. Select **Prepare**.

1750 Figure 2-156 Setup Assistant Configuration



1751
1752 16. **Configurator 2** will take several minutes to prepare the device and place it into **Supervised**
1753 **Mode**.

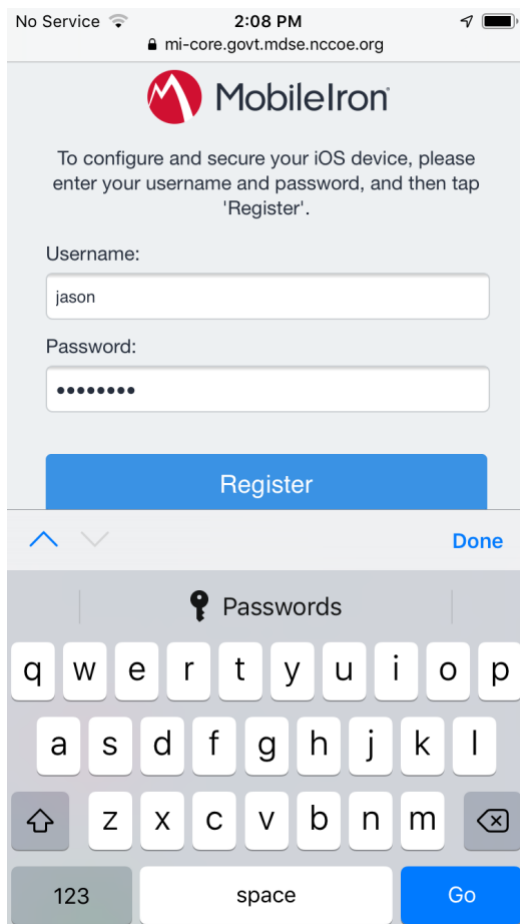
1754 Figure 2-157 Waiting for iPhone



1755
1756 [2.9.1.3 Registration with MobileIron Core](#)
1757 The following steps will register an iOS device in Supervised Mode with MobileIron Core, which uses a
1758 web-based process rather than the *Mobile@Work* app.

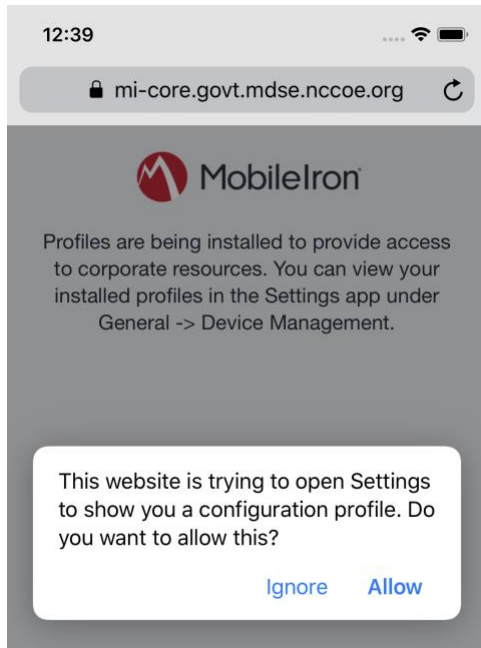
- 1759 1. Using **Safari**, navigate to **MobileIron Core** page, substituting <FQDN> for that of your
1760 organization's instance of MobileIron Core. In our example implementation, the resulting
1761 URL is <https://mi-core.govt.mdse.nccoe.org/go> .

1762 **Figure 2-158 MobileIron Registration Page**



- 1763
1764 2. At the **warning** that the web site is trying to open **Settings** to show a configuration profile,
1765 select **Allow**; the **Settings** built-in app will open.

1766 **Figure 2-159 Opening Settings Confirmation**



1767

1768

3. At the **Settings > Install Profile** screen:

1769

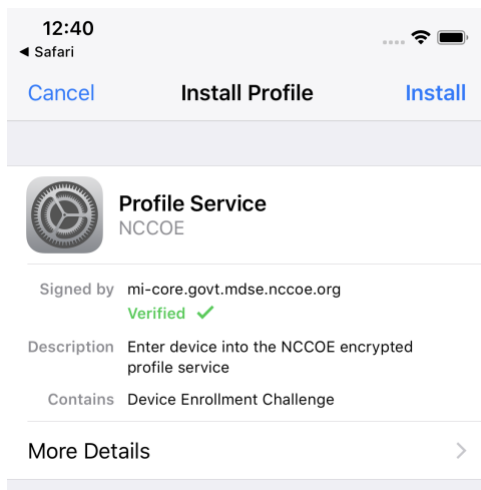
a. Verify the **Signed by** field indicates the server identity is **Verified**.

1770

b. Select **Install**.

1771

Figure 2-160 Profile Installation

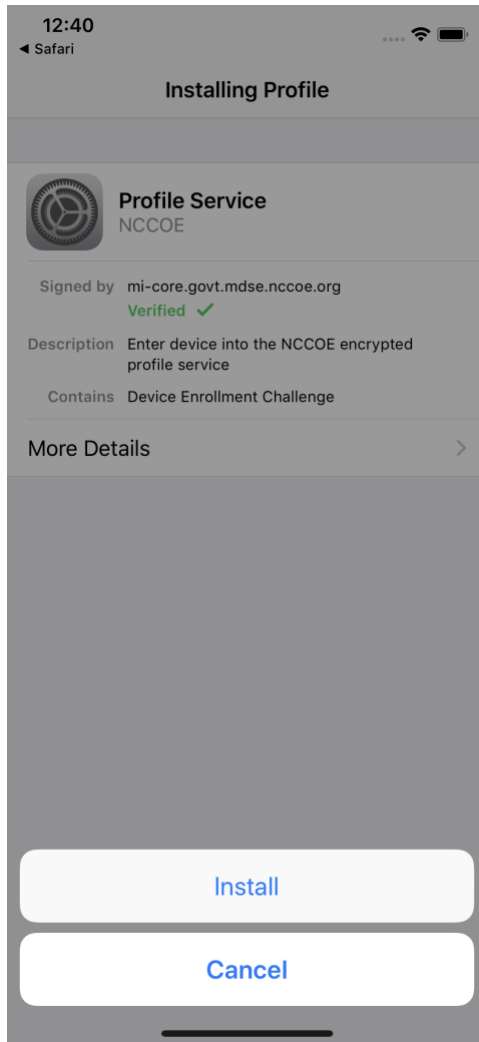


1772

1773

4. At the **Installing Profile** screen, select **Install**.

1774 **Figure 2-161 Profile Installation**



1775

1776

5. At the **Warning** screen:

1777

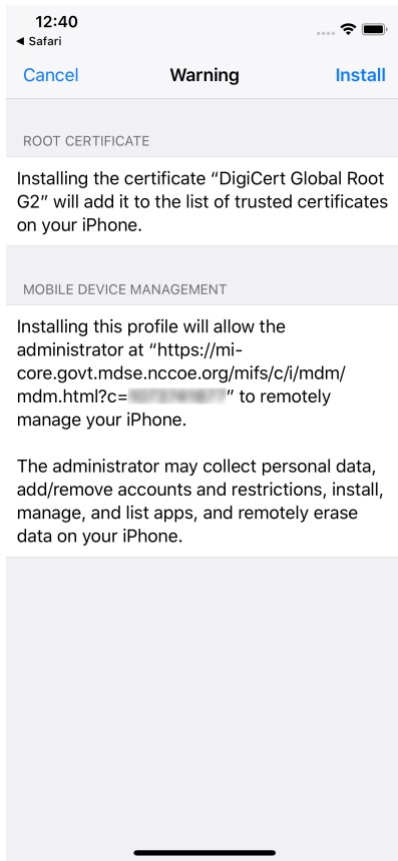
a. Verify that information under **Root Certificate** and **MDM** is consistent with information provided by your mobile device administrator.

1778

1779

b. Select **Install**.

1780 **Figure 2-162 Profile Installation Warning**

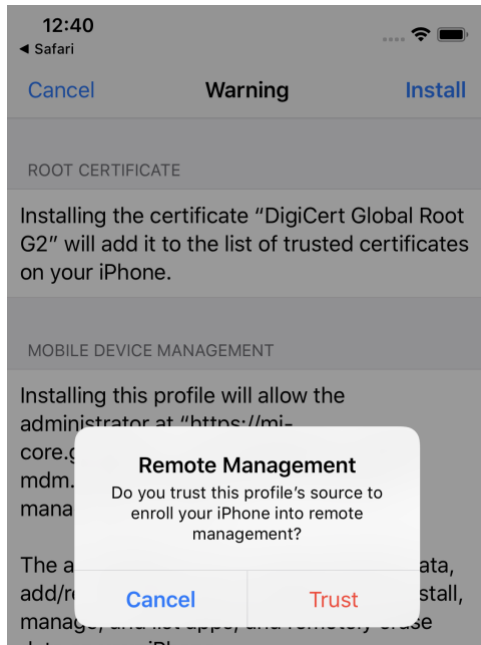


1781

1782

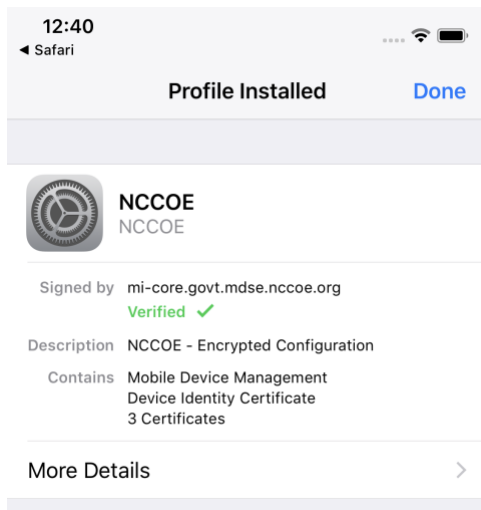
6. In the **Remote Management** dialogue, select **Trust**.

1783 **Figure 2-163 Profile Installation Trust Confirmation**



- 1784
 - 1785
 - 1786
 - 1787
 - 1788
 - 1789
 - 1790
7. At the **Profile Installed** screen, select **Done**. The device is now registered with MobileIron.

1786 **Figure 2-164 Profile Installation Confirmation**



- 1787
 - 1788
 - 1789
 - 1790
- ## 2.9.2 Activating Lookout for Work on iOS
- The configuration of the Lookout for Work (iOS) app in the MobileIron app catalog causes a configuration file to be included during automatic install. As a result, when a user first launches Lookout

1791 for Work, it should be activated without any user interaction. Additional action is required to grant
1792 Lookout for Work the permissions necessary for it to provide optimal protection.

1793 1. Launch the **Lookout for Work** app; activation occurs silently at the **splash** screen.

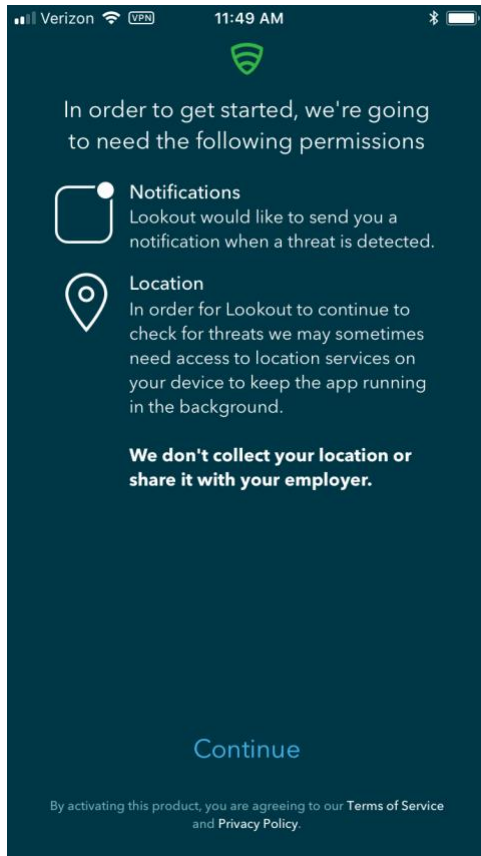
1794 **Figure 2-165 Lookout for Work Splash Screen**



1795

1796 2. At the **welcome** screen, select **Continue**.

1797 **Figure 2-166 Lookout for Work Permission Information**

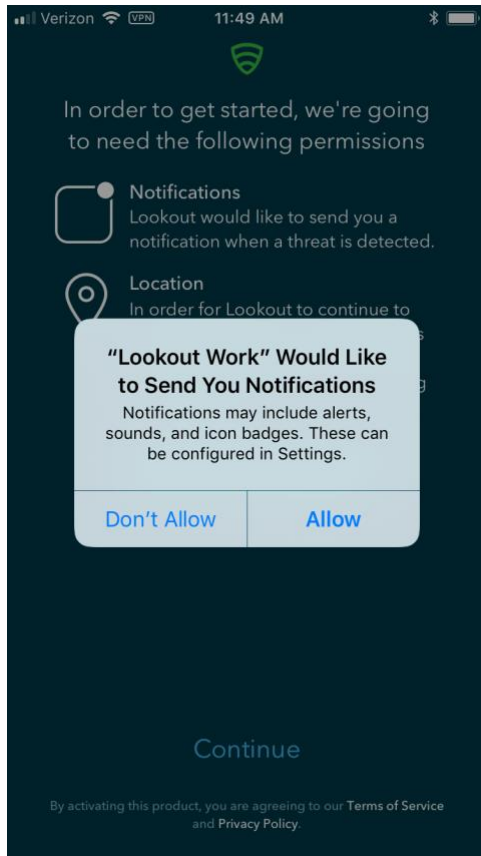


1798

1799

3. At the "**Lookout Work**" Would Like to Send You Notifications dialogue, select **Allow**.

1800 **Figure 2-167 Notifications Permissions Prompt**

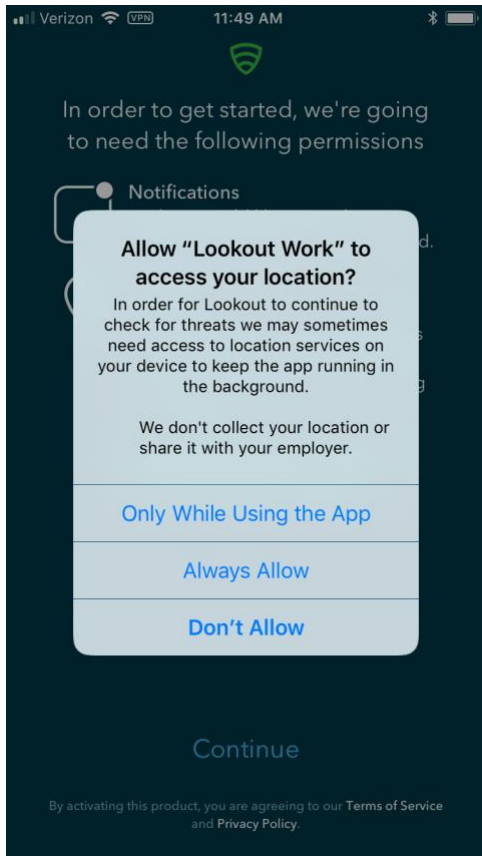


1801

1802

4. At the **Allow "Lookout Work" To Access Your Location?** dialogue, select **Always Allow**.

1803 **Figure 2-168 Locations Permission Prompt**



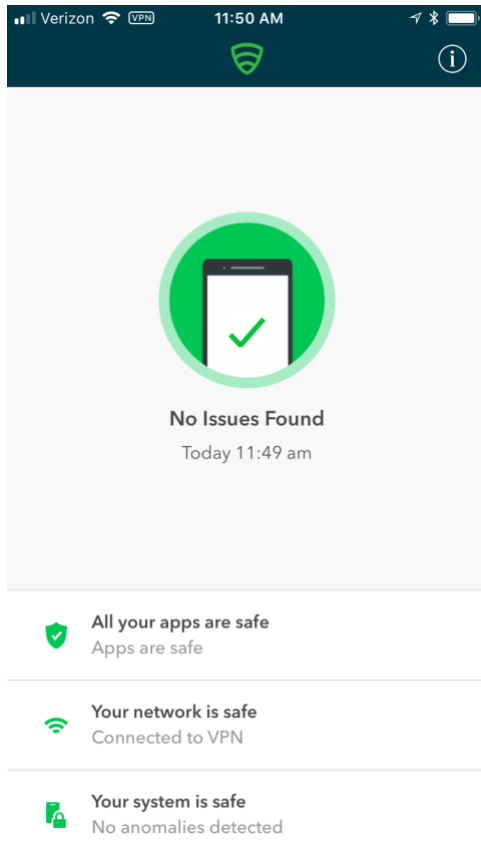
1804

1805

1806

5. **Lookout for Work** should automatically perform scans of device and app activity and provide feedback to the user.

1807 Figure 2-169 Lookout for Work Home Screen



1808

1809 2.9.3 Provisioning Work-Managed Android Devices with a Work Profile

1810 In this scenario, Android devices are deployed as work-managed with a work profile. Enabling this
 1811 feature for AFW-capable devices requires a change to the AFW configuration. It also requires that the
 1812 device user already has a personal Google account to provision the work profile; it is not created as part
 1813 of the workflow to register a device with MobileIron Core.

1814 2.9.3.1 Enable Work Profile on Work-Managed Devices

- 1815 1. In the **MobileIron Admin** Portal, navigate to **Policies > Configs > Configurations**.
- 1816 2. **Enable** the check box in the row for the **AFW** configuration.
- 1817 3. In the **Configuration Details** pane, select **Edit**.

1818 Figure 2-170 MobileIron AFW Configuration

Name	Configuration ...	Bundle/Package ID	Desc...	# Phones	Configuration Details
<input type="checkbox"/>	Activate Lookout	MANAGED AP...	com.lookout.work	Activ...	4
<input checked="" type="checkbox"/>	Android for Work Configur...	ANDROIDFOR...	Creat...	12	Android for Work Configuration Device Space: Global
<input type="checkbox"/>	Appthority Mobile Intellige...	MANAGED AP...	com.appthority.Appt...	Identi...	4

1819

1820

4. In the **Edit Android enterprise (all modes) Setting** dialogue:

1821

a. Enable **Enable Managed Devices with Work Profile** on the devices.

1822

b. Enable **Add Google account**.

1823

c. In the **Google Account** text box, provide a valid Google domain account. The example in our reference implementation will map a MobileIron user ID of gema to and email address of **mdse.gema@gmail.com**. See *MobileIron Core 9.4.0.0 Device Management Guide for AFW* for a list of variables to appropriately adapt this field to your existing identity management strategy.

1824

1825

1826

1827

1828

d. Select **Save**.

1829 Figure 2-171 AFW Configuration

Edit Android enterprise (all modes) Setting

Name

Description

Enable Managed Device with Work Profile on the devices

Auto update Mobile@Work app on the devices

For Android 6.0 and higher only

Enable Runtime Permissions

User Prompt

Always Accept

Always Deny

Add Google Account

Google Account

For Android 7.0 and higher only

Always-on VPN

Work Challenge

[Cancel](#) [Save](#)

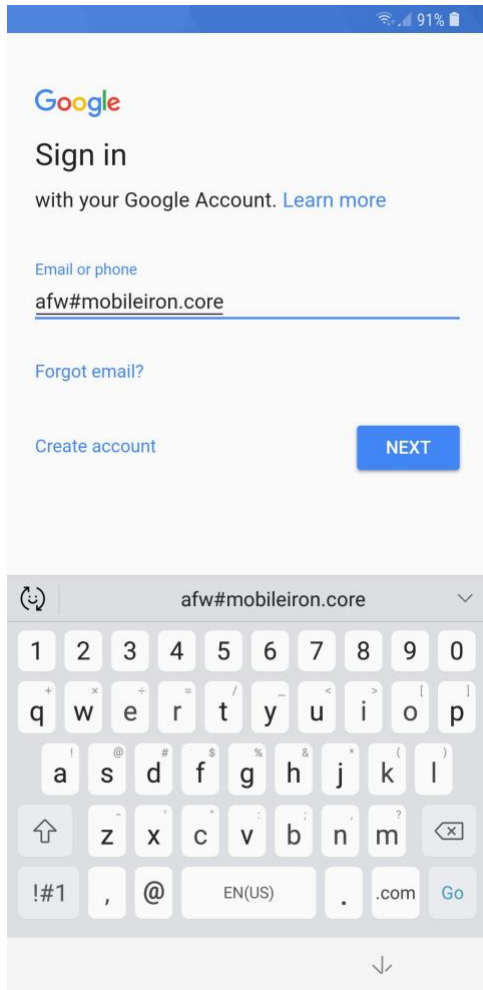
1830

1831 [2.9.3.2 Registering Android Devices](#)

1832 The following steps can only be completed when working with an Android device that is still set to (or
 1833 has been reset to) factory default settings.

- 1834 5. When prompted to **sign in** with your Google Account:
- 1835 a. In the **Email or phone field**, enter **afw#mobileiron.core**.
- 1836 b. Select **Next**.

1837 **Figure 2-172 MobileIron Enrollment Process**



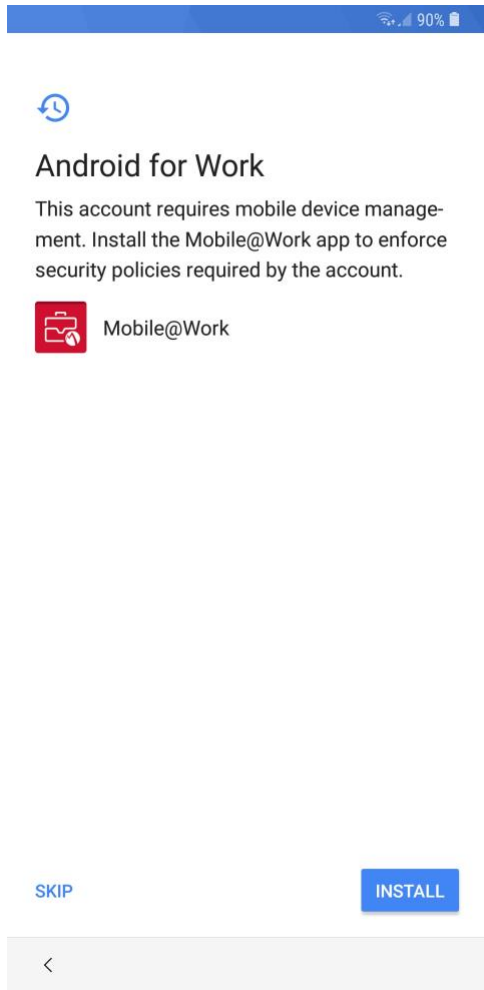
1838

1839

1840

6. When **AFW** prompts you to install *Mobile@Work*, select **Install**; this will download the *Mobile@Work* client to the device.

1841 **Figure 2-173 AFW Enrollment**

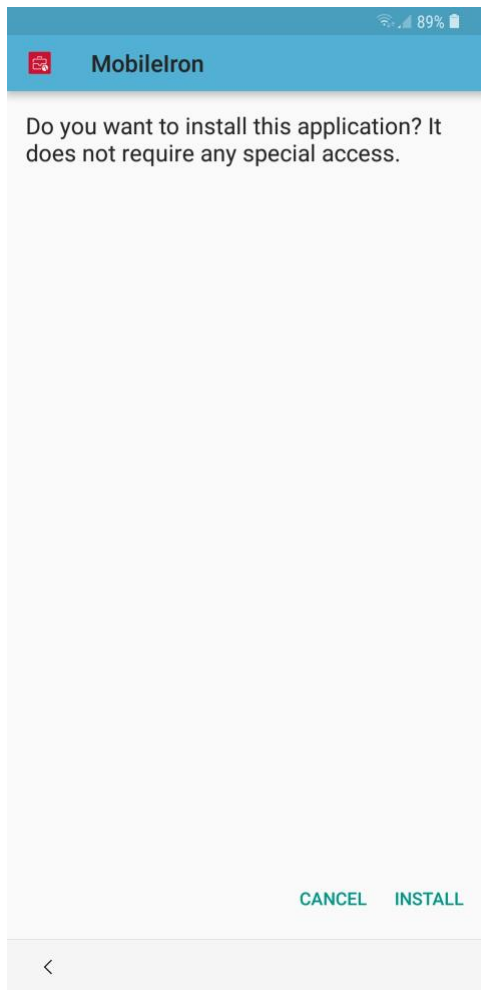


1842

1843

7. At the prompt to install MobileIron, select **Install**.

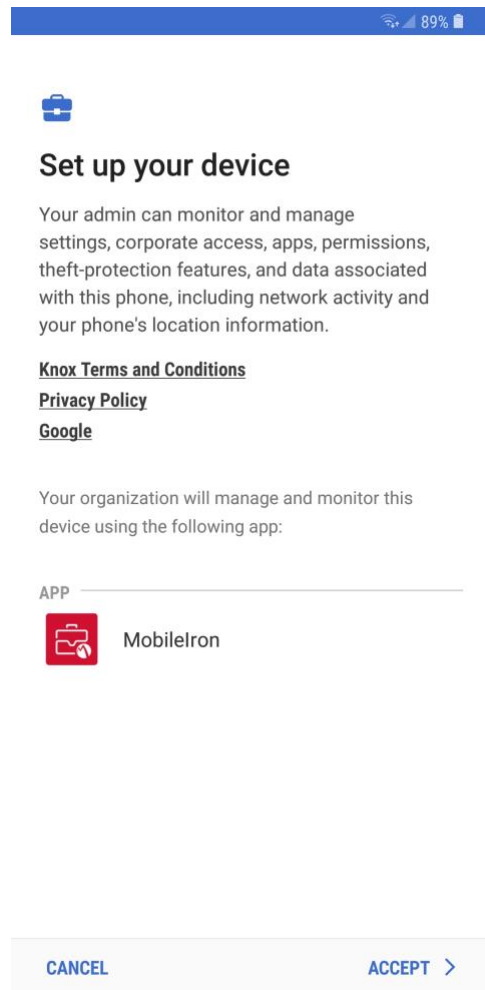
1844 **Figure 2-174 MobileIron Installation**



1845

1846 8. At the Set up your device screen, select **Accept**.

1847 **Figure 2-175 Accepting AFW Terms and Conditions**



1848

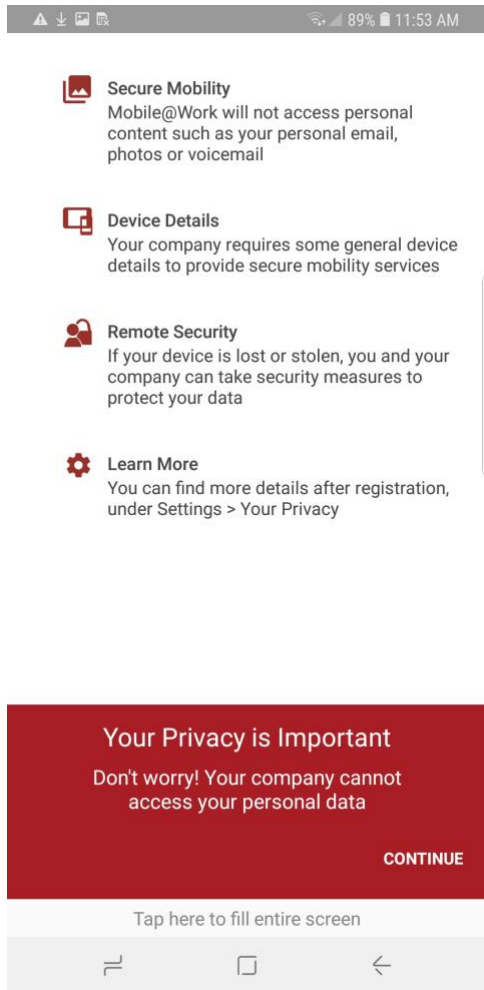
1849

1850

1851

9. This screen notifies the user of the data that *Mobile@Work* collects and how it is used. When this information has been reviewed, select **Accept**. Mobile@Work will minimize and return to the operating system home screen.

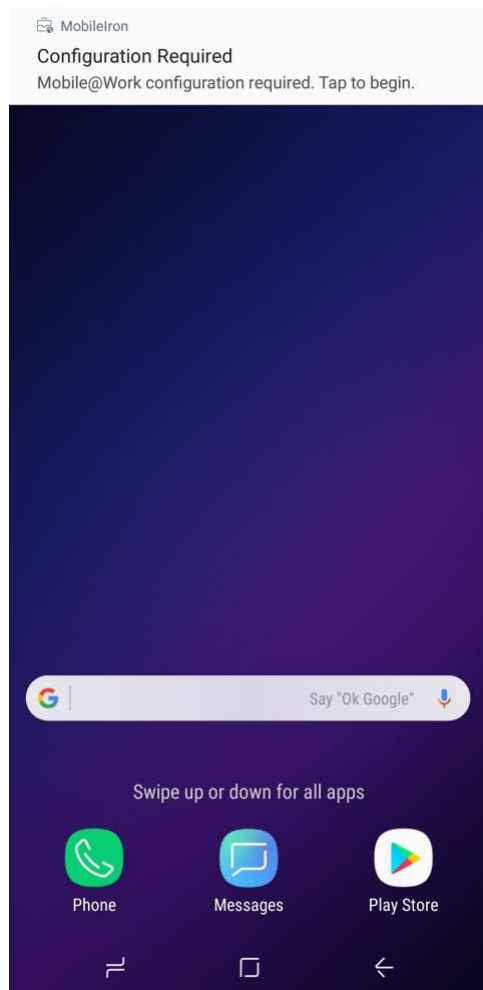
1852 **Figure 2-176 MobileIron Privacy Information**



1853

1854 10. When MobileIron sends a **Configuration Required** notification, select the **notification**.

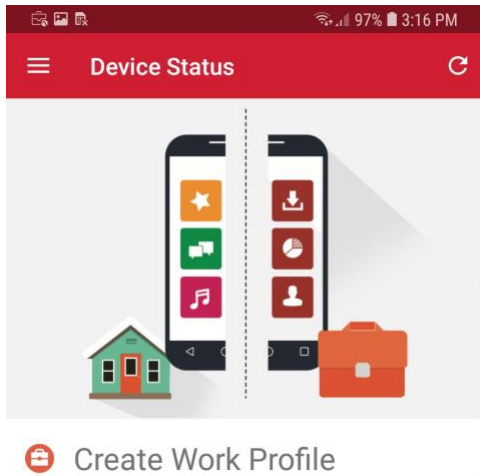
1855 **Figure 2-177 MobileIron Configuration Required Notification**



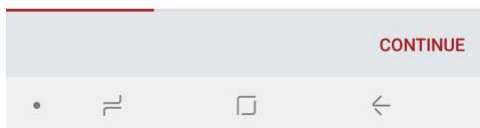
1856

1857 11. On the **Device Status > Create Work Profile** screen, select **Continue**.

1858 **Figure 2-178 MobileIron Device Status**



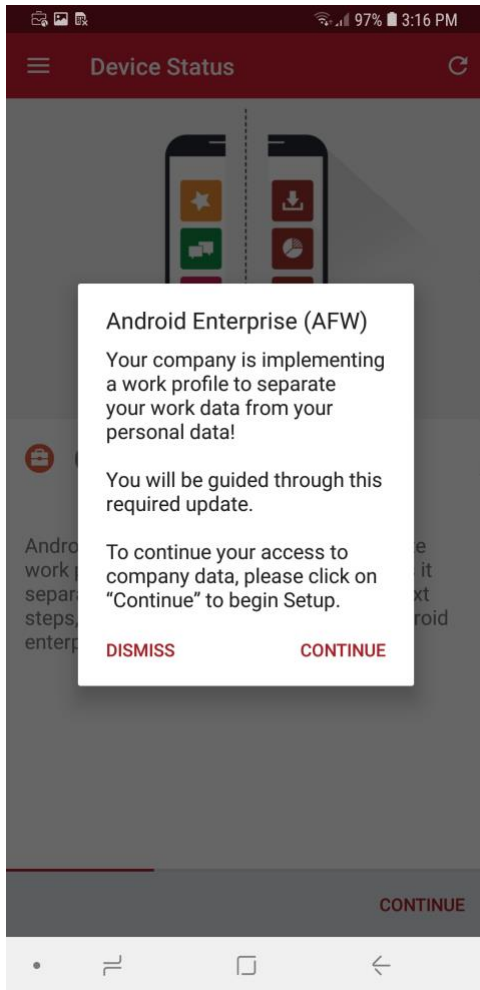
Android enterprise (AFW) creates a separate work profile to access work data and keeps it separate from your personal data. In the next steps, you will be guided to set up your Android enterprise (AFW) profile.



1859

1860 12. At the **AFW** prompt, select **Continue**.

1861 **Figure 2-179 AFW Configuration**



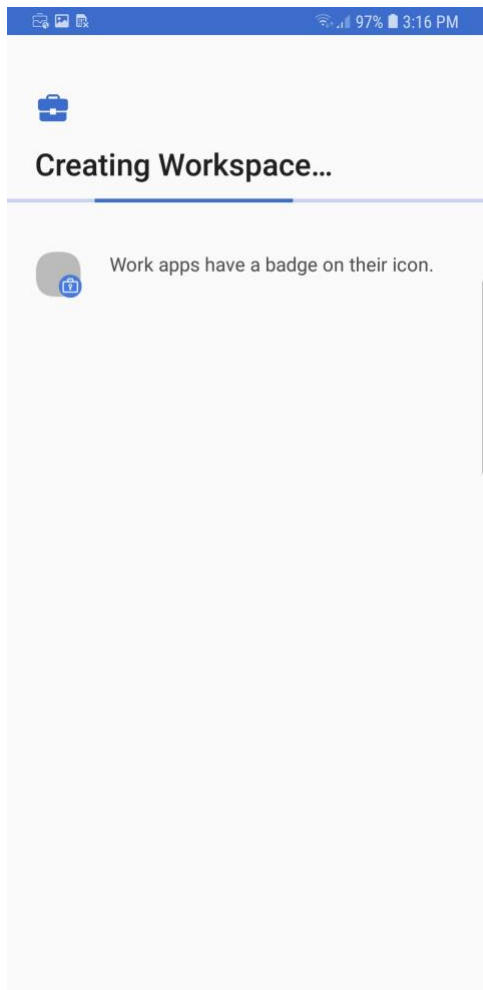
1862

1863

1864

13. **AFW** will notify the user that it is creating the personal workspace. The next two screens repeat **Steps 7** and **8** as above.

1865 **Figure 2-180 AFW Workspace Creation**

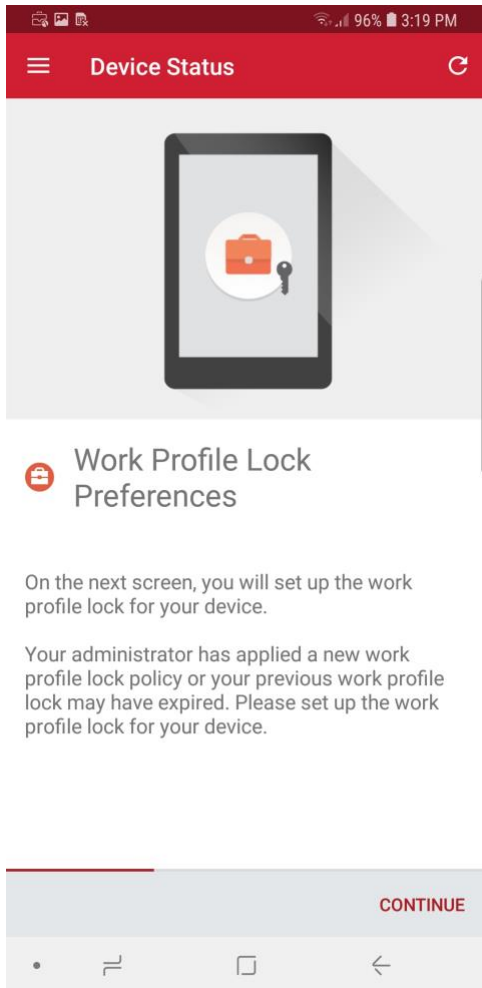


1866

1867

14. At the **Device Status > Work Profile Lock Preferences** screen, select **Continue**.

1868 **Figure 2-181 MobileIron Work Profile Lock Preferences**



1869

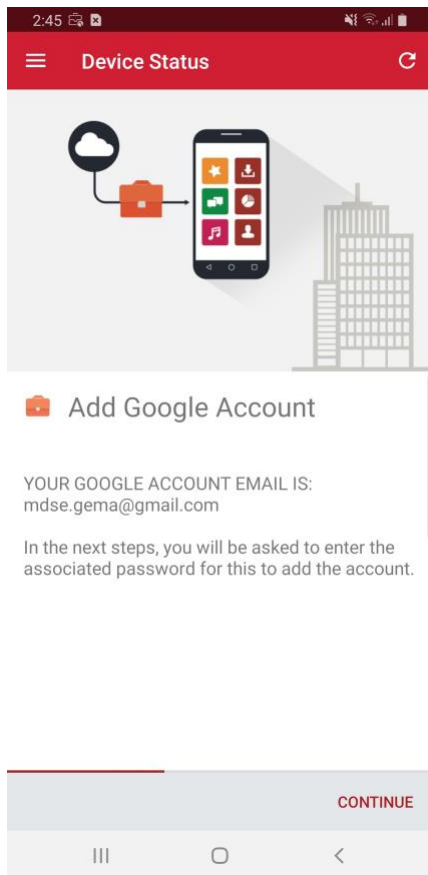
1870

15. The user will be prompted to create a passcode to protect the AFW container.

1871

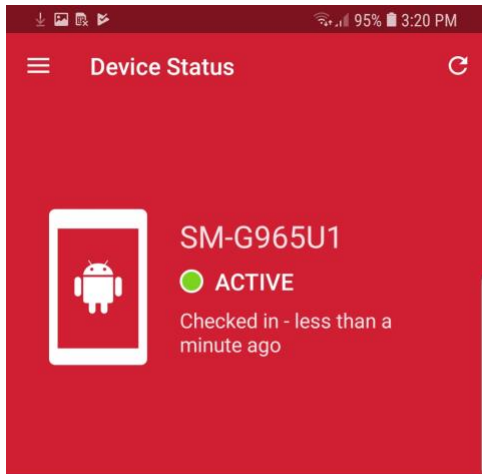
16. At the **Device Status > Add Google Account** screen, select **Continue**.

1872 **Figure 2-182 MobileIron Google Account Configuration**



- 1873
- 1874 17. The user will be prompted to authenticate to the same Google domain account mapped to
- 1875 their MobileIron account based on the email address set in the AFW configuration in
- 1876 MobileIron Core. In our example implementation, the mapped Google account is
- 1877 **mdse.gema@gmail.com.**
- 1878 18. Once the *Mobile@Work* app has been provisioned with the user's account, the Device
- 1879 Status screen should appear; the device has now successfully been provisioned into
- 1880 MobileIron.

1881 **Figure 2-183 MobileIron Device Status**



✔ You're all set!
Currently there are no updates needing
your attention.

1882



Appendix A List of Acronyms

AD	Active Directory
AFW	Android for Work
API	Application Programming Interface
CA	Certificate Authority
CN	Common Name
CSP	Common Service Provider
DMZ	Demilitarized Zone
DN	Distinguished Name
DNS	Domain Name System
DPC	Derived Personal Identity Verification Credential
EMM	Enterprise Mobility Management
FQDN	Fully Qualified Domain Name
GOVT	Government
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
IMEI	International Mobile Equipment Identity
ID	Identifier
IP	Internet Protocol
LAN	Local Area Network
LDAP	Lightweight Directory Access Protocol
MDM	Mobile Device Management
MDS	Mobile Device Security
MES	Mobile Endpoint Security
MTP	Mobile Threat Posture
NAT	Network Address Translation
NCCoE	National Cybersecurity Center of Excellence
NIST	National Institute of Standards and Technology
NTP	Network Time Protocol
OU	Organizational Unit
OVA	Open Virtualization Appliance
PLIST	Property List

DRAFT

SCEP	Simple Certificate Enrollment Protocol
SSH	Secure Shell
SSID	Service Set Identifier
SSL	Secure Sockets Layer
TLS	Transport Layer Security
URL	Uniform Resource Locator
USB	Universal Serial Bus
VLAN	Virtual Local Area Network
VPN	Virtual Private Network
WAN	Wide Area Network

Appendix B Glossary

Application Programming Interface (API)	A system access point or library function that has a well-defined syntax and is accessible from application programs or user code to provide well-defined functionality [1]
App-Vetting Process	The process of verifying that an app meets an organization's security requirements. An app vetting process comprises app testing and app approval/rejection activities [2]
Authenticate	Verifying the identity of a user, process, or device, often as a prerequisite to allowing access to resources in an information system [3]
Certificate	A data structure that contains an entity's identifier(s), the entity's public key (including an indication of the associated set of domain parameters) and possibly other information, along with a signature on that data set that is generated by a trusted party, i.e. a certificate authority, thereby binding the public key to the included identifier(s) [4]
Certificate Authority (CA)	A trusted entity that issues and revokes public key certificates [5]
Demilitarized Zone (DMZ)	An interface on a routing firewall that is similar to the interfaces found on the firewall's protected side. Traffic moving between the DMZ and other interfaces on the protected side of the firewall still goes through the firewall and can have firewall protection policies applied. [6]
Derived Personal Identity Verification (PIV)	A credential issued based on proof of possession and control of the PIV Card, so as not to duplicate the identity proofing process as defined in [SP 800-63-2]. A Derived PIV Credential token is a hardware or software-based token that contains the Derived PIV Credential. [7]
Hypertext Transfer Protocol (HTTP)	A standard method for communication between clients and Web servers [8]
Hypertext Transfer Protocol Secure (HTTPS)	HTTP transmitted over TLS [9]
Internet Protocol (IP) addresses	Standard protocol for transmission of data from source to destinations in packet-switched communications networks and interconnected systems of such networks [10]

Lightweight Directory Access Protocol (LDAP)	The Lightweight Directory Access Protocol, or LDAP, is a directory access protocol. In this document, LDAP refers to the protocol defined by RFC 1777, which is also known as LDAP V2. LDAP V2 describes unauthenticated retrieval mechanisms. [11]
Local Area Network (LAN)	A group of computers and other devices dispersed over a relatively limited area and connected by a communications link that enables any device to interact with any other on the network [12]
Mutual Authentication	The process of both entities involved in a transaction verifying each other [13]
Passphrase	A passphrase is a memorized secret consisting of a sequence of words or other text that a claimant uses to authenticate their identity. A passphrase is similar to a password in usage, but is generally longer for added security. [14]
Personal Identity Verification (PIV)	A physical artifact (e.g., identity card, “smart” card) issued to a government individual that contains stored identity credentials (e.g., photograph, cryptographic keys, digitized fingerprint representation) so that the claimed identity of the cardholder can be verified against the stored credentials by another person (human readable and verifiable) or an automated process (computer readable and verifiable). PIV requirements are defined in FIPS PUB 201. [15]
Risk Analysis	The process of identifying the risks to system security and determining the probability of occurrence, the resulting impact, and the additional safeguards that mitigate this impact. Part of risk management and synonymous with risk assessment. [16]
Risk Assessment	The process of identifying risks to organizational operations (including mission, functions, image, reputation), organizational assets, individuals, other organizations, and the Nation, resulting from the operation of an information system. [17]
Root Certificate Authority (CA)	In a hierarchical public key infrastructure (PKI), the certification authority (CA) whose public key serves as the most trusted datum (i.e., the beginning of trust paths) for a security domain [18]

Appendix C References

- [1] National Institute of Standards and Technology (NIST). Information Technology Laboratory (ITL) Glossary, "Application Programming Interface Definition," [Online]. Available: <https://csrc.nist.gov/glossary/term/Application-Programming-Interface>. [Accessed 1 May 2019].
- [2] NIST. ITL Glossary, "Application Programming Interface Definition," [Online]. Available: <https://csrc.nist.gov/glossary/term/App-Vetting-Process>. [Accessed 1 May 2019].
- [3] NIST. ITL Glossary, "Authenticate Definition," [Online]. Available: <https://csrc.nist.gov/glossary/term/authenticate>. [Accessed 1 May 2019].
- [4] NIST. ITL Glossary, "Certificate Definition," [Online]. Available: <https://csrc.nist.gov/glossary/term/certificate>. [Accessed 1 May 2019].
- [5] NIST. ITL Glossary, "Certificate Authority (CA) Definition," [Online]. Available: <https://csrc.nist.gov/glossary/term/Certificate-Authority>. [Accessed 1 May 2019].
- [6] NIST. ITL Glossary, "Demilitarized Zone (DMZ) Definition," [Online]. Available: <https://csrc.nist.gov/glossary/term/demilitarized-zone>. [Accessed 1 May 2019].
- [7] NIST. ITL Glossary, "Derived Personal Identity Verification (PIV) Credential Definition," [Online]. Available: <https://csrc.nist.gov/glossary/term/Derived-PIV-Credential>. [Accessed 1 May 2019].
- [8] NIST. ITL Glossary, "Hypertext Transfer Protocol (HTTP) Definition," [Online]. Available: <https://csrc.nist.gov/glossary/term/HTTP>. [Accessed 1 May 2019].
- [9] NIST. ITL Glossary, "Hypertext Transfer Protocol over Transport Layer Security Definition," [Online]. Available: <https://csrc.nist.gov/glossary/term/Hypertext-Transfer-Protocol-over-Transport-Layer-Security>. [Accessed 1 May 2019].
- [10] NIST. ITL Glossary, "Internet Protocol (IP) Definition," [Online]. Available: <https://csrc.nist.gov/glossary/term/internet-protocol>. [Accessed 1 May 2019].
- [11] NIST. ITL Glossary, "Lightweight Directory Access Protocol Definition," [Online]. Available: <https://csrc.nist.gov/glossary/term/Lightweight-Directory-Access-Protocol>. [Accessed 1 May 2019].

- [12] NIST. ITL Glossary, "Local Area Network (LAN) Definition," [Online]. Available: <https://csrc.nist.gov/glossary/term/Local-Area-Network>. [Accessed 1 May 2019].
- [13] NIST. ITL Glossary, "Mutual Authentication Definition," [Online]. Available: <https://csrc.nist.gov/glossary/term/mutual-authentication>. [Accessed 1 May 2019].
- [14] NIST. ITL Glossary, "Passphrase Definition," [Online]. Available: <https://csrc.nist.gov/glossary/term/Passphrase>. [Accessed 1 May 2019].
- [15] NIST. ITL Glossary, "Personal Identity Verification (PIV)," [Online]. Available: <https://csrc.nist.gov/glossary/term/personal-identity-verification>. [Accessed 1 May 2019].
- [16] NIST. ITL Glossary, "Risk Analysis," [Online]. Available: <https://csrc.nist.gov/glossary/term/risk-analysis>. [Accessed 1 May 2019].
- [17] NIST. "NIST Special Publication 800-39, Managing Information Security Risk," March 2011. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-39.pdf>. [Accessed 1 May 2019].
- [18] NIST. "NIST Special Publication 800-32, Introduction to Public Key Technology and the Federal PKI Infrastructure," February 2001. [Online]. Available: <https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-32.pdf>. [Accessed 1 May 2019].