

## NIST SPECIAL PUBLICATION 1800-22

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# Mobile Device Security:

## Bring Your Own Device (BYOD)

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Includes Executive Summary (A); Approach, Architecture, and Security Characteristics (B); Example Scenario: Putting Guidance into Practice (Supplement); and How-To Guides (C)

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

DRAFT

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<https://www.nccoe.nist.gov/projects/building-blocks/mobile-device-security/bring-your-own-device>



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DRAFT

March 2021



U.S. Department of Commerce  
*Gina M. Raimondo, Secretary*

National Institute of Standards and Technology  
*James K. Olthoff, Acting NIST Director and Acting Under Secretary of Commerce for Standards and Technology*

## NIST SPECIAL PUBLICATION 1800-22A

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# Mobile Device Security:

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### Volume A: Executive Summary

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# 1 Executive Summary

2 Many organizations now provide employees the flexibility to use their personal mobile devices to  
3 perform work-related activities. An ineffectively secured personal mobile device could expose an  
4 organization or employee to data loss or a privacy compromise. Ensuring that an organization's data is  
5 protected when it is accessed from personal devices poses unique challenges and threats.  
6 Allowing employees to use their personal mobile devices for work-related activities is commonly known  
7 as a bring your own device (BYOD) deployment. A BYOD deployment offers a convenient way to  
8 remotely access organizational resources, while avoiding the alternative of carrying both a work phone  
9 and personal phone. This NIST Cybersecurity Practice Guide demonstrates how organizations can use  
10 standards-based, commercially available products to help meet their BYOD security and privacy needs.

## 11 CHALLENGE

12 BYOD devices can be used interchangeably for  
13 work and personal purposes throughout the day.  
14 While flexible and convenient, BYOD can introduce  
15 challenges to an enterprise. These challenges can  
16 include additional responsibilities and complexity  
17 for information technology (IT) departments  
18 caused by supporting many types of personal mobile devices used by the employees, enterprise security  
19 threats arising from unprotected personal devices, as well as challenges protecting the privacy of  
20 employees and their personal data stored on their mobile devices.

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**An ineffectively secured personal mobile device could expose an organization or employee to data loss or a privacy compromise**

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## 21 SOLUTION

22 The National Cybersecurity Center of Excellence (NCCoE) collaborated with the mobile device  
23 community and cybersecurity technology providers to build a simulated BYOD environment. Using  
24 commercially available products, the example solution's technologies and methodologies can enhance  
25 the security posture of the adopting organization and help protect employee privacy and organizational  
26 information assets.

### This practice guide can help your organization:

- **protect data** from being accessed by unauthorized persons when a device is stolen or misplaced
- **reduce risk to employees** through enhanced privacy protections
- **improve the security of mobile devices and applications** by deploying mobile device technologies
- **reduce risks to organizational data** by separating personal and work-related information from each other
- **enhance visibility** into mobile device health to facilitate identification of device and data compromise, and permit efficient user notification
- **leverage industry best practices** to enhance mobile device security and privacy

27 The example solution uses technologies and security capabilities (shown below) from our project  
 28 collaborators. The technologies used in the solution support security and privacy standards and  
 29 guidelines including the NIST Cybersecurity Framework and NIST Privacy Framework, among others.  
 30 Both iOS and Android devices are supported by this guide's example solution.

Collaborator	Security Capability or Component
	Mobile Device Management that provisions configuration profiles to mobile devices, enforces security policies, and monitors policy compliance
	Application Vetting to determine if an application demonstrates behaviors that could pose a security or privacy risk
	Firewall and Virtual Private Network that controls network traffic and provides encrypted communication channels between mobile devices and other hosts
	Trusted Execution Environment that helps protect mobile devices from computer code with integrity issues
	Mobile Threat Defense detects unwanted activity and informs the device owner and BYOD administrators to prevent or limit harm that an attacker could cause

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

## 37 HOW TO USE THIS GUIDE

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

39 **Business decision makers, including chief information security and technology officers** can use this  
 40 part of the guide, *NIST SP 1800-22a: Executive Summary*, to understand the impetus for the guide, the  
 41 cybersecurity challenge we address, our approach to solving this challenge, and how the solution could  
 42 benefit your organization.

43 **Technology, security, and privacy program managers** who are concerned with how to identify,  
 44 understand, assess, and mitigate risk can use the following:

- 45 • *NIST SP 1800-22b: Approach, Architecture, and Security Characteristics*, which describes what  
 46 we built and why, the risk analysis performed, and the security/privacy control mappings.

- 47        • *NIST SP 1800-22 Supplement: Example Scenario: Putting Guidance into Practice*, which provides  
48            an example of a fictional company using this practice guide and other NIST guidance to  
49            implement a BYOD deployment with their security and privacy requirements.

50        **IT professionals** who want to implement an approach like this can make use of *NIST SP 1800-22c: How-  
51            To Guides*, which provides specific product installation, configuration, and integration instructions for  
52            building the example implementation, allowing you to replicate all or parts of this project.

## 53        SHARE YOUR FEEDBACK

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

60        To provide comments or to learn more by arranging a demonstration of this example implementation,  
61            contact the NCCoE at [mobile-nccoe@nist.gov](mailto:mobile-nccoe@nist.gov).

---

## 62        COLLABORATORS

64        Collaborators participating in this project submitted their capabilities in response to an open call in the  
65            Federal Register for all sources of relevant security capabilities from academia and industry (vendors  
66            and integrators). Those respondents with relevant capabilities or product components signed a  
67            Cooperative Research and Development Agreement (CRADA) to collaborate with NIST in a consortium to  
68            build this example solution.

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

## NIST SPECIAL PUBLICATION 1800-22B

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# Mobile Device Security: Bring Your Own Device (BYOD)

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**Volume B:**  
**Approach, Architecture, and Security Characteristics**

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## 1 DISCLAIMER

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

7 National Institute of Standards and Technology Special Publication 1800-22B Natl. Inst. Stand. Technol.  
8 Spec. Publ. 1800-22B, 121 pages, (March 2021), CODEN: NSPUE2

## 9 FEEDBACK

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

12 Comments on this publication may be submitted to: [mobile-nccoe@nist.gov](mailto:mobile-nccoe@nist.gov).

13 Public comment period: March 18, 2021 through May 03, 2021

14 All comments are subject to release under the Freedom of Information Act (FOIA).

## 21 **NATIONAL CYBERSECURITY CENTER OF EXCELLENCE**

22 The National Cybersecurity Center of Excellence (NCCoE), a part of the National Institute of Standards  
23 and Technology (NIST), is a collaborative hub where industry organizations, government agencies, and  
24 academic institutions work together to address businesses' most pressing cybersecurity issues. This  
25 public-private partnership enables the creation of practical cybersecurity solutions for specific  
26 industries, as well as for broad, cross-sector technology challenges. Through consortia under  
27 Cooperative Research and Development Agreements (CRADAs), including technology partners—from  
28 Fortune 50 market leaders to smaller companies specializing in information technology security—the  
29 NCCoE applies standards and best practices to develop modular, easily adaptable example cybersecurity  
30 solutions using commercially available technology. The NCCoE documents these example solutions in  
31 the NIST Special Publication 1800 series, which maps capabilities to the NIST Cyber Security Framework  
32 and details the steps needed for another entity to recreate the example solution. The NCCoE was  
33 established in 2012 by NIST in partnership with the State of Maryland and Montgomery County, Md.

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

## 36 **NIST CYBERSECURITY PRACTICE GUIDES**

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

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

## 46 **ABSTRACT**

47 Bring Your Own Device (BYOD) refers to the practice of performing work-related activities on personally  
48 owned devices. This practice guide provides an example solution demonstrating how to enhance  
49 security and privacy in Android and Apple smartphone BYOD deployments.

50 Incorporating BYOD capabilities into an organization can provide greater flexibility in how employees  
51 work and increase the opportunities and methods available to access organizational resources. For some  
52 organizations, the combination of traditional in-office processes with mobile device technologies  
53 enables portable communication approaches and adaptive workflows. For others, it fosters a mobile-  
54 first approach in which their employees communicate and collaborate primarily using their mobile  
55 devices.

- 56 However, some of the features that make BYOD mobile devices increasingly flexible and functional also  
57 present unique security and privacy challenges to both work organizations and device owners. The  
58 unique nature of these challenges is driven by the diverse range of devices available that vary in type,  
59 age, operating system (OS), and the level of risk posed.
- 60 Enabling BYOD capabilities in the enterprise introduces new cybersecurity risks to organizations.  
61 Solutions that are designed to secure corporate devices and on-premises data do not provide an  
62 effective cybersecurity solution for BYOD. Finding an effective solution can be challenging due to the  
63 unique risks that BYOD deployments impose. Additionally, enabling BYOD capabilities introduces new  
64 privacy risks to employees by providing their employer a degree of access to their personal devices,  
65 opening up the possibility of observation and control that would not otherwise exist.
- 66 To help organizations benefit from BYOD's flexibility while protecting themselves from many of its  
67 critical security and privacy challenges, this Practice Guide provides an example solution using  
68 standards-based, commercially available products and step-by-step implementation guidance.

## 69 **KEYWORDS**

70 *Bring your own device; BYOD; mobile device management; mobile device security.*

## 71 **ACKNOWLEDGMENTS**

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

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

Technology Partner/Collaborator	Build Involvement
<a href="#">IBM</a>	Mobile Device Management
<a href="#">Kryptowire</a>	Application Vetting
<a href="#">Palo Alto Networks</a>	Firewall; Virtual Private Network
<a href="#">Qualcomm</a>	Trusted Execution Environment
<a href="#">Zimperium</a>	Mobile Threat Defense

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## 254 1 Summary

255 This section familiarizes the reader with

- 256     ■ Bring Your Own Device (BYOD) concepts  
257     ■ Challenges, solutions, and benefits related to BYOD deployments

258 BYOD refers to the practice of performing work-related activities on personally owned devices. This  
259 practice guide provides an example solution demonstrating how to enhance security and privacy in  
260 Android and Apple mobile phone BYOD deployments.

261 Incorporating BYOD capabilities in an organization can provide greater flexibility in how employees work  
262 and can increase the opportunities and methods available to access organizational resources. For some  
263 organizations, the combination of in-office processes with mobile device technologies enables portable  
264 communication approaches and adaptive workflows. Other organizations may adopt a mobile-first  
265 approach in which their employees communicate and collaborate primarily using their mobile devices.

266 Extending mobile device use by enabling BYOD capabilities in the enterprise can introduce new  
267 information technology (IT) risks to organizations. Solutions that are designed to help secure corporate  
268 devices and the data located on those corporate devices do not always provide an effective  
269 cybersecurity solution for BYOD.

270 Deploying effective solutions can be challenging due to the unique risks that BYOD deployments impose.  
271 Some of the features that make personal mobile devices increasingly flexible and functional also present  
272 unique security and privacy challenges to both employers and device owners.

273 Additionally, enabling BYOD capabilities can introduce new privacy risks to employees by providing their  
274 employer a degree of access to their personal devices, opening the possibility of mobile device  
275 observation and control that would not otherwise exist.

276 This practice guide helps organizations deploy BYOD capabilities by providing an example solution that  
277 helps address BYOD challenges, solutions, and benefits. In this practice guide, the term mobile phone is  
278 used to describe an Apple iOS or Android mobile telephone device. Additionally, this practice guide's  
279 scope for BYOD does not include the deployment of laptops or devices similar to laptops.

### 280 1.1 Challenge

281 Many organizations now authorize employees to use their personal mobile devices to perform work-  
282 related activities. This provides employees with increased flexibility to access organizational information  
283 resources. However, BYOD architectures can also introduce vulnerabilities in the enterprise's IT  
284 infrastructure because personally owned mobile devices are typically unmanaged and may lack mobile  
285 device security protections. Unmanaged devices are at greater risk of unauthorized access to sensitive  
286 information, email phishing, eavesdropping, misuse of device sensors, or compromise of organizational  
287 data due to lost devices to name but a few risks.

288 BYOD deployment challenges can include:

289 **Supporting a broad ecosystem of mobile devices**

- 290     ■ with diverse technologies that rapidly evolve and vary in manufacturer, operating system (OS),  
291       and age of the device
- 292     ■ where each device has unique security and privacy requirements and capabilities
- 293     ■ whose variety can present interoperability issues that might affect organizational integration

294 **Reducing organizational risk and threats to the enterprise's sensitive information**

- 295     ■ posed by applications like games that may not usually be installed on devices issued by an  
296       organization
- 297     ■ that result from lost, stolen, or sold mobile devices that still contain or have access to  
298       organizational data
- 299     ■ created by a user who shares their personally owned device with friends and family members  
300       when that personally owned device may also be used for work activities
- 301     ■ due to personally owned mobile devices being taken to places that increase the risk of loss of  
302       control for the device
- 303     ■ that result from malicious applications compromising the device and subsequently the data to  
304       which the device has access
- 305     ■ produced by network-based attacks that can traverse a device's always-on connection to the  
306       internet
- 307     ■ caused by phishing attempts that try to collect user credentials or entice a user to install  
308       malicious software

309 **Protecting the privacy of employees**

- 310     ■ by helping to keep their personal photos, documents, and other data private and inaccessible to  
311       others (including the organization)
- 312     ■ by helping to ensure separation between their work and personal data while simultaneously  
313       meeting the organization's objectives for business functions, usability, security, and employee  
314       privacy
- 315     ■ by providing them with concise and understandable information about what data is collected  
316       and what actions are allowed and disallowed on their devices

317 **Clearly communicating BYOD concepts**

- 318     ■ among an organization's information technology team so it can develop the architecture to  
319       address BYOD's unique security and privacy concerns while using a repeatable, standardized,  
320       and clearly communicated risk framework language
- 321     ■ to organizational leadership and employees to obtain support in deploying BYOD

- 322     ▪ related to mobile device security technologies so that the organization can consistently plan for  
323       and implement the protection capabilities of their security tools

324     Given these challenges, it can be complex to manage the security and privacy aspects of personally  
325       owned mobile devices that access organizational information assets. This document provides an  
326       example solution to help organizations address these challenges.

## 327     **1.2 Solution**

328     To help organizations benefit from BYOD's flexibility while protecting themselves from many of its  
329       critical security and privacy challenges, this National Institute of Standards and Technology (NIST)  
330       Cybersecurity Practice Guide provides an example solution using standards-based, commercially  
331       available products and step-by-step implementation guidance.

332     In our lab at the National Cybersecurity Center of Excellence (NCCoE), engineers built an environment  
333       that contains an example solution for managing the security and privacy of BYOD deployments. In this  
334       guide, we show how an enterprise can leverage the concepts presented in this example solution to  
335       implement enterprise mobility management (EMM), mobile threat defense (MTD), application vetting, a  
336       trusted execution environment (TEE) supporting secure boot/image authentication, and virtual private  
337       network (VPN) services to support a BYOD solution.

338     We configured these technologies to protect organizational assets and employee privacy and provide  
339       methodologies to enhance the data protection posture of the adopting organization. The standards and  
340       best practices on which this example solution is based help ensure the confidentiality, integrity, and  
341       availability of enterprise data on BYOD Android and Apple mobile phones as well as the predictability,  
342       manageability, and disassociability of employee's data.

### 343     **The example solution in this practice guide helps**

- 344     ▪ detect and protect against installing mobile malware, phishing attempts, and network-based  
345       attacks
- 346     ▪ enforce passcode usage
- 347     ▪ protect organizational data by enabling selective device wipe capability of organizational data  
348       and applications
- 349     ▪ protect against organizational data loss by restricting an employee's ability to copy and paste,  
350       perform a screen capture, or store organizational data in unapproved locations
- 351     ▪ organizations view BYOD risks and remediate threats (e.g., risks from jailbroken or rooted  
352       devices)
- 353     ▪ provide users with access to protected business resources (e.g., SharePoint, knowledge base,  
354       internal wikis, application data)
- 355     ▪ support executed code authenticity, runtime state integrity, and persistent memory data  
356       confidentiality
- 357     ▪ protect data from eavesdropping while traversing a network

- 358     ▪ vet the security of mobile applications used for work-related activities  
359     ▪ organizations implement settings to protect employee privacy  
360     ▪ an organization deploy its own BYOD solution by providing a series of how-to guides—step-by-  
361       step instructions covering the initial setup (installation or provisioning) and configuration for  
362       each component of the architecture—to help security and privacy engineers rapidly deploy and  
363       evaluate a mobile device solution in their test environment

364 Commercial, standards-based products such as the ones used in this practice guide are readily available  
365 and interoperable with existing IT infrastructure and investments. Organizations can use this guidance in  
366 whole or in part to help understand and mitigate common BYOD security and privacy challenges.

### 367 **1.2.1 Standards and Guidance**

368 This guide leverages many standards and guidance, including the NIST *Framework for Improving Critical  
369 Infrastructure Cybersecurity*, Version 1.1 (Cybersecurity Framework) [1], the *NIST Privacy Framework: A  
370 Tool For Improving Privacy Through Enterprise Risk Management*, Version 1.0 (Privacy Framework) [2],  
371 NIST Special Publication (SP) 800-181 *National Initiative for Cybersecurity Education (NICE) Cybersecurity  
372 Workforce Framework (2017)* [3], the NIST Risk Management Framework [4], and the NIST Mobile  
373 Threat Catalogue [5]. For additional information, see [Appendix D](#), Standards and Guidance.

## 374 **1.3 Benefits**

375 Carrying two mobile devices, one for work and one for personal use, introduces inconveniences and  
376 disadvantages that some organizations and employees are looking to avoid. Recognizing that BYOD is  
377 being adopted, the NCCoE worked to provide organizations with guidance for improving the security and  
378 privacy of these solutions.

### 379 **For organizations, the potential benefits of this example solution include**

- 380     ▪ enhanced protection against both malicious applications and loss of data if a device is stolen or  
381       misplaced  
382     ▪ reduced adverse effects if a device is compromised  
383     ▪ visibility for system administrators into mobile security compliance, enabling automated  
384       identification and notification of a compromised device  
385     ▪ a vendor-agnostic, modular architecture based on technology roles  
386     ▪ demonstrated enhanced security options for mobile access to organizational resources such as  
387       intranet, email, contacts, and calendar

### 388 **For employees, the potential benefits of this example solution include**

- 389     ▪ safeguards to help protect their privacy  
390     ▪ better protected personal devices by screening work applications for malicious capability before  
391       installing them

- 392       ■ enhanced understanding about how their personal device will integrate with their organization  
393           through a standardized BYOD deployment

## 394       2 How to Use This Guide

395       This section familiarizes the reader with

- 396       ■ this practice guide's content  
397       ■ the suggested audience for each volume  
398       ■ typographic conventions used in this volume

399       This NIST Cybersecurity Practice Guide demonstrates a standards-based reference design and provides  
400       users with the information they need to replicate this BYOD example solution. This reference design is  
401       modular and can be deployed in whole or in part.

402       This guide contains four volumes:

- 403       ■ NIST SP 1800-22A: *Executive Summary* – high-level overview of the challenge, example solution,  
404           and benefits of the practice guide  
405       ■ NIST SP 1800-22B: *Approach, Architecture, and Security Characteristics* – what we built and why  
406           (you are here)  
407       ■ NIST SP 1800-22 Supplement: *Example Scenario: Putting Guidance into Practice* – how  
408           organizations can implement this example solution's guidance  
409       ■ NIST SP 1800-22C: *How-To Guides* – instructions for building the example solution

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

411       **Business decision makers, including chief security, privacy, and technology officers**, will be interested  
412       in the *Executive Summary*, *NIST SP 1800-22A*, which describes the following topics:

- 413       ■ challenges that enterprises face in securing BYOD deployments  
414       ■ example solution built at the NCCoE  
415       ■ benefits of adopting the example solution

416       **Technology, security, or privacy program managers** who are concerned with how to identify,  
417       understand, assess, and mitigate risk will be interested in this part of the guide, *NIST SP 1800-22B*, which  
418       describes what we did and why. The following sections will be of particular interest:

- 419       ■ [Appendix G](#), Example Security Subcategory and Control Map, maps the security characteristics  
420           of this example solution to cybersecurity standards and best practices.  
421       ■ [Appendix H](#), Example Privacy Subcategory and Control Map, describes how the privacy control  
422           map identifies the privacy characteristic standards mapping for the products as they were used  
423           in the example solution.

424 You might share the *Executive Summary*, *NIST SP 1800-22A*, with your leadership team members to help  
425 them understand the importance of adopting standards-based BYOD deployments.

426 **IT professionals** who want to implement an approach like this will find the whole practice guide useful.  
427 You can use the how-to portion of the guide, *NIST SP 1800-22C*, to replicate all or parts of the build  
428 created in our lab. The how-to portion of the guide provides specific product installation, configuration,  
429 and integration instructions for implementing the example solution. We do not re-create the product  
430 manufacturers' documentation, which is generally widely available. Rather, we show how we  
431 incorporated the products together in our environment to create an example solution.

432 This guide assumes that IT professionals have experience implementing security products within the  
433 enterprise. While we have used a suite of commercial products to address this challenge, this guide does  
434 not endorse these particular products. Your organization can adopt this solution or one that adheres to  
435 these guidelines in whole, or you can use this guide as a starting point for tailoring and implementing  
436 parts of this guide's example solution for BYOD security management. Your organization's security  
437 experts should identify the products that will effectively address the BYOD risks identified for your  
438 organization and best integrate with your existing tools and IT system infrastructure. We hope that you  
439 will seek products that are congruent with applicable standards and best practices. Section 4.3,  
440 Technologies that Support the Security and Privacy Goals of the Example Solution, lists the products we  
441 used and maps them to the cybersecurity controls provided by this reference solution.

442 **For those who would like to see how the example solution can be implemented**, this practice guide  
443 contains an example scenario about a fictional company called Great Seneca Accounting. The example  
444 scenario shows how BYOD objectives can align with an organization's priority security and privacy  
445 capabilities through NIST risk management standards, guidance, and tools. It is provided in this practice  
446 guide's supplement, *Example Scenario: Putting Guidance into Practice*.

- 447     ■ [Appendix F](#) of the Supplement, describes the risk analysis we performed, using an example  
448         scenario.
- 449     ■ [Appendix G](#) of the Supplement, describes how to conduct a privacy risk assessment and use it to  
450         improve mobile device architectures, using an example scenario.

451 A NIST Cybersecurity Practice Guide does not describe "the" solution, but a possible solution. This is a  
452 draft guide. We seek feedback on its contents and welcome your input. Comments, suggestions, and  
453 success stories will improve subsequent versions of this guide. Please contribute your thoughts to  
454 [mobile-nccoe@nist.gov](mailto:mobile-nccoe@nist.gov).

455 Acronyms used in figures can be found in the Acronyms Appendix.

## 456 [2.1 Typographic Conventions](#)

457 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 language use and style guidance, see the <i>NCCoE Style Guide</i> .
<b>Bold</b>	names of menus, options, command buttons, and fields	Choose <b>File &gt; Edit</b> .
Monospace	command-line input, onscreen computer output, sample code examples, and status codes	<code>Mkdir</code>
<b>Monospace Bold</b>	command-line user input contrasted with computer output	<b>service sshd start</b>
<a href="#">blue text</a>	link to other parts of the document, a web URL, or an email address	All publications from NIST's NCCoE are available at <a href="https://www.nccoe.nist.gov">https://www.nccoe.nist.gov</a> .

## 458 3 Approach

459 This section familiarizes the reader with

- 460     ▪ this guide's intended audience, scope, and assumptions  
 461     ▪ mobile device security and privacy risk assessments

462 To identify the cybersecurity challenges associated with deploying a BYOD solution, the team surveyed  
 463 reports of mobile device security trends and invited the mobile device security community to engage in  
 464 a discussion about pressing cybersecurity challenges.

465 Two broad and significant themes emerged from this research:

- 466     ▪ Administrators wanted to better understand what policies and standards should be  
 467 implemented.  
 468     ▪ Employees were concerned about the degree to which enterprises have control over their  
 469 personally owned mobile devices and might have visibility into the personal activity that takes  
 470 place on them.

471 The team addressed these two challenges by reviewing the primary standards, best practices, and  
 472 guidelines contained within [Appendix D, Standards and Guidance](#).

### 473 3.1 Audience

474 This practice guide is intended for organizations that want to adopt a BYOD architecture that enables  
 475 use of personal mobile phones and tablets. The target audience is executives, security managers, privacy  
 476 managers, engineers, administrators, and others who are responsible for acquiring, implementing,

477 communicating with users about, or maintaining mobile enterprise technology. This technology can  
478 include centralized device management, secure device/application security contexts, application vetting,  
479 and endpoint protection systems.

480 This document will interest system architects already managing mobile device deployments and those  
481 looking to integrate a BYOD architecture into existing organizational wireless systems. It assumes that  
482 readers have a basic understanding of mobile device technologies and enterprise security and privacy  
483 principles. Please refer to Section 2 for how different audiences can effectively use this guide.

### 484 **3.2 Scope**

485 The scope of this build includes managing Apple or Android mobile phones and tablets deployed in a  
486 BYOD configuration with cloud-based EMM. We excluded laptops and mobile devices with minimal  
487 computing capability, including feature phones, and wearables. We also do not address classified  
488 systems, devices, data, and applications within this publication.

489 While this document is primarily about mobile device security for BYOD implementations, BYOD  
490 introduces privacy risk to the organization and its employees who participate in the BYOD program.  
491 Therefore, the NCCoE found addressing privacy risk to be a necessary part of developing the BYOD  
492 architecture. The scope of privacy in this build is limited to those employees who use their devices as  
493 part of their organization's BYOD solution. The build does not explicitly address privacy considerations of  
494 other individuals whose information is processed by the organization through an employee's personal  
495 device.

496 We intend for the example solution proposed in this practice guide to be broadly applicable to  
497 enterprises, including both the public and private sectors.

### 498 **3.3 Assumptions**

500 This project is guided by the following assumptions:

- 501     ■ The example solution was developed in a lab environment. While the environment is based on a  
502         typical organization's IT enterprise, the example solution does not reflect the complexity of a  
503         production environment.
- 504     ■ The organization has access to the skills and resources required to implement a mobile device  
505         security and privacy solution.
- 506     ■ The example security and privacy control mappings provided as part of this practice guide are  
507         focused on mobile device needs, and do not include general control mappings that would also  
508         typically be used in an enterprise. Those general control mappings that do not specifically apply  
509         to this guide's mobile device security example solution are outside the scope of this guide's  
510         example solution.
- 511     ■ Because the organizational environment in which this build could be implemented represents a  
512         greater level of complexity than is captured in the current guide, we assume that organizations

512        will first examine the implications for their current environment before implementing any part  
513        of the proposed example solution.

- 514        ▪ The organization has either already invested or is willing to invest in the security of mobile  
515        devices used within it and in the privacy of participating employees, and in the organization's IT  
516        systems more broadly. As such, we assume that the organization either has the technology in  
517        place to support this implementation or has access to the off-the shelf technology used in this  
518        build, which we assume will perform as described by the respective product vendor.
- 519        ▪ The organization has familiarized itself with existing standards and any associated guidelines  
520        (e.g., NIST Cybersecurity Framework [1]; *NIST Privacy Framework* [2]; NIST SP 800-124 Revision 2  
521        (Draft), *Guidelines for Managing the Security of Mobile Devices in the Enterprise* [6]; NIST SP  
522        1800-4 *Mobile Device Security: Cloud and Hybrid Builds* [7]) relevant to implementation of the  
523        example solution proposed in this practice guide. We also assume that any existing technology  
524        used in the example solution has been implemented in a manner consistent with these  
525        standards.
- 526        ▪ The organization has instituted relevant mobile device security and privacy policies, and these  
527        will be updated based on implementation of this example solution.
- 528        ▪ The organization will provide guidance and training to its employees regarding BYOD usage and  
529        how to report device loss or suspected security issues in which their devices are involved. This  
530        guidance will be periodically reviewed and updated, and employees will be regularly trained on  
531        BYOD usage.

### 532        3.4 Risk Assessment

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

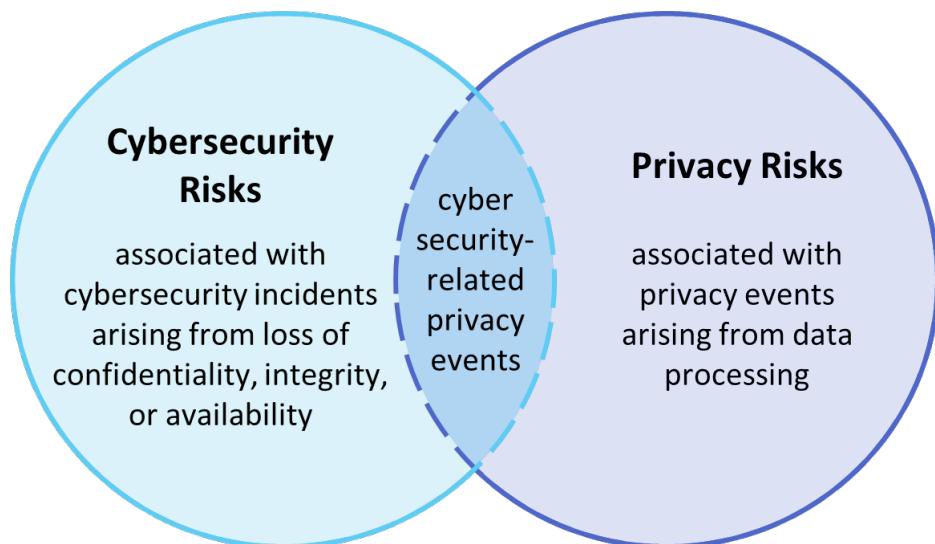
541        The NCCoE recommends that any discussion of risk management, particularly at the enterprise level,  
542        begins with a comprehensive review of [NIST SP 800-37 Revision 2, Risk Management Framework for](#)  
543        [Information Systems and Organizations](#)—material that is available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

546        We identified the security and privacy risks for this BYOD example solution by examining the  
547        relationship of risk between cybersecurity and privacy. Cybersecurity and privacy are two distinct risk  
548        areas, though the two intersect in significant ways. As noted in Section 1.2.1 of the *NIST Privacy*  
549        *Framework* [2], having a general understanding of the different origins of cybersecurity and privacy risks  
550        is important for determining the most effective solutions to address the risks. [Figure 3-1](#) illustrates this

551 relationship, showing that some privacy risks arise from cybersecurity risks, and some are unrelated to  
552 cybersecurity risks. Allowing an unauthorized device to connect to the organization's network through  
553 its BYOD implementation is an example of a security risk that may not impact privacy.

554 An example of a security risk that may also be considered a privacy risk is an employer having increased  
555 access to an employee's personal use applications such as personal contacts and personal calendars on  
556 their device. An example of a privacy risk that is not driven by a security risk is a BYOD implementation  
557 being used to track employee location, which may reveal information about the places they visit.

558 **Figure 3-1 Cybersecurity and Privacy Risk Relationship**



559  
560 The security capabilities in this build help address some of the privacy risks that arise for employees.  
561 This build also uses the *NIST Privacy Framework* [2] and Privacy Risk Assessment Methodology (PRAM)  
562 [8] to identify and address privacy risks that are beyond the scope of security risks. Regardless of  
563 whether cybersecurity and privacy are situated in the same part of the organization or in different parts,  
564 the two capabilities must work closely together to address BYOD risks.

565 A risk assessment can include additional analysis areas. For more information on the example solution's:

- 566     ▪ **Security and privacy threats**, and **goals to remediate those threats**, see Section 4.1
- 567     ▪ **Vulnerabilities** that influenced the reference architecture, see Appendix Section F-5 of the  
568         Supplement
- 569     ▪ **Risks** that influenced the architecture development, see Appendix Section F-6 of the  
570         Supplement
- 571     ▪ **Security Control Mapping** to cybersecurity and privacy standards and best practices, see  
572         Appendix G and Appendix H

## 573 **4 Architecture**

574 This section helps familiarize the reader with

- 575       ■ threats to BYOD architectures  
576       ■ example solution goals to remediate threats to BYOD architectures  
577       ■ how organizations might leverage the *Example Scenario: Putting Guidance into Practice*  
578       supplement of this practice guide to implement their mobile device solution  
579       ■ technologies to support the example solution goals  
580       ■ the example solution's architecture  
581       ■ how the example solution's products were integrated  
582       ■ mobile device data collection

## 583 **4.1 Understanding Common BYOD Architecture Threats and the Example 584       Solution's Goals to Remediate Those Threats**

585 This section contains examples of common security and privacy concerns in BYOD architectures. We  
586 provide a list of goals to address those challenges. Once completed, the architecture provides  
587 organizations with a security and privacy-enhanced design for their mobile devices. The example  
588 solution's challenges and goals are highlighted below, followed by the architecture that supports those  
589 goals.

### 590 **4.1.1 Threat Events**

591 Leveraging a system life cycle approach [9], this build considered threats relating to BYOD deployments.  
592 Information from the Open Web Application Security Project Mobile Top 10 [10], which provides a  
593 consolidated list of mobile application risks, and information from the NIST Mobile Threat Catalogue [5],  
594 which examines the mobile information system threats in the broader mobile ecosystem were used to  
595 develop applicable threats. Table 4-1 gives each threat an identifier for the purposes of this build, a  
596 description of each threat event (TE), and the related NIST Mobile Threat Catalogue Threat identifiers  
597 (IDs).

598 We limited inclusion of threat events to those that we generally expected to have a high likelihood of  
599 occurrence and high potential for adverse impact. Organizations applying this build should evaluate the  
600 NIST Mobile Threat Catalogue for additional threats that may be relevant to their architecture. For an  
601 example of how to determine the risk from these threats, see Appendix F in the Supplement.

602 **Table 4-1 Examples of BYOD Deployment Threats**

Threat Event ID	Threat Event Description	NIST Mobile Threat Catalogue Threat ID
<b>TE-1</b>	privacy-intrusive applications	APP-2, APP-12
<b>TE-2</b>	account credential theft through phishing	AUT-9
<b>TE-3</b>	malicious applications	APP-2, APP-5, APP-31, APP-40, APP-32, AUT-10
<b>TE-4</b>	outdated phones	APP-4, APP-26, STA-0, STA-9, STA-16
<b>TE-5</b>	camera and microphone remote access	APP-32, APP-36
<b>TE-6</b>	sensitive data transmissions	APP-0, CEL-18, LPN-2
<b>TE-7</b>	brute-force attacks to unlock a phone	AUT-2, AUT-4
<b>TE-8</b>	weak password practices protection	APP-9, AUT-0
<b>TE-9</b>	unmanaged device protection	EMM-5
<b>TE-10</b>	lost or stolen data protection	PHY-0
<b>TE-11</b>	protecting data from being inadvertently backed up to a cloud service	EMM-9
<b>TE-12</b>	personal identification number (PIN) or password-sharing protection	AUT-0, AUT-2, AUT-4, AUT-5

603 **4.1.2 Privacy Problematic Data Actions**

604 This build also considered operational activities of the example solution that interact with employee  
 605 data during BYOD processes (“data actions”). Additionally, it identified those that potentially cause  
 606 privacy-related problems for individuals (“problematic data actions”). Problematic data actions (PDAs)  
 607 are those actions that may cause an adverse effect for individuals.

608 The NIST PRAM [8] and accompanying Catalog of Problematic Data Actions and Problems [11] were used  
 609 to conduct this analysis. Table 4-2 provides the results of this analysis. See [Appendix G](#) of the  
 610 Supplement for an example of determining the privacy risks based on these data actions.

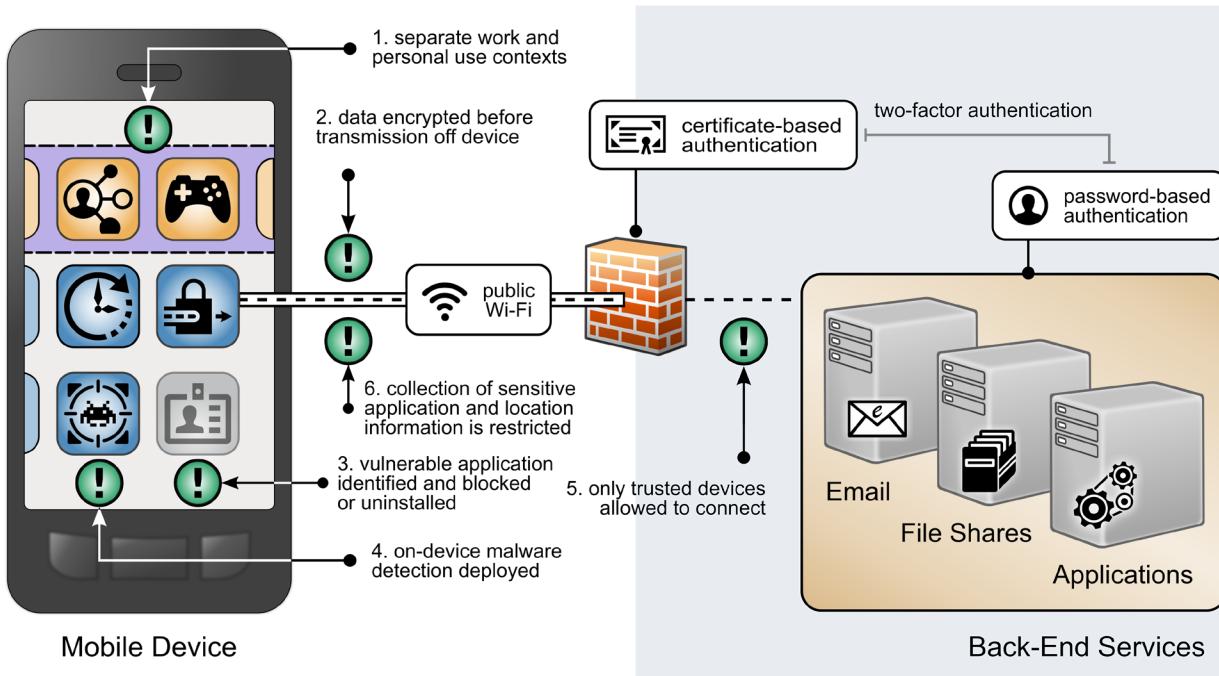
611 **Table 4-2 Examples of BYOD Potential Privacy Events and Problematic Data Actions**

Problematic Data Action ID	Mobile Data Actions	Problematic Data Actions
<b>PDA-1</b>	Devices can be wiped and reset to factory settings based on inputs regarding anomalous activity and untrusted applications.	Unwarranted restriction: Blocking device access or wiping devices entirely may result in loss of personal data, which can cause employee loss of autonomy in their interactions with their device, economic loss to recover personal data, or loss of trust in the organization’s BYOD implementation.

Problematic Data Action ID	Mobile Data Actions	Problematic Data Actions
PDA-2	The BYOD infrastructure comprehensively monitors device interactions related to enterprise connectivity and data processing.	<p>Surveillance:</p> <p>Monitoring BYOD resources on personal devices provides a degree of visibility into personal devices that employers would not otherwise have, which in turn can result in the employer creating an incomplete narrative about employees that could lead to issues such as discrimination or employee loss of trust in the employer if the employee discovers unanticipated monitoring. Additionally, employees who connect their personal mobile device to the organization's network may not be aware of the degree of visibility into their personal activities and data and may not want this to occur. For example, employers may be able to collect location information or application data that provides insights into employee health. Employees may feel as though they are being surveilled.</p>
PDA-3	Data about individuals and their devices flows between various applications and analytical tools, some of which may be shared with third parties and publicly.	<p>Unanticipated revelation:</p> <p>Transmission of employee device information and personal data to the employer and third parties beyond the employer may occur through monitoring, data sharing across parties for analytics, and other operational purposes. Administrator and co-worker awareness of otherwise private activities on devices may reveal information about employees that results in dignity losses, such as embarrassment or emotional distress.</p> <p>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 information about them. This transmission could reveal personal information about the employee to parties they would not expect to have such information. This lack of employee visibility and awareness of data-sharing practices may also cause employee loss of trust in the employer.</p>

#### 612 4.1.3 Security and Privacy Goals

- 613 To address the challenges stated in the previous sections, the architecture for this build addresses the  
 614 high-level security and privacy goals illustrated in [Figure 4-1](#).

615 **Figure 4-1 Security and Privacy Goals**

616 The following goals were highlighted above in [Figure 4-1 Security and Privacy Goals](#), with a green  
617 exclamation mark:

1. **Separate organization and personal information.** BYOD deployments can place organizational data at risk by allowing it to travel outside internal networks and systems when it is accessed on a personal device. BYOD deployments can also place personal data at risk by capturing information from employee devices. To help mitigate this, organizational and personal information can be separated by restricting data flow between organizationally managed and unmanaged applications. The goals include helping to prevent sensitive data from crossing between work and personal contexts.
2. **Encrypt data in transit.** Devices deployed in BYOD scenarios can leverage nonsecure networks, putting data at risk of interception. To help mitigate this, mobile devices can connect to the organization over a VPN or similar solution to encrypt all data before it is transmitted from the device, protecting otherwise unencrypted data from interception. A user would not be able to access the organization's resources without an active VPN connection and required certificates.
3. **Identify vulnerable applications.** Employees may install a wide range of applications on their personally owned devices, some of which may have security weaknesses. When vulnerable personal applications are identified, an organization can remove the employee's work profile or configuration file from the device rather than uninstalling the employee's personal applications.

- 636        4. **Detect malware.** On personally owned devices without restriction policies in place, users  
637        may obtain applications outside official application stores, increasing the risk of installing  
638        malware in disguise. To help protect from this risk, an organization could deploy  
639        malware detection to devices to identify malicious applications and facilitate  
640        remediation.
- 641        5. **Trusted device access.** Because mobile devices can connect from unknown locations, an  
642        organization can provision mobile devices with a security certificate that allows  
643        identifying and authenticating them at the connection point, which combines with user  
644        credentials to create two-factor authentication from mobile devices. An employee would  
645        not be able to access the organization's resources without the required certificates.
- 646        6. **Restrict information collection.** Mobile device management tools can track application  
647        inventory and location information, including physical address, geographic coordinates,  
648        location history, internet protocol (IP) address, and Secure Set Identifier (SSID). These  
649        capabilities may reveal sensitive information about employees, such as frequently visited  
650        locations or habits. Device management tools can be configured to exclude application  
651        and location information. Excluding the collection of information further protects  
652        employee privacy when device and application data is shared outside the organization  
653        for monitoring and analytics.

## 654        4.2 Example Scenario: Putting Guidance into Practice

655        The example solution's high-level goals underscore the need to use a thorough risk assessment process  
656        for organizations implementing mobile device security capabilities. To learn more about how your  
657        organization might implement this example solution, reference the *Example Scenario: Putting Guidance*  
658        *into Practice* supplement of this practice guide. The supplement provides an example approach for  
659        developing and deploying a BYOD architecture that directly addresses the mobile device threat events  
660        and problematic data actions discussed in this guide.

661        The example scenario supplement shows how a fictional organization used the guidance in NIST's  
662        Cybersecurity Framework [1], Privacy Framework [2], Risk Management Framework [9], and PRAM [8] to  
663        identify and address their BYOD security and privacy goals.

## 664        4.3 Technologies that Support the Security and Privacy Goals of the 665        Example Solution

666        This section describes the mobile-specific technology components used within this example solution.  
667        These technologies were selected to address the security goals, threat events, and problematic data  
668        actions identified in [Section 4.1](#). This section provides a brief description of each technology and  
669        discusses the security and privacy capabilities that each component provides.

670        The technology components in this section are combined into a cohesive enterprise architecture to help  
671        address BYOD security threats and problematic data actions and provide security-enhanced access to  
672        enterprise resources from mobile devices. The technologies described in this section provide protection  
673        for enterprise resources accessed by BYOD users.

#### 674 4.3.1 Trusted Execution Environment

675 A trusted execution environment (TEE) is “a tamper-resistant processing environment that runs on a  
676 ‘separation kernel’. It guarantees the authenticity of the executed code, the integrity of the runtime  
677 states (e.g., central processing unit (CPU) registers, memory and sensitive I/O), and the confidentiality of  
678 its code, data and runtime states stored on a persistent memory. In addition, it shall be able to provide  
679 remote attestation that proves its trustworthiness for third-parties” [12]. The TEE helps protect the  
680 mobile devices from executed code with integrity issues. This is important in BYOD environments due to  
681 an enterprise’s limited control over an employee’s personally owned device. Users can install and run  
682 many types of applications on personally owned devices without restriction from the enterprise.

#### 683 4.3.2 Enterprise Mobility Management

684 Organizations use EMM solutions to secure the mobile devices of users who are authorized to access  
685 organizational resources. Such solutions generally have two main components. The first is a backend  
686 service that mobile administrators use to manage the policies, configurations, and security actions  
687 applied to registered mobile devices. The second is an on-device agent, usually in the form of a mobile  
688 application, that integrates between the mobile OS and the solution’s backend service. iOS also supports  
689 a web-based EMM enrollment use case, which we do not discuss in this document.

690 At a minimum, an EMM solution can perform mobile device management (MDM) functions, which  
691 include the ability to provision configuration profiles to devices, enforce security policies on devices, and  
692 monitor compliance with those policies. The on-device MDM agent can typically notify the device user  
693 of any noncompliant settings and may be able to remediate some noncompliant settings automatically.  
694 The organization can use policy compliance data to inform its access control decisions so that it grants  
695 access only to a device that demonstrates the mandated level of compliance with the security policies in  
696 place.

697 EMM solutions commonly include any of the following capabilities: mobile application management,  
698 mobile content management, and implementations of or integrations with device- or mobile-OS-specific  
699 containerization solutions, such as Samsung Knox. These capabilities can be used in the following ways:

- 700     ■ Mobile application management can be used to manage the installation and usage of  
701         applications based on their trustworthiness and work relevance.
- 702     ■ Mobile content management can control how managed applications access and use  
703         organizational data.
- 704     ■ Containerization solutions can strengthen the separation between a user’s personal and  
705         professional usage of the device.
- 706     ■ Also, EMM solutions often have integrations with a diverse set of additional tools and security  
707         technologies that enhance their capabilities.

708 For further reading on this topic, NIST SP 800-124 Revision 2 (Draft), *Guidelines for Managing the*  
709 *Security of Mobile Devices in the Enterprise* [6] provides additional information on mobile device  
710 management with EMM solutions. The National Information Assurance Partnership’s (NIAP’s) *Protection*

711    *Profile for Mobile Device Management Servers and Extended Package for Mobile Device Management*  
712    Agents [13] describes important capabilities and security requirements to look for in EMM systems.

713    EMMs can help BYOD deployments improve the security posture of the organization by providing a  
714    baseline of controls to limit attack vectors and help protect enterprise information that is on a  
715    personally owned device. EMMs can also provide an additional layer of separation between enterprise  
716    data and personal data on a mobile device.

#### 717    4.3.3 Virtual Private Network

718    A VPN gateway increases the security of remote connections from authorized mobile devices to an  
719    organization's internal network. A VPN is a virtual network, built on top of existing physical networks,  
720    that can provide a secure communication channel for data and system control information transmitted  
721    between networks. VPNs are used most often to protect communications carried over public networks  
722    from eavesdropping and interception. A VPN can provide several types of data protection, including  
723    confidentiality, integrity, authentication of data origin, replay protection, and access control that help  
724    reduce the risks of transmitting data between network components.

725    VPN connections apply an additional layer of encryption to the communication between remote devices  
726    and the internal network, and VPN gateways can enforce access control decisions by limiting what  
727    devices or applications can connect to them. Integration with other security mechanisms allows a VPN  
728    gateway to base access control decisions on more risk factors than it may be able to collect on its own;  
729    examples include a device's level of compliance with mobile security policies or the list of installed  
730    applications as reported by an integrated EMM and/or MTD.

731    NIAP's *Module for Virtual Private Network (VPN) Gateways 1.0* [14], in combination with *Protection*  
732    *Profile for Network Devices* [15], describes important capabilities and security requirements to expect  
733    from VPN gateways.

734    In a BYOD deployment, an enterprise can also leverage a per-application VPN to provide a secure  
735    connection over the VPN tunnel strictly when using enterprise applications on the mobile device.  
736    Personal applications on the device would not be allowed to use the VPN, ensuring the enterprise has  
737    visibility into enterprise traffic only. This is especially important to BYOD deployments, whose devices  
738    may connect over a wide variety of wireless networks. It also provides a layer of privacy protection for  
739    employees by preventing personal mobile device traffic from being routed through the enterprise.

#### 740    4.3.4 Mobile Application Vetting Service

741    Mobile application vetting services use a variety of static, dynamic, and behavioral techniques to  
742    determine if an application demonstrates any behaviors that pose a security or privacy risk. The risk may  
743    be to a device owner or user, to parties that own data on the device, or to external systems to which the  
744    application connects. The set of detected behaviors is often aggregated to generate a singular score that  
745    estimates the level of risk (or conversely, trustworthiness) attributed to an application. Clients can often  
746    adjust the values associated with given behaviors (e.g., hardcoded cryptographic keys) to tailor the score

747 for their unique risk posture. Those scores may be further aggregated to present a score that represents  
748 the overall risk or trustworthiness posed by the set of applications currently installed on a given device.

749 Mobile applications, malicious or benign, can affect both security and user privacy negatively. A  
750 malicious application can contain code intended to exploit vulnerabilities present in potentially any  
751 targeted hardware, firmware, or software on the device. Alternatively, or in conjunction with exploit  
752 code, a malicious application may misuse any device, personal, or behavioral data to which it has been  
753 explicitly or implicitly granted access, such as contacts, clipboard data, or location services. Benign  
754 applications may still present vulnerabilities or weaknesses that malicious applications can exploit to  
755 gain unauthorized access to the device's data or functionality. Further, benign applications may place  
756 user privacy at risk by collecting more information than is necessary for it to deliver the functionality  
757 desired by the user.

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

761 While NIAP does not provide a protection profile for application vetting services, their *Protection Profile*  
762 for Application Software [16] describes security requirements to be expected from mobile applications.  
763 Many mobile application vetting vendors provide capabilities to automate evaluation of applications  
764 against NIAP's requirements.

765 Application vetting services help improve the security and privacy posture of the mobile devices by as-  
766 sessing the risk of the applications that may be installed on a personally owned device. Depending on  
767 the deployment strategy, the application vetting service may analyze all installed applications, enter-  
768 prise-only applications, or no applications.

#### 769 4.3.5 Mobile Threat Defense

770 MTD generally takes the form of an application that is installed on the device that provides information  
771 about the device's threat posture based on risks, security, and activity on the device. This is also known  
772 as endpoint protection. Ideally, the MTD solution will be able to detect unwanted activity and properly  
773 inform the user and BYOD administrators so they can act to prevent or limit the harm that an attacker  
774 could cause. Additionally, MTD solutions may integrate with EMM solutions to leverage the MTD agent's  
775 greater on-device management controls and enforcement capabilities, such as blocking a malicious  
776 application from being launched until the user can remove it.

777 While detecting threats, MTD products typically analyze device-based threats, application-based threats,  
778 and network-based threats. Device-based threats include outdated OS versions, nonsecure  
779 configurations, elevation of privileges, unmanaged profiles, and compromised devices. Application-  
780 based threat detection can provide similar functionality to that of dedicated application vetting services.  
781 However, application-based threat detection may not provide the same level of detail in its analysis as  
782 dedicated application vetting services. Network-based threats include use of unencrypted and/or public  
783 Wi-Fi networks and attacks such as active attempts to intercept and decrypt network traffic.

784 Because BYOD mobile phones can have a wide variety of installed applications and usage scenarios,  
785 MTD helps improve the security and privacy posture by providing an agent-based capability to detect  
786 unwanted activity.

### 787 **4.3.6 Mobile Operating System Capabilities**

788 Mobile OS capabilities are available without the use of additional security features. They are included as  
789 part of the mobile device's core capabilities. The following mobile OS capabilities can be found in mobile  
790 devices, particularly mobile phones.

#### 791 **4.3.6.1 Secure Boot**

792 Secure boot is a general term that refers to a system architecture that is designed to prevent and detect  
793 any unauthorized modification to the boot process. A system that successfully completes a secure boot  
794 has loaded its start-up sequence information into a trusted OS. A common mechanism is for the first  
795 program executed (a boot loader) to be immutable (stored on read-only memory or implemented  
796 strictly in hardware). Further, the integrity of mutable code is cryptographically verified by either  
797 immutable or verified code prior to execution. This process establishes a chain of trust that can be  
798 traced back to immutable, implicitly trustworthy code. Using an integrated TEE as part of a secure boot  
799 process is preferable to an implementation that uses software alone [17].

#### 800 **4.3.6.2 Device Attestation**

801 This is an extension of the secure boot process that involves the OS (or more commonly, an integrated  
802 TEE) providing cryptographically verifiable proof that it has a known and trusted identity and is in a  
803 trustworthy state. This means that all software running on the device is free from unauthorized  
804 modification.

805 Device attestation requires cryptographic operations using an immutable private key that can be verified  
806 by a trusted third party, which is typically the original equipment manufacturer of the TEE or device  
807 platform vendor. Proof of possession of a valid key establishes the integrity of the first link in a chain of  
808 trust that preserves the integrity of all other pieces of data used in the attestation. It will include unique  
809 device identifiers, metadata, the results of integrity checks on mutable software, and possibly metrics  
810 from the boot or attestation process itself [17].

#### 811 **4.3.6.3 Mobile Device Management Application Programming Interfaces**

812 Mobile OS and platform-integrated firmware can provide a number of built-in security features that are  
813 generally active by default. Examples include disk- and file-level encryption, verification of digital  
814 signatures for installed software and updates, a device unlock code, remote device lock, and automatic  
815 device wipe following a series of failed device unlock attempts. The user can directly configure some of  
816 these features via a built-in application or through a service provided by the device platform vendor.

817 Additionally, mobile operating systems expose an application programming interface (API) to MDM  
818 products that allow an organization that manages a device to have greater control over these and many  
819 more settings that might not be directly accessible to the device user. Management APIs allow

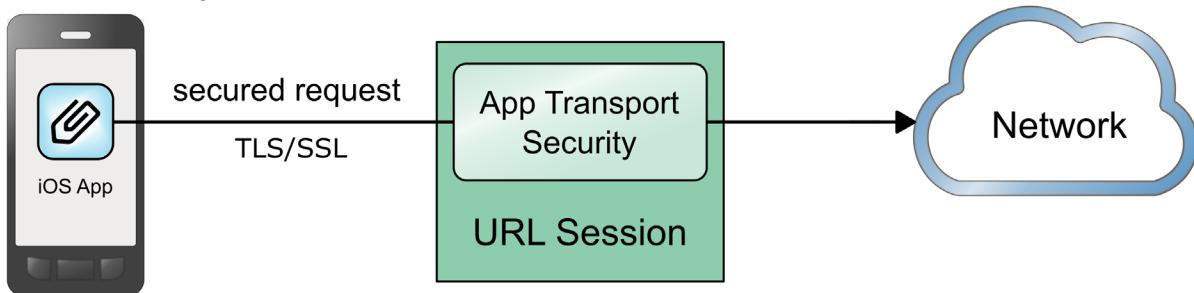
820 enterprises using integrated EMM or MDM products to manage devices more effectively and efficiently  
 821 than they could by using the built-in application alone.

#### 822 *4.3.6.4 iOS App Transport Security*

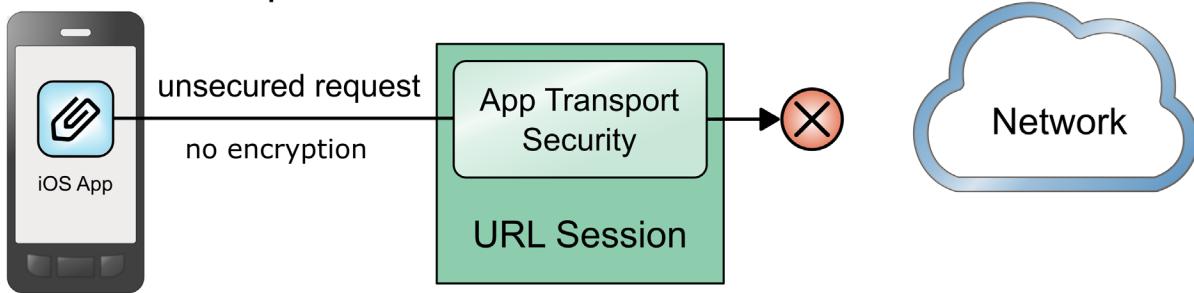
823 App Transport Security (ATS) is a networking security feature on Apple iOS devices that increases data  
 824 integrity and privacy for applications and extensions [18], [19]. ATS requires that the network  
 825 connections made by applications are secured through the Transport Layer Security protocol, which  
 826 uses reliable cipher suites and certificates. In addition, ATS blocks any connection that does not meet  
 827 minimum security requirements. For applications linked to iOS 9.0 and later, ATS is enabled by default.  
 828 Figure 4-2 shows how ATS compliant and noncompliant applications function. As demonstrated in the  
 829 figure, secured application requests are allowed, and nonsecure requests are blocked.

830 **Figure 4-2 iOS App Transport Security**

### ATS Compliant Scenario



### ATS Noncompliant Scenario



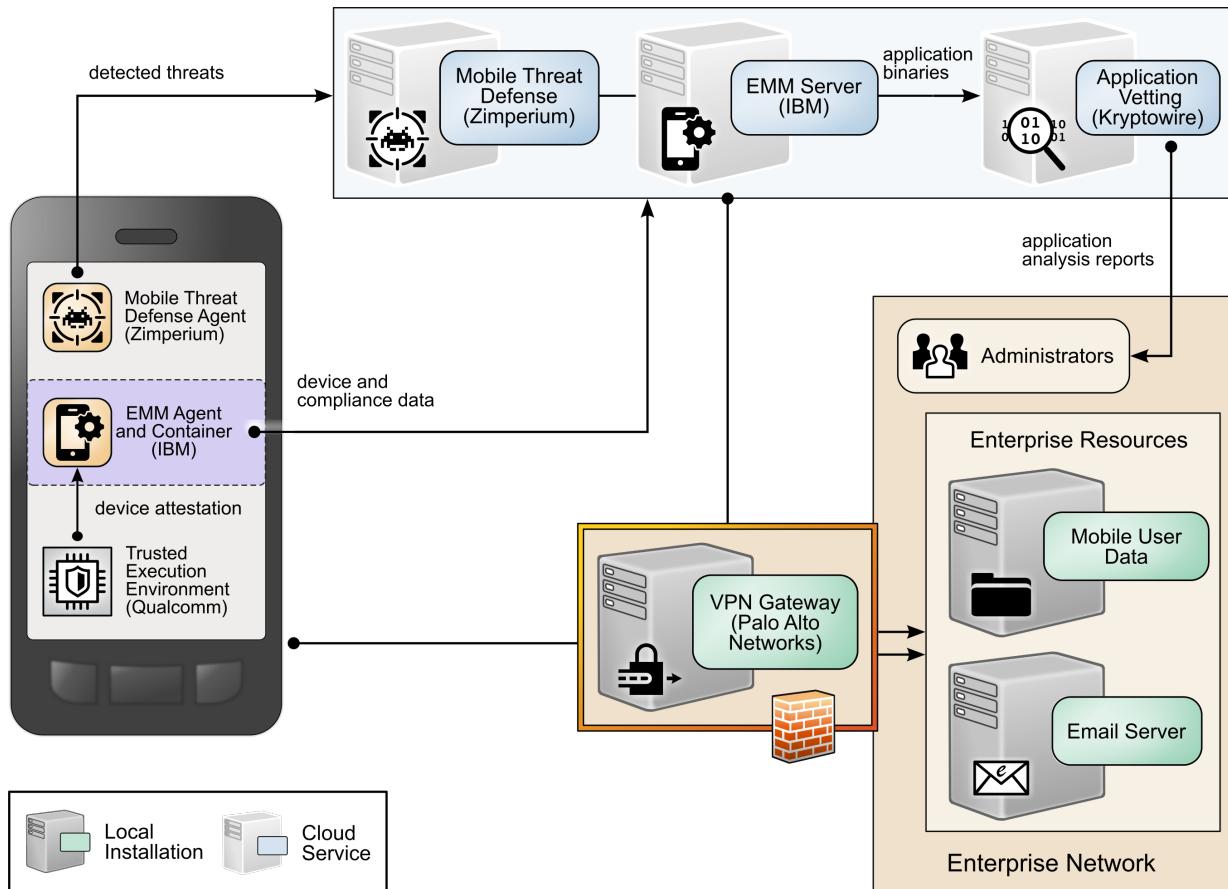
#### 831 *4.3.6.5 Android Network Security Configuration*

832 With data privacy becoming even more important, Google released mobile OS enhancements to protect  
 833 data that traverses Android devices and endpoints [20], [21]. The Android Network Security  
 834 Configuration prevents applications from transmitting sensitive data unintentionally in unencrypted  
 835 cleartext. By default, `cleartextTrafficPermitted` is set to `false`. Through the Android Network  
 836 Security Configuration feature, developers can designate what certification authorities are trusted to  
 837 ensure secure communications and issue certificates.

## 838 4.4 Architecture Description

839 The example solution architecture consists of the security technologies described in Section 4.3. The  
 840 security technologies are further integrated with broader enterprise security mechanisms and a VPN  
 841 gateway as shown in Figure 4-3. This example solution provides a broad range of capabilities to securely  
 842 provision and manage devices, protect against and detect device compromise, and provide secure  
 843 access to enterprise resources to only authorized mobile users and devices.

844 **Figure 4-3 Example Solution Architecture**



845 The NCCoE worked with industry experts to develop an open, standards-based, architecture using  
 846 commercially-available products to address the threats and problematic data actions identified in  
 847 Section 4.1.

848 Where possible, the architecture uses components that are present on the NIAP Product Compliant List,  
 849 meaning that the product has been successfully evaluated against a NIAP-approved protection profile.  
 850 The NIAP collaborates with a broad community, including industry, government, and international  
 851 partners, to publish technology-specific security requirements and tests in the form of protection  
 852 profiles. The requirements and tests in these protection profiles are intended to ensure that evaluated  
 853 products address identified security threats and provide risk mitigation measures.

854 The security and privacy characteristics of the architecture result from many of the capability  
855 integrations outlined in Section 4.5.

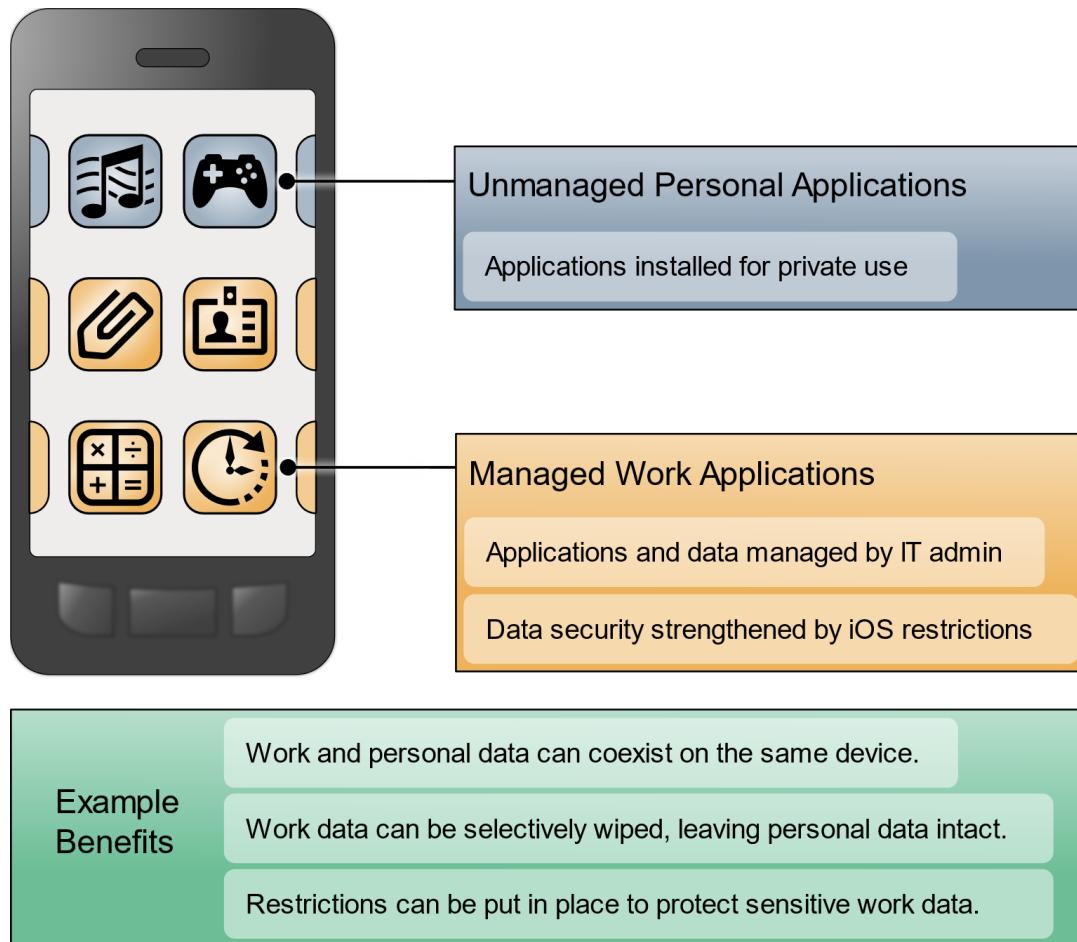
856 **4.5 Enterprise Integration of the Employees' Personally Owned Mobile  
857 Devices**

858 One key benefit of BYOD solutions for employees is the ability to access both work and personal data on  
859 the same device. While the technical approaches differ between iOS and Android devices, both  
860 operating systems offer the following types of features for managing the coexistence of work and  
861 personal data on devices [22], [23]:

- 862     ■ data flow restriction between enterprise and personal applications
- 863     ■ restriction of application installation from unknown sources
- 864     ■ selective wiping to remove enterprise data and preserve personal data
- 865     ■ device passcode requirement enforcement
- 866     ■ application configuration control
- 867     ■ identity and certificate authority certificate support

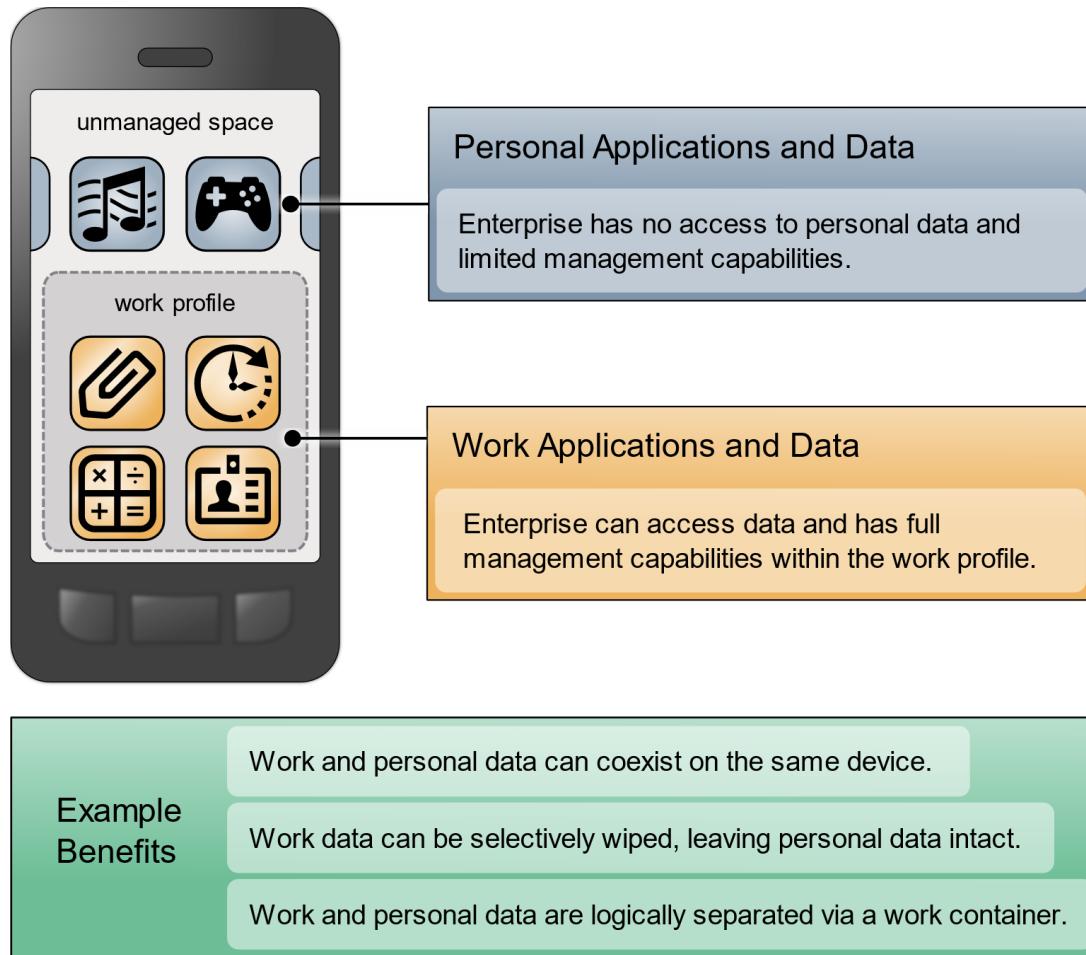
868 Illustrating this concept, Figure 4-4 iOS Application Management and Benefits, shows enterprise  
869 integration for managed and unmanaged applications on iOS devices. To protect sensitive work data,  
870 application restrictions, such as preventing the ability to copy data between work and personal  
871 application, are applied.

872 **Figure 4-4 iOS Application Management and Benefits**



873 As illustrated in Figure 4-5, for Android devices, work applications can be separated into a container,  
 874 with data access restricted between the personal and work container applications.

875 **Figure 4-5 Android Application Management and Benefits**



#### 876 [4.5.1 Microsoft Active Directory Integration](#)

877 The example solution is integrated with Microsoft Active Directory (AD), which provides both enterprise  
 878 identity management and certificate enrollment services via public key infrastructure. International  
 879 Business Machines (IBM) MaaS360 connects directly to the domain controller and the Network Device  
 880 Enrollment Service (NDES) servers via an IBM Cloud Extender installed on the local intranet, while  
 881 GlobalProtect connects to the domain controller via the Palo Alto Networks firewall's Lightweight  
 882 Directory Access Protocol service route.

883 By integrating directly with the AD infrastructure, administrators can configure MaaS360 to accept  
 884 enrollment requests based on user groups in AD. GlobalProtect can inherit these roles and enforce  
 885 access control protocols to restrict/deny permissions to the VPN. The AD integration is also used within  
 886 MaaS360 to provide policy-based access to the MaaS360 administration console.

887 The Certificate Integration module within the MaaS360 Cloud Extender allows user certificates to be  
888 installed on the user's devices when enrolling with MaaS360. These certificates are then validated in  
889 GlobalProtect during the VPN authentication sequence, along with the user's corporate username and  
890 password. The Cloud Extender requests these certificates from the NDES server by using the Simple  
891 Certificate Enrollment Protocol (SCEP).

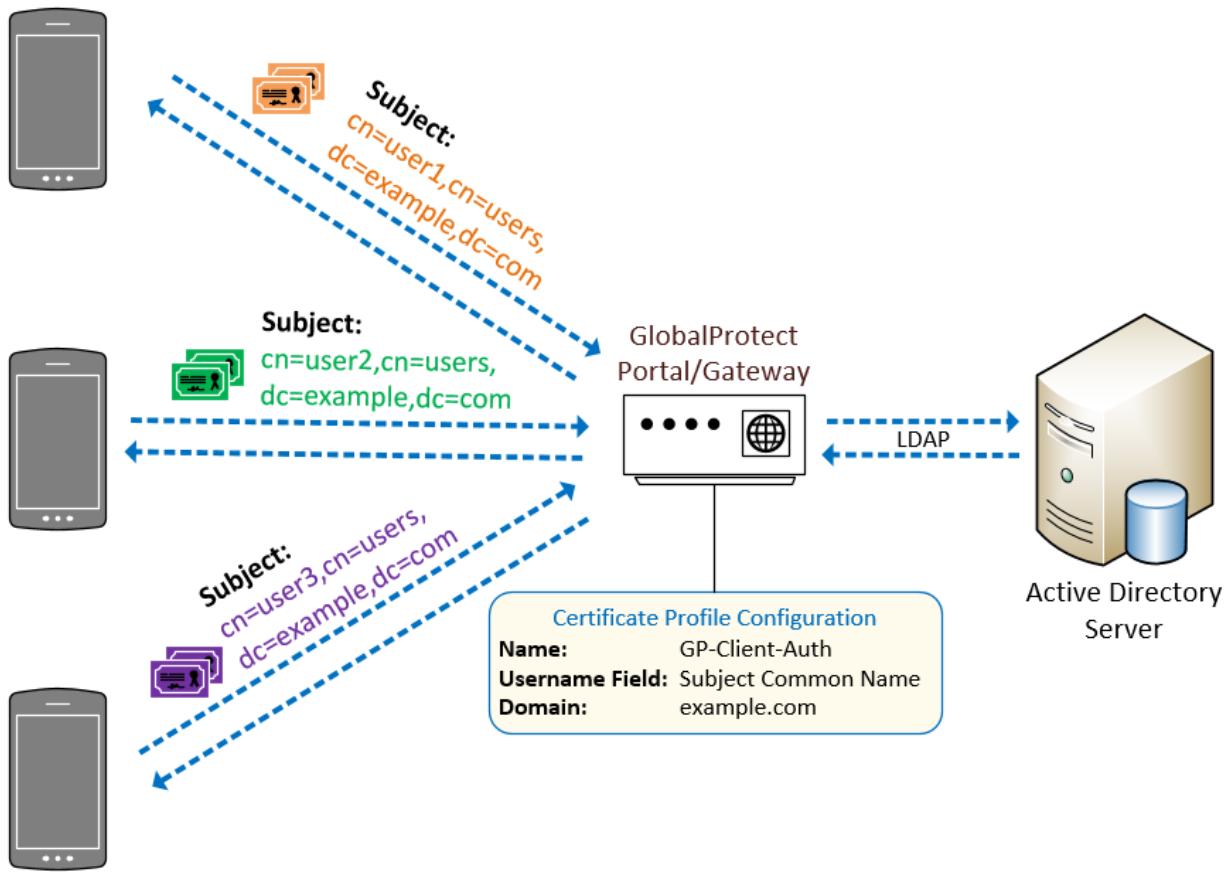
#### 892 **4.5.2 Mobile Device Enrollment**

893 The example solution shown in Figure 4-6 mitigates the potential for SCEP to be remotely exploited by  
894 restricting certificate enrollment to mobile devices that are connected to a dedicated enterprise-  
895 managed Wi-Fi network. The uniform resource locator (URL) of the NDES server is resolvable only on  
896 this managed Wi-Fi network.

897 Furthermore, the NDES server is configured to require a dynamic challenge with each request. The Cloud  
898 Extender does this by including a one-time password with each request. This helps prevent unknown  
899 devices from requesting certificates. These certificates can then be used to prove identity when  
900 authenticating with the GlobalProtect VPN.

901 The certificate template includes the user's username and email address. This allows the GlobalProtect  
902 gateway to enforce access control and identity verification.

903 Figure 4-6 Example Solution VPN Authentication Architecture

904 

## 4.6 Mobile Components Integration

905 IBM MaaS360 supports integration of third-party applications and cloud services via a representational  
 906 state transfer (REST) API [24]. External services are authenticated via access tokens, obtained through  
 907 MaaS360 support. Zimperium and Kryptowire used the REST API [25].

908 Table 4-3 identifies the commercially available products used in this example solution and how they  
 909 align with the mobile security technologies. For additional information, Appendices G and H contain a  
 910 mapping of these technologies to the cybersecurity and privacy standards and best practices that each  
 911 product provides in the example solution.

912 **Table 4-3 Commercially Available Products Used**

Commercially Available Product	Mobile Security Technology
IBM MaaS360 Mobile Device Management (SaaS) Version 10.73 IBM MaaS360 Mobile Device Management Agent Version 3.91.5 (iOS), 6.60 (Android) IBM MaaS360 Cloud Extender Cloud Extender Modules: Certificate Integration Module Version 2.96.000 Cloud Extender Base Module Version 2.96.000 Cloud Extender Basic Module Device Version 2.96.000 MaaS360 Configuration Utility Module Version 2.96.200 Mobile Device Management Module Version 2.31.020 User Authentication Module Version 2.96.200	mobile device management
Kryptowire Cloud Service	application vetting
Palo Alto Networks PA-VM-100 Version 9.0.1 Palo Alto Networks GlobalProtect VPN Client Version 5.0.6-14 (iOS), 5.0.2-6 (Android)	firewall virtual private network
Qualcomm (Version is mobile device dependent)	trusted execution environment
Zimperium Defense Suite Zimperium Console Version vGA-4.23.1 Zimperium zIPS Agent Version 4.9.2 (Android and iOS)	mobile threat defense

913 **4.6.1 Zimperium—MaaS360**

914 Through the MaaS360 REST API, Zimperium can retrieve various device attributes, such as device name,  
 915 model, OS, OS version, and owner's email address. It then continuously monitors the device's risk  
 916 posture through the Zimperium Intrusion Prevention System (zIPS) application and reports any changes  
 917 in the posture to MaaS360. This enables MaaS360 administrators to apply different device policies and  
 918 enforcement actions based on the risk posture of a device.

919 When a device is enrolled with MaaS360, the zIPS application is automatically installed and configured  
 920 on the device. When the user first launches the zIPS application, it will automatically enroll the device in  
 921 Zimperium's MTD service. zIPS will then continuously monitor the device for threats, and any detected

922 threats will be reported to Zimperium. Zimperium can then report to MaaS360 if any changes in risk  
923 posture occurred.

924 MaaS360 can respond to the following risk posture levels, as assigned by Zimperium:

- 925     ■ low  
926     ■ normal  
927     ■ elevated  
928     ■ critical

#### 929 [4.6.2 Kryptowire–MaaS360](#)

930 Through the MaaS360 REST API, Kryptowire can retrieve a list of enrolled devices, device metadata, and  
931 the inventory of applications installed on those devices. This allows Kryptowire to automatically analyze  
932 all new applications installed on enrolled devices, ensuring that the risk posture of the devices, and  
933 therefore the enterprise, stays at an acceptable level.

934 Kryptowire also has configurable threat scores for various factors, such as requested permissions and  
935 hardcoded encryption keys.

936 The threat scores can be configured to one of four levels:

- 937     ■ low  
938     ■ medium  
939     ■ high  
940     ■ critical

941 The administrator can configure a threat score alert threshold and an email address to receive alerts  
942 when an application's threat score is at or above the threshold. The administrator can then take  
943 appropriate action on the device in MaaS360.

944 Further, Kryptowire can provide information about applications including the latest version, when it was  
945 last seen, when tracking began, and the number of versions that have been seen.

#### 946 [4.6.3 Palo Alto Networks–MaaS360](#)

947 Palo Alto Networks GlobalProtect VPN secures remote connections from mobile devices. MaaS360  
948 offers specific configuration options for the GlobalProtect client, using certificate-based authentication  
949 to the GlobalProtect gateway and available for Android and iOS, that facilitate deployment of VPN  
950 clients and enabled VPN access. Section 4.5 presents details of the certificate enrollment process.

951 Two components of the Palo Alto Networks next-generation firewall compose the VPN architecture used  
952 in this example solution—a GlobalProtect portal and a GlobalProtect gateway. The portal provides the  
953 management functions for the VPN infrastructure. Every endpoint that participates in the GlobalProtect  
954 network receives configuration information from the portal, including information about available

955 gateways as well as any client certificates that may be required to connect to the GlobalProtect  
956 gateway(s). A GlobalProtect gateway provides security enforcement for network traffic. The  
957 GlobalProtect gateway in this example solution is configured to provide mobile device users with access  
958 to specific enterprise resources from the secure contexts after a successful authentication and  
959 authorization decision.

960 The VPN tunnel negotiation between the VPN endpoint/mobile device context and the VPN gateway has  
961 four steps: (1) The portal provides the client configuration, (2) a user logs into the system, (3) the agent  
962 automatically connects to the gateway and establishes a VPN tunnel, and (4) the security policy on the  
963 gateway enables access to internal and external applications.

964 For this example solution, a per-application VPN configuration is enforced on iOS and an always-on work  
965 container VPN configuration on Android. This configuration forces the device to automatically establish  
966 a VPN connection to the GlobalProtect gateway whenever an application in the predefined list of  
967 applications runs on the device or when an application in the work container is launched.

#### 968 **4.6.4 iOS and Android MDM Integration**

969 Both iOS and Android integrate directly with MaaS360. Configuration profiles manage iOS devices.  
970 Configuration profiles can force security policies such as VPN usage, ActiveSync support, access to cloud  
971 services, application compliance, passcode policy, device restrictions, and Wi-Fi settings.

972 Android devices are managed by Android Enterprise, which provides controls for both the device itself  
973 and the work container. The work container is a special folder on the phone that stores all the  
974 enterprise applications and data, ensuring separation from personal applications and data. This is  
975 implemented as a profile owner solution, as opposed to Corporate-Owned Personally-Enabled (COPE),  
976 which is implemented as a device owner solution.

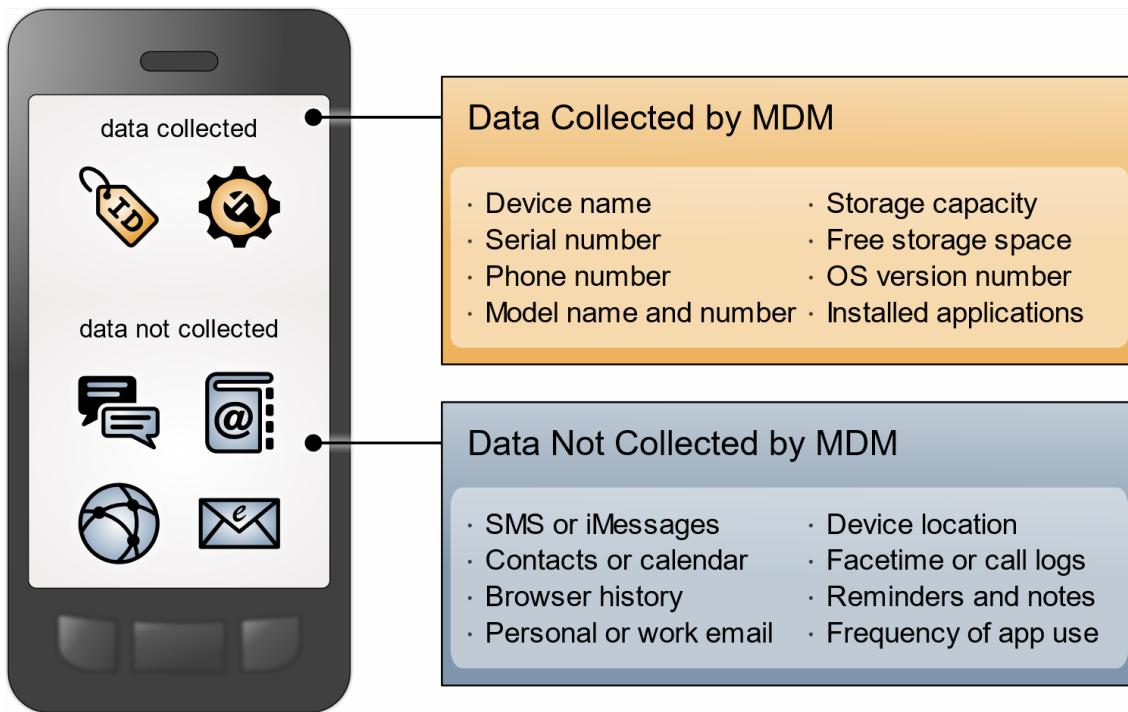
### 977 **4.7 Privacy Settings: Mobile Device Data Processing**

978 This section takes a look at components within the example architecture and the type of information an  
979 enterprise may access from an employee's personal mobile device through those components.  
980 Understanding the type of data an enterprise has access to can be helpful when understanding any  
981 privacy implications.

#### 982 **4.7.1 EMM: MaaS360**

983 When a personal mobile phone is connected to an EMM system, some data is collected and visible to  
984 the enterprise. While additional data can be collected, our example solution collects only the data  
985 shown in Figure 4-7 to help protect employee privacy. This information is provided by MaaS360 to  
986 Kryptowire's application vetting capability. Kryptowire then uses the MaaS360 supplied information to  
987 determine application security characteristics. IBM provides documentation with more details on the  
988 information that MaaS360 collects and processes [26].

989 Figure 4-7 Data Collected by Example Solution Mobile Device Management



990 As shown in Figure 4-8, administrators can restrict collection of location and/or application inventory  
 991 information. When an administrator restricts location collection, the administrator cannot see any  
 992 location information about devices. Similarly, when an administrator restricts application inventory  
 993 information, MaaS360 will not collect applications that are not distributed through the enterprise and  
 994 therefore, will not transmit them to third-party application-vetting services. Both privacy controls can be  
 995 applied to specific device groups—for example, COPE devices could have their location information  
 996 collected—but location collection can be disabled for personal devices.

997 **Figure 4-8 Example Solution Mobile Device Management Privacy Settings**

998 **4.7.2 MTD: Zimperium**

999 Zimperium provides configurable settings for both what data is collected, as well as when it is collected.  
 1000 Data is collected:

- 1001     ■ at login when the user launches the zIPS application
- 1002     ■ when a threat is reported
- 1003     ■ periodically, when the zIPS application checks in to the zConsole

1004 Table 4-4 shows the data that is collected during each of the three scenarios above. Additional information regarding data item contents follows the table.

1006 Note: Administrators who are managing Zimperium cannot disable the collection of the bolded data  
 1007 items (Network, Device, and Carrier Information) shown in Table 4-4 Data Collected by Zimperium.

1008 **Table 4-4 Data Collected by Zimperium**

Time	Data Item
At login	<ul style="list-style-type: none"> <li>▪ Location (Street, City, or Country)</li> <li>▪ Application Binaries (Android)</li> <li>▪ <b>Network</b></li> <li>▪ <b>Device</b></li> <li>▪ Application Forensics</li> <li>▪ <b>Carrier Information</b></li> <li>▪ User Details</li> </ul>
Threat	<ul style="list-style-type: none"> <li>▪ Location (Street, City, or Country)</li> <li>▪ Network</li> <li>▪ Application Forensics</li> <li>▪ Running Processes (Android)</li> <li>▪ Site Insight Risky URLs</li> <li>▪ Attacker's Network</li> </ul>
Periodically	<ul style="list-style-type: none"> <li>▪ Location (Street, City, or Country)</li> <li>▪ Network</li> <li>▪ Application Binaries (Android)</li> <li>▪ Application Forensics</li> </ul>

1009 The Device data item contains the following information:

- 1010     ▪ root/jailbreak status
- 1011     ▪ OS version
- 1012     ▪ OS known vulnerabilities
- 1013     ▪ developer mode enabled
- 1014     ▪ process list
- 1015     ▪ file system changes

1016       ■ device international mobile equipment identity (IMEI)

1017       ■ device IP

1018       ■ device media access control (MAC) address

1019       ■ location

1020      The Network data item contains the following information:

1021       ■ address resolution tables

1022       ■ routing tables

1023       ■ nearby networks

1024       ■ network SSID

1025       ■ external IP

1026       ■ gateway MAC

1027      The Application data item contains the following information:

1028       ■ application ID

1029       ■ application version

1030       ■ hash

1031       ■ malware detection (yes or no with type of malware)

1032       ■ libraries used

1033       ■ permissions

1034       ■ privacy risk

1035       ■ security risk

1036       ■ location in device file system

1037       ■ network connections

1038      zIPS must collect certain data items to properly communicate with the zConsole. These items include:

1039       ■ user credentials (email address, Zimperium-specific password)

1040       ■ device hash (MD5 of IMEI or serial number as an identifier)

1041       ■ device operating system

1042       ■ device push token

1043       ■ hash of local z9 database

1044       ■ time and name of threat detection when a threat occurs

#### 4.7.3 VPN: Palo Alto Networks

The Palo Alto Networks VPN uses information about the device as it establishes VPN connections. The data collected by the VPN includes information about:

- device name
- logon domain
- operating system
- app version
- mobile device network information to which the device is connected
- in addition, GlobalProtect collects whether the device is rooted or jailbroken

## 5 Security and Privacy Analysis

This section familiarizes the reader with:

- the example solution's assumptions and limitations
- results of the example solution's laboratory testing
- scenarios and findings that show the security and privacy characteristics addressed by the reference design
- the security and privacy control capabilities of the example solution

The purpose of the security and privacy characteristics evaluation is to understand the extent to which the project meets its objectives of demonstrating capabilities for securing mobile devices within an enterprise by deploying EMM, MTD, application vetting, secure boot/image authentication, and VPN services while also protecting the privacy of employees participating in the BYOD implementation.

### 5.1 Analysis Assumptions and Limitations

The security and privacy characteristics analysis has the following limitations:

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

### 5.2 Build Testing

Test activities are provided to show how the example architecture addresses each threat event and problematic data action. The NIST SP 1800-22 Supplement, *Example Scenario: Putting Guidance into*

1076 *Practice*, provides insights into how an organization may determine its susceptibility to the threat before  
1077 implementing the architecture detailed in this practice guide. The test activities contained in [Appendix E](#),  
1078 Build Testing Details, demonstrate to the reader how Great Seneca validated their desired outcomes for  
1079 the identified threat events and problematic data actions. [Appendix F](#), Threat Event Test Information,  
1080 shows examples of test results for this build.

## 1081 [5.3 Scenarios and Findings](#)

1082 One aspect of the security evaluation involved assessing how well the reference design addresses the  
1083 security characteristics that it was intended to support. The Cybersecurity Framework Subcategories  
1084 were used to provide structure to the security assessment by consulting the specific sections of each  
1085 standard that are cited in reference to a Subcategory. Using the Cybersecurity Framework Subcategories  
1086 as a basis for organizing the analysis, allowed systematic consideration of how well the reference design  
1087 supports the intended security characteristics.

1088 This section of the publication provides findings for the security and privacy characteristics that the ex-  
1089 ample solution was intended to support. These topics are described in the following subsections:

- 1090     ▪ development of the Cybersecurity Framework and NICE Framework mappings
- 1091     ▪ threat events related to security and example solution architecture mitigations
- 1092     ▪ problematic data actions related to privacy and potential mitigations that organizations could  
1093       employ

1094 An example scenario that demonstrates how an organization may use NIST SP 1800-22 and other NIST  
1095 tools to implement a BYOD use case is discussed more in the NIST SP 1800-22 Supplement, *Example*  
1096 *Scenario: Putting Guidance into Practice* of this practice guide.

### 1097 [5.3.1 Cybersecurity Framework and NICE Framework Work Roles Mappings](#)

1098 As we installed, configured, and used the products in the architecture, we determined and documented  
1099 the example solution's functions and their corresponding Cybersecurity Framework Subcategories, along  
1100 with other guidance alignment.

1101 This mapping will help users of this practice guide communicate with their organization's stakeholders  
1102 regarding the security controls that the practice guide recommends for helping mitigate BYOD threats,  
1103 and the workforce capabilities that the example solution will require.

1104 The products, frameworks, security controls, and workforce mappings are in [Appendix G](#).

### 1105 [5.3.2 Threat Events and Findings](#)

1106 As part of the findings, the threat events were mitigated in the example solution architecture using the  
1107 concepts and technology shown in Table 5-1. Each threat event was matched with functions that helped  
1108 mitigate the risks posed by the threat event.

1109 Note: TEE provided tamper-resistant processing environment capabilities that helped mitigate mobile  
 1110 device runtime and memory threats in the example solution. We do not show the Qualcomm TEE  
 1111 capability in the table because it is built into the phones used in this build.

1112 **Table 5-1 Threat Events and Findings Summary**

Threat Event	How the Example Solution Architecture Helped Mitigate the Threat Event	The Technology Function that Helps Mitigate the Threat Event
<b>Threat Event 1:</b> unauthorized access to sensitive information via a malicious or privacy-intrusive application	Provides administrators with insight into what corporate data that applications can access.	MTD EMM
<b>Threat Event 2:</b> theft of credentials through a short message service (SMS) or email phishing campaign	Utilized PAN-DB and URL filtering to block known malicious websites.	Firewall
<b>Threat Event 3:</b> unauthorized applications installed via URLs in SMS or email messages	Alerted the user and administrators to the presence of a sideloaded application.	EMM MTD
<b>Threat Event 4:</b> confidentiality and integrity loss due to exploitation of known vulnerability in the OS or firmware	Alerted the user that their OS is non-compliant.	EMM MTD
<b>Threat Event 5:</b> violation of privacy via misuse of device sensors	Application vetting reports indicated the sensors to which an application requested access.	Application vetting
<b>Threat Event 6:</b> 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
<b>Threat Event 7:</b> compromise of device integrity via observed, inferred, or brute-forced device unlock code	Enforced mandatory device wipe capabilities after ten failed unlock attempts.	EMM MTD
<b>Threat Event 8:</b> 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.	Application vetting

Threat Event	How the Example Solution Architecture Helped Mitigate the Threat Event	The Technology Function that Helps Mitigate the Threat Event
<b>Threat Event 9:</b> unauthorized access of enterprise resources from an unmanaged and potentially compromised device	Devices that were not enrolled in the EMM system were not able to connect to the corporate VPN.	VPN
<b>Threat Event 10:</b> loss of organizational data due to a lost or stolen device	Enforced passcode policies and device-wipe capabilities protected enterprise data.	EMM
<b>Threat Event 11:</b> 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
<b>Threat Event 12:</b> unauthorized access to work applications via bypassed lock screen	The VPN requires the user to reenter their password after a predefined amount of time.	VPN

1113    **5.3.3 Privacy Problematic Data Actions and Findings**

1114    The privacy risk analysis found that three data actions in the build were potentially problematic data  
 1115    actions for individuals. We identified potential technical mitigations that an organization could use to  
 1116    lessen their impact, as shown below in Table 5-2. Organizations may also need to supplement these  
 1117    technical mitigations with supporting policies and procedures.

1118    **Table 5-2 Summary of Privacy Problematic Data Actions and Findings**

Problematic Data Actions (for Employees)	How the Example Solution Architecture Helps Mitigate the Problematic Data Action	The Technology Function that Helps Mitigate the Problematic Data Action
<b>PDA-1:</b> unwarranted restriction	Blocks staff access to enterprise resources by removing the device from MDM control instead of wiping the device.	EMM

<b>Problematic Data Actions (for Employees)</b>	<b>How the Example Solution Architecture Helps Mitigate the Problematic Data Action</b>	<b>The Technology Function that Helps Mitigate the Problematic Data Action</b>
	<p>Enables only selectively wiping corporate resources on the device.</p> <p>Restricts staff access to system capabilities that permit removing device access or performing wipes.</p>	
<b>PDA-2:</b> surveillance	<p>Restricts staff access to system capabilities that permit reviewing data about employees and their devices.</p> <p>Limits or disables collection of specific data elements (e.g., location data).</p>	EMM
<b>PDA-3:</b> unanticipated revelation	<p>De-identifies personal and device data when not necessary to meet processing objectives.</p> <p>Encrypts data transmitted between parties.</p> <p>Limits or disables access to data.</p> <p>Limits or disables the collection of specific data elements.</p>	EMM

## 1119    5.4 Security and Privacy Control Mappings

- 1120    The security and privacy capabilities of the example solution were identified, and example security and  
 1121    privacy control maps were developed to show these in a standardized methodology.
- 1122    The control maps show the security and privacy characteristics for the products used in the example  
 1123    solution.

1124 The security control map can be found in [Appendix G](#). The privacy control map is in [Appendix H](#).

## 1125 **6 Example Scenario: Putting Guidance into Practice**

1126 To demonstrate how an organization may use NIST SP 1800-22 and other NIST tools to implement a  
1127 BYOD use case, the NCCoE created the *Example Scenario: Putting Guidance into Practice* supplement for  
1128 this practice guide.

1129 This example scenario shows how a fictional, small-to-mid-size organization (Great Seneca Accounting)  
1130 can successfully navigate common enterprise BYOD security challenges.

1131 In the narrative example, Great Seneca Accounting completes a security risk assessment by using the  
1132 guidance in NIST SP 800-30 [27] and the Mobile Threat Catalogue [5] to identify cybersecurity threats to  
1133 the organization. The company then uses the NIST PRAM [8] to perform a privacy risk assessment.

1134 [Appendix F](#) and [Appendix G](#) of the Supplement describe these risk assessments in more detail. These risk  
1135 assessments produce two significant conclusions:

- 1136 1. Great Seneca Accounting finds similar cybersecurity threats in its environment and problematic  
1137 data actions for employee privacy as those discussed in NIST SP 1800-22, validating that the  
1138 controls discussed in the example solution are relevant to their environment.
- 1139 2. The organization determines that it has a high-impact system, based on the impact guidance in  
1140 NIST FIPS 200, *Minimum Security Requirements for Federal Information and Information Systems*  
1141 [28], and needs to implement more controls beyond those identified in NIST SP 1800-22 to  
1142 support the additional system components in its own solution (e.g., underlying OS, the data  
1143 center where the equipment will reside).

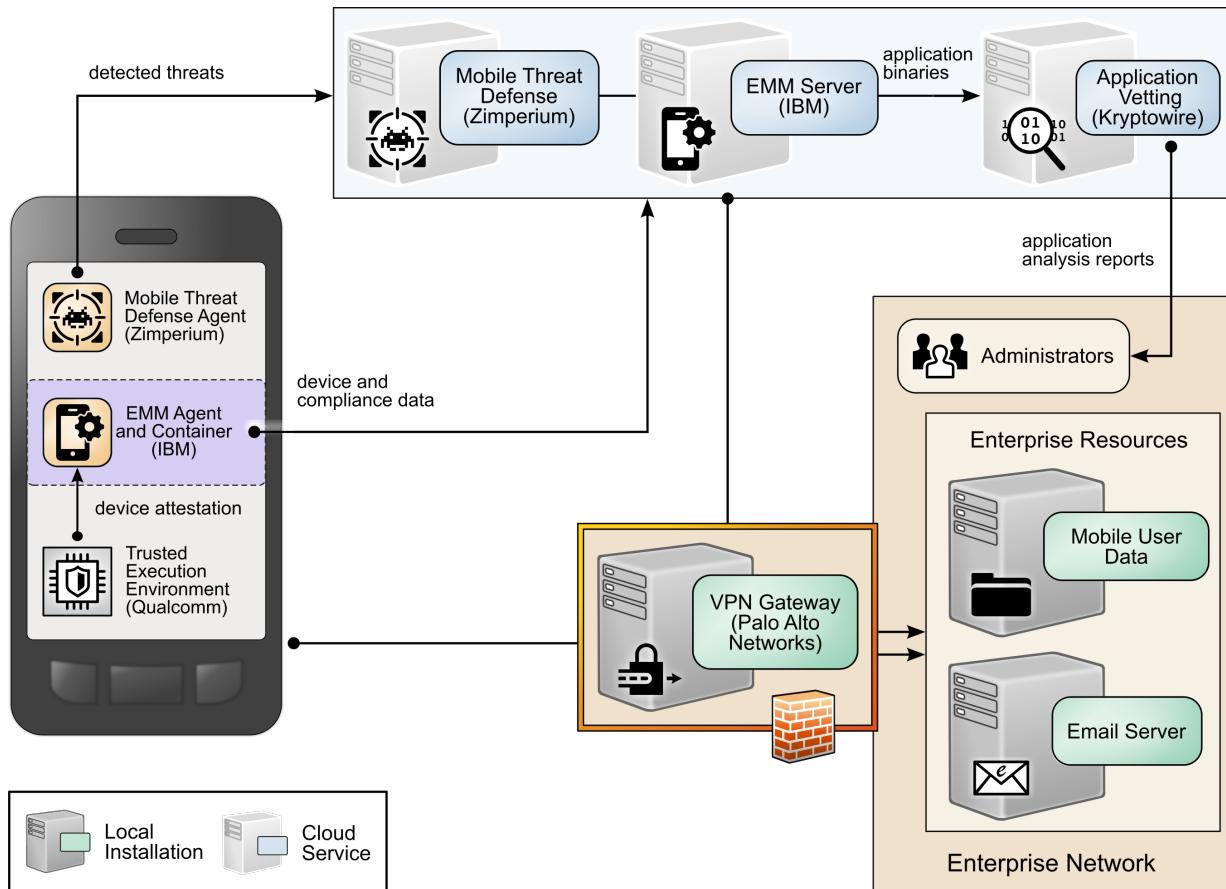
1144 As part of their review of NIST FIPS 200, Great Seneca Accounting selects security and privacy controls  
1145 from NIST SP 800-53 [29] for their BYOD architecture implementation. They then tailor the control  
1146 baselines based on the needs identified through the priority Subcategories in its cybersecurity and  
1147 privacy Target Profiles.

1148 A detailed description of the implementation process that the fictional organization Great Seneca  
1149 Accounting followed is provided in the NIST SP 1800-22 *Example Scenario: Putting Guidance into*  
1150 *Practice* supplement of this practice guide.

## 1151 **7 Conclusion**

1152 This practice guide provides an explanation of mobile device security and privacy concepts and an  
1153 example solution for organizations implementing a BYOD deployment. As shown in [Figure 7-1](#), this  
1154 example solution applied multiple mobile device security technologies. These included a cloud-based  
1155 EMM solution integrated with cloud- and agent-based mobile security technologies to help deploy a set  
1156 of security and privacy capabilities that support the example solution.

1157 Figure 7-1 Example Solution Architecture



- 1158 Our fictional Great Seneca Accounting organization example scenario contained in the *Example Scenario: Putting Guidance into Practice* supplement of this practice guide illustrates how the concepts and architecture from this guide may be applied by an organization. Great Seneca started with an information technology infrastructure that lacked mobile device security architecture concepts. Great Seneca then employed multiple NIST cybersecurity and privacy risk management tools to understand the gaps in its architecture and the methods available today to enhance the security and privacy of its BYOD deployment.
- 1165 This practice guide also includes in Volume C a series of how-to guides—step-by-step instructions covering the initial setup (installation or provisioning) and configuration for each component of the architecture—to help security engineers rapidly deploy and evaluate our example solution in their test environment.
- 1169 The example solution uses standards-based, commercially available products that can be used by an organization interested in deploying a BYOD solution. The example solution provides recommendations for enhancing the security and privacy infrastructure by integrating on-premises and cloud-hosted

1172 mobile security technologies. This practice guide provides an example solution that an organization may  
1173 use in whole or in part as the basis for creating a custom solution that best supports their unique needs.

## 1174 **8 Future Build Considerations**

1175 For a future build, the team is considering a virtual mobile infrastructure (VMI) or unified endpoint  
1176 management (UEM) solution.

1177 The VMI deployment could include installing an application on a device at enrollment time, which would  
1178 grant access to a virtual phone contained within the corporate infrastructure. The virtual phone would  
1179 then contain the corporate-supplied applications that an employee would require for performing  
1180 standard mobile work tasks. The thin client deployment limits the storage of organizational data on the  
1181 device and helps ensure that access to the organization's data uses security-enhancing capabilities.

1182 UEM would entail managing a user's mobile device ecosystem, potentially including laptops, mobile  
1183 phones, and IoT devices (e.g., smart watches and Bluetooth headsets).

**1184 Appendix A List of Acronyms**

<b>AD</b>	Active Directory
<b>API</b>	Application Programming Interface
<b>ATS</b>	App Transport Security
<b>BYOD</b>	Bring Your Own Device
<b>CIS</b>	Center for Internet Security
<b>COPE</b>	Corporate-Owned Personally-Enabled
<b>EMM</b>	Enterprise Mobility Management
<b>FIPS</b>	Federal Information Processing Standards
<b>HTTP</b>	Hypertext Transfer Protocol
<b>HTTPS</b>	Hypertext Transfer Protocol Secure
<b>IEC</b>	International Electrotechnical Commission
<b>IMEI</b>	International Mobile Equipment Identity
<b>IoT</b>	Internet of Things
<b>IP</b>	Internet Protocol
<b>ISO</b>	International Organization for Standardization
<b>IT</b>	Information Technology
<b>MDM</b>	Mobile Device Management
<b>MTD</b>	Mobile Threat Defense
<b>NCCoE</b>	National Cybersecurity Center of Excellence
<b>NIAP</b>	National Information Assurance Partnership
<b>NIST</b>	National Institute of Standards and Technology
<b>OS</b>	Operating System
<b>PII</b>	Personally Identifiable Information
<b>PIN</b>	Personal Identification Number
<b>REST</b>	Representational State Transfer
<b>RMF</b>	Risk Management Framework
<b>SCEP</b>	Simple Certificate Enrollment Protocol
<b>SMS</b>	Short Message Service
<b>SP</b>	Special Publication
<b>SSL</b>	Secure Sockets Layer
<b>TE</b>	Threat Event

<b>TEE</b>	Trusted Execution Environment
<b>TLS</b>	Transport Layer Security
<b>UEM</b>	Unified Endpoint Management
<b>URL</b>	Uniform Resource Locator
<b>VPN</b>	Virtual Private Network

1185 **Appendix B Glossary**

<b>Access Management</b>	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 [30].
<b>Availability</b>	Ensure that users can access resources through remote access whenever needed [31].
<b>Bring Your Own Device (BYOD)</b>	A non-organization-controlled telework client device [31].
<b>Confidentiality</b>	Ensure that remote access communications and stored user data cannot be read by unauthorized parties [31].
<b>Data Actions</b>	System operations that process PII [32].
<b>Disassociability</b>	Enabling the processing of PII or events without association to individuals or devices beyond the operational requirements of the system [32].
<b>Eavesdropping</b>	An attack in which an Attacker listens passively to the authentication protocol to capture information which can be used in a subsequent active attack to masquerade as the Claimant [33] (definition located under eavesdropping attack).
<b>Firewall</b>	Firewalls are devices or programs that control the flow of network traffic between networks or hosts that employ differing security postures [34].
<b>Integrity</b>	Detect any intentional or unintentional changes to remote access communications that occur in transit [31].
<b>Manageability</b>	Providing the capability for granular administration of PII including alteration, deletion, and selective disclosure [32].
<b>Mobile Device</b>	A portable computing device that: (i) has a small form factor such that it can easily be carried by a single individual; (ii) is designed to operate without a physical connection (e.g., wirelessly transmit or receive information); (iii) possesses local, non-removable or removable data storage; and (iv) includes a self-contained power source. Mobile devices may also include voice communication capabilities, on-board sensors that allow the devices to capture information, and/or built-in features for

	synchronizing local data with remote locations. Examples include smart phones, tablets, and E-readers [29].
<b>Personally Identifiable Information (PII)</b>	Any information about an individual maintained by an agency, including any information that can be used to distinguish or trace an individual's identity, such as name, Social Security number, date and place of birth, mother's maiden name, or biometric records; and any other information that is linked or linkable to an individual, such as medical, educational, financial, and employment information [35] (adapted from Government Accountability Office Report 08-536).
<b>Predictability</b>	Enabling of reliable assumptions by individuals, owners, and operators about PII and its processing by a system [32].
<b>Privacy Event</b>	The occurrence or potential occurrence of problematic data actions [2].
<b>Problematic Data Action</b>	A data action that could cause an adverse effect for individuals [2].
<b>Threat</b>	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 [27].
<b>Vulnerability</b>	Weakness in an information system, system security procedures, internal controls, or implementation that could be exploited by a threat source [27].

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## 1367      **Appendix D    Standards and Guidance**

- 1368      ▪ National Institute of Standards and Technology (NIST) *Framework for Improving Critical  
1369      Infrastructure Cybersecurity* (Cybersecurity Framework) Version 1.1 [1]
- 1370      ▪ *NIST Privacy Framework: A Tool for Improving Privacy Through Enterprise Risk Management*,  
1371      Version 1.0 (Privacy Framework) [2]
- 1372      ▪ NIST Mobile Threat Catalogue [5]
- 1373      ▪ NIST Risk Management Framework [4]
- 1374      ▪ NIST Special Publication (SP) 1800-4, *Mobile Device Security: Cloud and Hybrid Builds* [7]
- 1375      ▪ NIST SP 1800-21, *Mobile Device Security: Corporate-Owned Personally-Enabled (COPE)* [36]
- 1376      ▪ NIST SP 800-30 Revision 1, *Guide for Conducting Risk Assessments* [27]
- 1377      ▪ NIST SP 800-37 Revision 2, *Risk Management Framework for Information Systems and  
1378      Organizations: A System Life Cycle Approach for Security and Privacy* [9]
- 1379      ▪ NIST SP 800-46 Revision 2, *Guide to Enterprise Telework, Remote Access, and Bring Your Own  
1380      Device (BYOD) Security* [31]
- 1381      ▪ NIST SP 800-52 Revision 2, *Guidelines for the Selection, Configuration, and Use of Transport  
1382      Layer Security (TLS) Implementations* [37]
- 1383      ▪ NIST SP 800-53 Revision 4 (Final), *Security and Privacy Controls for Information Systems and  
1384      Organizations* [29]
- 1385      ▪ NIST SP 800-53 Revision 5 (Final), *Security and Privacy Controls for Information Systems and  
1386      Organizations* [38]
- 1387      ▪ NIST SP 800-63-3, *Digital Identity Guidelines* [33]
- 1388      ▪ NIST SP 800-113, *Guide to SSL VPNs* [39]
- 1389      ▪ NIST SP 800-114 Revision 1, *User's Guide to Telework and Bring Your Own Device (BYOD)  
1390      Security* [40]
- 1391      ▪ NIST SP 800-124 Revision 2 (Draft), *Guidelines for Managing the Security of Mobile Devices in the  
1392      Enterprise* [6]
- 1393      ▪ NIST SP 800-163 Revision 1, *Vetting the Security of Mobile Applications* [41]
- 1394      ▪ NIST SP 800-171 Revision 2, *Protecting Controlled Unclassified Information in Nonfederal  
1395      Systems and Organizations* [42]
- 1396      ▪ NIST SP 800-181, *National Initiative for Cybersecurity Education (NICE) Cybersecurity Workforce  
1397      Framework (2017)* [3]
- 1398      ▪ NIST Federal Information Processing Standards Publication (FIPS) 200, *Minimum Security  
1399      Requirements for Federal Information and Information Systems* [28]

- 1400     ▪ NIST Privacy Risk Assessment Methodology [8]
- 1401     ▪ Center for Internet Security [43]
- 1402     ▪ Executive Office of the President, Bring Your Own Device toolkit [44]
- 1403     ▪ Federal Chief Information Officers Council and Department of Homeland Security *Mobile*
- 1404       *Security Reference Architecture*, Version 1.0 [45]
- 1405     ▪ Digital Services Advisory Group and Federal Chief Information Officers Council, *Government Use*
- 1406       *of Mobile Technology Barriers, Opportunities, and Gap Analysis* [46]
- 1407     ▪ International Organization for Standardization (ISO), International Electrotechnical Commission
- 1408       (IEC) 27001:2013, “Information technology – Security techniques – Information security
- 1409       management systems – Requirements” [47]
- 1410     ▪ Mobile Computing Decision example case study [48]
- 1411     ▪ Mobile Services Category Team (MSCT) Advanced Technology Academic Research Center
- 1412       (ATARC), “Mobility Strategy Development Guidelines Working Group Document” [49]
- 1413     ▪ MSCT ATARC, “Mobile Threat Protection App Vetting and App Security,” Working Group
- 1414       Document [50]
- 1415     ▪ MSCT, “Device Procurement and Management Guidance” [51]
- 1416     ▪ MSCT, “Mobile Device Management (MDM),” MDM Working Group Document [52]
- 1417     ▪ MSCT, “Mobile Services Roadmap, MSCT Strategic Approach” [53]
- 1418     ▪ National Information Assurance Partnership (NIAP), U.S. Government Approved Protection
- 1419       Profile—Extended Package for Mobile Device Management Agents Version 2.0 [54]
- 1420     ▪ NIAP, Approved Protection Profiles—Protection Profile for Mobile Device Fundamentals Version
- 1421       3.1 [55]
- 1422     ▪ NIAP, Approved Protection Profiles—Protection Profile for Mobile Device Management Version
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- 1424     ▪ NIAP, Product Compliant List [57]
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- 1426       *Acquisition and Management of Common Information Technology: Mobile Devices and Services*
- 1427       [58]
- 1428     ▪ United States Government Configuration Baseline [59]
- 1429     ▪ Department of Homeland Security (DHS), “DHS S&T Study on Mobile Device Security” [60]
- 1430     ▪ NIST Interagency Report (NISTIR) 8170, *Approaches for Federal Agencies to Use the*
- 1431       *Cybersecurity Framework* [61]

## 1432 **Appendix E Example Solution Lab Build Testing Details**

1433 This section shows the test activities performed to demonstrate how this practice guide's example  
1434 solution that was built in the National Institute of Standards and Technology (NIST) National  
1435 Cybersecurity Center of Excellence (NCCoE) lab addresses the threat events and problematic data  
1436 actions defined from the risk assessment.

### 1437 **E.1 Threat Event 1**

1438 **Summary:** Unauthorized access to sensitive information via a malicious or privacy-intrusive application  
1439 is tested.

1440 **Test Activity:** Place mock sensitive enterprise contact list and calendar entries on devices, then attempt  
1441 to install and use applications that access and back up those entries.

1442 **Desired Outcome:** The enterprise's security architecture would either detect or prevent use of these  
1443 applications, or it would block the applications from accessing enterprise-controlled contact list and  
1444 calendar entries. The enterprise's security architecture should identify presence of the applications and  
1445 the fact that they access contact and calendar entries. The security architecture should block these  
1446 applications from installing, block them from running, or detect their presence and cause another  
1447 appropriate response, such as blocking the mobile device from accessing enterprise resources until the  
1448 applications are removed.

1449 Alternatively, built-in device mechanisms such as Apple's managed applications functionality and  
1450 Google's Android enterprise work profile functionality could be used to separate the contact and  
1451 calendar entries associated with enterprise email accounts so that they can only be accessed by  
1452 enterprise applications (applications that the enterprise mobility management (EMM) authorizes and  
1453 manages), not by applications manually installed by the user. The user should not be able to manually  
1454 provision their enterprise email account. Only the EMM should be able to provision the account,  
1455 enabling enterprise controls on the enterprise contact list and calendar data.

1456 **Observed Outcome:** Once MaaS360 was aware that an application had access to sensitive data (e.g.,  
1457 calendar entries, contacts), it applied a policy to the device and took appropriate actions automatically.  
1458 MaaS360 sent an alert to the mobile device about an application compliance policy violation and  
1459 requested that the user remove the application(s) within an administrator-set time frame. In our test,  
1460 the simulated user account did not remove the restricted applications within the predefined time frame,  
1461 and MaaS360 removed mobile device management (MDM) control from the mobile device.

### 1462 **E.2 Threat Event 2**

1463 **Summary:** A fictional phishing event was created to test protection against the theft of credentials  
1464 through a short message service (SMS) or email phishing campaign.

1465 **Test Activity:**

- 1466     ▪ This threat event can be tested by establishing a web page with a form that impersonates an  
1467       enterprise login prompt.  
1468     ▪ Then send the web page's uniform resource locator (URL) via SMS or email and attempt to  
1469       collect and use enterprise login credentials.

1470 **Desired Outcome:** The enterprise's security architecture should block the user from browsing to known  
1471 malicious websites. Additionally, the enterprise should use multifactor authentication or phishing-  
1472 resistant authentication methods such as those based on public key cryptography so that either there is  
1473 no password for a malicious actor to capture or capturing the password is insufficient to obtain access to  
1474 enterprise resources.

1475 **Observed Outcome:** The example solution used Palo Alto Networks' next-generation firewall. The  
1476 firewall includes PAN-DB, a URL filtering service that automatically blocks known malicious URLs. The  
1477 URL filtering database is updated regularly to help protect users from malicious URLs. The next-  
1478 generation firewall blocked the attempt to visit the phishing site. However, if the malicious URL were  
1479 not present in PAN-DB, the user would be allowed to access the website.

### 1480 **E.3 Threat Event 3**

1481 **Summary:** Testing to discover for unauthorized applications that are not present on the official Apple  
1482 App Store or Google Play Store, that can be installed via URL links in SMS, email messages, or third-party  
1483 websites.

1484 **Test Activity (Android):**

- 1485     ▪ Send an email to the user with a message urging the user to click the link to install the  
1486       application.  
1487     ▪ On the device, if not already enabled, attempt to enable the Unknown Sources toggle setting in  
1488       the device security settings to allow installing applications from sources other than the Google  
1489       Play Store.  
1490     ▪ On the device, read the received email, click the link, and attempt to install the application.  
1491     ▪ Observe whether the application could be successfully installed. If so, observe whether the  
1492       enterprise detected and responded to installation of the unauthorized application.

1493 **Test Activity (iOS):**

- 1494     ▪ Send an email to the user with a message urging the user to click the link to install the  
1495       application.  
1496     ▪ On the device, read the received email, click the link, and attempt to install the application.

1497   **Desired Outcome:** Zimperium should alert both the administrators and user of the presence of a side-  
1498 loaded application.

1499   **Observed Outcome:** Zimperium alerted both the user and MaaS360 about the presence of a side-loaded  
1500 application. MaaS360 sent an email notification to the user and administrator about the presence of  
1501 side-loaded applications and required actions.

#### 1502   **E.4 Threat Event 4**

1503   **Summary:** Confidentiality and integrity loss due to exploitation of known vulnerability in the operating  
1504 system or firmware.

1505   **Test Activity:** Attempt to access enterprise resources from a mobile device with known vulnerabilities  
1506 (e.g., running an older, unpatched version of iOS or Android).

1507   **Desired Outcome:** The enterprise's security architecture should identify the presence of devices that are  
1508 running an outdated version of iOS or Android susceptible to known vulnerabilities. It should be  
1509 possible, when warranted by the risks, to block devices from accessing enterprise resources until system  
1510 updates are installed.

1511   **Observed Outcome:** Zimperium was able to identify devices that were running an outdated version of  
1512 iOS or Android, and it informed MaaS360 when a device was out of compliance.

#### 1513   **E.5 Threat Event 5**

1514   **Summary:** This threat event test shows collection of location, camera, or microphone data by an  
1515 application that has no need to access this data.

1516   Note: Not all applications that have access to location, camera, or microphone data are malicious.  
1517   However, when applications are found collecting this information, additional vetting or testing may be  
1518 required to determine the intent of its use and then to determine if the application is malicious.

1519   **Test Activity:** Upload the application to Kryptowire; observe the output report.

1520   **Desired Outcome:** Output report identifies the use of location, camera, or microphone by the  
1521 application.

1522   **Observed Outcome:** The Kryptowire report identified the usage of privacy-intrusive permissions when  
1523 not required.

#### 1524   **E.6 Threat Event 6**

1525   **Summary:** Loss of confidentiality of sensitive information via eavesdropping on unencrypted device  
1526 communications.

1527   **Test Activity:** Test if applications will attempt to establish a hypertext transfer protocol or unencrypted  
1528   connection.

1529   **Desired Outcome:**

- 1530       ■ Android: Because all work applications are inside a work container, a container-wide virtual  
1531       private network (VPN) policy can be applied to mitigate this threat event; all communications,  
1532       both encrypted and unencrypted, will be sent through the VPN tunnel. This will prevent  
1533       eavesdropping on any communication originating from a work application.
- 1534       ■ iOS: Apply a per-application VPN policy that will send all data transmitted by managed  
1535       applications through the VPN tunnel. This will prevent eavesdropping on any unencrypted  
1536       communication originating from work applications.
- 1537       ■ Kryptowire can identify if an application attempts to establish an unencrypted connection.

1538   **Observed Outcome:** The Kryptowire report indicated that the application did not use in-transit data  
1539   encryption.

1540   **E.7 Threat Event 7**

1541   **Summary:** Compromise of device integrity via observed, inferred, or brute-forced device unlock code.

1542   **Test Activity:**

- 1543       ■ Attempt to completely remove the device unlock code. Observe whether the attempt succeeds.
- 1544       ■ Attempt to set the device unlock code to “1234,” a weak four-digit personal identification  
1545       number (PIN). Observe whether the attempt succeeds.
- 1546       ■ Attempt to continually unlock the device, confirming that the device is factory reset after 10  
1547       failed attempts.

1548   **Desired Outcome:** Policies set on the device by the EMM (MaaS360) should require a device unlock  
1549   code to be set, prevent the device unlock code from being removed, require a minimum complexity for  
1550   the device unlock code, and factory resetting the device after 10 failed unlock attempts.

1551   Additionally, Zimperium can identify and report devices with a disabled lock screen.

1552   **Observed Outcome:** MaaS360 applies a policy to the devices to enforce a mandatory PIN and device-  
1553   wide capability. Zimperium reports devices with a disabled lock screen.

1554   **E.8 Threat Event 8**

1555   **Summary:** Unauthorized access to backend services via authentication or credential storage  
1556   vulnerabilities in internally developed applications.

1557   **Test Activity:** Application was submitted to Kryptowire for analysis of credential weaknesses.

1558   **Desired Outcome:** Discover and report credential weaknesses.

1559   **Observed Outcome:** Kryptowire recognized within an application that the application uses hardcoded  
1560 credentials. The application's use of hardcoded credentials could introduce vulnerabilities if  
1561 unauthorized entities used the hardcoded credentials to access enterprise resources.

## 1562   **E.9 Threat Event 9**

1563   **Summary:** Unauthorized access of enterprise resources from an unmanaged and potentially  
1564 compromised device.

1565   **Test Activity:** Attempt to directly access enterprise services, e.g., Exchange email server or corporate  
1566 VPN, on a mobile device that is not enrolled in the EMM system.

1567   **Desired Outcome:** Enterprise services should not be accessible from devices that are not enrolled in the  
1568 EMM system. Otherwise, the enterprise is not able to effectively manage devices to prevent threats.

1569   **Observed Outcome:** Devices that were not enrolled in MaaS360 were unable to access enterprise  
1570 resources as the GlobalProtect VPN gateway prevented the devices from authenticating without proper  
1571 client certificates—obtainable only through enrolling in the EMM.

## 1572   **E.10 Threat Event 10**

1573   **Summary:** Loss of organizational data due to a lost or stolen device.

1574   **Test Activity:** Attempt to download enterprise data onto a mobile device that is not enrolled in the  
1575 EMM system (may be performed in conjunction with TE-9). Attempt to remove (in conjunction with TE-  
1576 7) the screen lock passcode or demonstrate that the device does not have a screen lock passcode in  
1577 place. Attempt to locate and selectively wipe the device through the EMM console (will fail if the device  
1578 is not enrolled in the EMM).

1579   **Desired Outcome:** It should be possible to locate or wipe EMM enrolled devices in response to a report  
1580 that they have been lost or stolen. As demonstrated by TE-9, only EMM enrolled devices should be able  
1581 to access enterprise resources. As demonstrated by TE-7, EMM enrolled devices can be forced to have a  
1582 screen lock with a passcode of appropriate strength, which helps resist exploitation (including loss of  
1583 organizational data) if the device has been lost or stolen.

1584   **Observed Outcome (Enrolled Devices):** Enrolled devices are protected. They have an enterprise policy  
1585 requiring a PIN/lock screen, and therefore, the enterprise data on the device could not be accessed.  
1586 After 10 attempts to access the device, the device was selectively wiped, removing all enterprise data.  
1587 Additionally, the device could be remotely wiped after it was reported as lost to enterprise mobile  
1588 device service management, ensuring no corporate data is left in the hands of attackers.

1589 **Observed Outcome (Unenrolled Devices):** As shown in Threat Event 9, only enrolled devices could  
1590 access enterprise services. When the device attempted to access enterprise data, no connection to the  
1591 enterprise services was available. Because the device cannot access the enterprise, the device would not  
1592 contain enterprise information.

1593 In both outcomes, both enrolled and unenrolled, it would be at the user's discretion if they wanted to  
1594 wipe all personal data as well. Because this is a Bring Your Own Device (BYOD) scenario, only corporate  
1595 data (managed applications on iOS, and the work container on Android) would be deleted from a device  
1596 if the device were lost or stolen.

## 1597 **E.11 Threat Event 11**

1598 **Summary:** Loss of confidentiality of organizational data due to its unauthorized storage in non-  
1599 organizationally managed services.

1600 **Test Activity:** Connect to the enterprise VPN. Open an enterprise website or application. Attempt to  
1601 extract enterprise data by taking a screenshot, or copy/paste and send it via an unmanaged email  
1602 account.

1603 **Desired Outcome:** The EMM will prohibit screenshots and other data-sharing actions while using  
1604 managed applications.

1605 **Observed Outcome:** Through MaaS360 device policies, an administrator could prevent the following  
1606 actions on BYODs:

### 1607 **Android**

- 1608     ■ clipboard sharing
- 1609     ■ screen capture
- 1610     ■ share list
- 1611     ■ backup to Google
- 1612     ■ Secure Digital card write
- 1613     ■ Universal Serial Bus storage
- 1614     ■ video recording
- 1615     ■ Bluetooth
- 1616     ■ background data sync
- 1617     ■ Android Beam
- 1618     ■ Sbeam

1620   **iOS**

- 1621    ▪ opening, writing, and saving from managed to unmanaged applications
- 1622    ▪ AirDrop for managed applications
- 1623    ▪ screen capture
- 1624    ▪ AirPlay
- 1625    ▪ iCloud backup
- 1626    ▪ document, photo stream, and application sync
- 1627    ▪ print
- 1628    ▪ importing files

1629   **E.12 Threat Event 12**

1630   **Summary:** Unauthorized access to work applications via bypassed lock screen (e.g., sharing the device's  
1631   PIN with family members).

1632   **Test Activity:** Assume the user is an unauthorized person attempting to access enterprise resources.  
1633   Unlock the device and attempt to open a work application.

1634   **Desired Outcome:** The user will be prompted to log in to the VPN using their corporate username and  
1635   password. Because the user does not know this password, they are unable to log in and access  
1636   corporate resources. However, if the user attempts to access a work application within the idle log-out  
1637   time, they will be granted access because no password will be requested.

1638   **Observed Outcome:** GlobalProtect prompted the unauthorized user for a password. Not knowing the  
1639   password, the unauthorized user was unable to access corporate resources.

1640   **E.13 Problematic Data Action 1**

1641   **Summary:** The user retains personal data and applications while access to corporate applications and  
1642   data is removed.

1643   **Test Activity:** Selectively wipe a device using MaaS360.

1644   **Desired Outcome:** The user will no longer be able to access work applications and data on the device  
1645   and retains all access to their personal applications and data.

1646   **Observed Outcome:** Corporate data and applications are removed while personal data is untouched.

1647   **E.14 Problematic Data Action 2**

1648   **Summary:** Collection of application and location data is restricted.

- 1649    **Test Activity:** Disable location and application inventory collection in MaaS360.
- 1650    **Desired Outcome:** The MDM does not collect an inventory of applications on the device and does not  
1651    collect location information, including physical address, geographic coordinates and history, internet  
1652    protocol (IP) address, and secure set identifier (SSID).
- 1653    **Observed Outcome:** When inspecting a device, location and application inventory information are not  
1654    shown to the user, and application inventory information is not transmitted to Kryptowire.

## 1655    E.15    Problematic Data Action 3

- 1656    **Summary:** Access to monitoring data from the device is restricted to administrators. Application and  
1657    location data are not shared with third parties that support monitoring, data analytics, and other  
1658    functions for operating the BYOD solution.
- 1659    **Test Activity:** Attempt to log in to the MaaS360 admin portal without domain administrator permissions.
- 1660    **Desired Outcome:** System provides access controls to monitoring functions and logs. Data flow between  
1661    the organization and third parties does not contain location information, including physical address,  
1662    geographic coordinates and history, IP address, and SSID.
- 1663    **Observed Outcome:** Domain administrators were allowed to log in, but non-administrator users were  
1664    not.

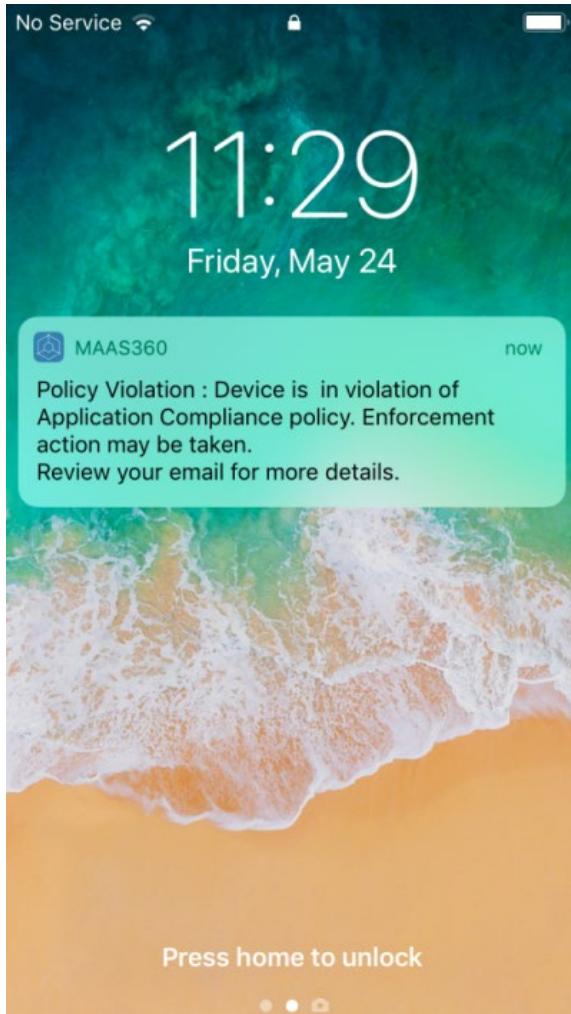
## 1665 **Appendix F Threat Event Test Information**

1666 Detailed information for some of this practice guide's threat events and their testing results appears  
1667 below.

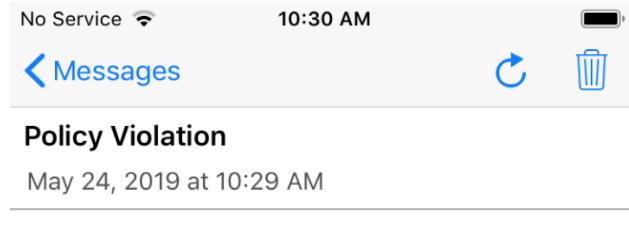
### 1668 **F.1 Threat Event 1**

1669 Threat Event 1 demonstrates unauthorized access attempts to sensitive information via a malicious or  
1670 privacy-intrusive application. The following figures show the alerts that the device user received  
1671 regarding the policy violations and their remediation actions.

1672 **Figure F-1 Policy Violation Notification**



1673 Figure F-2 Policy Violation Email



1674 Figure F-3 Policy Violation Alert Details Email

The screenshot shows an email from IBM MaaS360. The subject line is "Policy Violation Alert". The email contains the following information:

**Device Name:** MDS's iPhone  
**Username:** c\_n@\_com  
**Policy Violation:** Application Compliance

Restricted App detected: My Calendar  
Restricted App detected: PhoneCopy  
Restricted App detected: Editor  
Restricted App detected: PCalendars

Review executed and planned enforcement actions below:

**Action(s) Performed:**  
Alert. Alert from your administrator.

**Action(s) Planned:**  
Remove Control. Device will stop being managed. (1 hour)

**Instructions from Admin:** Please uninstall this application. Otherwise, MDM control will be removed in 1 hour.

1675 **Figure F-4 Enterprise Mobility Management Removal Alert**

To ensure timely and successful delivery of email from MaaS360, add [maas360@fiberlink.com](mailto:maas360@fiberlink.com) to your address book.

**Policy Violation Alert**

**Device Name:** iPhone  
**Username:** o\_\_\_\_\_n (@\_\_\_\_\_ .com)  
**Policy Violation:** Application Compliance  
    Restricted App detected: PhoneCopy  
    Restricted App detected: My Calendar  
    Restricted App detected: PCalendars

Review executed and planned enforcement actions below:

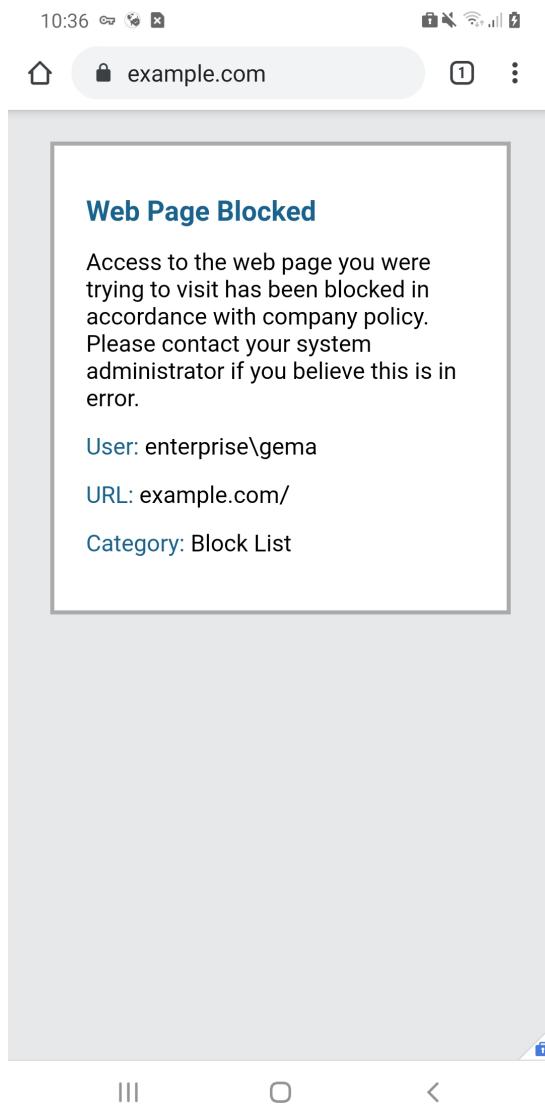
**Action(s) Performed:**  
Remove Control. Device will stop being managed.  
**Action(s) Planned:** None

**Instructions from Admin:** Enterprise Mobile Device Management control is removed from your device due to failure to comply to application requirements.

**1676 F.2 Threat Event 2**

- 1677 The following screen capture shows Threat Event 2's testing outcome, where Palo Alto Networks' PAN-  
1678 DB is blocking a website manually added to the malicious uniform resource locator (URL) database.

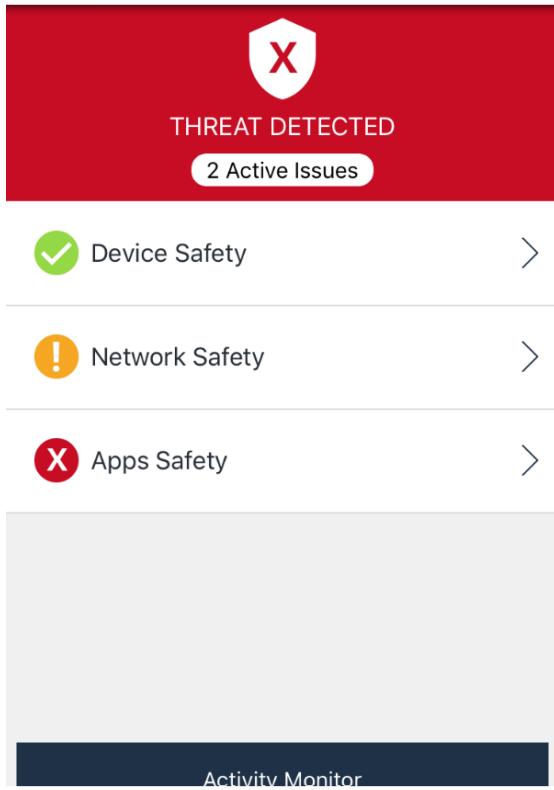
1679 **Figure F-5 PAN-DB Blocked Website**



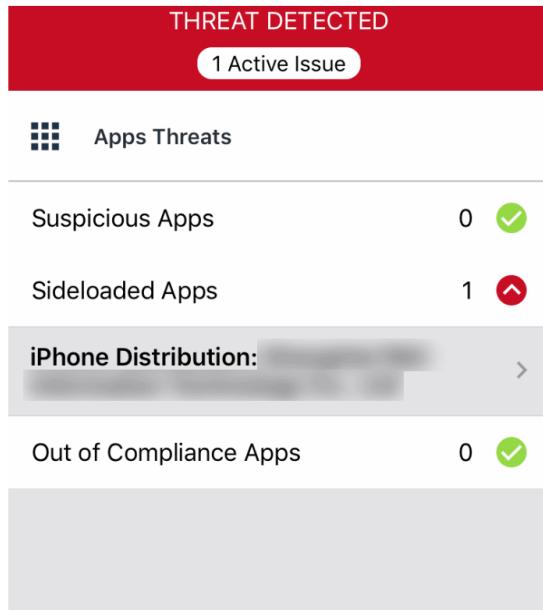
1680 **F.3 Threat Event 3**

1681 Threat Event 3 shows applications that are not present on the official Apple App Store or Google Play  
1682 Store being installed via unauthorized means (sideloading).

1683 Figure F-6 Zimperium Threat Detected



1684 Figure F-7 Zimperium Sideloaded Application Alert



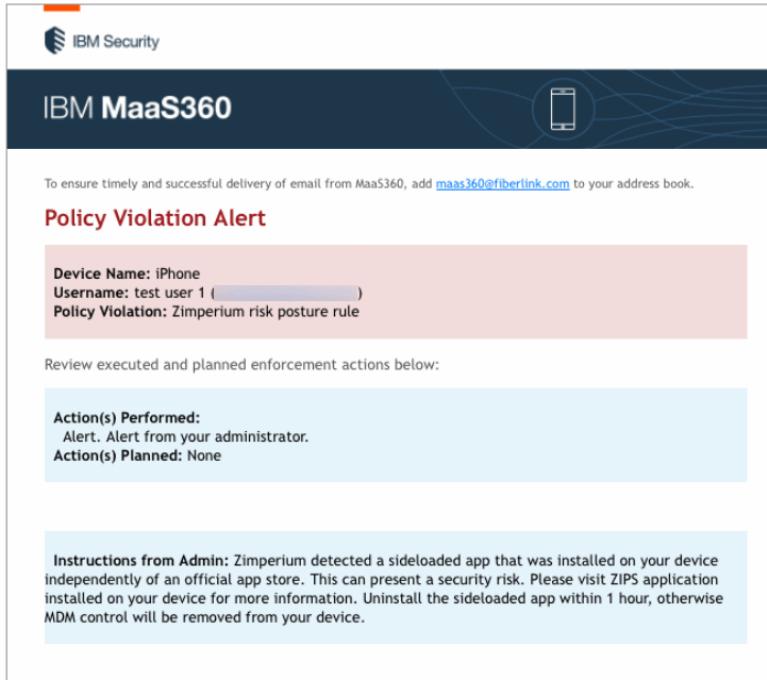
1685 Figure F-8 Zimperium Threat Log with Sideloaded Application Alert

Threat Log		06/03/2019 - 06/03/2019		Actions		Export		CSV			
		Severity	Threat Na...	Labels	Group	App Name	State	Action Triggered	Timestamp		
<input type="checkbox"/>	Critical	Sideloaded App!	No info		IBM MaaS360 - All Devic	zIPS	Pending	No info	06/03/2019 - 16:21		
<input type="checkbox"/>	Elevated	Unsecured WiFi!	No info		IBM MaaS360 - All Devic	zIPS	Pending	No info	06/03/2019 - 16:11		

Showing 2 of 2 Threats 0 selected [select all 2 events](#)

1 – 2 of 2

1686 Figure F-9 Email Regarding MaaS360 Policy Violation Alert



1687 **F.4 Threat Event 4**

1688 Threat Event 4 shows a risk detection during an operating system rules compliance status check.

1689 Figure F-10 MaaS360 Policy Violation Alert

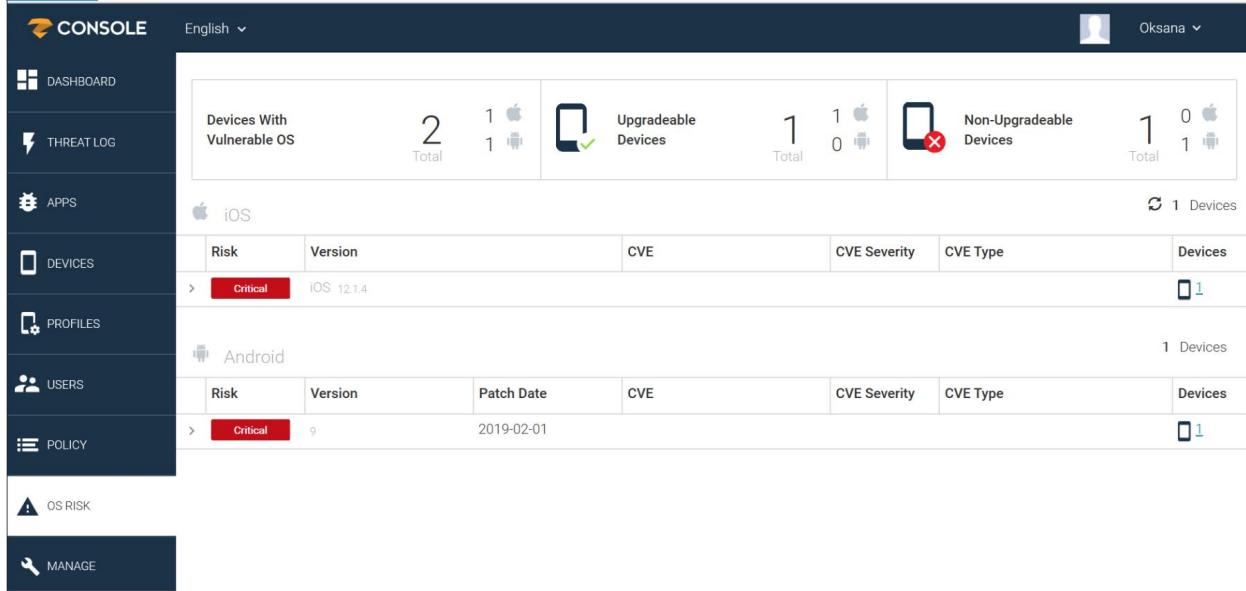


1690 Figure F-11 Zimperium Risk Detected

The screenshot shows a mobile application interface for 'Device Safety'. At the top, there is a status bar with 'No Service' and signal strength, the time '10:13 AM', and battery level. Below the status bar is a navigation bar with a back arrow labeled 'Back' and the text 'Device Safety'. The main screen has a yellow header with a shield icon containing an exclamation mark and the text 'RISK DETECTED'. Below the header, a button says '1 Active Issue'. The body of the screen is titled 'Details' and contains a table of device information. The table rows are as follows:

Model	iPhone
iOS	12.1.4
Vulnerable iOS Version	Yes <input checked="" type="checkbox"/>
Compromised	No <input checked="" type="checkbox"/>
Untrusted Profile	No <input checked="" type="checkbox"/>
BlueBorne Vulnerable	No <input checked="" type="checkbox"/>
Screen Lock	Enabled <input checked="" type="checkbox"/>
Device Protection	Enabled <input checked="" type="checkbox"/>

1691 Figure F-12 Zimperium OS Risk



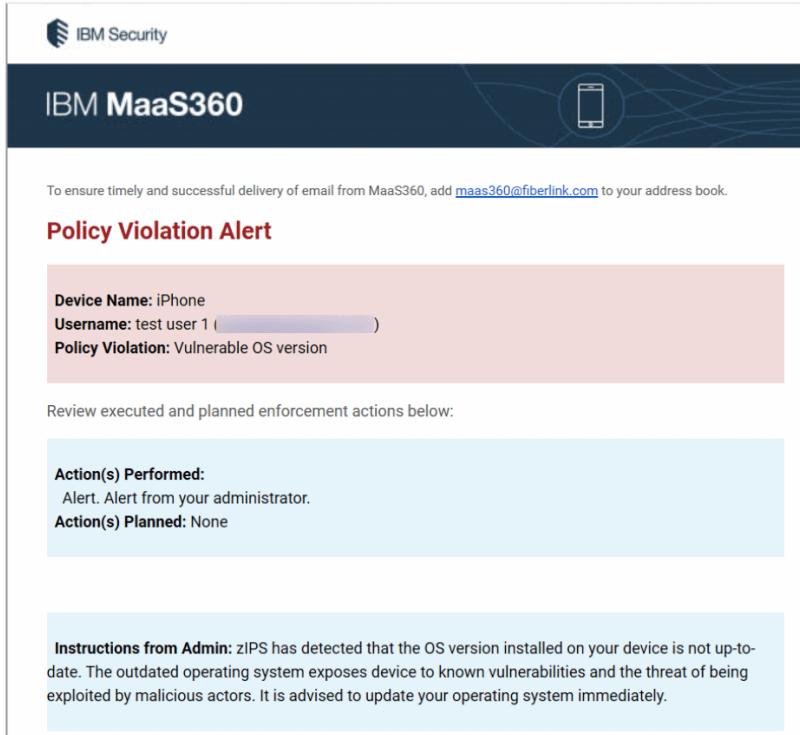
1692 Figure F-13 MaaS360 Compliance Rule Violation

Operating System				Manufacturer	Apple
Model				IMEI/MEID	
Device ID				Ownership	Employee Owned
Device Enrollment Mode				Non-DEP to DEP Converted	No/NA

**WorkPlace & Security**

Managed Status	Enrolled	Applied Policy	MDM: Default iOS MDM Policy (90) WorkPlace Persona: WorkPlace Persona Policy (4)
Last Reported	06/04/2019 12:15 EDT(Reachable)	Jailbroken/Rooted	No
Failed Settings	No	Selective Wipe Status	Not Applied
Encryption Level	Block-level & File-level	Passcode Status	MDM:Compliant WorkPlace: Enabled
Policy Compliance State	In Compliance	Rules Compliance Status	Out of Compliance
Out of Compliance Reasons	Rule:Vulnerable OS version	Rule Set Name	TE4

1693 **Figure F-14 MaaS360 Policy Violation Email**



1694 **F.5 Threat Event 5**

1695 Threat Event 5 demonstrates a report detailing collection of information such as location, camera, or  
1696 microphone data by an application.

1697 **Figure F-15 Kryptowire iOS Application Report**

The screenshot displays the Kryptowire iOS Mobile Application Analysis report. At the top right, it shows "iOS Mobile Application Analysis" and the date "02/14/2019, 6:00:57 pm". The main section is titled "Automated Analysis Summary" and is divided into three panels:

- Security:**
  - ⚠️ No data at rest encryption
  - ⚠️ Does not use iOS provided encryption
  - ⚠️ No data in transit encryption
  - ✓ No hard coded credentials
  - ✓ No hard coded initialization vector (IV)
  - ✓ No external library loaded dynamically
  - ✓ No malware detected
- Privacy & Information Access:**
  - ⚠️ Integrates with an ad network
  - ⚠️ Integrates with a social network
  - ⚠️ Accesses calendar
  - ⚠️ Has in app purchases
  - ✓ Does not get information about the user
  - ✓ No cloud storage integration
  - ✓ Does not expose sensitive information
- Device Access:**
  - ⚠️ Can interactive with sending SMS/MMS messages
  - ⚠️ Accesses the Internet
  - ⚠️ Can access microphone
  - ⚠️ Accesses photos and/or videos
  - ⚠️ Accesses location
  - ✓ Does not interact with email client
  - ✓ Does not access Bluetooth
  - ✓ Does not access camera
  - ✓ No access to contacts/address book

1698 **F.6 Threat Event 6**

1699 Threat Event 6 demonstrates a report of an application that can lose confidentiality of sensitive  
 1700 information via eavesdropping on unencrypted device communications.

1701 Figure F-16 Kryptowire Android Application Report

The screenshot shows the 'Automated Analysis Summary' page from the Kryptowire Android Mobile Application Analysis tool. At the top, there's a logo for 'kryptowire' and the text 'Android Mobile Application Analysis' with a date '05/02/2019, 9:12:28 am'. Below this, the main title is 'Automated Analysis Summary'. The page is divided into two main sections: 'Security' and 'Privacy & Information Access'. The 'Security' section contains two yellow warning icons: 'No data at rest encryption' and 'No data in transit encryption', both of which are highlighted with red boxes. The 'Privacy & Information Access' section contains one yellow warning icon: 'Does not request authentication tokens'. Underneath these warnings, there are lists of green checkmarks indicating best practices or secure behaviors.

Security	Privacy & Information Access
<ul style="list-style-type: none"><li>⚠ No data at rest encryption</li><li>⚠ No data in transit encryption</li></ul>	<ul style="list-style-type: none"><li>⚠ Does not request authentication tokens</li></ul>
<ul style="list-style-type: none"><li>✓ No hard coded credentials</li><li>✓ Uses proper SSL verification</li><li>✓ No Java classes loaded dynamically</li><li>✓ No external library loaded dynamically</li></ul>	<ul style="list-style-type: none"><li>✓ Does not track user behaviour</li><li>✓ No ad network integration</li><li>✓ No cloud storage integration</li><li>✓ No social network integration</li><li>✓ No access to Account Manager</li></ul>

## 1702 F.7 Threat Event 7

1703 Two scenarios are shown for Threat Event 7:

- 1704     ■ The first scenario shows MaaS360 applying a policy to the devices to enforce a mandatory PIN and device-wipe capability.
- 1705
- 1706     ■ The second scenario shows Zimperium reporting a disabled lock screen.

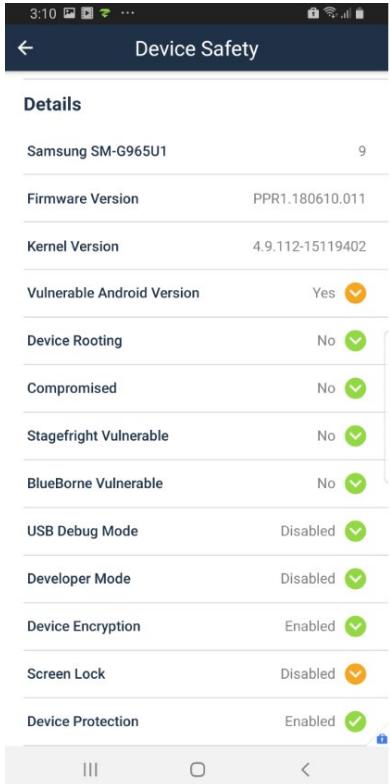
1707 The diagram shows the MaaS360 configuration requirements for Passcode Settings for its managed  
1708 devices, including a mandatory PIN configuration.

1709 **Figure F-17 MaaS360 Applying Mandatory PIN Policy**

The screenshot displays the IBM MaaS360 web interface. At the top, there is a navigation bar with links for HOME, DEVICES, USERS, SECURITY, APPS, DOCS, REPORTS, and SETUP. A search bar is located at the top right. Below the navigation bar, the main content area shows a policy titled "Default Android MDM Policy" (version 45, published). On the left, a sidebar lists settings categories: Device Settings, Advanced Settings, Android Enterprise Settings, and Passcode (which is selected and highlighted in blue). The main panel shows the "Passcode Settings" configuration. Under "Configure Passcode Policy", there is a checked checkbox labeled "Select this option to enforce the use of a Passcode before using Android for Work". Below this, under "Minimum Passcode Quality", a dropdown menu is set to "Numeric". To the right, a note indicates compatibility with "Android 5.0+ (PO & DO)". Further down, there are fields for "Minimum Passcode Length (4-16 characters)" and "Delay for Passcode prompt after lock screen", both currently set to their default values. To the right of these fields, notes specify compatibility with "Android 5.0+ (PO & DO)" and "DO With KNOX (SAFE 2.0+)".

1710 The figure shows Zimperium reporting discovery of a disabled lock screen.

1711 **Figure F-18 Zimperium Reporting Devices with a Disabled Lock Screen**



## 1712 **F.8 Threat Event 8**

1713 Threat Event 8 testing images show a report that detected unauthorized access to backend services via authentication or credential storage vulnerabilities in internally developed applications.

1715 Figure F-19 Application Report with Hardcoded Credentials

The screenshot shows the Kryptowire Android Mobile Application Analysis interface. At the top, there's a logo for 'kryptowire' and a title 'Android Mobile Application Analysis'. Below this is a section titled 'Automated Analysis Summary'.

**Security:**

- ⚠️ Uses hard coded credentials for secure operations (highlighted with a red border)
- ⚠️ Kills background processes from other apps
- ⚠️ Loads an external library
- ⚠️ Requested excessive permissions
- ✓ Uses proper SSL verification
- ✓ No Java classes loaded dynamically

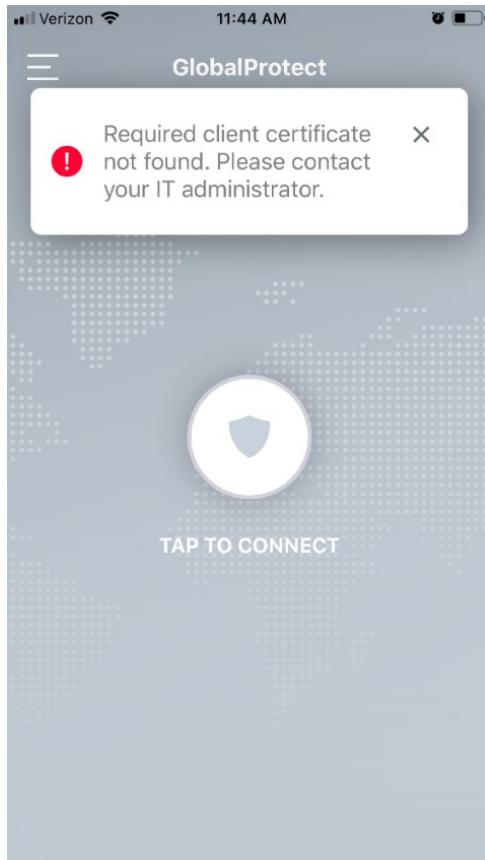
**Privacy & Information Access:**

- ⚠️ Accesses subscriber ID of the user
- ⚠️ Accesses unique ID of the device
- ⚠️ Creates resources accessible from outside parties
- ✓ Does not track user behaviour
- ✓ No ad network integration
- ✓ No cloud storage integration
- ✓ No social network integration

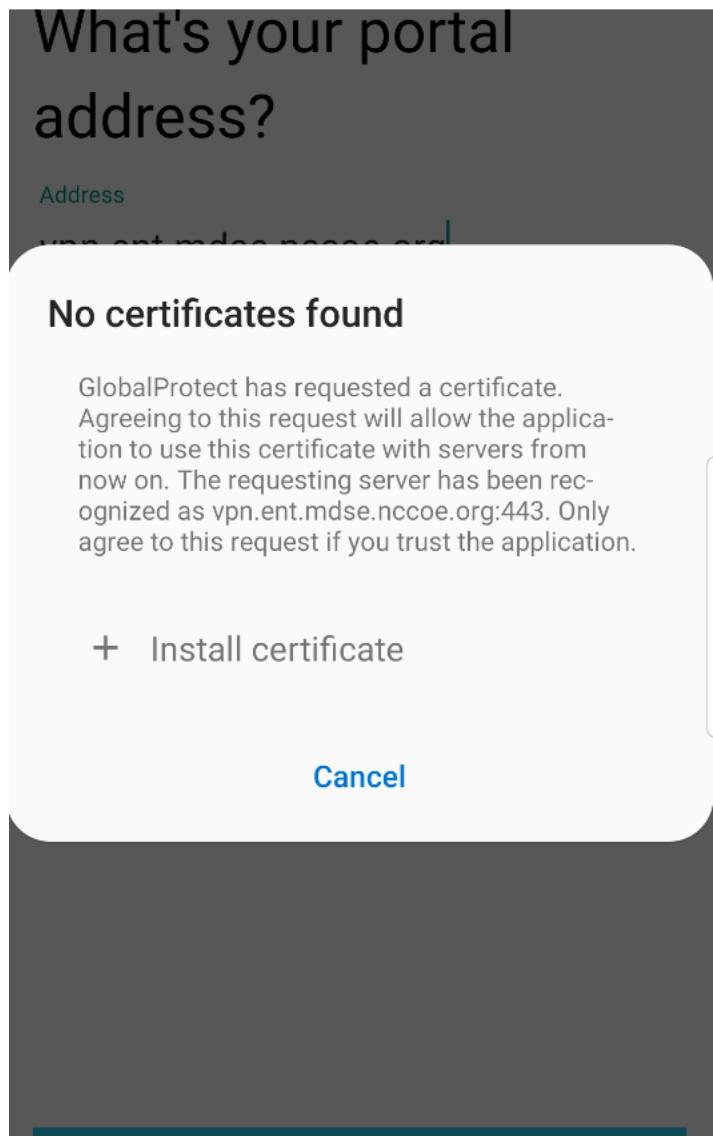
## 1716 F.9 Threat Event 9

1717 Threat Event 9 shows an unsuccessful attempt to access enterprise resources from an unmanaged and  
1718 potentially compromised device.

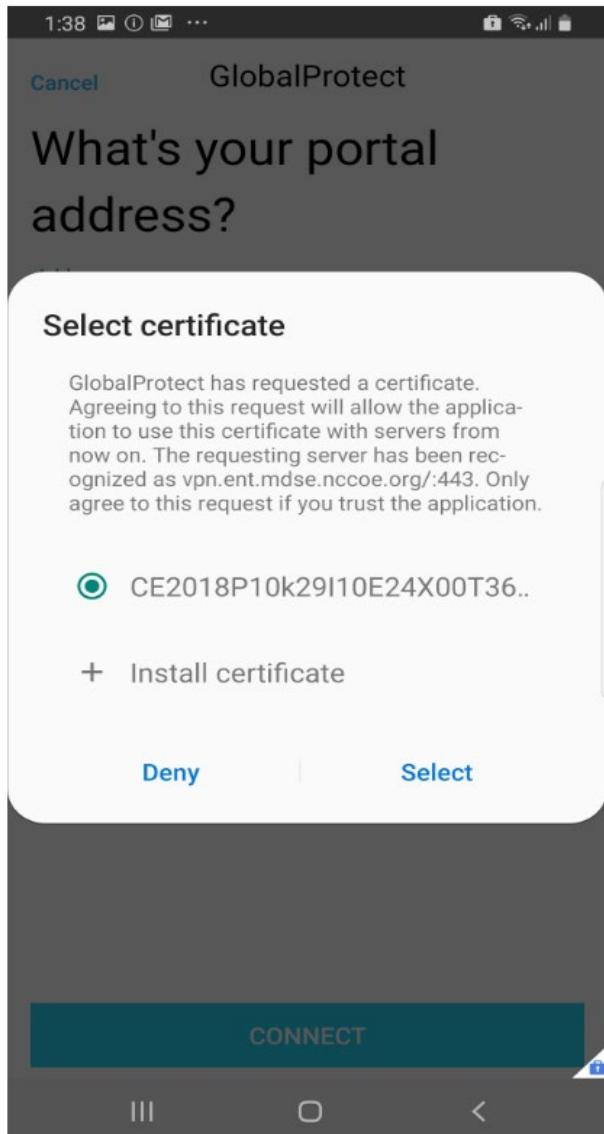
1719 Figure F-20 Attempting to Access the Virtual Private Network (VPN) on an Unmanaged Device



1720 Figure F-21 Android: Attempting to Access the VPN on an Unmanaged Device



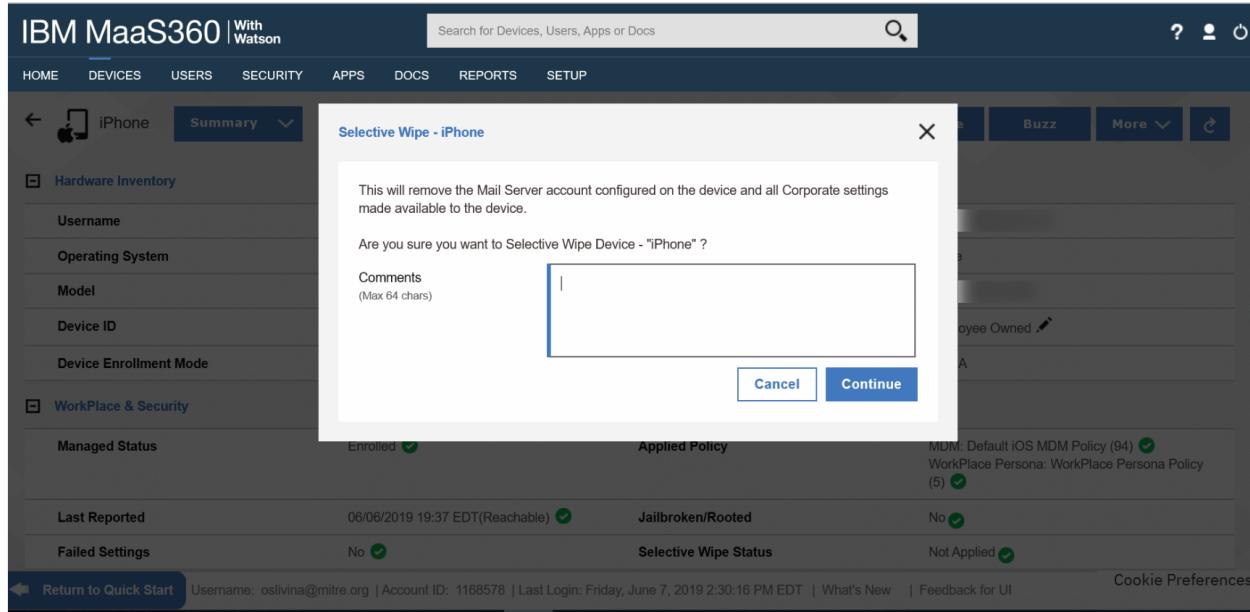
1721 Figure F-22 Android: Attempting to Access the VPN on a Managed Device



## 1722 F.10 Threat Event 10

1723 These screen captures show selectively wiping the device to remove organizational data. This prevents  
1724 the loss of organizational data due to a lost or stolen device.

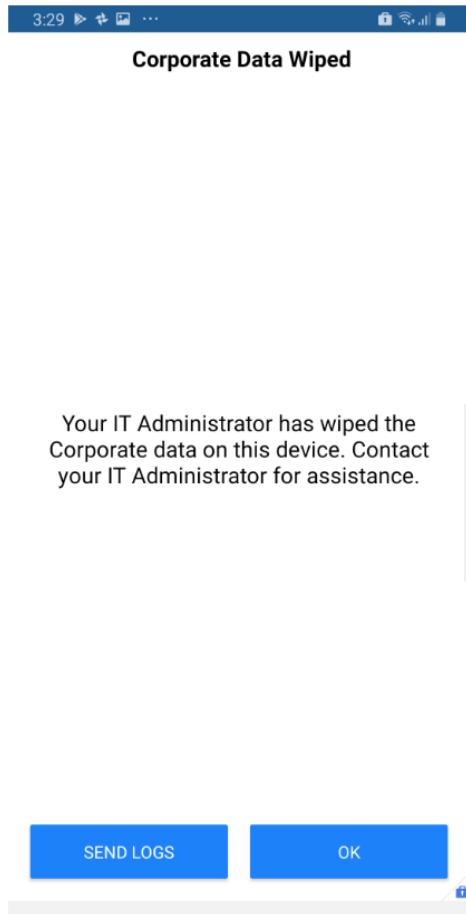
1725 Figure F-23 Selectively Wiping an iOS Device



1726 Figure F-24 Selective-Wipe Completed

Last Reported	06/07/2019 13:36 EDT	Android Blocked Permissions	Camera (Core) Usage Access (Core) Location (Core)
Jailbroken/Rooted	No	Google Device Attestation Failed	No
Samsung Device Attestation Failed	-	Last Device Attestation Result	06/06/2019 16:23 EDT
Factory Reset Protection	Not Supported	Failed Settings	No
Selective Wipe Status	Completed (06/07/2019 15:27 EDT)	Encryption Level	Encryption Complete
Passcode Status	MDM:Compliant WorkPlace: Not Enabled	Policy Compliance State	In Compliance
Rules Compliance Status	In Compliance	Out of Compliance Reasons	-
Rule Set Name	TE7	Kiosk Mode	Not Applicable
Usage Policy	-		
<b>Network Information</b>			
Phone Number	-	ICCID	-
Is Roaming	Not Enabled	International Data Roaming	Not Enabled

1727 **Figure F-25 No Corporate Data Left on Device**



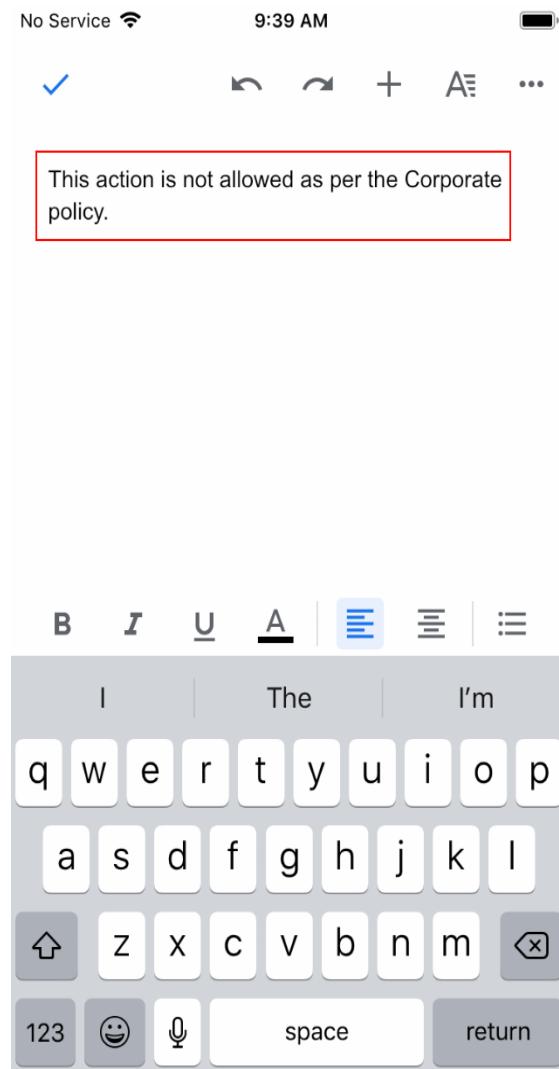
1728 **F.11 Threat Event 11**

1729 These images show an example configuration and outcome to prevent data from being pasted from one  
1730 application to another application.

1731 Figure F-26 MaaS360 DLP Configuration

The screenshot shows the IBM MaaS360 DLP Configuration interface. The left sidebar lists various settings under 'Device Settings': Passcode, Restrictions (selected), Application Compliance, ActiveSync, Wi-Fi, VPN, AirPrint, Accounts, and Advanced Settings. The main panel is titled 'Configure Device Restrictions' and contains a note: 'Unencrypted backups are restricted for all APNS managed devices. Select this option to configure restrictions on use of device features, application and content.' A checkbox next to this note is checked. Below this, the 'Device Functionality' section is expanded, showing three options with checkboxes: 'Allow Open from Managed to Unmanaged apps' (unchecked, iOS 7.0+), 'Allow Open from Unmanaged to Managed Apps' (unchecked, iOS 7.0+), and 'Allow AirDrop for Managed Apps' (unchecked, iOS 9.0+).

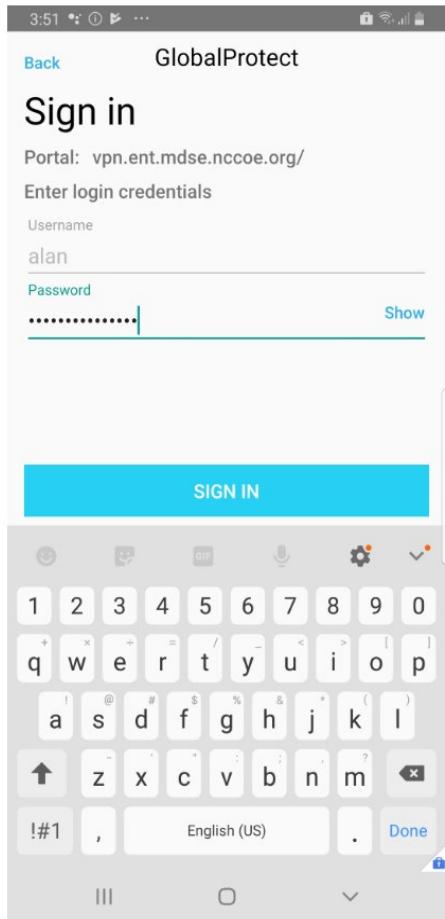
1732 **Figure F-27 Attempting to Paste Text on iOS**



## 1733 **F.12 Threat Event 12**

- 1734 This image shows a required password to prevent unauthorized access to work applications via a bypassed lock screen. If the lock screen is bypassed, individuals would not be able to connect to the VPN without knowing the user's domain password.
- 1735
- 1736

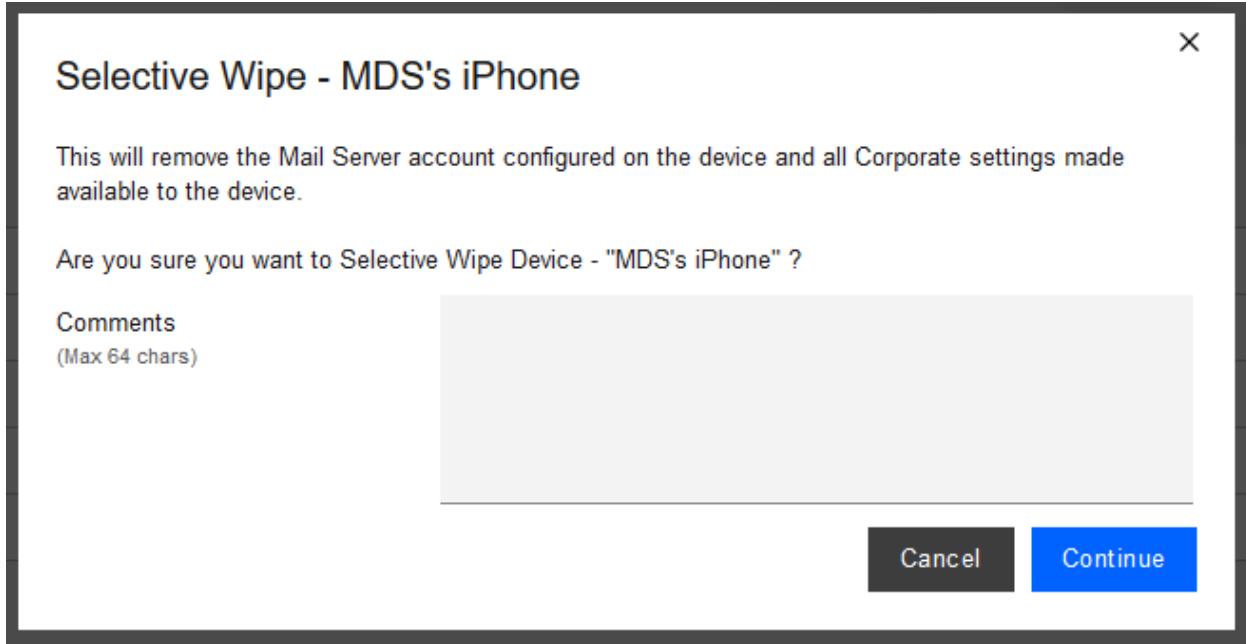
1737 **Figure F-28 GlobalProtect Requires the User's Password**



1738 **F.13 Problematic Data Action 1**

1739 This image shows initiation of a selective wipe. The selective wipe will remove the Mail Server account  
1740 and all corporate settings available to the device.

1741 **Figure F-29 Initiating a Selective Wipe**



## 1742 **F.14 Problematic Data Action 2**

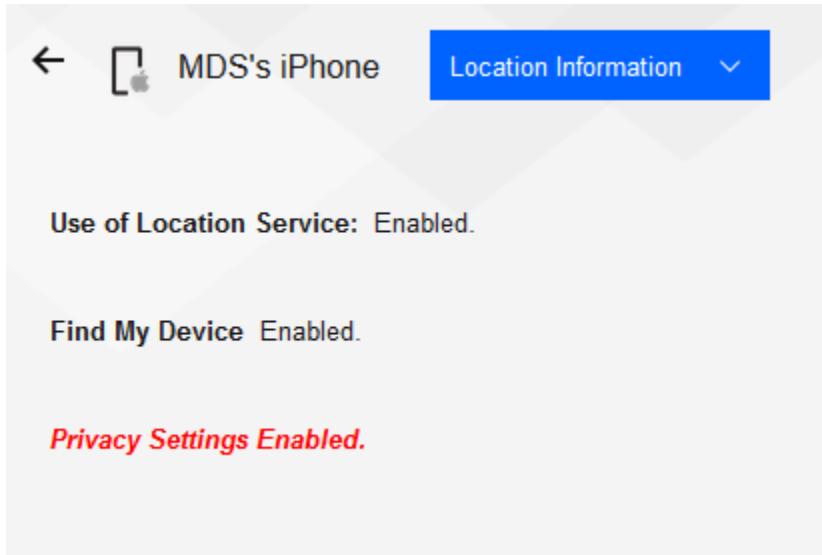
1743 This shows inventory information for applications and the location information restriction.

1744 **Figure F-30 Application Inventory Information**

MDS's iPhone		Apps Installed	Locate	Message	Buzz	More	
<b>▼ Apps Installed</b>							
Application...	App ID	Full Version	Application...	Data Size (...)	Managed	App Source	Compliance...
GlobalProtect	com.paloaltonet.works.globalprotect.vpn	5.1.1	8.46	0.77	Installed by MDM	iTunes	Required
MaaS360	com.fiberlink.maaS360forios	3.97.36	147.02	2.99	Installed by MDM	iTunes	Required
MaaS360 VPN	com.fiberlink.maaS360.maas360vpn	3.20.50	7.53	0.02	Installed by MDM	iTunes	Required
zIPS	com.zimperium.zIPS.appstore	4.12.0	36.94	0.05	Installed by MDM	iTunes	Required
< < 1 > >		Jump To Page	Displaying 1 - 4 of 4 Records			CSV	Export

1745 When privacy restrictions are configured, only corporate application inventory information is collected.

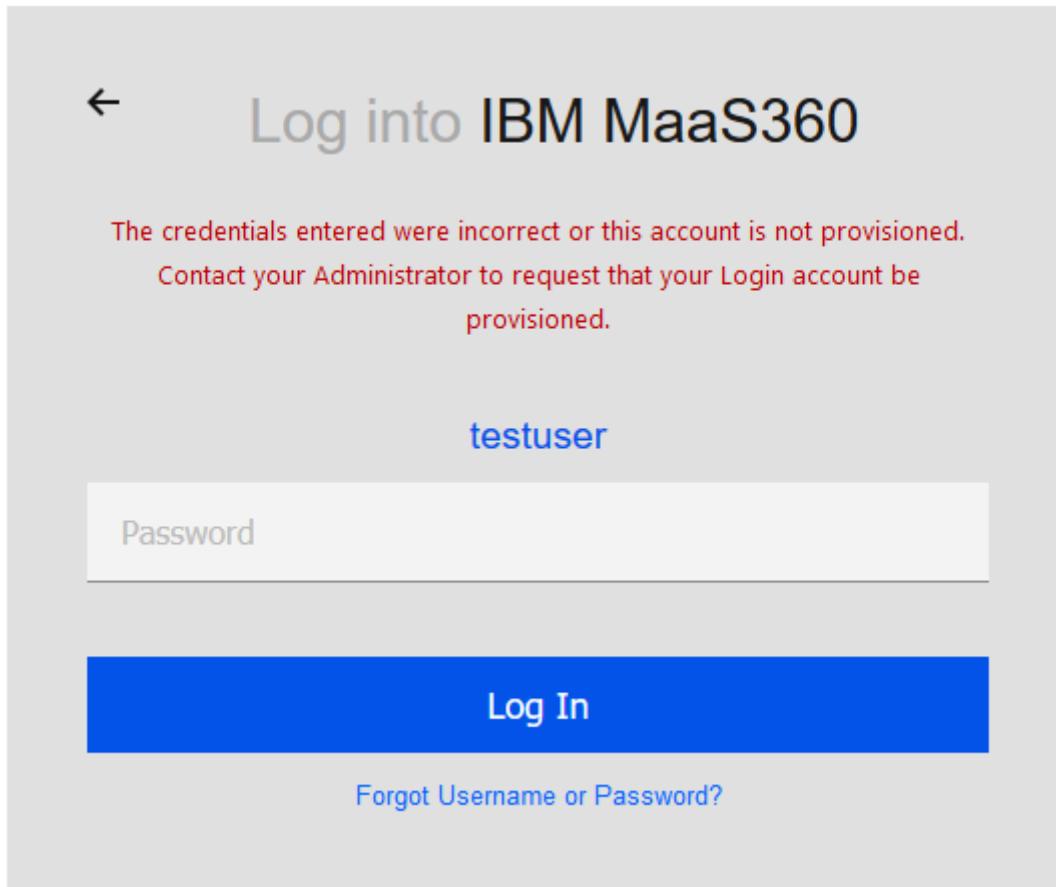
1746 Figure F-31 Location Information Restricted



1747 **F.15 Problematic Data Action 3**

1748 This demonstrates how a non-administrator account will be prevented from logging in to the MaaS360  
1749 portal.

1750 Figure F-32 Non-Administrator Failed Portal Login



## Appendix G Example Security Subcategory and Control Map

Using the developed risk information as input, the security characteristics of the example solution were identified. A security control map was developed documenting the example solution's capabilities with applicable Subcategories from the National Institute of Standards and Technology (NIST) *Framework for Improving Critical Infrastructure Cybersecurity*, Version 1.1 (Cybersecurity Framework) [1]; NIST Special Publication (SP) 800-53 Revision 5, *Security and Privacy Controls for Information Systems and Organizations* [38]; International Organization for Standardization (ISO); International Electrotechnical Commission (IEC) 27001:2013 *Information technology – Security techniques – Information security management systems – Requirements* [47]; the Center for Internet Security's (CIS) control set Version 6 [43]; and NIST SP 800-181, *National Initiative for Cybersecurity Education (NICE) Cybersecurity Workforce Framework (Work Roles from 2017 version)* [3].

Table G-1's example security control map identifies the security characteristic standards mapping for the products as they were used in the example solution. The products may have additional capabilities that we did not use in this example solution. For that reason, it is recommended that the mapping not be used as a reference for all of the security capabilities these products may be able to address.

**Table G-1 Example Solution's Cybersecurity Standards and Best Practices Mapping**

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
<b>Mobile Threat Defense</b>						
Kryptowire Cloud Service	Application Vetting	ID.RA-1: Asset vulnerabilities are identified and documented.	CA-2, CA-7, CA-8: Security Assessment and Authorization  RA-3, RA-5: Risk Assessment  SA-4: Acquisition Process	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

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
	<b>ID.RA-3:</b> Threats, both internal and external, are identified and documented.		<b>SI-7:</b> Software, Firmware, and Information Integrity			
			<b>RA-3:</b> Risk Assessment  <b>SI-7:</b> Software, Firmware, and Information Integrity  <b>PM-12, PM-16:</b> Insider Threat Program	<b>6.1.2:</b> Information risk assessment process	<b>CSC 4:</b> Continuous Vulnerability Assessment and Remediation	<b>SP-RSK-002:</b> Security Control Assessor  <b>OM-ANA-001:</b> Systems Security Analyst  <b>OV-SPP-001:</b> Cyber Workforce Developer and Manager  <b>OV-TEA-001:</b> Cyber Instructional Curriculum Developer  <b>PR-VAM-001:</b> Vulnerability Assessment Analyst

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
	<b>DE.CM-4:</b> Malicious code is detected.		<b>SI-7:</b> Software, Firmware, and Information Integrity	<b>A.12.2.1:</b> Controls Against Malware	<b>CSC 4:</b> Continuous Vulnerability Assessment and Remediation  <b>CSC 7:</b> Email and Web Browser Protections  <b>CSC 8:</b> Malware Defenses  <b>CSC 12:</b> Boundary Defense	<b>PR-VAM-001:</b> Vulnerability Assessment Analyst  <b>PR-CIR-001:</b> Cyber Defense Incident Responder  <b>PR-CDA-001:</b> Cyber Defense Analyst
	<b>DE.CM-5:</b> Unauthorized mobile code is detected.		<b>SC-18:</b> Mobile Code  <b>SI-7:</b> Software, Firmware, and	<b>A.12.5.1:</b> Installation of Software on Operational Systems	<b>CSC 7:</b> Email and Web Browser Protections	<b>PR-CDA-001:</b> Cyber Defense Analyst

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
			Information Integrity	<b>A.12.6.2:</b> Restrictions on Software Installation	<b>CSC 8:</b> Malware Defenses	<b>SP-DEV-002:</b> Secure Software Assessor
<b>Zimperium Console version vGA-4.23.1</b>	Cloud service that complements the zIPS Agent	<b>ID.AM-1:</b> Physical devices and systems within the organization are inventoried.	<b>CM-8:</b> Information System Component Inventory  <b>PM-5:</b> Information System Inventory	<b>A.8.1.1:</b> Inventory of Assets  <b>A.8.1.2:</b> Ownership of Assets	<b>CSC 1:</b> Inventory of Authorized and Unauthorized Devices	<b>OM-STS-001:</b> Technical Support Specialist  <b>OM-NET-001:</b> Network Operations Specialist  <b>OM-ADM-001:</b> System Administrator

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
<b>zIPS agent Version 4.9.2 (iOS), 4.9.2 (Android)</b>	Endpoint security for mobile device threats	<b>ID.AM-2:</b> Software platforms and applications within the organization are inventoried.	<b>CM-8:</b> Information System Component Inventory  <b>PM-5:</b> Information System Inventory	<b>A.8.1.1:</b> Inventory of Assets  <b>A.8.1.2:</b> Ownership of Assets  <b>A.12.5.1:</b> Installation of Software on Operational Systems	<b>CSC 2:</b> Inventory of Authorized and Unauthorized Software	<b>SP-DEV-002:</b> Secure Software Assessor  <b>SP-DEV-001:</b> Software Developer  <b>SP-TRD-001:</b> Research and Development Specialist
		<b>DE.CM-8:</b> Vulnerability scans are performed.	<b>RA-5:</b> Vulnerability Monitoring and Scanning	<b>A.12.6.1:</b> Management of technical vulnerabilities	<b>CSC 4:</b> Continuous Vulnerability Assessment and Remediation  <b>CSC 20:</b> Penetration Tests and Red Team Exercises	<b>PR-VAM-001:</b> Vulnerability Assessment Analyst  <b>PR-INF-001:</b> Cyber Defense Infrastructure Support Specialist  <b>PR-CDA-001:</b> Cyber Defense Analyst

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
		DE.AE-5: Incident alert thresholds are established.	IR-4: Incident Handling IR-5: Incident Monitoring IR-8: Incident Response Plan	A.16.1.4: Assessment of and decision on information security events	CSC 6: Maintenance, Monitoring, and Analysis of Audit Logs  CSC 19: Incident Response and Management	PR-CIR-001: Cyber Defense Incident Responder  AN-TWA-001: Threat/Warning Analyst
		DE.CM-5: Unauthorized mobile code is detected.	SC-18: Mobile Code  SI-7: Software, Firmware, and Information Integrity	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  SP-DEV-002: Secure Software Assessor
<b>Enterprise Mobility Management</b>						
IBM MaaS360 Mobile Device Management (SaaS)	Enforces organizational mobile endpoint security policy	ID.AM-1: Physical devices and systems within the organization are inventoried.	CM-8: System Component Inventory  PM-5: System Inventory	A.8.1.1: Inventory of Assets  A.8.1.2: Ownership of Assets	CSC 1: Inventory of Authorized and Unauthorized Devices	OM-STS-001: Technical Support Specialist  OM-NET-001: Network Operations Specialist

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
<b>Version 10.73</b>						<b>OM-ADM-001:</b> System Administrator
	<b>ID.AM-2:</b> Software platforms and applications within the organization are inventoried.	<b>CM-8:</b> System Component Inventory  <b>PM-5:</b> System Inventory	<b>A.8.1.1:</b> Inventory of Assets  <b>A.8.1.2:</b> Ownership of Assets  <b>A.12.5.1:</b> Installation of Software on Operational Systems	<b>CSC 2:</b> Inventory of Authorized and Unauthorized Software		<b>SP-DEV-002:</b> Secure Software Assessor  <b>SP-DEV-001:</b> Software Developer  <b>SP-TRD-001:</b> Research and Development Specialist

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
		<b>PR.AC-1:</b> Identities and credentials are issued, managed, verified, revoked, and audited for authorized devices, users, and processes.	<b>AC-3:</b> Access Enforcement  <b>IA-1, IA-2, IA-3, IA-4, IA-5, IA-6, IA-7, IA-8, IA-9, IA-10, IA-11:</b> Identification and Authentication Family	<b>A.9.2.1:</b> User Registration and De-Registration  <b>A.9.2.2:</b> User Access Provisioning  <b>A.9.2.3:</b> Management of Privileged Access Rights  <b>A.9.2.4:</b> Management of Secret Authentication Information of Users  <b>A.9.2.6:</b> Removal or Adjustment of Access Rights  <b>A.9.3.1:</b> Use of Secret Authentication Information	<b>CSC 1:</b> Inventory of Authorized and Unauthorized Devices  <b>CSC 5:</b> Controlled Use of Administrative Privileges  <b>CSC 15:</b> Wireless Access Control  <b>CSC 16:</b> Account Monitoring and Control	<b>OV-SPP-002:</b> Cyber Policy and Strategy Planner  <b>OM-ADM-001:</b> System Administrator  <b>OV-MGT-002:</b> Communications Security (COMSEC) Manager

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
				<b>A.9.4.2:</b> Secure logon Procedures  <b>A.9.4.3:</b> Password Management System		

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
	<b>PR.AC-3:</b> Remote access is managed.		<b>AC-1:</b> Access Control Policy and Procedures <b>AC-17:</b> Remote Access <b>AC-19:</b> Access Control for Mobile Devices <b>AC-20:</b> Use of External Systems <b>SC-15:</b> Collaborative Computing Devices and Applications	<b>A.6.2.1:</b> Mobile Device Policy <b>A.6.2.2:</b> Tele-working <b>A.11.2.6:</b> Security of equipment and assets off premises <b>A.13.1.1:</b> Network Controls <b>A.13.2.1:</b> Information Transfer Policies and Procedures	<b>CSC 12:</b> Boundary Defense	<b>OV-SPP-002:</b> Cyber Policy and Strategy Planner  <b>OV-MGT-002:</b> Communications Security (COMSEC) Manager
	<b>PR.AC-6:</b> Identities are proofed and bound to credentials and asserted in interactions.		<b>AC-1, AC-3:</b> Access Control Policy and Procedures <b>IA-2, IA-4, IA-5:</b> Identification	<b>A.7.1.1:</b> Screening <b>A.9.2.1:</b> User Registration and De-Registration	<b>CSC 16:</b> Account Monitoring and Control	<b>OV-SPP-002:</b> Cyber Policy and Strategy Planner  <b>OV-MGT-002:</b> Communications Security

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
			and Authentication <b>PE-2:</b> Physical Access Authorizations			(COMSEC) Manager
	<b>PR.IP-1:</b> A baseline configuration of information technology/industrial control systems is created and maintained, incorporating security principles (e.g., concept of least functionality).		<b>CM-8:</b> System Component Inventory  <b>SA-10:</b> Developer Configuration Management	<b>A.12.1.2:</b> Change Management  <b>A.12.5.1:</b> Installation of Software on Operational Systems  <b>A.12.6.2:</b> Restrictions on Software Installation  <b>A.14.2.2:</b> System Change Control Procedures  <b>A.14.2.3:</b> Technical Review of Applications After Operating Platform Changes	<b>CSC 3:</b> Secure Configurations for Hardware and Software on Mobile Devices, Laptops, Workstations, and Servers  <b>CSC 9:</b> Limitation and Control of Network Ports, Protocols, and Services  <b>CSC 11:</b> Secure Configurations for Network Devices such as	<b>SP-ARC-002:</b> Security Architect  <b>OV-SPP-002:</b> Cyber Policy and Strategy Planner  <b>SP-SYS-001:</b> Information Systems Security Developer  <b>OM-ADM-001:</b> System Administrator  <b>PR-VAM-001:</b> Vulnerability Assessment Analyst

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
				<b>A.14.2.4:</b> Restrictions on Changes to Software Packages	Firewalls, Routers, and Switches	

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
<b>IBM MaaS360 Mobile Device Management Agent Version 3.91.5 (iOS), 6.60 (Android)</b>	<p>Endpoint software that complements IBM MaaS360 Mobile Device Management console—provides root/jail-break detection and other functions</p>	<p><b>PR.DS-6:</b> Integrity checking mechanisms are used to verify software, firmware, and information integrity.</p>	<p><b>SC-16:</b> Transmission of Security and Privacy Attributes</p> <p><b>SI-7:</b> Software, Firmware, and Information Integrity</p>	<p><b>A.12.2.1:</b> Controls Against Malware</p> <p><b>A.12.5.1:</b> Installation of Software on Operational Systems</p> <p><b>A.14.1.2:</b> Securing Application Services on Public Networks</p> <p><b>A.14.1.3:</b> Protecting Application Services Transactions</p> <p><b>A.14.2.4:</b> Restrictions on Changes to Software Packages</p>	<p><b>CSC 2:</b> Inventory of Authorized and Unauthorized Software</p> <p><b>CSC 3:</b> Secure Configurations for Hardware and Software on Mobile Devices, Laptops, Workstations, and Servers</p>	<p><b>OV-SPP-002:</b> Cyber Policy and Strategy Planner</p> <p><b>SP-ARC-001:</b> Enterprise Architect</p>

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
<b>Trusted Execution Environment</b>						
Qualcomm <b>(version is mobile device dependent)</b>	Secure boot and image integrity	PR.DS-1: Data-at-rest is protected.	SC-28: Protection of Information at Rest	A.8.2.3: Handling of Assets	<b>CSC 13:</b> Data Protection  <b>CSC 14:</b> Controlled Access Based on the Need to Know	<b>OV-SPP-002:</b> Cyber Policy and Strategy Planner  <b>PR-INF-001:</b> Cyber Defense Infrastructure Support Specialist  <b>OV-LGA-002:</b> Privacy Officer/Privacy Compliance Manager  <b>OV-MGT-002:</b> Communications Security (COMSEC) Manager

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
	<b>PR.DS-6:</b> Integrity checking mechanisms are used to verify software, firmware, and information integrity.		<b>SA-10(1):</b> Developer Configuration Management  <b>SI-7:</b> Software, Firmware, and Information Integrity	<b>A.12.2.1:</b> Controls Against Malware  <b>A.12.5.1:</b> Installation of Software on Operational Systems  <b>A.14.1.2:</b> Securing Application Services on Public Networks  <b>A.14.1.3:</b> Protecting Application Services Transactions  <b>A.14.2.4:</b> Restrictions on Changes to Software Packages	<b>CSC 2:</b> Inventory of Authorized and Unauthorized Software  <b>CSC 3:</b> Secure Configurations for Hardware and Software on Mobile	<b>OV-SPP-002:</b> Cyber Policy and Strategy Planner  <b>PR-CDA-001:</b> Cyber Defense Analyst  <b>SP-ARC-001:</b> Enterprise Architect
	<b>PR.DS-8:</b> Integrity checking mechanisms are used to verify hardware integrity.		<b>SA-10:</b> Developer Configuration Management	<b>A.11.2.4:</b> Equipment maintenance	Not applicable	<b>OM-ADM-001:</b> System Administrator

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
	<b>DE.CM-4:</b> Malicious code is detected.		<b>SI-7:</b> Software, Firmware, and Information Integrity			<b>SP-ARC-001:</b> Enterprise Architect
			<b>SC-35:</b> External Malicious Code Identification <b>SI-7:</b> Software, Firmware, and Information Integrity	<b>A.12.2.1:</b> Controls Against Malware	<b>CSC 4:</b> Continuous Vulnerability Assessment and Remediation <b>CSC 7:</b> Email and Web Browser Protections <b>CSC 8:</b> Malware Defenses <b>CSC 12:</b> Boundary Defense	<b>PR-CDA-001:</b> Cyber Defense Analyst <b>PR-INF-001:</b> Cyber Defense Infrastructure Support Specialist
<b>Virtual Private Network</b>						
<b>Palo Alto Networks PA-220</b>	Enforces network security policy for remote devices	<b>PR.AC-3:</b> Remote access is managed.	<b>AC-1, AC-3:</b> Access Control Policy and Procedures	<b>A.6.2.1:</b> Mobile Device Policy <b>A.6.2.2:</b> Teleworking	<b>CSC 12:</b> Boundary Defense	<b>OV-SPP-002:</b> Cyber Policy and Strategy Planner <b>OV-MGT-002:</b>

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
	<b>PR.AC-5:</b> Network integrity is protected (e.g., network segregation, network segmentation).		<b>AC-19:</b> Access Control for Mobile Devices	<b>A.11.2.6:</b> Security of equipment and assets off-premises  <b>A.13.1.1:</b> Network Controls  <b>A.13.2.1:</b> Information Transfer Policies and Procedures		Communications Security (COMSEC) Manager
			<b>AC-3:</b> Access Enforcement  <b>SC-7:</b> Boundary Protection	<b>A.13.1.1:</b> Network Controls  <b>A.13.1.3:</b> Segregation in Networks  <b>A.13.2.1:</b> Information Transfer Policies and Procedures  <b>A.14.1.2:</b> Securing Application	<b>CSC 9:</b> Limitation and Control of Network Ports, Protocols, and Services  <b>CSC 14:</b> Controlled Access Based on the Need to Know  <b>CSC 15:</b> Wireless Access Control	<b>PR-CDA-001:</b> Cyber Defense Analyst  <b>OM-ADM-001:</b> System Administrator

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
				Services on Public Networks <b>A.14.1.3:</b> Protecting Application Services Transactions	<b>CSC 18:</b> Application Software Security	
	<b>PR.AC-6:</b> Identities are proofed and bound to credentials and asserted in interactions.	<b>AC-3:</b> Access Enforcement <b>IA-2, IA-4, IA-5, IA-8:</b> Identification and Authentication (Organizational Users) <b>PE-2:</b> Physical Access Authorizations <b>PS-3:</b> Personnel Screening	<b>A.7.1.1:</b> Screening <b>A.9.2.1:</b> User Registration and De-Registration	<b>CSC 16:</b> Account Monitoring and Control	<b>OV-SPP-002:</b> Cyber Policy and Strategy Planner <b>OV-MGT-002:</b> Communications Security (COMSEC) Manager	

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
	PR.DS-2: Data-in-transit is protected.	AC-17(2): Protection of Confidentiality and Integrity Using Encryption  SC-8: Transmission Confidentiality and Integrity	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  A.14.1.2: Securing Application Services on Public Networks  A.14.1.3: Protecting Application Services Transactions	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
	PR.PT-4: Communications and control networks are protected.	AC-3, AC-4, AC-17, AC-18: Access Control Family	A.13.1.1: Network Controls	CSC 8: Malware Defenses		PR-INF-001: Cyber Defense Infrastructure

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles (2017)
			<b>CP-2:</b> Contingency Plan  <b>SC-7, SC-20, SC-21, SC-22, SC-23, SC-24, SC-25, SC-29, SC-32, SC-38, SC-39, SC-40, SC-41, SC-43:</b> System and Communications Protection Family	<b>A.13.2.1:</b> Information Transfer Policies and Procedures  <b>A.14.1.3:</b> Protecting Application Services Transactions	<b>CSC 12:</b> Boundary Defense  <b>CSC 15:</b> Wireless Access Control	Support Specialist  <b>OV-SPP-002:</b> Cyber Policy and Strategy Planner  <b>PR-CDA-001:</b> Cyber Defense Analyst

## Appendix H Example Privacy Subcategory and Control Map

Using the developed privacy information as input, we identified the privacy characteristics of the example solution. We developed a privacy control map documenting the example solution's capabilities with applicable Functions, Categories, and Subcategories from the National Institute of Standards and Technology (*NIST*) *Privacy Framework* [2]; and NIST SP 800-53 Revision 5 [38]; and NIST SP 800-181, *National Initiative for Cybersecurity Education (NICE) Cybersecurity Workforce Framework (Work Roles from 2017 version)* [3].

The table that follows maps component functions in the build to the related Subcategories in the NIST Privacy Framework as well as to controls in the NIST SP 800-53, Revision 5 controls catalog. Each column maps independently to the build component's functions and, given the specific capabilities of this mobile device security solution, may differ from other NIST-provided mappings for the Privacy Framework and SP 800-53 revision. For example, build functions may provide additional capabilities beyond what is contemplated by a Privacy Framework Subcategory or that are implemented by additional controls beyond those that NIST identified as an informative reference for the Subcategory.

Table H-1's example privacy control map identifies the privacy characteristic mapping for the products as they were used in the example solution. The products may have additional capabilities that we did not use in this example solution. For that reason, it is recommended that the mapping not be used as a reference for all of the privacy capabilities these products may be able to address. The comprehensive mapping of the NIST Privacy Framework to NIST SP 800-53, Revision 5 controls can be found on the NIST Privacy Framework Resource Repository website, in the event an organization's mobile device security solution is different to determine other controls that are appropriate for their environment [62].

**Table H-1 Example Solution's Privacy Standards and Best Practices Mapping**

Product	How the component functions in the build	Applicable Privacy Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Privacy-Related Controls	Applicable NIST SP 800-181, NICE Framework Work Roles (2017)
IBM MaaS360	MaaS360 can be used to capture an inventory of the types and number of devices deployed and shows the administrative	<b>ID.IM-P7:</b> The data processing environment is identified (e.g., geographic location, internal, cloud, third parties).	<b>CM-12:</b> Information Location  <b>CM-13:</b> Data Action Mapping	<b>OV-LGA-002:</b> Privacy Officer/Privacy Compliance Manager  <b>OV-TEA-001:</b> Cyber Instructional Curriculum Developer

Product	How the component functions in the build	Applicable Privacy Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Privacy-Related Controls	Applicable NIST SP 800-181, NICE Framework Work Roles (2017)
	tors what data is collected from each enrolled device.		<b>PM-5(1):</b> System Inventory   Inventory of Personally Identifiable Information  <b>PT-3:</b> Personally Identifiable Information Processing Purposes  <b>RA-3:</b> Risk Assessment  <b>RA-8:</b> Privacy Impact Assessment	
	Administrators can view data elements in the administration portal. Users can see collected data within the MaaS360 application on their device. Data can be edited and deleted from within the administration console.	<b>CT.DM-P1:</b> Data elements can be accessed for review.	<b>AC-2:</b> Account Management  <b>AC-3:</b> Access Enforcement  <b>AC-3(14):</b> Access Enforcement   Individual Access  <b>PM-21:</b> Accounting of Disclosures	<b>OM-DTA-002:</b> Data Analyst

Product	How the component functions in the build	Applicable Privacy Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Privacy-Related Controls	Applicable NIST SP 800-181, NICE Framework Work Roles (2017)
		<b>CT.DM-P3:</b> Data elements can be accessed for alteration.	<b>AC-2:</b> Account Management  <b>AC-3:</b> Access Enforcement  <b>AC-3(14):</b> Access Enforcement   Individual Access  <b>PM-21:</b> Accounting of Disclosures  <b>SI-18:</b> Personally Identifiable Information Quality Operations	<b>OM-DTA-002:</b> Data Analyst
	<b>CT.DM-P4:</b> Data elements can be accessed for deletion.	<b>AC-2:</b> Account Management  <b>AC-3:</b> Access Enforcement  <b>SI-18:</b> Personally Identifiable Information Quality Operations	<b>OM-DTA-002:</b> Data Analyst	

Product	How the component functions in the build	Applicable Privacy Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Privacy-Related Controls	Applicable NIST SP 800-181, NICE Framework Work Roles (2017)
		<b>CT.DM-P5:</b> Data are destroyed according to policy.	<b>MP-6:</b> Media Sanitization  <b>SA-8(33):</b> Security and Privacy Engineering Principles   Minimization  <b>SI-18:</b> Personally Identifiable Information Quality Operations  <b>SR-12:</b> Component Disposal	<b>OM-DTA-002:</b> Data Analyst
		<b>CT.DP-P4:</b> System or device configurations permit selective collection or disclosure of data elements.	<b>CM-6:</b> Configuration Settings  <b>SA-8(33):</b> Minimization  <b>SC-42(5):</b> Collection Minimization  <b>SI-12(1):</b> Information Management and Retention   Limit Personally Identifiable Information Elements	<b>OV-LGA-002:</b> Privacy Officer/Privacy Compliance Manager

Product	How the component functions in the build	Applicable Privacy Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Privacy-Related Controls	Applicable NIST SP 800-181, NICE Framework Work Roles (2017)
	Devices may be backed up to the cloud.	<b>PR.PO-P3:</b> Backups of information are conducted, maintained, and tested.	<b>CP-4:</b> Contingency Plan Testing  <b>CP-6:</b> Alternate Storage Site  <b>CP-9:</b> System Backup	<b>OM-ADM-001:</b> System Administrator
	Devices are issued identity certificates via on-premises certificate infrastructure.	<b>PR.AC-P1:</b> Identities and credentials are issued, managed, verified, revoked, and audited for authorized individuals, processes, and devices.	<b>IA-2:</b> Identification and Authentication (Organizational Users)  <b>IA-3:</b> Device Identification and Authentication  <b>IA-4:</b> Identifier Management  <b>IA-4(4):</b> Identifier Management   Identifier User Status	<b>SP-ARC-002:</b> Security Architect  <b>PR-CDA-001:</b> Cyber Defense Analyst
	MaaS360 enforces a device personal identification number (PIN) for access.	<b>PR.AC-P2:</b> Physical access to data and devices is managed.	<b>PE-2:</b> Physical Access Authorizations  <b>PE-3:</b> Physical Access Control  <b>PE-3(1):</b> System Access	<b>OM-DTA-001:</b> Database Administrator  <b>OM-DTA-002:</b> Data Analyst

Product	How the component functions in the build	Applicable Privacy Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Privacy-Related Controls	Applicable NIST SP 800-181, NICE Framework Work Roles (2017)
			<b>PE-4:</b> Access Control for Transmission  <b>PE-5:</b> Access Control for Output Devices  <b>PE-6:</b> Monitoring Physical Access  <b>PE-18:</b> Location of System Components  <b>PE-20:</b> Asset Monitoring and Tracking	
	<b>PR.DS-P1:</b> Data-at-rest are protected.	<b>MP-2:</b> Media Access  <b>MP-4:</b> Media Storage  <b>PM-5(1):</b> System Inventory   Inventory of Personally Identifiable Information  <b>SC-28:</b> Protection of Information at Rest	<b>OM-DTA-001:</b> Database Administrator  <b>OM-DTA-002:</b> Data Analyst	

Product	How the component functions in the build	Applicable Privacy Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Privacy-Related Controls	Applicable NIST SP 800-181, NICE Framework Work Roles (2017)
	Data flowing between the device and MaaS360 is encrypted with Transport Layer Security.	<b>PR.DS-P2:</b> Data-in-transit are protected.	<b>PM-5(1):</b> System Inventory   Inventory of Personally Identifiable Information  <b>SC-8:</b> Transmission Confidentiality and Integrity	<b>PR-CIR-001:</b> Cyber Defense Incident Responder
	Restrictions are used that prevent data flow between enterprise and personal applications.	<b>PR.DS-P5:</b> Protections against data leaks are implemented.	<b>PM-5(1):</b> System Inventory   Inventory of Personally Identifiable Information  <b>AC-4:</b> Information Flow Enforcement	<b>PR-CIR-001:</b> Cyber Defense Incident Responder
	Devices that are jailbroken or otherwise modified beyond original equipment manufacturer status can be detected.	<b>PR.DS-P6:</b> Integrity checking mechanisms are used to verify software, firmware, and information integrity.	<b>PM-22:</b> Personally Identifiable Information Quality Management  <b>SI-7:</b> Software, Firmware, and Information Integrity  <b>SI-18:</b> Personally Identifiable Information Quality Operations	<b>OM-DTA-002:</b> Data Analyst  <b>OM-ANA-001:</b> Systems Security Analyst

Product	How the component functions in the build	Applicable Privacy Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Privacy-Related Controls	Applicable NIST SP 800-181, NICE Framework Work Roles (2017)
<b>Zimperium</b>	Zimperium checks the device for unauthorized modifications.	<b>PR.DS-P1:</b> Data-at-rest are protected.	<b>PM-5(1):</b> System Inventory   Inventory of Personally Identifiable Information  <b>SC-28:</b> Protection of Information at Rest	<b>SP-ARC-002:</b> Security Architect  <b>PR-CDA-001:</b> Cyber Defense Analyst
		<b>PR.DS-P2:</b> Data-in-transit are protected.	<b>PM-5(1):</b> System Inventory   Inventory of Personally Identifiable Information  <b>SC-8:</b> Transmission Confidentiality and Integrity  <b>SC-11:</b> Trusted Path	<b>OM-DTA-002:</b> Data Analyst  <b>OM-ANA-001:</b> Systems Security Analyst

Product	How the component functions in the build	Applicable Privacy Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Privacy-Related Controls	Applicable NIST SP 800-181, NICE Framework Work Roles (2017)
		<b>PR.DS-P6:</b> Integrity checking mechanisms are used to verify software, firmware, and information integrity.	<b>PM-22:</b> Personally Identifiable Information Quality Management  <b>SC-16:</b> Transmission of Security Attributes  <b>SI-7:</b> Boundary Protection  <b>SI-10:</b> Network Disconnect  <b>SI-18:</b> Personally Identifiable Information Quality Operations	<b>OM-DTA-002:</b> Data Analyst  <b>OM-ANA-001:</b> Systems Security Analyst
<b>Kryptowire</b>	Kryptowire can identify applications that do not use best practices, such as lack of encryption or hardcoded credentials.	<b>CM.AW-P1:</b> Mechanisms (e.g., notices, internal or public reports) for communicating data processing purposes, practices, associated privacy risks, and options for enabling individuals' data processing preferences and requests	<b>AC-8:</b> System Use Notification	<b>SP-ARC-002:</b> Security Architect  <b>PR-CDA-001:</b> Cyber Defense Analyst

Product	How the component functions in the build	Applicable Privacy Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Privacy-Related Controls	Applicable NIST SP 800-181, NICE Framework Work Roles (2017)
		are established and in place.		
		<b>CM.AW-P3:</b> System/ product/ service design enables data processing visibility.	<b>PL-8:</b> Security and Privacy Architecture  <b>PM-5(1):</b> System Inventory   Inventory of Personally Identifiable Information	<b>SP-ARC-002:</b> Security Architect  <b>PR-CDA-001:</b> Cyber Defense Analyst
		<b>CM.AW-P6:</b> Data provenance and lineage are maintained and can be accessed for review or transmission/ disclosure.	<b>AC-16:</b> Security and Privacy Attributes  <b>SC-16:</b> Transmission of Security Attributes	<b>SP-ARC-002:</b> Security Architect  <b>PR-CDA-001:</b> Cyber Defense Analyst
		<b>PR.DS-P1:</b> Data-at-rest are protected.	<b>PM-5(1):</b> System Inventory   Inventory of Personally Identifiable Information  <b>SC-28:</b> Protection of Information at Rest	<b>SP-ARC-002:</b> Security Architect  <b>PR-CDA-001:</b> Cyber Defense Analyst
		<b>PR.DS-P2:</b> Data-in-transit are protected.	<b>PM-5(1):</b> System Inventory   Inventory of Personally Identifiable Information	<b>SP-ARC-002:</b> Security Architect  <b>PR-CDA-001:</b> Cyber Defense Analyst

Product	How the component functions in the build	Applicable Privacy Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Privacy-Related Controls	Applicable NIST SP 800-181, NICE Framework Work Roles (2017)
			<b>SC-8:</b> Transmission Confidentiality and Integrity  <b>SC-11:</b> Trusted Path	
<b>Palo Alto Networks PA-220</b>	Provides firewall and virtual private network capabilities.	<b>PR.DS-P2:</b> Data-in-transit are protected.	<b>PM-5(1):</b> System Inventory   Inventory of Personally Identifiable Information  <b>SC-8:</b> Transmission Confidentiality and Integrity  <b>SC-11:</b> Trusted Path	<b>SP-ARC-002:</b> Security Architect  <b>PR-CDA-001:</b> Cyber Defense Analyst
		<b>PR.AC-P4:</b> Access permissions and authorizations are managed, incorporating the principles of least privilege and separation of duties.	<b>AC-2:</b> Account Management  <b>AC-3:</b> Access Enforcement  <b>AC-5:</b> Separation of Duties  <b>AC-6:</b> Least Privilege  <b>AC-24:</b> Access Control Decisions	<b>SP-ARC-002:</b> Security Architect  <b>PR-CDA-001:</b> Cyber Defense Analyst

Product	How the component functions in the build	Applicable Privacy Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Privacy-Related Controls	Applicable NIST SP 800-181, NICE Framework Work Roles (2017)
		<b>PR.AC-P5:</b> Network integrity is protected (e.g., network segregation, network segmentation).	<b>AC-4:</b> Information Flow Enforcement  <b>AC-10:</b> Access Control  <b>SC-7:</b> Boundary Protection  <b>SC-10:</b> Network Disconnect	<b>OM-DTA-002:</b> Data Analyst  <b>OM-ANA-001:</b> Systems Security Analyst
		<b>PR.PT-P3:</b> Communications and control networks are protected.	<b>AC-12:</b> Session Termination  <b>AC-17:</b> Remote Access  <b>AC-18:</b> Wireless Access  <b>SC-5:</b> Denial of Service Protection  <b>SC-7:</b> Boundary Protection  <b>SC-10:</b> Network Disconnect  <b>SC-11:</b> Trusted Path	<b>OV-LGA-002:</b> Privacy Officer/Privacy Compliance Manager  <b>PR-CDA-001:</b> Cyber Defense Analyst

Product	How the component functions in the build	Applicable Privacy Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Privacy-Related Controls	Applicable NIST SP 800-181, NICE Framework Work Roles (2017)
			<p><b>SC-21:</b> Secure Name/Address Resolution Service (Recursive or Caching Resolver)</p> <p><b>SC-23:</b> Session Authenticity</p>	
Qualcomm	The trusted execution environment provides data confidentiality and integrity.	<b>PR.DS-P6:</b> Integrity checking mechanisms are used to verify software, firmware, and information integrity.	<p><b>PM-22:</b> Personally Identifiable Information Quality Management</p> <p><b>SC-16:</b> Transmission of Security and Privacy Attributes</p> <p><b>SI-7:</b> Software, Firmware, and Information Integrity</p> <p><b>SI-10:</b> Information Input Validation</p> <p><b>SI-18:</b> Personally Identifiable Information Quality Operations</p>	<p><b>PR-INF-001:</b> Cyber Defense Infrastructure Support Specialist</p> <p><b>OM-ANA-001:</b> Systems Security Analyst</p>

## NIST SPECIAL PUBLICATION 1800-22 Supplement

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# Mobile Device Security: Bring Your Own Device (BYOD)

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### Supplement:

Example Scenario: Putting Guidance into Practice

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This publication is available free of charge from

<https://www.nccoe.nist.gov/projects/building-blocks/mobile-device-security/bring-your-own-device>

## 1 **1 Applying This Build: Example Scenario**

2 An example scenario about a fictional company named Great Seneca Accounting illustrates how  
3 organizations can use this practice guide's example solution. The example shows how Bring Your Own  
4 Device (BYOD) objectives can align with a fictional organization's security and privacy priorities through  
5 the use of risk management standards, guidance, and tools.

6 To demonstrate how an organization may use this National Institute of Standards and Technology (NIST)  
7 Special Publication (SP) and other NIST tools to implement a BYOD use case, the National Cybersecurity  
8 Center of Excellence created an example scenario that centers around a fictional, small-to-mid-size  
9 organization called Great Seneca Accounting. This scenario exemplifies the issues that an organization  
10 may face when addressing common enterprise BYOD security challenges.

### 11 **1.1 Standards and Guidance Used in this Example Scenario**

12 In addition to the Executive Summary contained in Volume A, and the architecture description in  
13 Volume B, this practice guide also includes a series of how-to instructions in Volume C. The how-to  
14 instructions in Volume C provide step-by-step instructions covering the initial setup (installation or  
15 provisioning) and configuration for each component of the architecture. These step-by-step instructions  
16 can help security engineers rapidly deploy and evaluate the example solution in their test environment.

17 The example solution uses standards-based, commercially available products that can be used by an  
18 organization interested in deploying a BYOD solution. The example solution provides recommendations  
19 for enhancing the security and privacy infrastructure by integrating on-premises and cloud-hosted  
20 mobile security technologies. This practice guide provides an example solution that an organization may  
21 use in whole or in part as the basis for creating a custom solution that best supports their unique needs.

22 The fictional Great Seneca Accounting organization illustrates how this guide may be applied by an  
23 organization, starting with a mobile device infrastructure that lacked mobile device security architecture  
24 concepts. Great Seneca employed multiple NIST cybersecurity and privacy risk management tools to  
25 understand the gaps in its architecture and methods to enhance security of its systems and privacy for  
26 its employees.

27 This example scenario provides useful context for using the following NIST Frameworks and other  
28 relevant tools to help mitigate some of the security and privacy challenges that organizations may  
29 encounter when deploying BYOD capabilities:

- 30     • *NIST Framework for Improving Critical Infrastructure Cybersecurity*, Version 1.1 (Cybersecurity  
31         Framework) [\[1\]](#)
- 32     • the *NIST Privacy Framework: A Tool For Improving Privacy Through Enterprise Risk Management*,  
33         Version 1.0 (Privacy Framework) [\[2\]](#)
- 34     • *NIST Special Publication (SP) 800-181 National Initiative for Cybersecurity Education (NICE)*  
35         *Cybersecurity Workforce Framework* [\[3\]](#)
- 36     • *NIST Risk Management Framework* [\[4\]](#)

- 37        • NIST Mobile Threat Catalogue [5]  
38      For additional information, see Volume B's Appendix D.

## 39      **2 About Great Seneca Accounting**

40      In the example scenario, Great Seneca Accounting is a fictional accounting firm that grew from a single  
41      office location into a larger firm with a regional presence. Great Seneca Accounting performs accounting  
42      functions related to capturing, communicating, processing, transmitting, and analyzing financial data  
43      and accounting services for its customers.

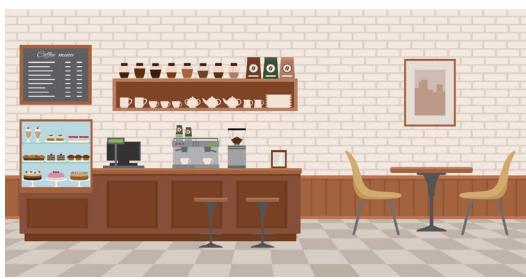
44      When the firm was first created, most of its employees worked from the Great Seneca Accounting  
45      office, with minimal use of mobile devices. They were able to do this without actively embracing mobile  
46      device usage because most of the employees worked at their desks at the company's single location.

47      Over the years, the Great Seneca Accounting company grew from a local company, where all of its  
48      employees performed work at their desks by using desktop computers provided by the organization,  
49      into a regional firm with employees who work remotely and who support regional customers.

50      Now, many of the employees spend part of their week traveling and working from customer or other  
51      remote locations. This has prompted the organization to specify, as a strategic priority, the need to  
52      support employees to work remotely, while both traveling and working from a customer location. As  
53      such, the company wants to embrace BYOD solutions to support its remote work.

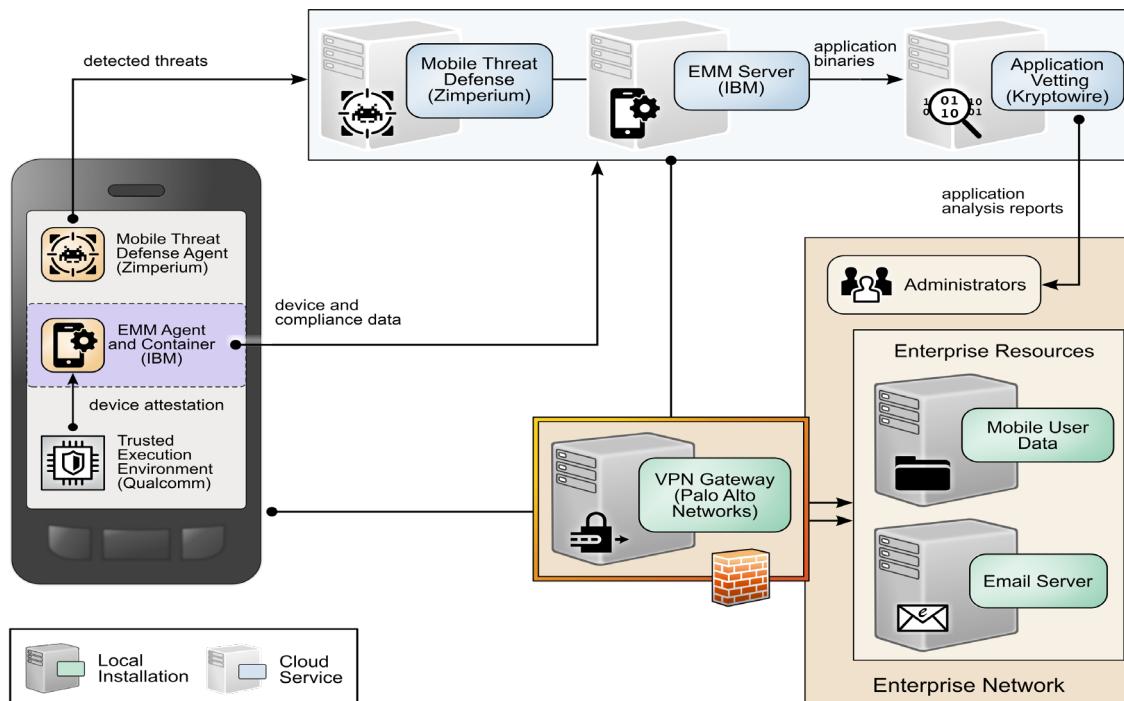
54      [Figure 1-1](#) shows an overview of the typical work environments for a Great Seneca Accounting  
55      employee. Many employees work remotely while using their own mobile phones and tablets to perform  
56      both work and personal activities throughout the day.

### 57      **Figure 1-1 Great Seneca Accounting's Work Environments**



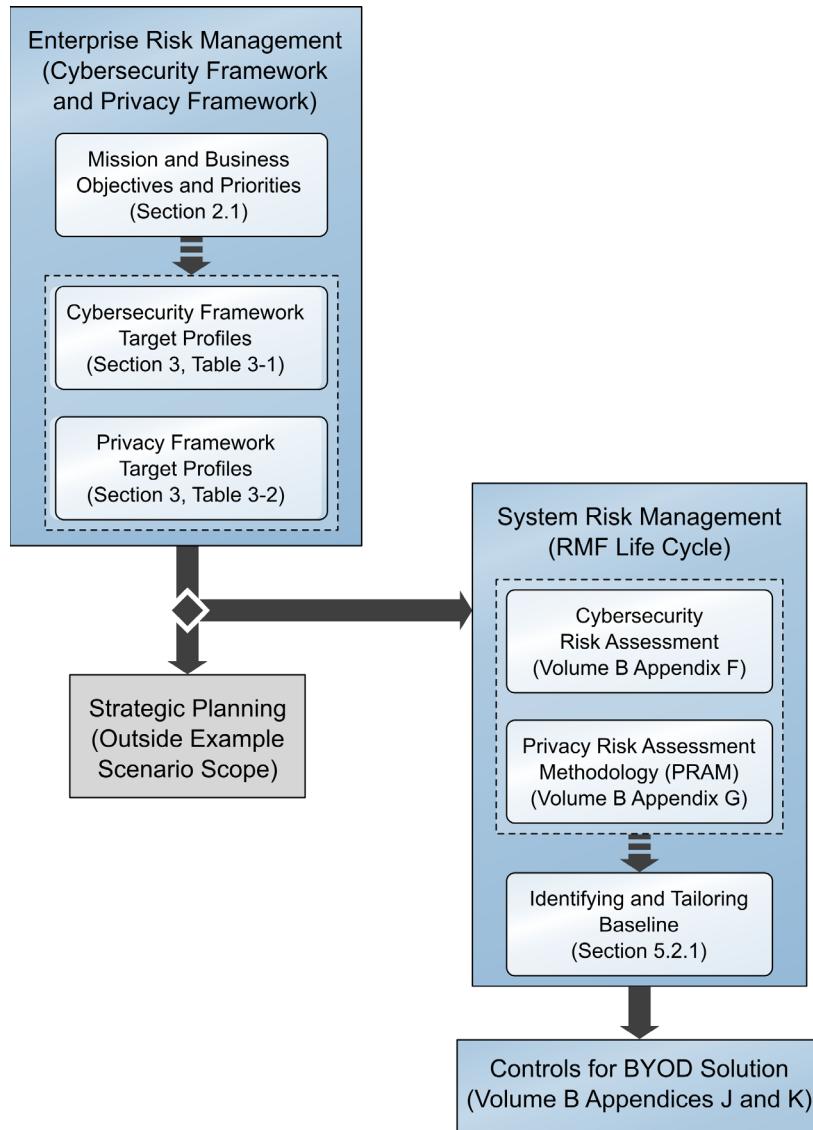
- 58 Great Seneca Accounting's corporate management initiated a complete review of all policies,  
 59 procedures, and technology relating to its mobile deployment to ensure that the company is well  
 60 protected against attacks involving personal mobile devices. This includes mitigating risks against its  
 61 devices, custom applications, and corporate infrastructure supporting mobile services. Management  
 62 identified NIST's Risk Management Framework (RMF) [4] and Privacy Risk Assessment Methodology  
 63 (PRAM) [6] as useful tools for supporting this analysis. The company developed Cybersecurity  
 64 Framework and Privacy Framework Target Profiles to guide Great Seneca Accounting's decision-making  
 65 because the Target Profiles link Great Seneca Accounting's mission and business priorities with  
 66 supporting cybersecurity and privacy activities.
- 67 Great Seneca Accounting identified the scope of their mobile solution to be both Android and Apple  
 68 personally owned mobile phones and tablets. While this example scenario intends to provide an  
 69 exemplar of organization guidance with a description of BYOD concepts and how to apply those  
 70 concepts, this example scenario should not suggest a limit on BYOD uses.
- 71 Great Seneca Accounting plans to use NIST SP 1800-22 (this practice guide) to inform its updated BYOD  
 72 architecture as well as NIST's Mobile Threat Catalogue to identify threats to mobile deployment. These  
 73 NIST frameworks and tools used are described further in [Appendix E](#).
- 74 As shown in [Figure 2-1](#), this example solution applied multiple mobile device security technologies.  
 75 These included a cloud-based Enterprise Mobility Management solution integrated with cloud- and  
 76 agent-based mobile security technologies to help deploy a set of security and privacy capabilities that  
 77 support the example solution.

78 **Figure 2-2 Example Solution Architecture**



79 [Figure 2-2](#) shows the overall process that Great Seneca Accounting plans to follow. It highlights key  
 80 activities from various NIST guidance documents related to security and privacy risk management, each  
 81 of which is discussed in the sections identified in [Figure 2-2](#). Please note that this process is an  
 82 abbreviated version of steps provided in NIST SP 800-37 Revision 2 [7], which shows how some available  
 83 resources may be used by any organization.

84 [Figure 2-3 Great Seneca Accounting's Security and Privacy Risk Management Steps](#)



## 85 [2.1 Great Seneca Accounting's Business/Mission Objectives](#)

86 Great Seneca Accounting developed a mission statement and a set of supporting business/mission  
 87 objectives to ensure that its activities align with its core purpose. The company has had the same  
 88 mission since it was founded:

### 3 Great Seneca Accounting's Target Profiles

98 Great Seneca Accounting used the NIST Cybersecurity Framework and *NIST Privacy Framework* as key  
99 strategic planning tools to improve its security and privacy programs. It followed the processes outlined  
100 in the frameworks, and as part of that effort, created *two* Target Profiles—one for cybersecurity and one  
101 for privacy.

102 These Target Profiles describe the desired or aspirational state of Great Seneca Accounting by  
103 identifying and prioritizing the cybersecurity and privacy activities and outcomes needed to support its  
104 enterprise business/mission objectives. The Subcategories in each Framework Core articulate those  
105 cybersecurity and privacy activities and outcomes.

106   **Note:** See [Appendix E](#) for a high-level description of the Cybersecurity Framework and Privacy  
107   Framework.

108 To understand what Subcategories to prioritize implementing in each framework, Great Seneca  
109 Accounting considered the importance of the Subcategories for accomplishing each business/mission  
110 objective. The Target Profiles reflect that discussion by designating prioritized Subcategories as low,  
111 moderate, or high.

112 Subcategory improvements important for BYOD deployment also became part of its Target Profiles  
113 because Great Seneca Accounting was upgrading its existing information technology infrastructure as  
114 part of its BYOD implementation.

115 The Cybersecurity Framework Target Profile in [Table 3-1](#) and the Privacy Framework Target Profile in  
116 [Table 3-2](#) are included as examples of Great Seneca Accounting's identification of the business/mission  
117 objectives that are relevant to their BYOD deployment.

118 Great Seneca Accounting chose to address the Subcategories that are prioritized as moderate and high  
119 for multiple business/mission objectives in its Target Profiles for this year's BYOD deployment with plans  
120 to address the low Subcategories in the future.

121    [Table 3-1](#) and [Table 3-2](#) include only those Subcategories that are prioritized as moderate or high for the  
122    business/mission Objectives. Any Subcategory designated as low is included in [Table 3-1](#) and [Table 3-2](#)  
123    only because it is high or moderate for another business/mission objective.

124    Great Seneca Accounting used the Target Profiles to help guide risk management decisions throughout  
125    the organization's activities, including making decisions regarding budget allocation, technology design,  
126    and staffing for its programs and technology deployments. Discussions for developing and using the  
127    Target Profiles include stakeholders in various parts of the organization, such as business/mission  
128    program owners, data stewards, cybersecurity practitioners, privacy practitioners, legal and compliance  
129    experts, and technology experts.

130    **Note:** Low, moderate, and high designations indicate the level of relative importance among  
131    Subcategories for Great Seneca to accomplish a business/mission objective.

132 Table 3-1 Great Seneca Accounting's Cybersecurity Framework Target Profile

Cybersecurity Framework Core			BYOD-Related Business/Mission Objectives			
Function	Category	Subcategory	(1) Provide Good Data Stewardship	(2) Enable timely communication with clients	(3) Provide Innovative Financial Services	(4) Enable Workforce Flexibility
IDENTIFY	Asset Management	<b>ID.AM-1:</b> Physical devices and systems within the organization are inventoried.	moderate	moderate	moderate	low
		<b>ID.AM-2:</b> Software platforms and applications within the organization are inventoried.	moderate	moderate	moderate	low
	Risk Assessment	<b>ID.RA-1:</b> Asset vulnerabilities are identified and documented.	moderate	moderate	moderate	moderate
		<b>ID.RA-3:</b> Threats, both internal and external, are identified and documented.	moderate	moderate	moderate	moderate
PROTECT	Identity Management and Access Control	<b>PR.AC-1:</b> Identities and credentials are issued, managed, verified, revoked, and audited for authorized devices, users, and processes.	moderate	high	moderate	high
		<b>PR.AC-3:</b> Remote access is managed.	moderate	high	high	high
		<b>PR.AC-5:</b> Network integrity is protected (e.g., network)	high	high	high	high

Cybersecurity Framework Core			BYOD-Related Business/Mission Objectives			
Function	Category	Subcategory	(1) Provide Good Data Stewardship	(2) Enable timely communication with clients	(3) Provide Innovative Financial Services	(4) Enable Workforce Flexibility
<b>Data Security</b>		segregation, network seg-mentation).				
		<b>PR.AC-6:</b> Identities are proofed and bound to credentials and asserted in interactions.	moderate	high	high	high
		<b>PR.DS-1:</b> Data-at-rest is protected.	high	moderate	moderate	high
		<b>PR.DS-2:</b> Data-in-transit is protected.	moderate	high	moderate	high
		<b>PR.DS-6:</b> Integrity-checking mechanisms are used to verify software, firmware, and information integrity.	high	moderate	moderate	high
		<b>PR.DS-8:</b> Integrity checking mechanisms are used to verify hardware integrity.	moderate	moderate	moderate	low
		<b>PR.IP-1:</b> A baseline configuration of information technology/industrial control systems is created and maintained incorporating security principles.	moderate	moderate	moderate	low

Cybersecurity Framework Core			BYOD-Related Business/Mission Objectives			
Function	Category	Subcategory	(1) Provide Good Data Stewardship	(2) Enable timely communication with clients	(3) Provide Innovative Financial Services	(4) Enable Workforce Flexibility
	Protective Technology	PR.PT-4: Communications and control networks are protected.	low	moderate	moderate	low
DETECT	Anomalies and Events	DE.AE-5: Incident alert thresholds are established.	high	high	high	high
	Security Continuous Monitoring	DE.CM-4: Malicious code is detected.	high	high	high	high
		DE.CM-5: Unauthorized mobile code is detected.	moderate	moderate	moderate	low
		DE.CM-8: Vulnerability scans are performed.	high	high	high	high

133 Table 3-2 Great Seneca Accounting's Privacy Target Profile

Privacy Framework Core			BYOD-Related Business/Mission Objectives			
Function	Category	Subcategory	(1) Provide Good Data Stewardship	(2) Enable timely communication with clients	(3) Provide Innovative Financial Services	(4) Enable Workforce Flexibility
IDENTIFY-P	Inventory and Mapping	ID.IM-P7: The data processing environment is identified (e.g., geographic location, internal, cloud, third parties).	high	high	high	high
GOVERN-P	Governance Policies, Processes, and Procedures	GV.PO-P1: Organizational privacy values and policies (e.g., conditions on data processing, individuals' prerogatives with respect to data processing) are established and communicated.	high	high	high	high
		GV.PO-P5: Legal, regulatory, and contractual requirements regarding privacy are understood and managed.	high	high	high	high
	Monitoring and Review	GV.MT-P3: Policies, processes, and procedures for assessing compliance with legal requirements and privacy policies are established and in place.	high	high	high	high

Privacy Framework Core			BYOD-Related Business/Mission Objectives			
Function	Category	Subcategory	(1) Provide Good Data Stewardship	(2) Enable timely communication with clients	(3) Provide Innovative Financial Services	(4) Enable Workforce Flexibility
		<b>GV.MT-P5:</b> Policies, processes, and procedures are established and in place to receive, analyze, and respond to problematic data actions disclosed to the organization from internal and external sources (e.g., internal discovery, privacy researchers, professional events).	high	high	high	high
CONTROL-P	Data Management	<b>CT.DM-P1:</b> Data elements can be accessed for review.	high	moderate	high	moderate
		<b>CT.DM-P3:</b> Data elements can be accessed for alteration.	high	moderate	high	moderate
		<b>CT.DM-P4:</b> Data elements can be accessed for deletion.	high	moderate	high	moderate
		<b>CT.DM-P5:</b> Data are destroyed according to policy.	high	moderate	high	moderate
	Disassociated Processing	<b>CT.DP-P4:</b> System or device configurations permit	high	high	high	high

Privacy Framework Core			BYOD-Related Business/Mission Objectives			
Function	Category	Subcategory	(1) Provide Good Data Stewardship	(2) Enable timely communication with clients	(3) Provide Innovative Financial Services	(4) Enable Workforce Flexibility
		selective collection or disclosure of data elements.				
COMMUNICATE-P	Data Processing Awareness	<b>CM.AW-P5:</b> Data corrections or deletions can be communicated to individuals or organizations (e.g., data sources) in the data processing ecosystem.	high	moderate	moderate	moderate
PROTECT-P	Data Protection Policies, Processes, and Procedures	<b>PR.PO-P3:</b> Backups of information are conducted, maintained, and tested.	high	moderate	high	moderate
		<b>PR.AC-P1:</b> Identities and credentials are issued, managed, verified, revoked, and audited for authorized individuals, processes, and devices.	moderate	high	moderate	high
	Identity Management, Authentication, and Access Control	<b>PR.AC-P2:</b> Physical access to data and devices is managed.	high	moderate	high	moderate
		<b>PR.AC-P4:</b> Access permissions and authorizations are managed, incorporating the principles of least privilege and separation of duties.	high	moderate	high	moderate

Privacy Framework Core			BYOD-Related Business/Mission Objectives			
Function	Category	Subcategory	(1) Provide Good Data Stewardship	(2) Enable timely communication with clients	(3) Provide Innovative Financial Services	(4) Enable Workforce Flexibility
<b>Data Security</b>		<b>PR.AC-P5:</b> Network integrity is protected (e.g., network segregation, network segmentation).	high	high	high	high
		<b>PR.DS-P1:</b> Data-at-rest are protected.	high	moderate	moderate	high
		<b>PR.DS-P2:</b> Data-in-transit are protected.	moderate	high	moderate	high
		<b>PR.DS-P5:</b> Protections against data leaks are implemented.	high	moderate	high	moderate
		<b>PR.DS-P6:</b> Integrity checking mechanisms are used to verify software, firmware, and information integrity.	high	moderate	moderate	high
		<b>PR.PT-P3:</b> Communications and control networks are protected.	moderate	high	moderate	high

## 134    4 Great Seneca Accounting Embraces BYOD

135 Great Seneca Accounting now allows its staff to use their personal mobile devices to perform their daily  
136 work duties on an as-needed basis. Accountants use the devices for various tasks including  
137 communicating with client organizations and other employees, collecting confidential client information,  
138 analyzing financial transactions, generating reports, accessing tax and payroll information, and creating  
139 and reviewing comprehensive financial statements.

140 Great Seneca accountants work from many locations including their corporate office building, their  
141 homes, their customers' offices, and other locations. And to be able to work in all of these locations,  
142 they require the use of mobile devices to perform their job functions.

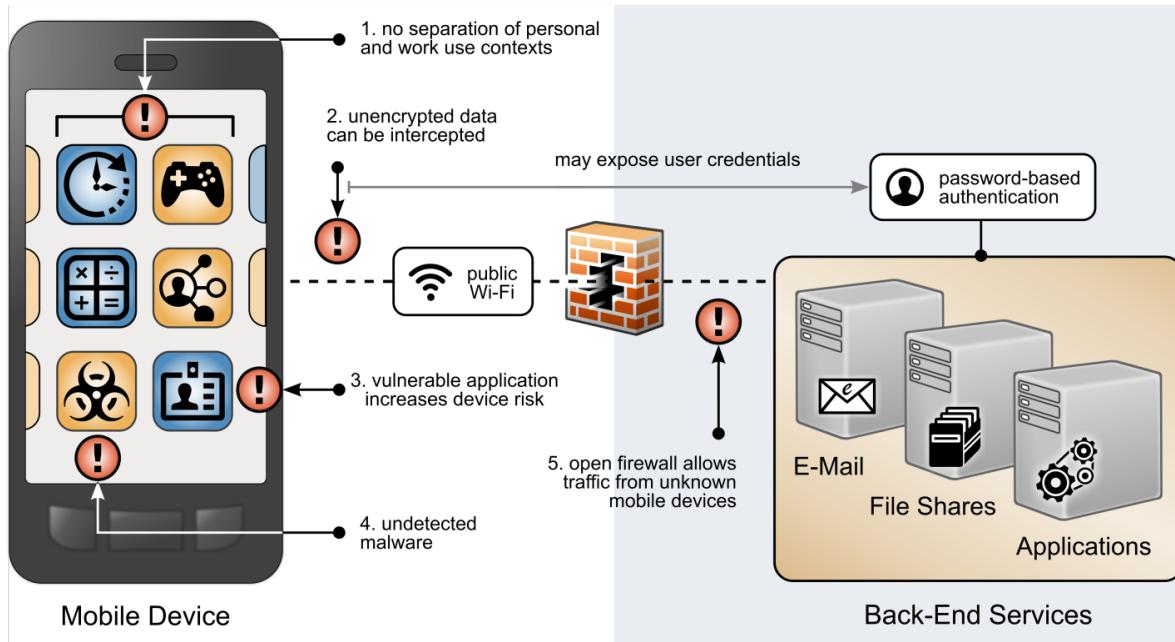
143 Great Seneca Accounting's current mobile infrastructure enables accountants to perform their job  
144 duties by using their personally owned devices, despite minimal security installed and enforced on these  
145 devices. Examples of security concerns with the use of personally owned devices are:

- 146    ▪ Employees can connect to any Wi-Fi network to perform work-related activities when they are  
147        working on the road, including at a client's site.
- 148    ▪ Custom mobile applications being sideloaded onto devices that employees use.
- 149    ▪ The personally owned devices allow users to install applications on an as-needed basis without  
150        separation of enterprise and personal data.

151 While not affecting Great Seneca Accounting, a string of well-publicized cybersecurity attacks have  
152 recently been reported in the news, and this prompted Great Seneca to review its mobile device security  
153 and privacy deployment strategy. When making BYOD deployment decisions, Great Seneca Accounting  
154 plans to prioritize implementing cybersecurity and privacy capabilities that would enable it to  
155 accomplish its business/mission objectives (i.e., its reasons for deploying BYOD capabilities).

156 To do this, Great Seneca Accounting conducted a technical assessment of its current BYOD architecture  
157 to help it understand ways to improve the confidentiality, integrity, availability, and privacy of data and  
158 devices associated with its BYOD deployment. The company identified several vulnerabilities based on  
159 its current mobile device deployment. [Figure 4-1](#) below presents a subset of those vulnerabilities.

160    **Figure 4-1 Great Seneca Accounting's Current Mobile Deployment Architecture (Before Security and**  
 161    **Privacy Enhancements)**



162    Figure 4-1 highlights the following vulnerabilities with a red exclamation mark:

1. BYOD deployments can place organizational and personal data, as well as employees' privacy, at risk. 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) as applications for both personal and work usage are installed. This also puts employees' privacy at risk, as the organization can have visibility into their personal life outside work.
2. BYOD deployments can leverage nonsecure networks. As employees use nonsecure Wi-Fi hotspots, mobile devices that are connecting to Great Seneca Accounting from those unencrypted networks place data transmitted prior to a secure connection at risk of discovery and eavesdropping, including passwords.
3. As employees install applications on their personally owned devices, the applications can have unidentified vulnerabilities or weaknesses that increase the risk of device compromise (e.g., applications that access contacts may now have access to the organization's client contact information). Further, legitimate, privacy-intrusive applications can legally collect data through terms and conditions and requested permissions.
4. On personally owned devices without restriction policies in place, employees may inadvertently download applications outside official application stores, which are malware in disguise.

180        5. Because personally owned mobile devices can connect from unknown locations, firewall rules  
181            must allow inbound connections from unrecognized, potentially malicious Internet Protocol  
182            addresses.

183        In addition to identifying the technical assets and the vulnerabilities, Great Seneca Accounting identified  
184            the scope of the mobile solution (i.e., both Android and Apple personally owned mobile phones and  
185            tablets) and the regulatory requirements or guidance that will apply to their deployment and solution  
186            (e.g., encryption will be Federal Information Processing Standards [FIPS]-validated to protect sensitive  
187            accounting information).

## 188        **5 Applying NIST Risk Management Methodologies to Great 189            Seneca Accounting's BYOD Architecture**

190        Sections 2 and 3 described Great Seneca Accounting, their business mission, and what security and  
191            privacy areas they consider most important. Great Seneca created Target Profiles that mapped their  
192            BYOD-related mission/business objectives and priorities with the Functions, Categories, and  
193            Subcategories of both the Cybersecurity Framework and the Privacy Framework. Those Cybersecurity  
194            Framework and Privacy Framework Target Profiles are provided in [Table 3-1](#) and [Table 3-2](#) in Section 3  
195            of this document.

196        Now, the Target Profiles provided in Section 3 will demonstrate the role they play in identifying and  
197            prioritizing the implementation of the security and privacy controls, as well as the capabilities that Great  
198            Seneca would like to include in its new BYOD security and privacy-enhanced architecture.

### 199        **5.1 Using Great Seneca Accounting's Target Profiles**

200        The Cybersecurity Framework maps its Subcategories to Informative References. The Informative  
201            References contained in the Framework Core provide examples of methods that Great Seneca can use  
202            to achieve its desired outcomes. The Cybersecurity Framework's Subcategory and Informative  
203            References mappings include NIST SP 800-53 controls.

204        An illustrative segment of the Cybersecurity Framework's Framework Core is shown in [Figure 5-1](#).  
205        Highlighted in the green box is an example of how the Cybersecurity Framework provides a mapping of  
206            Subcategories to Informative References.

207

**Figure 5-1 Cybersecurity Framework Subcategory to Informative Reference Mapping**

Function	Category	Subcategory	Informative References
IDENTIFY (ID)	<b>Asset Management (ID.AM):</b> The data, personnel, devices, systems, and facilities that enable the organization to achieve business purposes are identified and managed consistent with their relative importance to organizational objectives and the organization's risk strategy.	<b>ID.AM-1:</b> Physical devices and systems within the organization are inventoried	<b>CIS CSC 1</b> <b>COBIT 5</b> BAI09.01, BAI09.02 <b>ISA 62443-2-1:2009</b> 4.2.3.4 <b>ISA 62443-3-3:2013</b> SR 7.8 <b>ISO/IEC 27001:2013</b> A.8.1.1, A.8.1.2 <b>NIST SP 800-53 Rev. 4</b> CM-8, PM-5
		<b>ID.AM-2:</b> Software platforms and applications within the organization are inventoried	<b>CIS CSC 2</b> <b>COBIT 5</b> BAI09.01, BAI09.02, BAI09.05 <b>ISA 62443-2-1:2009</b> 4.2.3.4 <b>ISA 62443-3-3:2013</b> SR 7.8 <b>ISO/IEC 27001:2013</b> A.8.1.1, A.8.1.2, A.12.5.1 <b>NIST SP 800-53 Rev. 4</b> CM-8, PM-5
		<b>ID.AM-3:</b> Organizational communication and data flows are mapped	<b>CIS CSC 12</b> <b>COBIT 5</b> DSS05.02 <b>ISA 62443-2-1:2009</b> 4.2.3.4 <b>ISO/IEC 27001:2013</b> A.13.2.1, A.13.2.2 <b>NIST SP 800-53 Rev. 4</b> AC-4, CA-3, CA-9, PL-8
		<b>ID.AM-4:</b> External information systems are catalogued	<b>CIS CSC 12</b> <b>COBIT 5</b> APO02.02, APO10.04, DSS01.02 <b>ISO/IEC 27001:2013</b> A.11.2.6 <b>NIST SP 800-53 Rev. 4</b> AC-20, SA-9

- 208 To provide a starting point for Great Seneca's mapping of their Cybersecurity Framework and Privacy Framework Target Profiles to the NIST SP 800-53 security and privacy controls and capabilities, Great  
 209 Seneca leveraged the mapping provided in the Cybersecurity Framework. An example of the  
 210 Cybersecurity Framework's mapping is provided in [Figure 5-1](#).  
 211
- 212 See Volume B's Appendixes G and H for additional information on the security and privacy outcomes  
 213 that this document's example solution supports. Appendixes G and H provide a mapping of this  
 214 document's example solution capabilities with the related Subcategories in the Cybersecurity  
 215 Framework and Privacy Framework.  
 216 Volume B's Appendix G provides the Cybersecurity Framework Subcategory mappings, and Volume B's  
 217 Appendix H provides the Privacy Framework Subcategory mappings. An excerpt of Volume B's Appendix  
 218 G is shown below in [Figure 5-2](#).

219 **Figure 5-2 Volume B Appendix G Example Solution Cybersecurity Framework Mapping Excerpt**

Specific product used	How the component functions in the example solution	Applicable NIST Cybersecurity Framework Subcategories	Applicable NIST SP 800-53 Revision 5 Controls	ISO/IEC 27001:2013	CIS 6	Applicable NIST SP 800-181 NICE Framework Work Roles
<b>Mobile Threat Defense</b>						
Kryptowire Cloud Service	Application Vetting	<b>ID.RA-1:</b> Asset vulnerabilities are identified and documented.	<b>CA-2, CA-7, CA-8:</b> Security Assessment and Authorization  <b>RA-3, RA-5:</b> Risk Assessment  <b>SA-4:</b> Acquisition Process  <b>SI-7:</b> Software, Firmware, and Information Integrity	<b>A.12.6.1:</b> Control of technical vulnerabilities  <b>A.18.2.3:</b> Technical Compliance Review	<b>CSC 4:</b> Continuous Vulnerability Assessment and Remediation	<b>SP-RSK-002:</b> Security Control Assessor  <b>SP-ARC-002:</b> Security Architect  <b>OM-ANA-001:</b> Systems Security Analyst

220

## 221 **5.2 Great Seneca Uses the Target Profiles to Help Prioritize Security and** 222 **Privacy Control Deployment**

223 Due to budget constraints, Great Seneca Accounting will focus on implementing the higher priority  
224 security and privacy controls that were identified in the organization’s two Target Profiles first. The  
225 company will then focus on implementing lower priority controls when more funding becomes available.  
226 This is accomplished by Great Seneca Accounting comparing the prioritized Subcategories contained in  
227 Section 3’s [Table 3-1](#) and [Table 3-2](#) with the outcomes that the example solution supports.

228 By comparing its Cybersecurity Framework Target Profile ([Table 3-1](#)) with the Subcategories supported  
229 by the example solution that are shown in Volume B’s Appendix G, Great Seneca Accounting determines  
230 that the example solution will help it achieve its desired Cybersecurity Framework Target Profile  
231 outcomes.

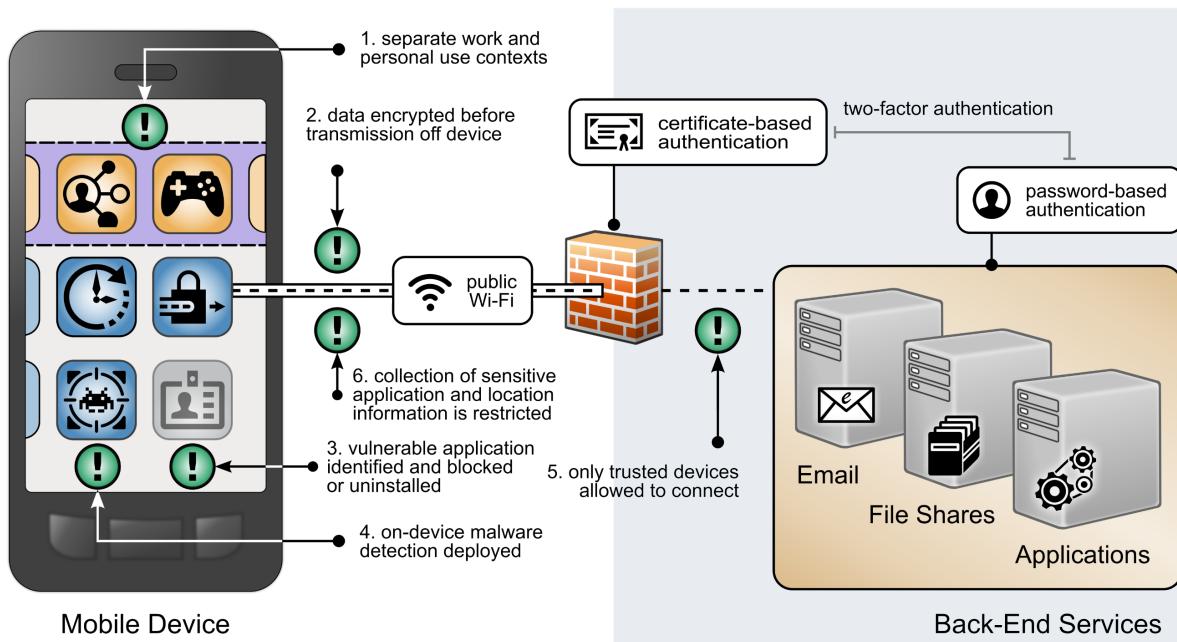
232 Great Seneca performs a similar comparison of the Privacy Framework Target Profile in [Table 3-2](#) with  
233 the Subcategories supported by the example solution that are shown in Volume B’s Appendix H. From  
234 that comparison of the example solution’s capabilities and Great Seneca’s privacy-related architecture  
235 goals, Great Seneca determines that the example solution provided in this practice guide will help it to  
236 achieve the privacy-related outcomes that were identified in [Table 3-2](#)’s Privacy Framework Target  
237 Profile.

### 238 **5.2.1 Identifying and Tailoring the Baseline Controls**

239 Now that Great Seneca Accounting understands how the Target Profiles will help prioritize the  
240 implementation of the high-level security and privacy goals shown in [Figure 5-3](#), it would like to look

more closely at the NIST SP 800-53 controls it will initially implement in its new BYOD architecture. This will help Great Seneca identify the capabilities it will deploy first to meet its architecture needs.

**Figure 5-3 Security and Privacy Goals**



244

245 Volume B's Appendix G and H provide a list of the controls that the example solution implements, 246 including how the controls in the example solution align to the Subcategories in both the Cybersecurity 247 Framework and Privacy Framework. Because these controls only focus on the example solution, Great 248 Seneca will need to implement additional controls that address the unique risks associated with its 249 environment.

250 To help identify the specific controls Great Seneca Accounting will be implementing to support the new 251 BYOD architecture, it uses the NIST RMF process to manage security and privacy risk for its systems. The 252 organization decides to follow the RMF guidance in NIST SP 800-37 [7] to conduct security and privacy 253 risk assessments as it continues preparing to design its new solution.

### 254 **5.3 Great Seneca Accounting Performs a Risk Assessment**

255 Great Seneca Accounting completes a security risk assessment by using the guidance in NIST SP 800-30 256 [8] and the Mobile Threat Catalogue [5] to identify cybersecurity threats to the organization. The 257 company then uses the NIST PRAM [6] to perform a privacy risk assessment. Appendix F and G describe 258 these risk assessments in more detail. These risk assessments produce two significant conclusions:

- 259        1. Great Seneca Accounting finds similar cybersecurity threats in its environment and problematic  
260        data actions for employee privacy as those discussed in NIST SP 1800-22, validating that the  
261        controls discussed in the example solution are relevant to their environment.  
262        2. The organization determines that it has a high-impact system, based on the impact guidance in  
263        NIST FIPS 200, *Minimum Security Requirements for Federal Information and Information Systems*  
264        [9], and needs to implement more controls beyond those identified in NIST SP 1800-22 and its  
265        Target Profiles to support the additional system components in its own solution (e.g., underlying  
266        OS, the data center where the equipment will reside).

267        **5.4 Great Seneca Accounting Tailors Their Security and Privacy Control  
268        Baselines**

269        As part of their review of NIST FIPS 200 [9], Great Seneca Accounting selects the high controls baseline in  
270        NIST SP 800-53 [10] for their BYOD architecture implementation. They then tailor the control baselines  
271        based on the needs identified through the priority Subcategories in its cybersecurity and privacy Target  
272        Profiles.

273        Control baselines are tailored to meet their organization's needs. NIST SP 800-53 [10] defines tailoring as  
274        "The process by which security control baselines are modified by: (i) identifying and designating  
275        common controls; (ii) applying scoping considerations on the applicability and implementation of  
276        baseline controls; (iii) selecting compensating security controls; (iv) assigning specific values to  
277        organization-defined security control parameters; (v) supplementing baselines with additional security  
278        controls or control enhancements; and (vi) providing additional specification information for control  
279        implementation."

280        While not discussed in this example scenario, Great Seneca also plans to make tailoring decisions based  
281        on other unique needs in its environment (e.g., legal and regulatory requirements).

282        **5.4.1 An Example Tailoring of the System and Communications Protection Security  
283        Control Family**

284        As Great Seneca Accounting reviews the System and Communications Protection (SC) control family in  
285        NIST SP 800-53 [10], it notes there are opportunities for tailoring.

286        For example, the NIST SP 800-53 baseline includes control enhancements, whereas the Cybersecurity  
287        Framework Informative References contain only base controls. Great Seneca Accounting decides to  
288        implement the enhancements that are applicable to a high-impact system for the SC controls they have  
289        selected.

290        Using this decision as a guide, Great Seneca Accounting also makes the following tailoring decisions  
291        related to the NIST SP 800-53 SC control family:

- 292        ▪ NIST SP 800-53 provides recommendations regarding implementation priorities for controls. The  
293        implementation priorities of controls related to some Cybersecurity Framework Subcategories

294            were adjusted to be higher or lower based on their alignment with Subcategory prioritization in  
 295            the Target Profile.

- 296        ▪ For example, the implementation priority for Cybersecurity Framework Subcategory DE.CM-5  
 297            was identified as having low or moderate importance for accomplishing all four BYOD-Related  
 298            Business/Mission Objectives. NIST SP 800-53 designates control SC-18, which supports the  
 299            implementation of Cybersecurity Framework Subcategory DE.CM-5, as high priority. However,  
 300            since Cybersecurity Framework Subcategory DE.CM-5 is moderate or low priority in this context,  
 301            Great Seneca makes a tailoring decision to lower the implementation priority for the SC-18 NIST  
 302            SP 800-53 control to moderate.
  - 303              ○ DE.CM-5's importance designations for accomplishing the BYOD-Related  
 304              Business/Mission Objectives are highlighted in green in [Figure 5-4](#).

305            **Figure 5-4 Subcategory DE.CM-5 Mapping to BYOD-Related Business/Mission Objectives**

Cybersecurity Framework Core			BYOD-Related Business/Mission Objectives			
Function	Category	Subcategory	(1) Provide Good Data Stewardship	(2) Enable Workforce Flexibility	(3) Provide Innovative Financial Services	(4) Enable Workforce Flexibility
DETECT	Security Continuous Monitoring	DE.CM-5: Unauthorized mobile code is detected.				

- 306        ▪ Conversely, just as the implementation priority for the NIST SP 800-53 control that supports  
 307            implementation of Subcategory DC-CM-5 was lowered based on the Target Profile, the  
 308            implementation priority for the NIST SP 800-53 controls that supports implementation of  
 309            Cybersecurity Framework Subcategory PR.AC-5 was raised. This is because Subcategory PR.AC-5  
 310            was identified as having high importance for accomplishing all four BYOD-Related  
 311            Business/Mission Objectives.
  - 312              ○ The NIST SP 800-53 SC Family security control related to the Cybersecurity Framework  
 313              Subcategory PR.AC-5 is SC-7. NIST SP 800-53 prioritizes control SC-7 as low. Since control  
 314              SC-7 supports the implementation of a Cybersecurity Framework Subcategory that is  
 315              designated as high priority in Great Seneca's Target Profile (Cybersecurity Framework  
 316              Subcategory PR.AC-5), Great Seneca makes a tailoring decision to increase the priority of  
 317              NIST SP 800-53 control SC-7 to high.
  - 318              ○ PR.AC-5's high importance designation for accomplishing the BYOD-Related  
 319              Business/Mission Objectives are highlighted in green in [Figure 5-5](#). All Subcategory  
 320              prioritizations (including PR.AC-5's shown below) can be found in [Table 3-1](#).

322 Figure 5-5 Subcategory PR.AC-5 Mapping to BYOD-Related Business/Mission Objectives

Cybersecurity Framework Core			BYOD-Related Business/Mission Objectives			
Function	Category	Subcategory	(1) Provide Good Data Stewardship	(2) Enable Workforce Flexibility	(3) Provide Innovative Financial Services	(4) Enable Workforce Flexibility
PROTECT	Identity Management and Access Control	PR.AC-5: Network integrity is protected (e.g., network segregation, network segmentation).				

323

324 Great Seneca Accounting follows the same approach for the privacy controls in NIST SP 800-53, using  
 325 the Privacy Framework Target Profile and controls identified through its PRAM analysis (for more  
 326 information reference [Appendix G](#)).

327 Great Seneca Accounting will evaluate the security controls as they come up for review under its  
 328 continuous monitoring program to determine whether there are enhancements to the implemented  
 329 security controls that can be made over time.

330 In addition to identifying controls to select, the priorities articulated in Target Profiles will also help  
 331 Great Seneca Accounting decide how to align financial resources for controls implementation (e.g.,  
 332 buying a tool to automate a control as opposed to relying on policy and procedures alone). The Target  
 333 Profiles will help Great Seneca identify how robustly to re-assess the efficacy of implemented controls  
 334 before new system components or capabilities are enabled in a production environment. Great Seneca  
 335 will also be able to use the Target Profiles to help evaluate the residual risks of the architecture in the  
 336 context of Great Seneca Accounting's business/mission objectives, and the frequency and depth of  
 337 continued monitoring requirements over time.

338 **Note:** All of the tailoring decisions discussed above are for example purposes only. An organization's  
 339 actual tailoring decision will be based upon their own unique business/mission objectives, risk  
 340 assessment results, and organizational needs that may significantly vary from these examples.

341 **Appendix A List of Acronyms**

<b>BYOD</b>	Bring Your Own Device
<b>FIPS</b>	Federal Information Processing Standards
<b>NCCoE</b>	National Cybersecurity Center of Excellence
<b>NIST</b>	National Institute of Standards and Technology
<b>PII</b>	Personally Identifiable Information
<b>PRAM</b>	Privacy Risk Assessment Methodology
<b>RMF</b>	Risk Management Framework
<b>SP</b>	Special Publication

342 **Appendix B Glossary**

<b>Access Management</b>	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 [11].
<b>Availability</b>	Ensure that users can access resources through remote access whenever needed [12].
<b>Bring Your Own Device (BYOD)</b>	A non-organization-controlled telework client device [12].
<b>Confidentiality</b>	Ensure that remote access communications and stored user data cannot be read by unauthorized parties [12].
<b>Data Actions</b>	System operations that process PII [13].
<b>Disassociability</b>	Enabling the processing of PII or events without association to individuals or devices beyond the operational requirements of the system [13].
<b>Eavesdropping</b>	An attack in which an Attacker listens passively to the authentication protocol to capture information which can be used in a subsequent active attack to masquerade as the Claimant [14] (definition located under eavesdropping attack).
<b>Firewall</b>	Firewalls are devices or programs that control the flow of network traffic between networks or hosts that employ differing security postures [15].
<b>Integrity</b>	Detect any intentional or unintentional changes to remote access communications that occur in transit [12].
<b>Manageability</b>	Providing the capability for granular administration of PII including alteration, deletion, and selective disclosure [13].
<b>Mobile Device</b>	A portable computing device that: (i) has a small form factor such that it can easily be carried by a single individual; (ii) is designed to operate without a physical connection (e.g., wirelessly transmit or receive information); (iii) possesses local, non-removable or removable data storage; and (iv) includes a self-contained power source. Mobile devices may also include voice communication capabilities, on-board sensors that allow the devices to capture information, and/or built-in features for

synchronizing local data with remote locations. Examples include smart phones, tablets, and E-readers [10].

<b>Personally Identifiable Information (PII)</b>	Any information about an individual maintained by an agency, including any information that can be used to distinguish or trace an individual's identity, such as name, Social Security number, date and place of birth, mother's maiden name, or biometric records; and any other information that is linked or linkable to an individual, such as medical, educational, financial, and employment information [16] (adapted from Government Accountability Office Report 08-536).
<b>Problematic Data Action</b>	A data action that could cause an adverse effect for individuals [2].
<b>Threat</b>	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 [8].
<b>Vulnerability</b>	Weakness in an information system, system security procedures, internal controls, or implementation that could be exploited by a threat source [8].

## 343      **Appendix C    References**

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393 <https://nvlpubs.nist.gov/nistpubs/ir/2020/NIST.IR.8170.pdf>.
- 394 [19] NIST. Risk Management Framework (RMF) Overview. [Online]. Available:  
395 [https://csrc.nist.gov/projects/risk-management/risk-management-framework-\(rmf\)-overview](https://csrc.nist.gov/projects/risk-management/risk-management-framework-(rmf)-overview).

## 396 **Appendix D A Note Regarding Great Seneca Accounting**

397 A description of a fictional organization, Great Seneca Accounting, was included in the National Institute  
398 of Standards and Technology (NIST) Special Publication (SP) 1800-22 Mobile Device Security: Bring Your  
399 Own Device (BYOD) Practice Guide.

400 This fictional organization demonstrates how a small-to-medium sized, regional organization imple-  
401 mented the example solution in this practice guide to assess and protect their mobile-device-specific  
402 security and privacy needs. It illustrates how organizations with office-based, remote-working, and trav-  
403 eling personnel can be supported in their use of personally owned devices that enable their employees  
404 to work while on the road, in the office, at customer locations, and at home.

405 **Figure D-1 Great Seneca Accounting's Work Environments**



## 406    **Appendix E How Great Seneca Accounting Applied NIST Risk 407       Management Methodologies**

408    This practice guide contains an example scenario about a fictional organization called Great Seneca  
409    Accounting. The example scenario shows how to deploy a Bring Your Own Device (BYOD) solution to be  
410    in alignment with an organization's security and privacy capabilities and objectives.

411    The example scenario uses National Institute of Standards and Technology (NIST) standards, guidance,  
412    and tools. It is provided in the *Example Scenario: Putting Guidance into Practice* supplement of this  
413    practice guide.

414    This appendix provides a brief description of some of the key NIST tools referenced in the example  
415    scenario supplement of this practice guide.

416    In this Appendix, Section E.1 provides descriptions of the risk frameworks and tools, along with a high-  
417    level discussion of how Great Seneca Accounting applied each framework or tool in the example  
418    scenario. Section E.2 describes how the *NIST Cybersecurity Framework* and *NIST Privacy Framework* can  
419    be used to establish or improve cybersecurity and privacy programs.

### 420    **E.1 Overview of Risk Frameworks and Tools That Great Seneca Used**

421    Great Seneca used NIST frameworks and tools to identify common security and privacy risks related to  
422    BYOD solutions and to guide approaches to how they were addressed in the architecture described in  
423    Section 4. Great Seneca used additional standards and guidance, listed in Appendix D of Volume B, to  
424    complement these frameworks and tools when designing their BYOD architecture.

425    Both the Cybersecurity Framework and Privacy Framework include the concept of Framework Profiles,  
426    which identify the organization's existing activities (contained in a Current Profile) and articulate the  
427    desired outcomes that support its mission and business objectives within its risk tolerance (that are  
428    contained in the Target Profile). When considered together, Current and Target Profiles are useful tools  
429    for identifying gaps and for strategic planning.

#### 430    **E.1.1 Overview of the NIST Cybersecurity Framework**

431    **Description:** The NIST Cybersecurity Framework "is voluntary guidance, based on existing standards,  
432    guidelines, and practices for organizations to better manage and reduce cybersecurity risk. In addition to  
433    helping organizations manage and reduce risks, it was designed to foster risk and cybersecurity  
434    management communications amongst both internal and external organizational stakeholders." [17]

435    **Application:** This guide refers to two of the main components of the Cybersecurity Framework: the  
436    Framework Core and the Framework Profiles. As described in Section 2.1 of the Cybersecurity  
437    Framework, the Framework Core provides a set of activities to achieve specific cybersecurity outcomes,

438 and reference examples of guidance to achieve those outcomes (e.g., controls found in NIST Special  
439 Publication [SP] 800-53). Section 2.3 of the Cybersecurity Framework identifies Framework Profiles as  
440 the alignment of the Functions, Categories, and Subcategories (i.e., the Framework Core) with the  
441 business requirements, risk tolerance, and resources of the organization.

442 The Great Seneca Accounting example scenario assumed that the organization used the Cybersecurity  
443 Framework Core and Framework Profiles, specifically the Target Profiles, to align cybersecurity  
444 outcomes and activities with its overall business/mission objectives for the organization. In the case of  
445 Great Seneca Accounting, its Cybersecurity Framework Target Profile helps program owners and system  
446 architects understand business and mission-driven priorities and the types of cybersecurity capabilities  
447 needed to achieve them. Great Seneca Accounting also used the NIST Interagency Report (NISTIR) 8170,  
448 *The Cybersecurity Framework, Implementation Guidance for Federal Agencies* [18], for guidance in using  
449 the NIST Cybersecurity Framework.

### 450 E.1.2 Overview of the NIST Privacy Framework

451 **Description:** The *NIST Privacy Framework* is a voluntary enterprise risk management tool intended to  
452 help organizations identify and manage privacy risk and build beneficial products and services while  
453 protecting individuals' privacy. It follows the structure of the Cybersecurity Framework to facilitate using  
454 both frameworks together [2].

455 **Application:** This guide refers to two of the main components of the Privacy Framework: the Framework  
456 Core and Framework Profiles. As described in Section 2.1 of the Privacy Framework, the Framework  
457 Core provides an increasingly granular set of activities and outcomes that enable dialog about managing  
458 privacy risk as well as resources to achieve those outcomes (e.g., guidance in NISTIR 8062, *An*  
459 *Introduction to Privacy Engineering and Risk Management in Federal Systems* [13]). Section 2.2 of the  
460 Privacy Framework identifies Framework Profiles as the selection of specific Functions, Categories, and  
461 Subcategories from the core that an organization has prioritized to help it manage privacy risk.

462 Great Seneca Accounting used the Privacy Framework as a strategic planning tool for its privacy program  
463 as well as its system, product, and service teams. The Great Seneca Accounting example scenario  
464 assumed that the organization used the Privacy Framework Core and Framework Profiles, specifically  
465 Target Profiles, to align privacy outcomes and activities with its overall business/mission objectives for  
466 the organization. Its Privacy Framework Target Profile helped program owners and system architects to  
467 understand business and mission-driven priorities and the types of privacy capabilities needed to  
468 achieve them.

### 469 E.1.3 Overview of the NIST Risk Management Framework

470 **Description:** The NIST Risk Management Framework (RMF) "provides a process that integrates security  
471 and risk management activities into the system development life cycle. The risk-based approach to  
472 security control selection and specification considers effectiveness, efficiency, and constraints due to

473 applicable laws, directives, Executive Orders, policies, standards, or regulations” [19]. Two of the key  
474 documents that describe the RMF are NIST SP 800-37 Revision 2, *Risk Management Framework for*  
475 *Information Systems and Organizations: A System Life Cycle Approach for Security and Privacy*; and NIST  
476 SP 800-30, *Guide for Conducting Risk Assessments*.

477 **Application:** The RMF has seven steps: Prepare, Categorize, Select, Implement, Assess, Authorize, and  
478 Monitor. These steps provide a method for organizations to characterize the risk posture of their  
479 information and systems and identify controls that are commensurate with the risks in the system’s  
480 environment. They also support organizations with selecting beneficial implementation and assessment  
481 approaches, reasoning through the process to understand residual risks, and monitoring the efficacy of  
482 implemented controls over time.

483 The Great Seneca Accounting example solution touches on the risk assessment activities conducted  
484 under the *Prepare* step, identifying the overall risk level of the BYOD system architecture in the  
485 *Categorize* step, and, consistent with example approach 8 in NISTIR 8170, reasoning through the  
486 controls that are necessary in the *Select* step. The influence of the priorities provided in Great Seneca  
487 Accounting’s Cybersecurity Framework Target Profile is also briefly mentioned regarding making  
488 decisions for how to apply controls during *Implement* (e.g., policy versus tools), how robustly to verify  
489 and validate controls during *Assess* (e.g., document review versus “hands on the keyboard” system  
490 testing), and the degree of evaluation required over time as part of the *Monitor* step.

#### 491 E.1.4 Overview of the NIST Privacy Risk Assessment Methodology

492 **Description:** The NIST Privacy Risk Assessment Methodology (PRAM) is a tool for analyzing, assessing,  
493 and prioritizing privacy risks to help organizations determine how to respond and select appropriate  
494 solutions. A blank version of the PRAM is available for download on NIST’s website.

495 **Application:** The PRAM uses the privacy risk model and privacy engineering objectives described in  
496 NISTIR 8062 to analyze for potential problematic data actions. Data actions are any system operations  
497 that process data. Processing can include, collection, retention, logging, analysis, generation,  
498 transformation or merging, disclosure, transfer, and disposal of data. A problematic data action is one  
499 that could cause an adverse effect, or problem, for individuals. The occurrence or potential occurrence  
500 of problematic data actions is a privacy event. While there is a growing body of technical privacy  
501 controls, including those found in NIST SP 800-53, applying the PRAM may result in identifying controls  
502 that are not yet available in common standards. This makes it an especially useful tool for managing  
503 risks that may otherwise go unaddressed.

504 The Great Seneca Accounting example solution assumed that a PRAM was used to identify problematic  
505 data actions and mitigating controls for employees. The controls in this build include some technical  
506 controls, such as controls that can be handled by security capabilities, as well as policy and procedure-  
507 level controls that need to be implemented outside yet supported by the system.

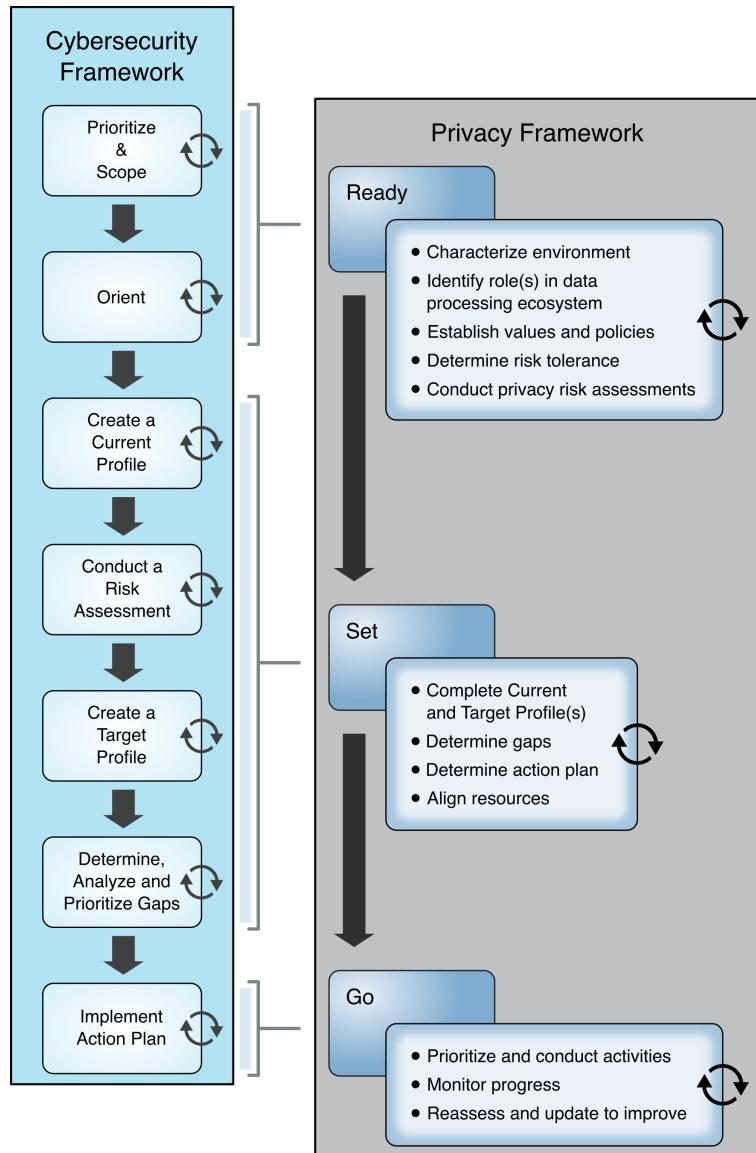
508    **E.2 Using Frameworks to Establish or Improve Cybersecurity and Privacy**  
509    **Programs**

510    While their presentation differs, the NIST Cybersecurity Framework and *NIST Privacy Framework* also  
511    both provide complementary guidance for establishing and improving cybersecurity and privacy  
512    programs. The NIST Cybersecurity Framework's process for establishing or improving programs provides  
513    seven steps that an organization could use iteratively and as necessary throughout the program's life  
514    cycle to continually improve its cybersecurity posture:

- 515        ▪ Step 1: Prioritize and scope the organization's mission.
- 516        ▪ Step 2: Orient its cybersecurity program activities to focus efforts on applicable areas.
- 517        ▪ Step 3: Create a current profile of what security areas it currently supports.
- 518        ▪ Step 4: Conduct a risk assessment.
- 519        ▪ Step 5: Create a Target Profile of the security areas that the organization would like to improve  
520        in the future.
- 521        ▪ Step 6: Determine, analyze, and prioritize cybersecurity gaps.
- 522        ▪ Step 7: Implement an action plan to close those gaps.

523    The *NIST Privacy Framework* includes the same types of activities for establishing and improving privacy  
524    programs, described in a three-stage Ready, Set, Go model. Figure E-1 below shows a comparison of  
525    these two approaches, demonstrating their close alignment.

526 Figure E-1 Comparing Framework Processes to Establish or Improve Programs



527 Both approaches are equally effective. Regardless of the approach selected, an organization begins with  
 528 orienting around its business/mission objectives and high-level organizational priorities and carry out  
 529 the remaining activities in a way that makes the most sense for the organization. The organization  
 530 repeats these steps as necessary throughout the program's life cycle to continually improve its risk  
 531 posture.

## 532    **Appendix F    How Great Seneca Accounting Used the NIST 533                      Risk Management Framework**

534    This practice guide contains an example scenario about a fictional organization called Great Seneca  
535    Accounting. The example scenario shows how to deploy a Bring Your Own Device (BYOD) solution to be  
536    in alignment with an organization's security and privacy capabilities and objectives.

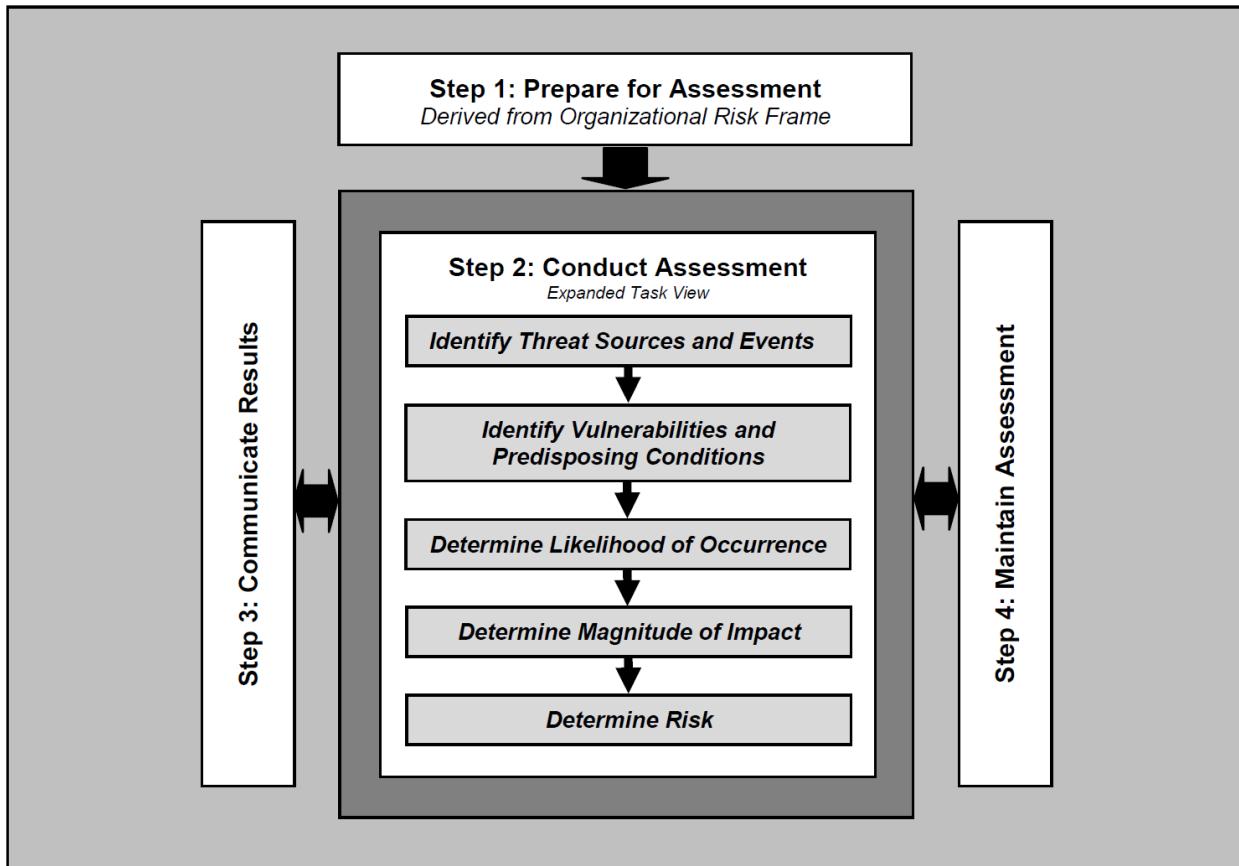
537    The example scenario uses National Institute of Standards and Technology (NIST) standards, guidance,  
538    and tools. It is provided in the *Example Scenario: Putting Guidance into Practice* supplement of this  
539    practice guide.

540    In the example scenario supplement of this practice guide, Great Seneca Accounting decided to use the  
541    NIST Cybersecurity Framework, the *NIST Privacy Framework*, and the NIST Risk Management Framework  
542    to help improve its mobile device architecture. The following material provides information about how  
543    Great Seneca Accounting used the NIST Risk Management Framework to improve its BYOD deployment.

### 544    **F.1    Understanding the Risk Assessment Process**

545    This section provides information on the risk assessment process employed to improve the mobile  
546    security posture of Great Seneca Accounting. Typically, a risk assessment based on NIST SP 800-30  
547    Revision 1 follows a four-step process as shown in [Figure F-1](#): prepare for assessment, conduct  
548    assessment, communicate results, and maintain assessment.

549 Figure F-1 Risk Assessment Process

550 

## F.2 Risk Assessment of Great Seneca Accounting's BYOD Program

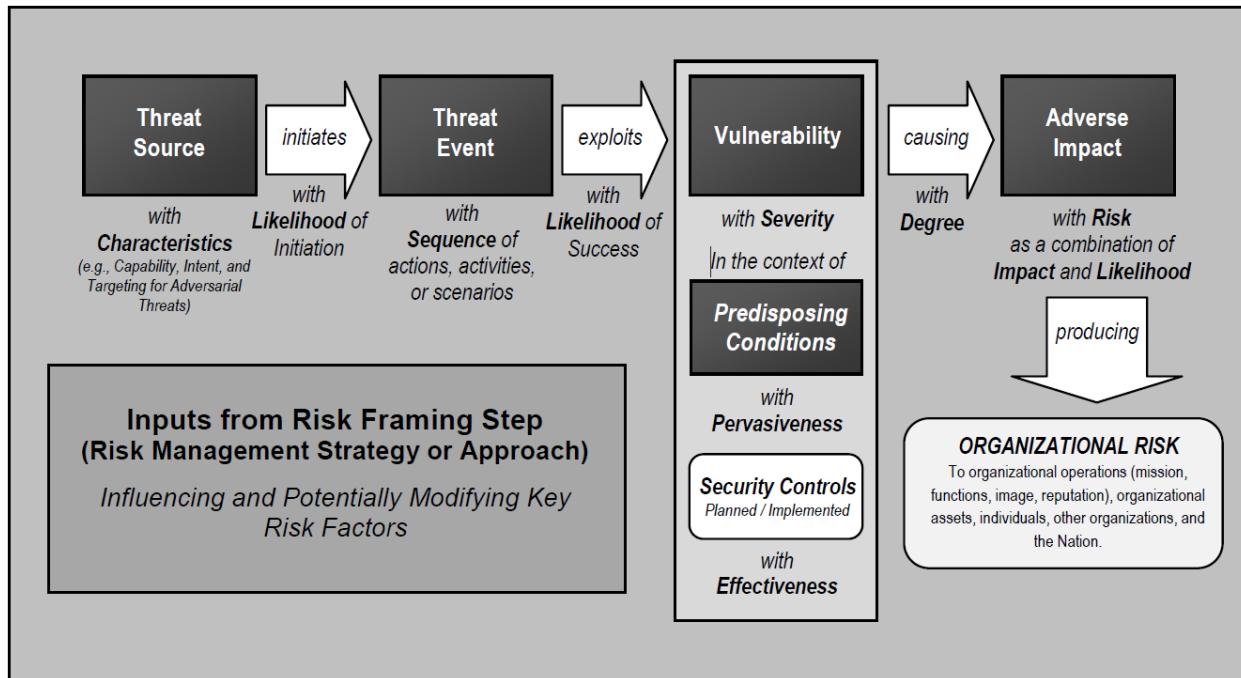
551 This risk assessment is scoped to Great Seneca Accounting's mobile deployment, which includes the  
 552 mobile devices used to access Great Seneca Accounting's enterprise resources, along with any  
 553 information technology components used to manage or provide services to those mobile devices.

554 Risk assessment assumptions and constraints were developed by using a NIST SP 800-30 Revision 1  
 555 generic risk model as shown in [Figure F-2](#) to identify the following components of the risk assessment:

- 556     ■ threat sources
- 557     ■ threat events
- 558     ■ vulnerabilities
- 559     ■ predisposing conditions
- 560     ■ security controls

- 561        □ adverse impacts  
 562        □ organizational risks

563 **Figure F-2 NIST SP 800-30 Generic Risk Model**



### 564 **F.3 Development of Threat Event Descriptions**

565 Great Seneca Accounting developed threat event tables based on NIST SP 800-30 Revision 1 and used  
 566 those to help analyze the sources of mobile threats. Using this process, Great Seneca Accounting  
 567 leadership identified the following potential mobile device threat events that are described in the  
 568 following subsections.

#### 569 **A note about selection of the threat events:**

570 This practice guide's example solution helps protect organizations from the threat events shown in [Table F-1](#).  
 571 A mapping of these threat events to the NIST Mobile Threat Catalogue is provided in [Table F-2](#).

572 **Table F-1 Great Seneca Accounting's BYOD Deployment Threats**

Great Seneca Accounting's Threat Event Identification Number	Threat Event Description
<b>TE-1</b>	privacy-intrusive applications
<b>TE-2</b>	account credential theft through phishing
<b>TE-3</b>	malicious applications
<b>TE-4</b>	outdated phones
<b>TE-5</b>	camera and microphone remote access
<b>TE-6</b>	sensitive data transmissions
<b>TE-7</b>	brute-force attacks to unlock a phone
<b>TE-8</b>	protection against weak password practices
<b>TE-9</b>	protection against unmanaged devices
<b>TE-10</b>	protection against lost or stolen data
<b>TE-11</b>	protecting data from being inadvertently backed up to a cloud service
<b>TE-12</b>	protection against sharing personal identification number (PIN) or password

573 Great Seneca Accounting's 12 threat events and their mapping to the NIST Mobile Threat Catalogue [5]  
 574 are shown in [Table F-2](#).

575 **Table F-2 Threat Event Mapping to the Mobile Threat Catalogue**

Great Seneca Accounting's Threat Event Identification Number	NIST Mobile Threat Catalogue Threat ID
<b>TE-1</b>	APP-2, APP-12
<b>TE-2</b>	AUT-9
<b>TE-3</b>	APP-2, APP-5, APP-31, APP-40, APP-32, AUT-10
<b>TE-4</b>	APP-4, APP-26, STA-0, STA-9, STA-16
<b>TE-5</b>	APP-32, APP-36

Great Seneca Accounting's Threat Event Identification Number	NIST Mobile Threat Catalogue Threat ID
<b>TE-6</b>	APP-0, CEL-18, LPN-2
<b>TE-7</b>	AUT-2, AUT-4
<b>TE-8</b>	APP-9, AUT-0
<b>TE-9</b>	EMM-5
<b>TE-10</b>	PHY-0
<b>TE-11</b>	EMM-9
<b>TE-12</b>	AUT-0, AUT-2, AUT-4, AUT-5

576    **F.4 Great Seneca Accounting's Leadership and Technical Teams Discuss**  
 577    **BYOD's Potential Threats to Their Organization**

578    Great Seneca Accounting's leadership team wanted to understand real-world examples of each threat  
 579    event and what the risk was for each. Great Seneca Accounting's leadership and technical teams then  
 580    discussed those possible threats that BYOD could introduce to their organization.

581    The analysis performed by Great Seneca Accounting's technical team included analyzing the likelihood  
 582    of each threat, the level of impact, and the threat level that the BYOD deployment would pose. The  
 583    following are leadership's questions and the technical team's responses regarding BYOD threats during  
 584    that discussion using real-world examples. A goal of the example solution contained within this practice  
 585    guide is to mitigate the impact of these threat events. Reference [Table 5-1](#) for a listing of the technology  
 586    that addresses each of the following threat events.

587    **F.4.1 Threat Event 1**

588    **What happens if an employee installs risky applications?**

589    A mobile application can attempt to collect and exfiltrate any information to which it has been granted  
 590    access. This includes any information generated during use of the application (e.g., user input), user-  
 591    granted permissions (e.g., contacts, calendar, call logs, photos), and general device data available to any  
 592    application (e.g., International Mobile Equipment Identity, device make and model, serial number).  
 593    Further, if a malicious application exploits a vulnerability in other applications, the operating system  
 594    (OS), or device firmware to achieve privilege escalation, it may gain unauthorized access to any data  
 595    stored on or otherwise accessible through the device.

596 **Risk assessment analysis:**

597 Overall likelihood: very high

598 *Justification:* Employees have access to download any application at any time. If an employee requires  
599 an application that provides a desired function, the employee can download that application from any  
600 available source (trusted or untrusted) that provides a desired function. If an application performs an  
601 employee's desired function, the employee may download an application from an untrusted source  
602 and/or disregard granted privacy permissions.

603 Level of impact: high

604 *Justification:* Employees may download an application from an untrusted source and/or disregard  
605 granted privacy permissions. This poses a threat for sensitive corporate data, as some applications may  
606 include features that could access corporate data, unbeknownst to the user.

607 **BYOD-specific threat:** In a BYOD scenario, users are still able to download and install applications at  
608 their leisure. This capability allows users to unintentionally side-load or install a malicious application  
609 that may harm the device or the enterprise information on the device.

#### 610 F.4.2 Threat Event 2

611 **Can account information be stolen through phishing?**

612 Malicious actors may create fraudulent websites that mimic the appearance and behavior of legitimate  
613 ones and entice users to authenticate to them by distributing phishing messages over short message  
614 service (SMS) or email. Effective social engineering techniques such as impersonating an authority figure  
615 or creating a sense of urgency may compel users to forgo scrutinizing the message and proceed to  
616 authenticate to the fraudulent website; it then captures and stores the user's credentials before  
617 (usually) forwarding them to the legitimate website to allay suspicion.

618 **Risk assessment analysis:**

619 Overall likelihood: very high

620 *Justification:* Phishing campaigns are a very common threat that occurs almost every day.

621 Level of impact: high

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

625 **BYOD-specific threat:** The device-level controls applied to personal devices do not inhibit a user's  
626 activities. This allows the user to access personal/work messages and emails on their device that could

627 be susceptible to phishing attempts. If the proper controls are not applied to a user's enterprise  
628 messages and email, successful phishing attempts could allow an attacker unauthorized access to  
629 enterprise data.

### 630 F.4.3 Threat Event 3

#### 631 How much risk do malicious applications pose to Great Seneca Accounting?

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

#### 641 Risk assessment analysis:

642 Overall likelihood: high

643 *Justification:* Installation of malicious applications via URLs is less common than other phishing attempts.  
644 The process for side-loading applications requires much more user input and consideration (e.g.,  
645 trusting the developer certificate) than standard phishing, which solely requests a username and  
646 password. A user may proceed through sideloading an application to acquire a desired capability from  
647 an application.

648 Level of impact: high

649 *Justification:* Once a user installs a malicious side-loaded application, an adversary could gain full access  
650 to a mobile device, and therefore access to corporate data and credentials, without the user's  
651 knowledge.

652 **BYOD-specific threat:** Like Threat Event 1, BYOD deployments may have fewer restrictions to avoid  
653 preventing the user from performing desired personal functions. This increases the attack surface for  
654 malicious actors to take advantage.

### 655 F.4.4 Threat Event 4

#### 656 What happens when outdated phones access Great Seneca Accounting's network?

657 When malware successfully exploits a code execution vulnerability in the mobile OS or device drivers,  
658 the delivered code generally executes with elevated privileges and issues commands in the context of

659 the root user or the OS kernel. This may be enough for some malicious actors to accomplish their goal,  
660 but those that are advanced will usually attempt to install additional malicious tools and to establish a  
661 persistent presence. If successful, the attacker will be able to launch further attacks against the user, the  
662 device, or any other systems to which the device connects. As a result, any data stored on, generated  
663 by, or accessible to the device at that time – or in the future – may be compromised.

664 **Risk assessment analysis:**

665 Overall likelihood: high

666 *Justification:* Many public vulnerabilities specific to mobile devices have been seen over the years. In  
667 these, users can jailbreak iOS devices and root Android devices to download third-party applications and  
668 apply unique settings/configurations that the device would not typically be able to apply/access.

669 Level of impact: high

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

674 **BYOD-specific threat:** As with any device, personal devices are susceptible to device exploitation if not  
675 properly used or updated.

676 **F.4.5 Threat Event 5**

677 **Can Great Seneca Accounting stop someone from turning on a camera or microphone?**

678 Malicious actors with access (authorized or unauthorized) to device sensors (microphone, camera,  
679 gyroscope, Global Positioning System receiver, and radios) can use them to conduct surveillance. It may  
680 be directed at the user, as when tracking the device location, or it may be applied more generally, as  
681 when recording any nearby sounds. Captured sensor data may be immediately useful to a malicious  
682 actor, such as a recording of an executive meeting. Alternatively, the attacker may analyze the data in  
683 isolation or in combination with other data to yield sensitive information. For example, a malicious actor  
684 can use audio recordings of on-device or proximate activity to probabilistically determine user inputs to  
685 touchscreens and keyboards, essentially turning the device into a remote keylogger.

686 **Risk assessment analysis:**

687 Overall likelihood: very high

688 *Justification:* This has been seen on public application stores, with applications allegedly being used for  
689 data-collection. As mentioned in Threat Event 1, unbeknownst to the user, a downloaded application  
690 may be granted privacy intrusive permissions that allow access to device sensors.

691 Level of impact: high

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

694 **BYOD-specific threat:** Applications commonly request access to these sensors. In a BYOD deployment,  
695 the enterprise does not have control over what personal applications the user installs on their device.  
696 These personal applications may access sensors on the device and eavesdrop on a user's enterprise-  
697 related activities (e.g., calls and meetings).

#### 698 F.4.6 Threat Event 6

699 **Is sensitive information protected when the data travels between the employee's mobile device and  
700 Great Seneca Accounting's network?**

701 Malicious actors can readily eavesdrop on communication over unencrypted, wireless networks such as  
702 public Wi-Fi access points, which coffee shops and hotels commonly provide. While a device is  
703 connected to such a network, a malicious actor could gain unauthorized access to any data sent or  
704 received by the device for any session that has not already been protected by encryption at either the  
705 transport or application layers. Even if the transmitted data were encrypted, an attacker would be privy  
706 to the domains, internet protocol (IP) addresses, and services (as indicated by port numbers) to which  
707 the device connects; an attacker could use such information in future watering hole or person-in-the-  
708 middle attacks against the device user.

709 Additionally, visibility into network-layer traffic enables a malicious actor to conduct side-channel  
710 attacks against the network's encrypted messages, which can still result in a loss of confidentiality.  
711 Further, eavesdropping on unencrypted messages during a handshake to establish an encrypted session  
712 with another host or endpoint may facilitate attacks that ultimately compromise the security of the  
713 session.

714 **Risk assessment analysis:**

715 Overall likelihood: moderate

716 **Justification:** Unlike installation of an application, installations of enterprise mobility management  
717 (EMM)/mobile device management (MDM), network, virtual private network (VPN) profiles, and  
718 certificates require additional effort and understanding from the user to properly implement.

719 Level of impact: very high

720 **Justification:** If malicious actor can install malicious configuration profiles or certificates, they would be  
721 able to perform actions such as decrypting network traffic and possibly even control the device.

722 **BYOD-specific threat:** Like Threat Event 2, personal devices may not have the benefit of an always-on  
723 device-wide VPN. This leaves application communications at the discretion of the developer.

#### 724 F.4.7 Threat Event 7

##### 725 Is Great Seneca Accounting's data protected from brute-force PIN attacks?

726 A malicious actor may be able to obtain a user's device unlock code by direct observation, side-channel  
727 attacks, or brute-force attacks. Both the first and second can be attempted with at least proximity to the  
728 device; only the third technique requires physical access. However, applications with access to any  
729 peripherals that detect sound or motion (microphone, gyroscope, or accelerometer) can attempt side-  
730 channel attacks that infer the unlock code by detecting taps and swipes to the screen. Once the device  
731 unlock code has been obtained, a malicious actor with physical access to the device will gain immediate  
732 access to any data or functionality not already protected by additional access control mechanisms.  
733 Additionally, if the user employs the device unlock code as a credential to any other systems, the  
734 malicious actor may further gain unauthorized access to those systems.

##### 735 Risk assessment analysis:

736 Overall likelihood: moderate

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

740 Level of impact: very high

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

744 **BYOD-specific threat:** Because BYODs are prone to travel (e.g., vacations, restaurants, and other  
745 nonwork locations), the risk that the device's passcode is obtained increases due to the heightened  
746 exposure to threats in different environments.

#### 747 F.4.8 Threat Event 8

##### 748 Can Great Seneca Accounting protect its data from weak password practices?

749 If a malicious actor gains unauthorized access to a mobile device, they also have access to the data and  
750 applications on that mobile device. The mobile device may contain an organization's in-house  
751 applications that a malicious actor can subsequently use to gain access to sensitive data or backend  
752 services. This could result from weaknesses or vulnerabilities present in the authentication or credential  
753 storage mechanisms implemented within an in-house application.

754   **Risk assessment analysis:**

755   Overall likelihood: moderate

756   *Justification:* Often applications include hardcoded credentials for the default password of the admin account. Default passwords are readily available online. The user might not change these passwords to allow access and eliminate the need to remember a password.

759   Level of impact: high

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

762   **BYOD-specific threat:** The risk of hardcoded credentials residing in an application on the device is the same for any mobile device deployment scenario.

#### 764   F.4.9 Threat Event 9

765   **Can unmanaged devices connect to Great Seneca Accounting?**

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

774   **Risk assessment analysis:**

775   Overall likelihood: very high

776   *Justification:* This may occur accidentally when an employee attempts to access their email or other corporate resources.

778   Level of impact: high

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

782   **BYOD-specific threat:** The risk of an unmanaged mobile device accessing the enterprise is the same for any mobile deployment scenario.

784 **F.4.10 Threat Event 10**785 **Can Great Seneca Accounting protect its data when a phone is lost or stolen?**

786 Due to the nature of the small form factor of mobile devices, they can be misplaced or stolen. A  
787 malicious actor who gains physical custody of a device with inadequate security controls may be able to  
788 gain unauthorized access to sensitive data or resources accessible to the device.

789 **Risk assessment analysis:**

790 Overall likelihood: very high

791 *Justification:* Mobile devices are small and can be misplaced. Enterprise devices may be lost or stolen at  
792 the same frequency as personally owned devices.

793 Level of impact: high

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

796 **BYOD-specific threat:** Due to the heightened mobility of BYODs, they are more prone to being  
797 accidentally lost or stolen.

798 **F.4.11 Threat Event 11**799 **Can data be protected from unauthorized cloud services?**

800 If employees violate data management policies by using unmanaged services to store sensitive  
801 organizational data, the data will be placed outside organizational control, where the organization can  
802 no longer protect its confidentiality, integrity, or availability. Malicious actors who compromise the  
803 unauthorized service account or any system hosting that account may gain unauthorized access to the  
804 data.

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

809 **Risk assessment analysis:**

810 Overall likelihood: high

811 *Justification:* This could occur either intentionally or accidentally (e.g., taking a screenshot and having  
812 pictures backed up to an unmanaged cloud service).

813 Level of impact: high

814   *Justification:* Storage in unmanaged services presents a risk to the confidentiality and availability of  
815   corporate data because the corporation would no longer control it.  
  
816   **BYOD-specific threat:** In a BYOD deployment, employees are more likely to have some backup or  
817   automated cloud storage solution configured on their device, which may lead to unintentional backup of  
818   enterprise data.

#### 819   F.4.12 Threat Level 12

##### 820   **Can Great Seneca Accounting protect its data from PIN or password sharing?**

821   Many individuals choose to share the PIN or password to unlock their personal device with family  
822   members. This creates a scenario where a nonemployee can access the device, the work applications,  
823   and therefore the work data.

##### 824   **Risk assessment analysis:**

825   Overall likelihood: moderate

826   *Justification:* Even though employees are conditioned almost constantly to protect their work  
827   passwords, personal device PINs and passwords are not always protected with that same level of  
828   security. Anytime individuals share a password or PIN, there is increased risk that it might be exposed or  
829   compromised.

830   Level of impact: very high

831   *Justification:* If a malicious actor can bypass a device lock and gain access to the device, they can  
832   potentially access sensitive corporate data.

833   **BYOD-specific threat:** The passcode of an individual's personal mobile device is more likely to be shared  
834   among family and/or friends to provide access to applications (e.g., games). Although sharing passcodes  
835   may be convenient for personal reasons, this increases the risk of an unauthorized individual gaining  
836   access to enterprise data through a personal device.

### 837   F.5 Identification of Vulnerabilities and Predisposing Conditions

838   In this section we identify vulnerabilities and predisposing conditions that increase the likelihood that  
839   identified threat events will result in adverse impacts for Great Seneca Accounting. We list each  
840   vulnerability or predisposing condition in [Table F-3](#), along with the corresponding threat events and  
841   ratings of threat pervasiveness. More details on threat event ratings can be found in Appendix Section  
842   [F.3](#).

843 **Table F-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-9, TE-10	very high
VULN-2	Public Wi-Fi networks are regularly used by employees for remote connectivity from their mobile devices.	TE-6	very high
VULN-3	No EMM/MDM deployment exists to enforce and monitor compliance with security-relevant policies on mobile devices.	TE-1, TE-3, TE-4, TE-5, TE-6, TE-7, TE-8, TE-9, TE-10, TE-11, TE-12	very high

844 **F.6 Summary of Risk Assessment Findings**

845 Table F-4 summarizes the risk assessment findings. More detail about the methodology used to rate  
 846 overall likelihood, level of impact, and risk is in the Appendix Section F.3.

847 **Table F-4 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

Threat Event	Vulnerabilities, Predisposing Conditions	Overall Like-lihood	Level of Impact	Risk
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: loss of confidentiality of sensitive information via eavesdropping on unencrypted device communications	VULN-2, VULN-3	moderate	very high	high
TE-7: compromise of device integrity via observed, inferred, or brute-forced device unlock code	VULN-3	moderate	very high	high
TE-8: unauthorized access to backend services via authentication or credential storage vulnerabilities in internally developed applications	VULN-3	moderate	high	high
TE-9: unauthorized access of enterprise resources from an unmanaged and potentially compromised device	VULN-1, VULN-3	very high	high	high
TE-10: loss of organizational data due to a lost or stolen device	VULN-1, VULN-3	very high	high	high
TE-11: loss of confidentiality of organizational data due to its unauthorized storage in non-organizationally managed services	VULN-3	high	high	high
TE-12: unauthorized access to work applications via bypassed lock screen	VULN-3	moderate	very high	high

848   **Note 1:** Risk is stated in qualitative terms based on the scale in Table I-2 of Appendix I in NIST SP 800-30  
849   Revision 1 [8].

850   **Note 2:** The risk rating is derived from both the overall likelihood and level of impact using Table I-2 of  
851   Appendix I in NIST SP 800-30 Revision 1 [8]. Because these are modified interval scales, the combined  
852   overall risk ratings from Table I-2 do not always reflect a strict mathematical average of these two  
853   variables. The table above demonstrates this where levels of moderate weigh more heavily than other  
854   ratings.

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

## 860 **Appendix G How Great Seneca Accounting Used the NIST 861 Privacy Risk Assessment Methodology**

862 This practice guide contains an example scenario about a fictional organization called Great Seneca  
863 Accounting. The example scenario shows how to deploy a Bring Your Own Device (BYOD) solution to be  
864 in alignment with an organization's security and privacy capabilities and objectives.

865 The example scenario uses National Institute of Standards and Technology (NIST) standards, guidance,  
866 and tools. It is provided in the *Example Scenario: Putting Guidance into Practice* supplement of this  
867 practice guide.

868 In the example scenario, Great Seneca Accounting decided to use the NIST Privacy Risk Assessment  
869 Methodology (PRAM) to conduct a privacy risk assessment and help improve the company's mobile  
870 device architecture. The PRAM helps an organization analyze and communicate about how it conducted  
871 its data processing to achieve business/mission objectives.

872 At Great Seneca Accounting, the PRAM helped elucidate how enabling employees to use their personal  
873 devices for work-related functions can present privacy concerns for individuals. The PRAM also supports  
874 the risk assessment task in the Prepare step of the NIST Risk Management Framework as discussed in  
875 Appendix section E.1. The privacy events that were identified are below, along with potential  
876 mitigations.

### 877 **G.1 Problematic Data Action 1: Unwarranted restriction through blocking 878 access and wiping devices**

879 **Data Action:** Devices can be wiped and reset to factory settings based on inputs regarding anomalous  
880 activity and untrusted applications.

881 **Potential Problem for Individuals:** In a BYOD environment, employees are likely to use their devices for  
882 both personal and work-related purposes; thus, in a system that features robust security information  
883 and event management capable of wiping a device entirely, there could be an issue of employees losing  
884 personal data and employees may not even expect that this is a possibility. A hypothetical example is  
885 that a Great Seneca Accounting employee stores personal photos on their mobile device, but these  
886 photos are lost when their device is wiped after anomalous activity is detected.

888 **Mitigations:**

889 **Block access to corporate resources by removing device from mobile device management (MDM)  
890 control instead of wiping devices.**

891 As an alternative to wiping data entirely, section F.4.3, Threat Event 3, discusses blocking a device from  
892 accessing enterprise resources until an application is removed. Temporarily blocking access ensures that

893 an individual will not lose personal data through a full wipe of a device. This approach may help bring  
894 the system's capabilities into alignment with employees' expectations about what can happen to their  
895 devices, especially if they are unaware that devices can be wiped by administrators—providing greater  
896 predictability in the system.

897 Related mitigation: If this mitigation approach is taken, the organization may also wish to consider  
898 establishing and communicating these remediation processes to employees. It is important to have a  
899 clear remediation process in place to help employees regain access to resources on their devices at the  
900 appropriate time. It is also important to clearly convey this remediation process to employees. A  
901 remediation process provides greater manageability in the system supporting employees' ability to  
902 access resources. If well communicated to employees, this also provides greater predictability as  
903 employees will know the steps to regain access.

904 **Enable only selective wiping of corporate resources on the device.**

905 An alternative mitigation option for wiping device data is to limit what can be wiped. International  
906 Business Machines' (IBM's) MaaS360 can be configured to selectively wipe instead of performing a full  
907 factory reset. When configured this way, a wipe preserves employees' personal configurations,  
908 applications, and data while removing only the corporate configurations, applications, and data.  
909 However, on Android, a selective wipe will preserve restrictions imposed via policy on the device. To  
910 fully remove MDM control, the Remove Work Profile action must be used.

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

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

914 **Restrict staff access to system capabilities that permit removing device access or performing wipes.**

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

## 918 **G.2 Problematic Data Action 2: Employee surveillance**

919 **Data Action:** The assessed infrastructure offers Great Seneca Accounting and its employees a number of  
920 security capabilities, including reliance on comprehensive monitoring capabilities, as noted in Section 4,  
921 Architecture. Multiple parties could collect and analyze a significant amount of data relating to employ-  
922 ees, their devices, and their activities.

923

924 **Potential Problem for Individuals:** Employees may not be aware that the organization has the ability to  
925 monitor their interactions with the system and may not want this monitoring to occur. Collection and  
926 analysis of information might enable Great Seneca Accounting or other parties to craft a narrative about

927 an employee based on the employee's interactions with the system, which could lead to a power  
928 imbalance between Great Seneca Accounting and the employee and loss of trust in the employer if the  
929 employee discovers monitoring that they did not anticipate.

930 **Mitigations:**

931 **Restrict staff access to system capabilities that permit reviewing data about employees and their  
932 devices.**

933 This may be achieved using role-based access controls. Access can be limited to any dashboard in the  
934 system containing data about employees and their devices but is most sensitive for the MaaS360  
935 dashboard, which is the hub for data about employees, their devices, and threats. Minimizing access to  
936 sensitive information can enhance disassociability for employees using the system.

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

938 Conduct a system-specific privacy risk assessment to determine what elements can be limited. In the  
939 configuration of MaaS360, location services and application inventory collection may be disabled. iOS  
940 devices can be configured in MaaS360 to collect only an inventory of applications that have been  
941 installed through the corporate application store instead of all applications installed on the device.

942 While these administrative configurations may help provide disassociability in the system, there are also  
943 some opportunities for employees to limit the data collected. Employees can choose to disable location  
944 services in their device OS to prevent collection of location data. MaaS360 can also be configured to  
945 provide employees with the ability to manage their own devices through the IBM User Portal.

946 Each of these controls contributes to limiting the number of attributes regarding employees and their  
947 devices that is collected, which can impede administrators' ability to associate information with specific  
948 individuals.

949 **Dispose of personally identifiable information (PII).**

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

956    **G.3 Problematic Data Action 3: Unanticipated revelations through data**  
957    **sharing across parties**

958    **Data Action:** The infrastructure involves several parties that serve different purposes supporting Great  
959    Seneca Accounting's security objectives. As a result, device usage information could flow across various  
960    parties.

961

962    **Potential Problems for Individuals:** This transmission among a variety of different parties could be  
963    confusing for employees who might not know who has access to information about them. If  
964    administrators and co-workers know which colleagues are conducting activity on their device that  
965    triggers security alerts, employees could be embarrassed by its disclosure. Information being revealed  
966    and associated with specific employees could also lead to stigmatization and even impact Great Seneca  
967    Accounting upper management in its decision-making regarding the employee. Further, clear text  
968    transmissions could leave information vulnerable to attackers and therefore to unanticipated release of  
969    employee information.

970    **Mitigations:**

971    **De-identify personal and device data when such data is not necessary to meet processing objectives.**

972    De-identifying data helps decrease the chances that a third party is aggregating information pertaining  
973    to one individual. While de-identification can help reduce privacy risk, there are residual risks of re-  
974    identification.

975    **Encrypt data transmitted between parties.**

976    Encryption reduces the risk of compromise of information transmitted between parties. MaaS360  
977    encrypts all communications over the internet with Transport Layer Security.

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

979    Conduct a system-specific privacy risk assessment to determine how access to data can be limited. Using  
980    access controls to limit staff access to compliance information, especially when associated with  
981    individuals, can be important in preventing association of specific events with particular employees.

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

983    Conduct a system-specific privacy risk assessment to determine what elements can be limited. MaaS360  
984    can be configured to limit collection of application and location data. Further, instead of collecting a list  
985    of all the applications installed on the device, MaaS360 can collect only the list of those applications that  
986    were installed through the corporate application store (called "managed applications"). This would  
987    prevent insight into the employees' applications that employees downloaded for personal use.  
988    Zimperium provides privacy policies that can be configured to collect or not collect data items when  
989    certain events occur.

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

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

#### 993 **G.4 Mitigations Applicable Across Various Data Actions**

994 Several mitigations benefit employees in all three data actions identified in the privacy risk assessment.  
995 The following training and support mitigations can help Great Seneca Accounting appropriately inform  
996 employees about the system and its data processing.

997 **Mitigations:**

998 **Train employees about the system, parties involved, data processing, and actions that administrators  
999 can take.**

1000 Training sessions can also highlight any privacy-preserving techniques used, such as for disclosures to  
1001 third parties. Training should include confirmation from employees that they understand the actions  
1002 that administrators can take on their devices and their consequences—whether this is blocking access or  
1003 wiping data. Employees may also be informed of data retention periods and when their data will be  
1004 deleted. This can be more effective than sharing a privacy notice, which research has shown, individuals  
1005 are unlikely to read. Still, MaaS360 should also be configured to provide employees with access to a  
1006 visual privacy policy, which describes what device information is collected and why, as well as what  
1007 actions administrators can take on the device. This enables employees to make better informed  
1008 decisions while using their devices, and it enhances predictability.

1009 **Provide ongoing notifications or reminders about system activity.**

1010 This can be achieved using notifications to help directly link administrative actions on devices to relevant  
1011 threats and to also help employees understand why an action is being taken. MaaS360 also notifies  
1012 employees when changes are made to the privacy policy or MDM profile settings. These notifications  
1013 can help increase system predictability by setting employee expectations appropriately regarding the  
1014 way the system processes data and the resulting actions.

1015 **Provide a support point of contact.**

1016 By providing employees with a point of contact in the organization who can respond to inquiries and  
1017 concerns regarding the system, employees can better understand how the system processes their data,  
1018 which enhances predictability.

#### 1019 **G.5 Privacy References for Example Solution Technologies**

1020 Additional privacy information on the example solution's technologies appears below.

1021 **Table G-1 Privacy References for the Example Solution Technologies**

Commercially Available Product	Mobile Security Technology	Product Privacy Information Location
IBM MaaS360 Mobile Device Management (SaaS) Version 10.73  IBM MaaS360 Mobile Device Management Agent Version 3.91.5 (iOS), 6.60 (Android)  IBM MaaS360 Cloud Extender / Cloud Extender Modules	mobile device management	<a href="https://www.ibm.com/support/pages/node/1093156?mhsrc=ibm-search_a&amp;mhq=maas360%20privacy">https://www.ibm.com/support/pages/node/1093156?mhsrc=ibm-search_a&amp;mhq=maas360%20privacy</a>  <a href="https://www.ibm.com/support/pages/node/571227">https://www.ibm.com/support/pages/node/571227</a>  <a href="https://www.ibm.com/support/knowledge-center/SS8H2S/com.ibm.mc.doc/pag_source/tasks/pag_sec_privacy.htm">https://www.ibm.com/support/knowledge-center/SS8H2S/com.ibm.mc.doc/pag_source/tasks/pag_sec_privacy.htm</a>  <a href="http://public.dhe.ibm.com/software/security/products/maas360/GDPR/">http://public.dhe.ibm.com/software/security/products/maas360/GDPR/</a>
Kryptowire Cloud Service	application vetting	<a href="https://www.kryptowire.com">https://www.kryptowire.com</a>
Palo Alto Networks PA-VM-100 Version 9.0.1  Palo Alto Networks GlobalProtect VPN Client Version 5.0.6-14 (iOS), 5.0.2-6 (Android)	virtual private network (VPN) and firewall/filtering	<a href="https://docs.paloaltonetworks.com/globalprotect/8-0/globalprotect-admin/host-information/about-host-information/what-data-does-the-globalprotect-agent-collect#">https://docs.paloaltonetworks.com/globalprotect/8-0/globalprotect-admin/host-information/about-host-information/what-data-does-the-globalprotect-agent-collect#</a>  <a href="https://www.paloaltonetworks.com/resources/datasheets/url-filtering-privacy-datasheet">https://www.paloaltonetworks.com/resources/datasheets/url-filtering-privacy-datasheet</a>
Qualcomm (Version is mobile device dependent)	trusted execution environment	<a href="https://www.qualcomm.com/documents/files/guard-your-data-with-the-qualcomm-snapdragon-mobile-platform.pdf">https://www.qualcomm.com/documents/files/guard-your-data-with-the-qualcomm-snapdragon-mobile-platform.pdf</a>
Zimperium Defense Suite  Zimperium Console Version vGA-4.23.1  Zimperium zIPS Agent Version 4.9.2 (Android and iOS)	mobile threat defense	<a href="https://www.zimperium.com/mobile-app-protection">https://www.zimperium.com/mobile-app-protection</a>

## NIST SPECIAL PUBLICATION 1800-22C

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# Mobile Device Security:

## Bring Your Own Device (BYOD)

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**Volume C:**  
How-To Guides

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DRAFT

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<https://www.nccoe.nist.gov/projects/building-blocks/mobile-device-security/bring-your-own-device>



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9    **FEEDBACK**

- 10   You can improve this guide by contributing feedback. As you review and adopt this solution for your  
11   own organization, we ask you and your colleagues to share your experience and advice with us.  
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40 security community how to implement example solutions that help them align with relevant standards  
41 and best practices, and provide users with the materials lists, configuration files, and other information  
42 they need to implement a similar approach.

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

## 46 **ABSTRACT**

47 Bring Your Own Device (BYOD) refers to the practice of performing work-related activities on personally  
48 owned devices. This practice guide provides an example solution demonstrating how to enhance  
49 security and privacy in Android and Apple smartphone BYOD deployments.

50 Incorporating BYOD capabilities into an organization can provide greater flexibility in how employees  
51 work and increase the opportunities and methods available to access organizational resources. For some  
52 organizations, the combination of traditional in-office processes with mobile device technologies  
53 enables portable communication approaches and adaptive workflows. For others, it fosters a mobile-

54 first approach in which their employees communicate and collaborate primarily using their mobile  
55 devices.

56 However, some of the features that make BYOD mobile devices increasingly flexible and functional also  
57 present unique security and privacy challenges to both work organizations and device owners. The  
58 unique nature of these challenges is driven by the diverse range of devices available that vary in type,  
59 age, operating system (OS), and the level of risk posed.

60 Enabling BYOD capabilities in the enterprise introduces new cybersecurity risks to organizations.  
61 Solutions that are designed to secure corporate devices and on-premises data do not provide an  
62 effective cybersecurity solution for BYOD. Finding an effective solution can be challenging due to the  
63 unique risks that BYOD deployments impose. Additionally, enabling BYOD capabilities introduces new  
64 privacy risks to employees by providing their employer a degree of access to their personal devices,  
65 opening up the possibility of observation and control that would not otherwise exist.

66 To help organizations benefit from BYOD's flexibility while protecting themselves from many of its  
67 critical security and privacy challenges, this Practice Guide provides an example solution using  
68 standards-based, commercially available products and step-by-step implementation guidance.

## 69 **KEYWORDS**

70 *Bring your own device; BYOD; mobile device management; mobile device security.*

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Viji Raveendran	Qualcomm
Mikel Draghici	Zimperium

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

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

Technology Partner/Collaborator	Build Involvement
<a href="#">IBM</a>	Mobile Device Management
<a href="#">Kryptowire</a>	Application Vetting
<a href="#">Palo Alto Networks</a>	Firewall; Virtual Private Network
<a href="#">Qualcomm</a>	Trusted Execution Environment
<a href="#">Zimperium</a>	Mobile Threat Defense

## 78 DOCUMENT CONVENTIONS

79 The terms “shall” and “shall not” indicate requirements to be followed strictly to conform to the  
 80 publication and from which no deviation is permitted. The terms “should” and “should not” indicate that  
 81 among several possibilities, one is recommended as particularly suitable without mentioning or  
 82 excluding others, or that a certain course of action is preferred but not necessarily required, or that (in  
 83 the negative form) a certain possibility or course of action is discouraged but not prohibited. The terms

84 “may” and “need not” indicate a course of action permissible within the limits of the publication. The  
85 terms “can” and “cannot” indicate a possibility and capability, whether material, physical, or causal.

## 86 **CALL FOR PATENT CLAIMS**

87 This public review includes a call for information on essential patent claims (claims whose use would be  
88 required for compliance with the guidance or requirements in this Information Technology Laboratory  
89 (ITL) draft publication). Such guidance and/or requirements may be directly stated in this ITL Publication  
90 or by reference to another publication. This call also includes disclosure, where known, of the existence  
91 of pending U.S. or foreign patent applications relating to this ITL draft publication and of any relevant  
92 unexpired U.S. or foreign patents.

93 ITL may require from the patent holder, or a party authorized to make assurances on its behalf, in writ-  
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97 b) assurance that a license to such essential patent claim(s) will be made available to applicants desiring  
98 to utilize the license for the purpose of complying with the guidance or requirements in this ITL draft  
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101 or
- 102 2. without compensation and under reasonable terms and conditions that are demonstrably free  
103 of any unfair discrimination.

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106 sions sufficient to ensure that the commitments in the assurance are binding on the transferee, and that  
107 the transferee will similarly include appropriate provisions in the event of future transfers with the goal  
108 of binding each successor-in-interest.

109 The assurance shall also indicate that it is intended to be binding on successors-in-interest regardless of  
110 whether such provisions are included in the relevant transfer documents.

111 Such statements should be addressed to: [mobile-nccoe@nist.gov](mailto:mobile-nccoe@nist.gov)

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## 192 1 Introduction

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

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

### 200 1.1 Practice Guide Structure

201 This National Institute of Standards and Technology (NIST) Cybersecurity Practice Guide demonstrates a  
202 standards-based reference design and provides users with the information they need to replicate  
203 enhancing the security of bring your own device (BYOD) solutions. This reference design is modular and  
204 can be deployed in whole or in part.

205 This guide contains four volumes:

- 206     ■ NIST SP 1800-22A: *Executive Summary*
- 207     ■ NIST SP 1800-22B: *Approach, Architecture, and Security Characteristics* – what we built and why
- 208     ■ NIST SP 1800-22 Supplement: *Example Scenario: Putting Guidance into Practice* – how  
209       organizations can implement this example solution's guidance
- 210     ■ NIST SP 1800-22C: *How-To Guides* – instructions for building the example solution (**you are  
211       here**)

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

214 **Business decision makers, including chief security and technology officers**, will be interested in the  
215 *Executive Summary*, *NIST SP 1800-22A*, which describes the following topics:

- 216     ■ challenges that enterprises face in managing the security of BYOD deployments
- 217     ■ the example solution built at the NCCoE
- 218     ■ benefits of adopting the example solution

219 **Technology or security program managers** who are concerned with how to identify, understand, assess,  
220 and mitigate risk will be interested in *NIST SP 1800-22B*, which describes what we did and why. The  
221 following sections will be of particular interest:

- 222     ■ Section 4.1.4, Conduct a Risk Assessment, describes the risk analysis we performed.

223       ■ Appendix I, Example Security Control Map, maps the security characteristics of this example  
224       solution to cybersecurity standards and best practices.

225       You might share the *Executive Summary*, *NIST SP 1800-22A*, with your leadership team members to help  
226       them understand the importance of adopting standards-based BYOD solutions.

227       **IT professionals** who want to implement an approach like this will find this whole practice guide useful.  
228       You can use this How-To portion of the guide, *NIST SP 1800-22C*, to replicate all or parts of the build  
229       created in our lab. This How-To portion of the guide provides specific product installation, configuration,  
230       and integration instructions for implementing the example solution. We do not recreate the product  
231       manufacturers' documentation, which is generally widely available. Rather, we show how we  
232       incorporated the products together in our environment to create an example solution.

233       This guide assumes that IT professionals have experience implementing security products within the  
234       enterprise. While we have used a suite of commercial products to address this challenge, this guide does  
235       not endorse these particular products. Your organization can adopt this solution or one that adheres to  
236       these guidelines in whole, or you can use this guide as a starting point for tailoring and implementing  
237       parts of a BYOD solution. Your organization's security experts should identify the products that will best  
238       integrate with your existing tools and IT system infrastructure. We hope that you will seek products that  
239       are congruent with applicable standards and best practices. Volume B, Section 3.7, Technologies, lists  
240       the products that we used and maps them to the cybersecurity controls provided by this reference  
241       solution.

242       **For those who would like to see how the example solution can be implemented**, this practice guide  
243       contains an example scenario about a fictional company called Great Seneca Accounting. The example  
244       scenario shows how BYOD objectives can align with an organization's priority security and privacy  
245       capabilities through NIST risk management standards, guidance, and tools. It is provided in this practice  
246       guide's supplement, *NIST SP 1800-22 Example Scenario: Putting Guidance into Practice*.

247       A NIST Cybersecurity Practice Guide does not describe "the" solution, but a possible solution. This is a  
248       draft guide. We seek feedback on its contents and welcome your input. Comments, suggestions, and  
249       success stories will improve subsequent versions of this guide. Please contribute your thoughts to  
250       [mobile-nccoe@nist.gov](mailto:mobile-nccoe@nist.gov).

## 251       1.2 Build Overview

252       In our lab at the National Cybersecurity Center of Excellence (NCCoE), NIST engineers built an  
253       environment that contains an example solution for managing the security of BYOD deployments. In this  
254       guide, we show how an enterprise can leverage this example solution's concepts to implement  
255       Enterprise Mobility Management (EMM), mobile threat defense, application vetting, secure boot/image  
256       authentication, and virtual private network (VPN) services in support of a BYOD solution.

257 These technologies were configured to protect organizational assets and end-user privacy, providing  
258 methodologies to enhance the data protection posture of the adopting organization. The standards,  
259 best practices, and certification programs that this example solution is based upon help ensure the  
260 confidentiality, integrity, and availability of enterprise data on mobile systems.

### 261 **1.3 Typographic Conventions**

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

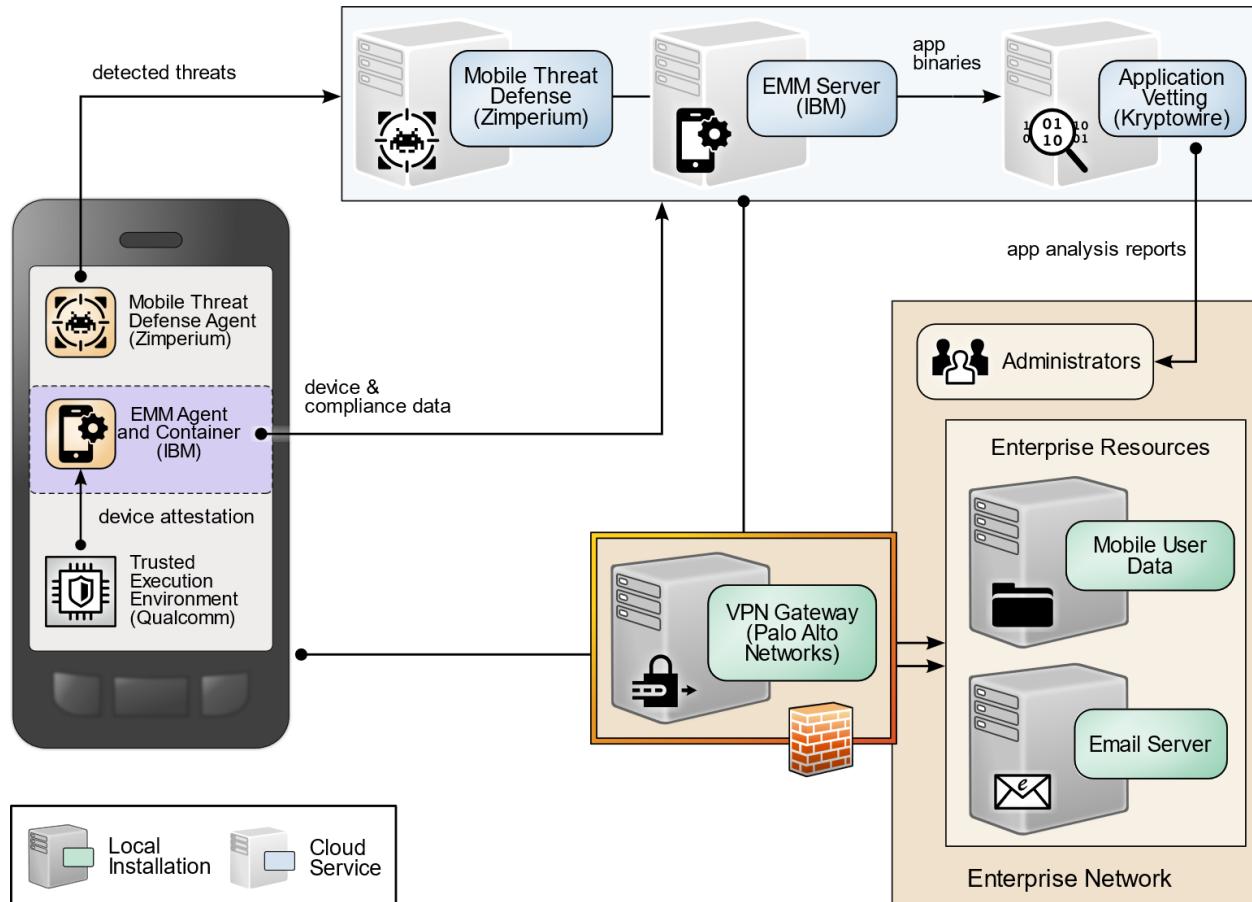
Typeface/Symbol	Meaning	Example
<i>Italics</i>	file names and path names; references to documents that are not hyperlinks; new terms; and placeholders	For language use and style guidance, see the <i>NCCoE Style Guide</i> .
<b>Bold</b>	names of menus, options, command buttons, and fields	Choose <b>File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

263 Acronyms used in figures can be found in the Acronyms appendix.

### 264 **1.4 Logical Architecture Summary**

265 The graphic below shows the components of the build architecture and how they interact on a high  
266 level.

267 Figure 1-1 High-Level Build Architecture

268 

## 2 Product Installation Guides

269 This section of the practice guide contains detailed instructions for installing and configuring all of the  
270 products used to build an instance of the example solution.

271 This guide assumes that a basic active directory (AD) infrastructure has been configured. The domain  
272 controller (DC) is used to authenticate users when enrolling devices as well as when connecting to the  
273 virtual private network (VPN). In this implementation, the domain *enterprise.mds.local* was used.

274 

### 2.1 Network Device Enrollment Services Server

275 A Network Device Enrollment Service (NDES)/Simple Certificate Enrollment Protocol (SCEP) server was  
276 used to issue client certificates to new devices that were enrolled by using MaaS360. This guide assumes  
277 that a basic AD infrastructure is in place.

278    **2.1.1 Certificate Authority (CA) Configuration**

279    The guide followed for the build is linked below, followed by the specific configuration changes used.

280    Configuration guide: <https://gallery.technet.microsoft.com/Windows-Server-2016-Active-165e88d1>

281    Configuration changes that were made:

- 282        ▪ The Root CA Name was changed to ROOT-CA.  
283        ▪ The Issuing CA Name was changed to SUB-CA.  
284        ▪ The entry for DC=srv,DC=lab was replaced with DC=enterprise,DC=mds,DC=local at various  
285        points throughout the guide.

286    **2.1.1.1 Export Certificates**

287    This section assumes that a location exists that is accessible by all machines on the network, such as a  
288    shared folder or network drive. Furthermore, this section assumes that configuration of the root and  
289    subordinate CA has been completed.

- 290        1. Log in to the root CA.
- 291        2. Open the start menu, and search for *cmd*.
- 292        3. Right-click **Command Prompt**, and select **Run as administrator**.
- 293        4. Navigate to the shared storage location.
- 294        5. Run the command `certutil -ca.cert root.cer`.
- 295        6. The file named *root.cer* will now contain a base64-encoded copy of the root CA certificate.
- 296        7. Repeat steps 1–6 with the sub CA, replacing *root.cer* with *sub.cer*.
- 297        8. (optional) Disconnect and shut down the root CA.

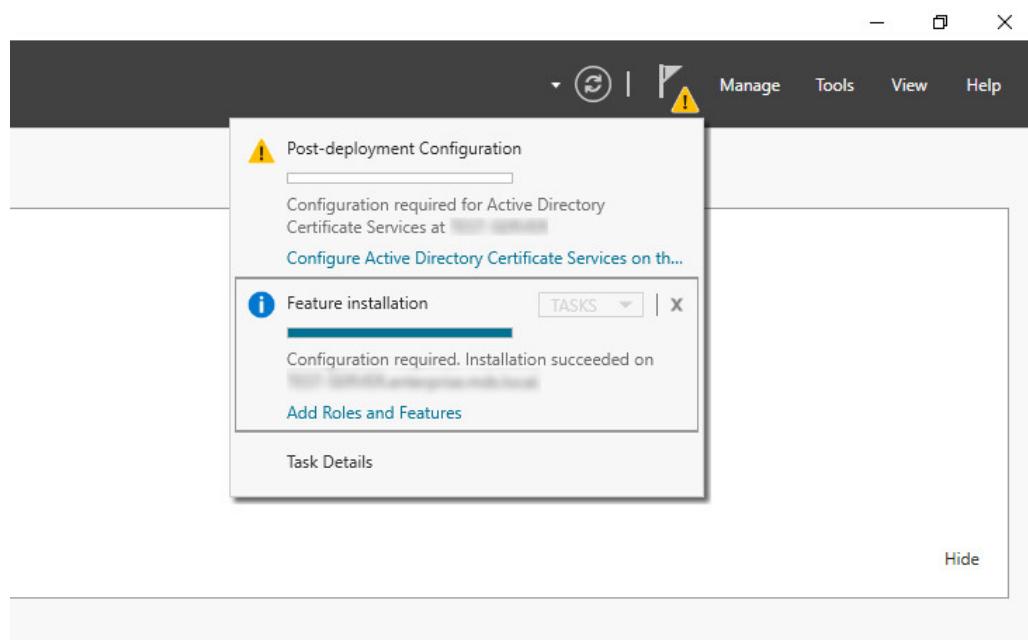
298    **2.1.2 NDES Configuration**

299    This section outlines configuration of an NDES that resides on its own server. Alternatively, the NDES can  
300    be installed on the SUB-CA. This section assumes a new domain-attached Windows Server is running.

- 301        1. From the Server Manager, select **Manage > Add Roles and Features**.
- 302        2. Click **Next** three times until **Server Roles** is highlighted.
- 303        3. Check the box next to **Active Directory Certificate Services**.
- 304        4. Click **Next** three times until **Role Services** is highlighted.

- 305        5. Uncheck **Certification Authority**. Check **Network Device Enrollment Service**.  
306        6. Click **Add Features** on the pop-up.  
307        7. Click **Next** three times.  
308        8. Click **Install**.  
309        9. When installation completes, click the flag in the upper right-hand corner, and click **Configure**  
310        **Active Directory Certificate Services**.

311 **Figure 2-1 Post-Deployment Configuration**

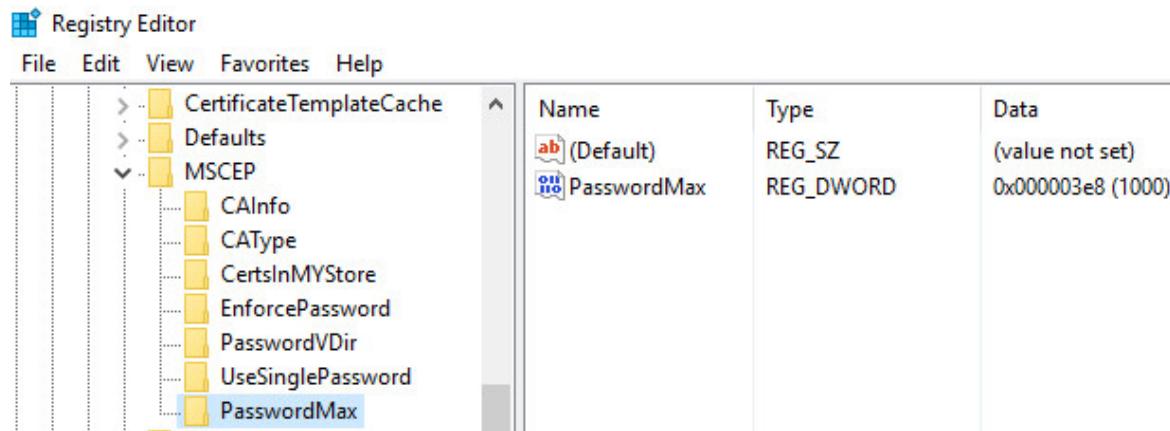


- 312        10. Specify the credentials of a Domain Administrator. Click **Next**.  
313        Note: The domain administrator credentials are required only to configure the NDES. Once the service is  
314        configured, the service is executed as the NDES service account, which does not require domain  
315        administrator permissions, created in step 12 below.  
316        11. Check **Network Device Enrollment Service**. Click **Next**.  
317        12. Configure an NDES service account by performing the following actions:  
318            a. On the active directory server, open **Active Directory Users and Computers**.  
319            b. Click **Users** and create a new user for the service. For this example, it will be named  
320            NDES. Be sure the password never expires.

- 321           c. On the NDES server, open **Edit local users and groups**.
- 322           d. Click **Groups**. Right-click **IIS\_IUSRS**, click **Add to Group**, and click **Add**.
- 323           e. Search for the service account name—in this case, NDES. Click **Check Names**, and click **OK** if no errors were displayed.
- 324           f. Click **Apply**, and click **OK**.
- 325           g. Close all windows except the NDES configuration window.
- 326           13. Click **Select** next to the box, and enter the service account credentials. Click **Next**.
- 328           14. Because the NDES runs on its own server, we will target it at the SUB-CA. Select **Computer name** and click **Select**. Type in the computer name—in this case, SUB-CA. Click **Check Names**, and if no errors occurred, click **OK**.
- 330           15. Click **Next** three times.
- 332           16. Click **Configure**.
- 333           17. On the SUB-CA, open the Certification Authority application.
- 334           18. Expand the SUB-CA node, right-click on **Certificate Templates**, and click **Manage**.
- 335           19. Right-click on **IPSec (Offline Request)**, and click **Duplicate Template**.
- 336           20. Under the **General** tab, set the template display name to **NDES**.
- 337           21. Under the **Security** tab, click **Add**.
- 338           22. Select the previously configured NDES service account.
- 339           23. Click **OK**. Ensure the NDES service account is highlighted, and check **Read** and **Enroll**.
- 340           24. Click **Apply**.
- 341           25. In the Certification Authority program, right-click on **Certificate Templates**, and select **New > Certificate Template to Issue**.
- 343           26. Select the NDES template created in step 24.
- 344           27. Click **OK**.
- 345           28. On the NDES server, open the Registry Editor (`regedit`).
- 346           29. Expand the following key: `HKLM\SOFTWARE\Microsoft\Cryptography`.
- 347           30. Select the **MSCEP** key and update all entries besides (Default) to be **NDES**.

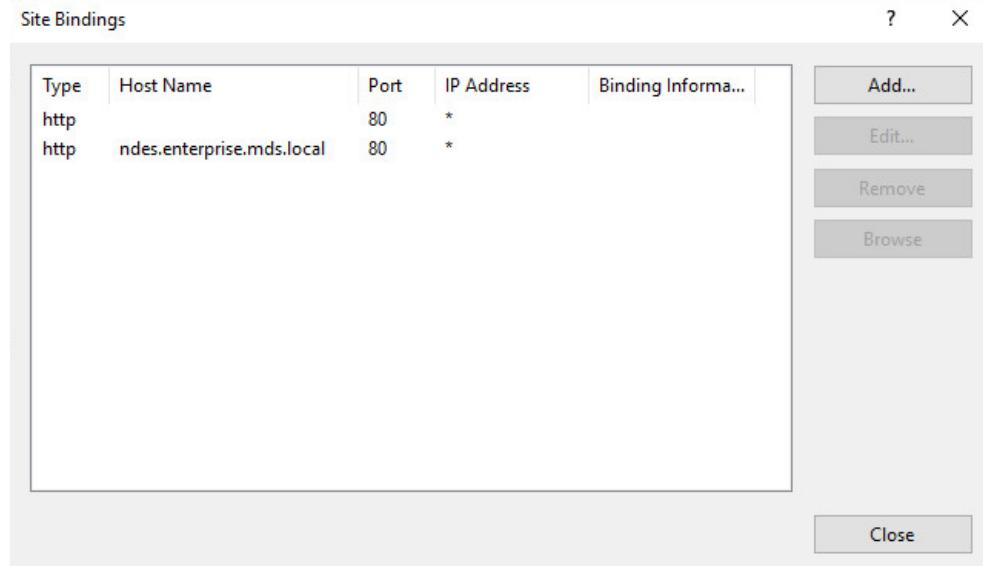
- 348        31. Expand the following key: HKLM\SOFTWARE\Microsoft\Cryptography\MSCEP .
- 349        32. Right-click on **MSCEP**, and select **New > Key**. Name it **PasswordMax**.
- 350        33. Right-click on the newly created key and select **New > DWORD (32-bit) Value**.
- 351        34. Name it **PasswordMax**, and give it a value of **0x00003e8**. This increases the NDES password cache to 1,000 entries instead of the default 5. This value can be further adjusted based on NDES demands.

354 **Figure 2-2 PasswordMax Registry Configuration**



355 **Note:** The **PasswordMax** key governs the maximum number of NDES passwords that can reside in the cache. A password is cached when a valid certificate request is received, and it is removed from the cache when the password is used or when 60 minutes have elapsed, whichever occurs first. If the **PasswordMax** key is not present, the default value of 5 is used.

- 359        1. In an elevated command prompt, execute `%windir%\system32\inetsrv\appcmd set config /section:requestFiltering /requestLimits.maxQueryString:8192` to increase the maximum query string. This prevents requests longer than 2,048 bytes from being dropped.
- 360        2. Open the **Internet Information Services (IIS) Manager**.
- 361        3. On the left, expand **NDES > Sites**, and select **Default Web Site**.
- 362        4. On the right, click **Bindings...**
- 363        5. Click **Add**.
- 364        6. Below **Host Name**, enter the host name of the server. For this implementation, *ndes.enterprise.mds.local* was used.
- 365        7. Click **OK**.

369 **Figure 2-3 NDES Domain Bindings**

370

371 8. Click **Close**, and close the IIS Manager.

372 9. In an elevated command prompt, execute `iisreset`, or reboot the NDES server.

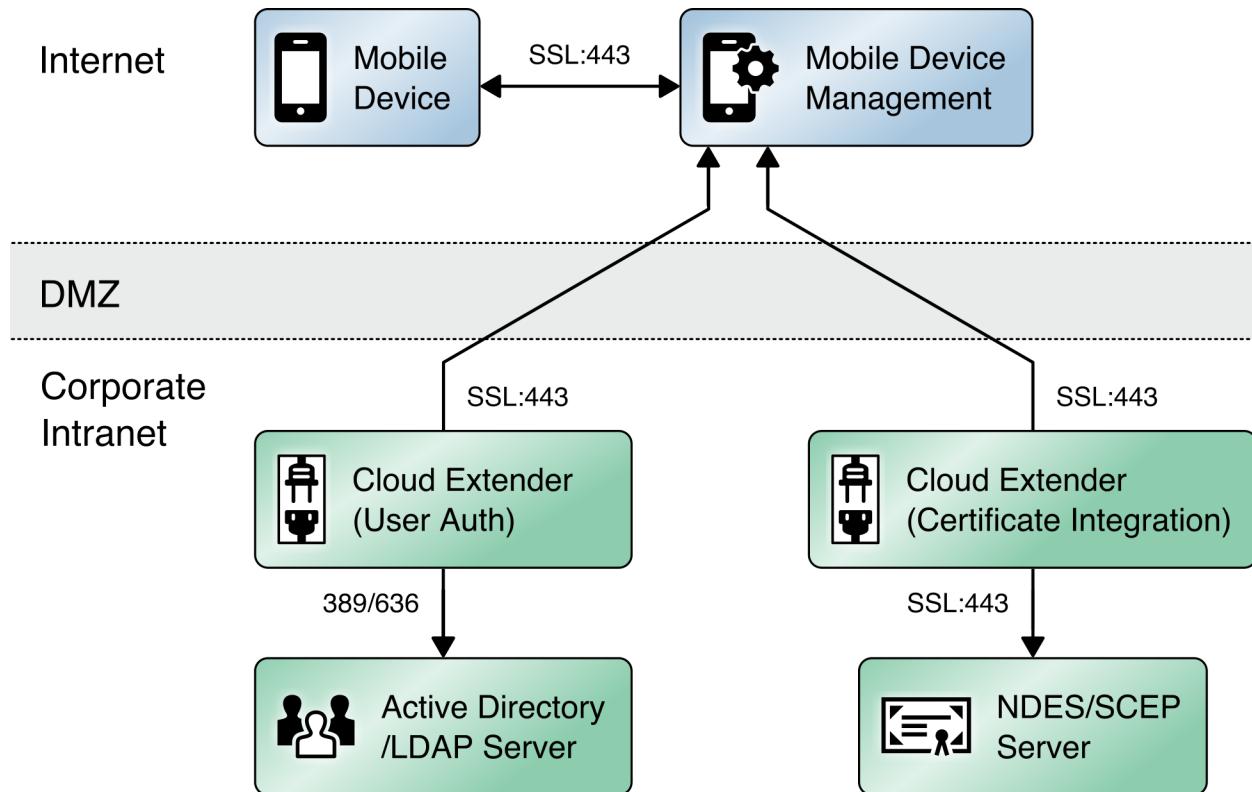
## 373 **2.2 International Business Machines MaaS360**

374 International Business Machines (IBM) contributed an instance of MaaS360 (<https://www.ibm.com/us-en/marketplace/unified-endpoint-management>) to deploy as the mobile device management (MDM) solution.

### 377 **2.2.1 Cloud Extender**

378 The IBM MaaS360 Cloud Extender is installed within the AD domain to provide AD and lightweight  
379 directory access protocol (LDAP) authentication methods for the MaaS360 web portal, as well as  
380 corporate VPN capabilities. The cloud extender architecture [1], as shown in Figure 2-4, gives a visual  
381 overview of how information flows between the web portal and the MaaS360 Cloud Extender.

382 Figure 2-4 Cloud Extender Architecture

383 *2.2.1.1 Cloud Extender Download*

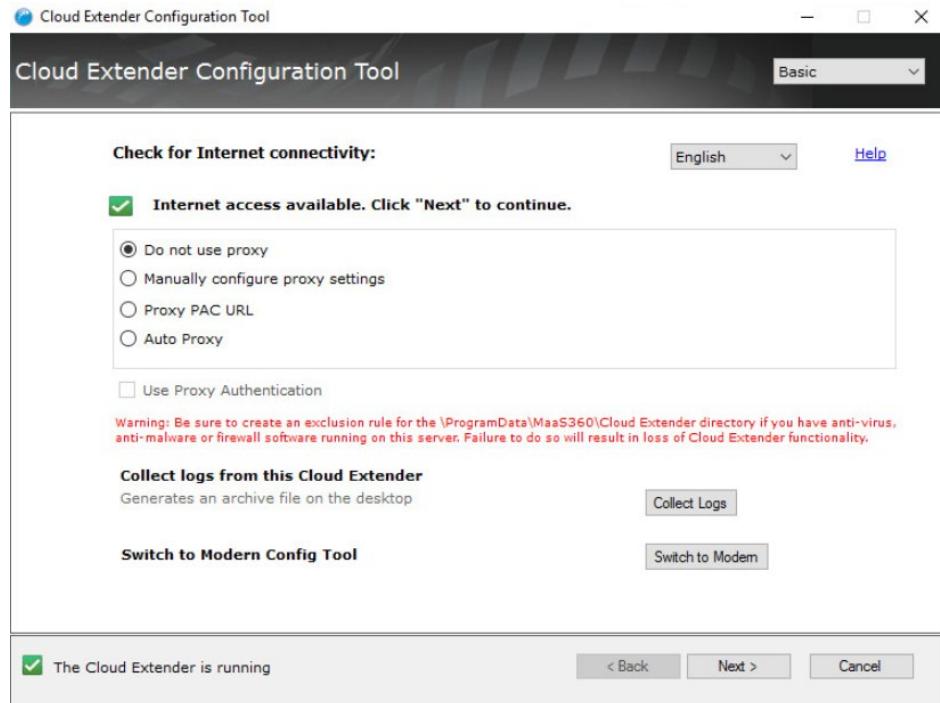
- 384 1. Log in to the MaaS360 web portal.
- 385 2. Click **Setup > Cloud Extender**.
- 386 3. Click the link that says **Click here to get your License Key**. The license key will be emailed to the currently logged-in user's email address.
- 388 4. Click the link that says **Click here to download the Cloud Extender**. Save the binary.
- 389 5. Move the binary to a machine behind the corporate firewall that is always online. Recommendation: Install it while logged in as a domain user on a machine that is not the domain controller.
- 391 6. Install **.NET 3.5 Features** in the **Server Manager** on the machine where the MaaS360 Cloud Extender will run.

393 *2.2.1.2 Cloud Extender Active Directory Configuration*

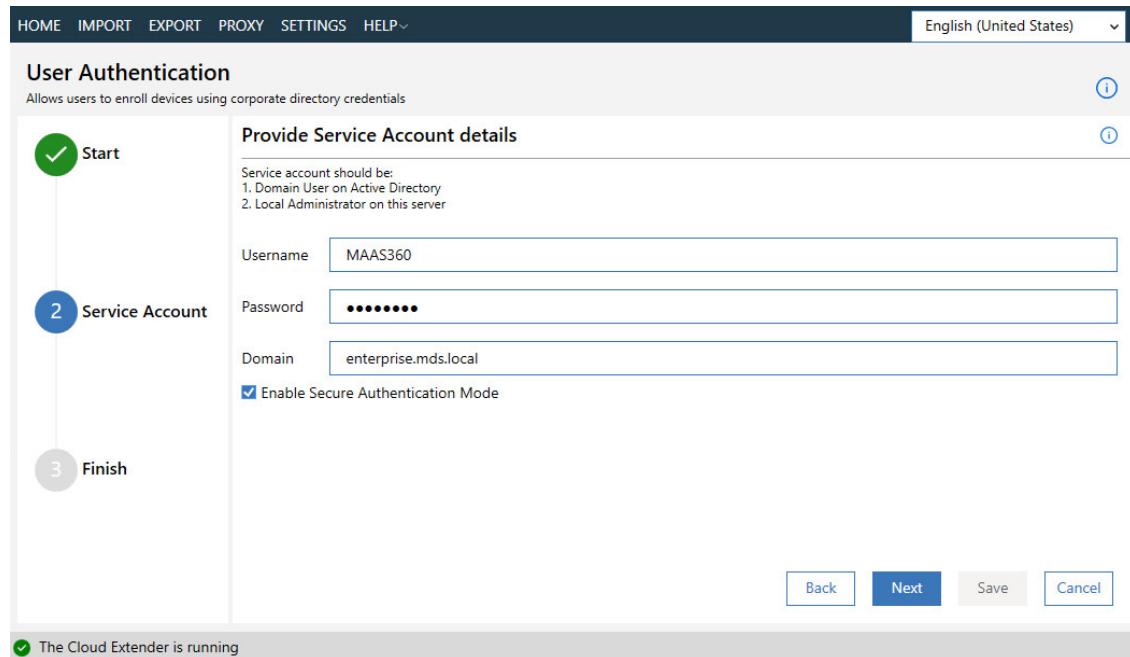
- 394 1. On the target machine, run the installation binary.

- 395        2. Enter the license key when prompted.
- 396        3. Proceed through the setup until the Cloud Extender Configuration Utility opens.
- 397        4. If using the old cloud extender interface, click **Switch to Modern**.

398 **Figure 2-5 Old Cloud Extender Interface**



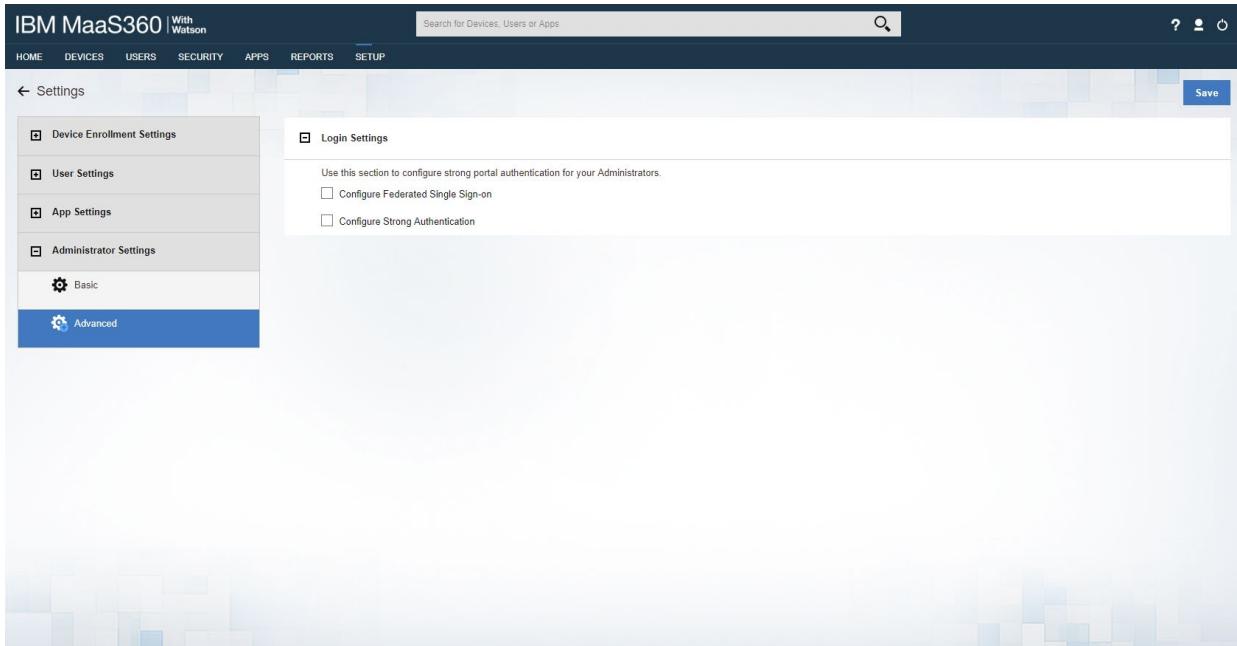
- 399        5. Enable the toggle below User Authentication.
- 400        6. Create a new authentication profile by entering the username, password, and domain of the  
401           created service account.

402 **Figure 2-6 Cloud Extender Service Account Details**

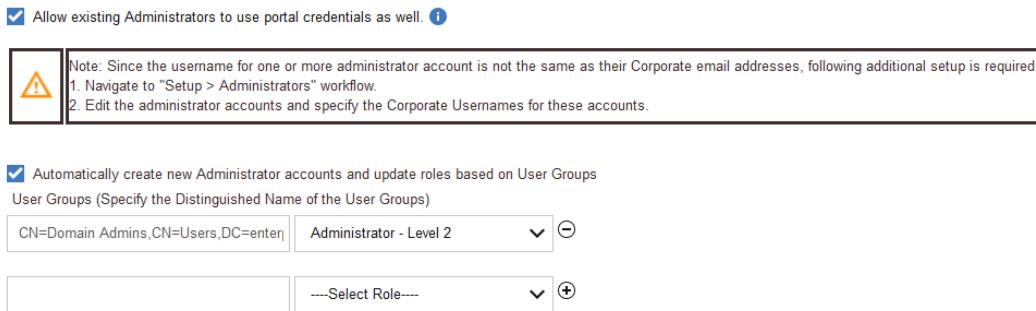
- 403 7. Click **Next**.
- 404 8. (optional) Use the next page to test the active directory integration.
- 405 9. Click **Save**.
- 406 10. In MaaS360, navigate to **Setup > Cloud Extender**. Ensure that configuration information is displayed, indicating that the MaaS360 Cloud Extender is running.

#### 408 *2.2.1.3 MaaS360 Portal Active Directory Authentication Configuration*

- 409 1. Log in to the MaaS360 web portal as an administrator.
- 410 2. Go to **Setup > Settings**.
- 411 3. Expand **Administrator Settings**, and click **Advanced**.

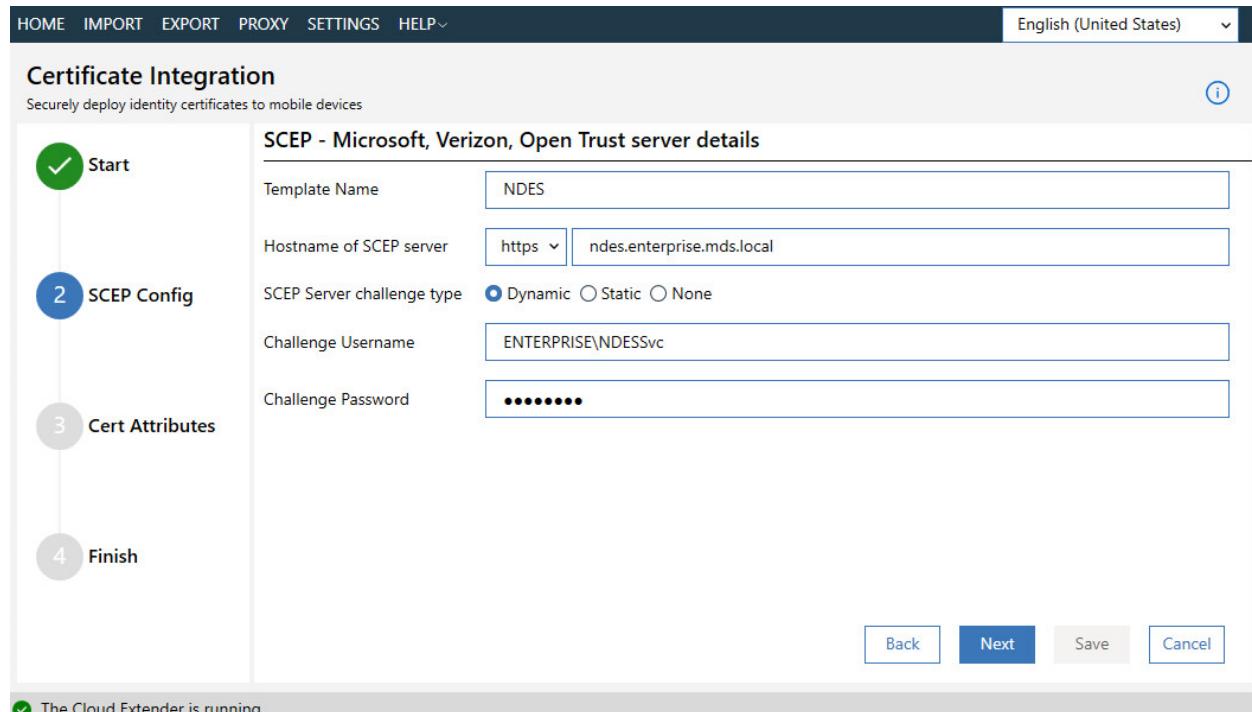
412 **Figure 2-7 Administrator Settings**

- 413 4. Select **Configure Federated Single Sign-on**.
- 414 5. Select **Authenticate against Corporate User Directory**.
- 415 6. Next to **Default Domain**, enter the active directory domain. In this implementation, *enterprise.mds.local* was used.
- 416
- 417 7. Check the box next to **Allow existing Administrators to use portal credentials as well**.
- 418 8. Check the box next to **Automatically create new Administrator accounts and update roles based on user groups**.
- 419
- 420 9. Under **User Groups**, enter the distinguished name of the group(s) that should be allowed to log in. In this implementation, CN=Domain Admins, CN=Users, DC=enterprise, DC=mds, DC=local was used.
- 421
- 422
- 423 10. Next to the box, select **Administrator–Level 2**. This allows domain admins to log in as MaaS360 administrators.
- 424

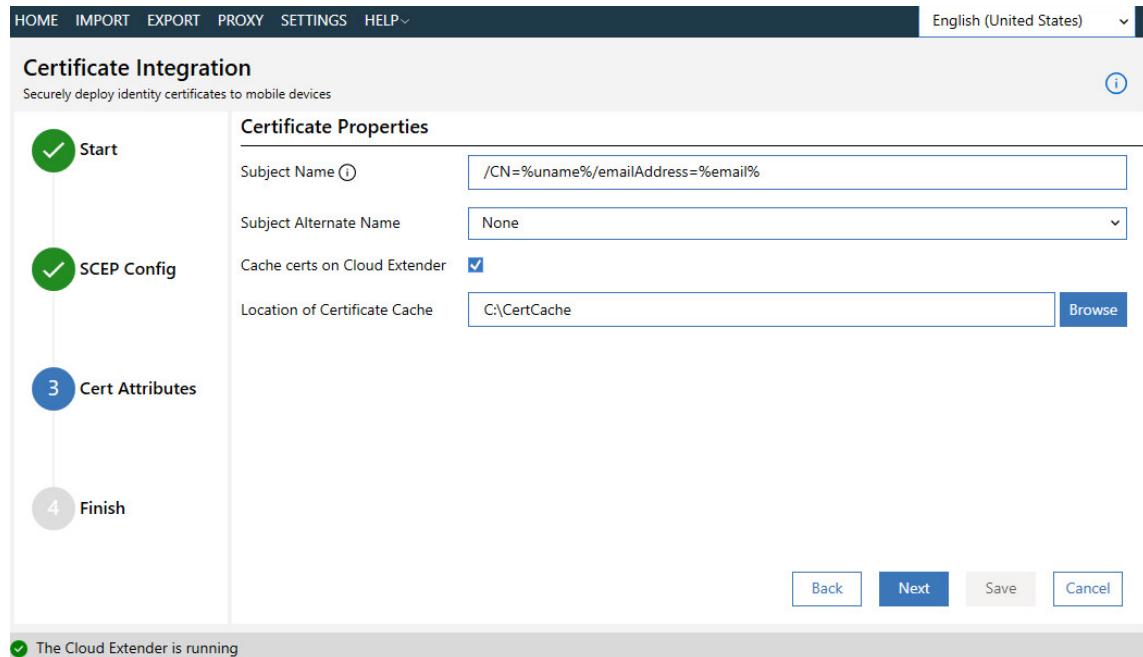
425 **Figure 2-8 Administrator Configuration Options**426 11. Click **Save**.427 **2.2.1.4 Cloud Extender NDES Integration**428 To properly generate device certificates, MaaS360 must be integrated with the on-premises public key  
429 infrastructure (PKI).

- 430 1. Log in to the server running the MaaS360 Cloud Extender.
- 431 2. Launch the Cloud Extender Configuration Tool.
- 432 3. Toggle the button below Certificate Integration.
- 433 4. Click **Add New Template**.
- 434 5. Ensure **Microsoft CA** and **Device Identity Certificates** are selected.
- 435 6. Click **Next**.
- 436 7. Enter **NDES** for the Template Name and SCEP Default Template.
- 437 8. Enter the uniform resource locator (URL) of the NDES server next to **SCEP Server**.
- 438 9. Enter credentials of a user with enroll permissions on the template for **Challenge Username** and  
**Challenge Password**. For this demo implementation, we use the NDES service account.

440 Figure 2-9 Cloud Extender SCEP Configuration

441 10. Click **Next**.442 11. (optional) Check the box next to **Cache certs on Cloud Extender** and specify a cache path on the  
443 machine.

444 Figure 2-10 Cloud Extender Certificate Properties

445 12. Click **Next**.446 13. (optional) Enter values for uname and email and generate a test certificate to test the configura-  
447 tion.448 14. Click **Save**.

449 Note: If a file access message appears, delete the file, and re-save the file.

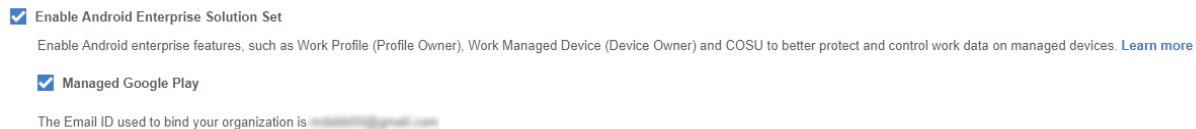
## 450 2.2.2 Android Enterprise Configuration

451 A Google account was used to provision Android Enterprise on the mobile devices. A managed domain  
452 can be used, but in this use case it was not necessary. A managed domain is necessary only if the  
453 corporation already has data stored in Google's cloud.

- 454 1. Create a Google account if you do not have one you wish to bind with.
- 455 2. From the MaaS360 portal, navigate to **Setup > Services**.
- 456 3. Click **Mobile Device Management**.
- 457 4. Check the box next to **Enable Android Enterprise Solution Set**.
- 458 5. Enter your password, and click **Enable**.

- 459        6. Click **Mobile Device Management**.
- 460        7. Click the radio button next to **Enable via Managed Google Play Accounts (no G Suite)**.
- 461        8. Ensure all pop-up blockers are disabled. Click the link on the word **here**.
- 462        9. Enter your password, and click **Enable**.
- 463        10. In the new page that opens, ensure you are signed into the Google account you wish to bind.
- 464        11. Click **Get started**.
- 465        12. Enter your business name, and click **Next**.
- 466        13. If General Data Protection Regulation compliance is not required, scroll to the bottom, check the **I agree** box, and click **Confirm**. If compliance is required, fill out the requested information first.
- 468        14. Click **Complete Registration**.
- 469        15. Confirm binding on the **Setup** page under **Mobile Device Management**. The settings should look like Figure 2-11, where the blurred-out portion is the Google email address used to bind.

471 **Figure 2-11 Enterprise Binding Settings Confirmation**



472 **2.2.3 iOS APNs Certificate Configuration**

473 For the iOS Apple Push Notification services (APNs) certificate configuration, the build team followed the  
474 [IBM documentation](#).

475 **2.2.4 Android Configuration**

476 **2.2.4.1 Policy Configuration**

- 477        1. Navigate to **Security > Policies**.
- 478        2. Click the appropriate deployed Android policy.
- 479        3. Click **Edit**.
- 480        4. Navigate to **Android Enterprise Settings > Passcode**.
- 481        5. Check the box next to Configure Passcode Policy.

- 482        6. Configure the passcode settings based on corporate requirements.
- 483        7. Navigate to **Android Enterprise Settings > Restrictions**.
- 484        8. Check the box next to Configure Restrictions.
- 485        9. Configure restrictions based on corporate requirements.
- 486        10. Click **Save**.

#### *2.2.4.2 VPN Configuration*

- 488        1. Navigate to **Security > Policies**.
- 489        2. Click the currently deployed Android device policy.
- 490        3. Click **Edit**.
- 491        4. Navigate to **Android Enterprise Settings > Certificates**.
- 492        5. Check the box next to **Configure CA Certificates**.
- 493        6. Click **Add New**.
- 494        7. Give the certificate a name, such as Internal Root.
- 495        8. Click **Browse**, and navigate to the exported root CA certificate from earlier in the document.
- 496        9. Click **Save**.
- 497        10. Select **Internal Root** from the drop-down next to **CA Certificate**.
- 498        11. Click the + icon on the far right.
- 499        12. Repeat steps 6–10 with the internal sub CA certificate.
- 500        13. Check the box next to **Configure Identity Certificates**.
- 501        14. From the drop-down next to **Identity Certificate**, select the profile that matches the name con-
- 502        figured on the MaaS360 Cloud Extender—for this example, **NDES**.
- 503        15. Click **Save and Publish**, and follow the prompts to publish the updated policy. Click **Apps**.
- 504        16. Click **Add > Android > Google Play App**.
- 505        17. Select the radio button next to **Add via Public Google Play Store**.
- 506        18. Search for **GlobalProtect**.
- 507        19. Select the matching result.

- 508        20. Click **I Agree** when prompted to accept the permissions.
- 509        21. Check the three boxes next to **Remove App on**.
- 510        22. Check the box next to **Instant Install**.
- 511        23. Select **All Devices** next to **Distribute to**.
- 512        24. Click **Add**.
- 513        25. Next to the newly added GlobalProtect application, select **More > Edit App Configurations**.
- 514        26. Click **Check for Settings**.
- 515        27. Next to **Portal**, enter the GlobalProtect portal address. In this implementation,  
516              *vpn.ent.mdse.nccoe.org* was used.
- 517        28. Next to **Username**, enter **%username%**.
- 518        29. Next to **Connection Method**, enter **user-logon**. (Note: This will enable an always-on VPN con-  
519              nection for the work profile. The user will always see the VPN key icon, but it will apply only to  
520              applications contained within the work container.)
- 521        30. Click **Save**, and follow the prompts to update the application configuration.
- 522        31. Navigate to **Security > Policies**.
- 523        32. Click the used Android policy.
- 524        33. Select **Android Enterprise Settings > App Compliance**.
- 525        34. Click **Edit**.
- 526        35. Click the + on the row below **Configure Required Apps**.
- 527        36. Enter the App Name, **GlobalProtect**.
- 528        37. Enter the App ID, **com.paloaltonetworks.globalprotect**.
- 529        38. Click **Save And Publish**, and follow the prompts to publish the policy.

530 Figure 2-12 Android GlobalProtect Application Compliance

The screenshot shows the IBM MaaS360 interface with the 'SECURITY' tab selected. A policy titled 'Default Android MDM Policy' is displayed, last published on 01/30/2020 at 14:23 EST [Version:59] with a current status of 'Needs Publish'. The left sidebar includes sections for Device Settings, Advanced Settings, and Android Enterprise Settings, with sub-options like Passcode, Security, Restrictions, and Accounts. The main content area is titled 'Configure Application Compliance' and contains two sections: 'Configure allowed system applications' (checkbox 'Allowed apps will be available for use on device and in work profile if available for the device' is checked, with a note 'No' and 'Android 5.0+ (PO & DO)') and 'Configure Required Apps' (checkbox 'Apps that cannot be uninstalled by user.' is checked, with a note 'Yes' and 'Android 5.0+ (PO & DO)'). Below these is a section for 'Application Name' with the value 'com.paloaltonetworks.globalprotect'.

531 

## 2.2.5 iOS Configuration

532 

### 2.2.5.1 Policy Configuration

- 533 1. Navigate to **Security > Policies**.
- 534 2. Click the deployed iOS policy.
- 535 3. Click **Edit**.
- 536 4. Check the box next to **Configure Passcode Policy**.
- 537 5. Check the box next to **Enforce Passcode on Mobile Device**.
- 538 6. Configure the rest of the displayed options based on corporate requirements.
- 539 7. Click **Restrictions**.
- 540 8. Check the box next to **Configure Device Restrictions**.
- 541 9. Configure restrictions based on corporate requirements.
- 542 10. Click **Save**.

543 

### 2.2.5.2 VPN Configuration

- 544 1. Click **Device Settings > VPN**.

- 545        2. Click **Edit**.
- 546        3. Next to **Configure for Type**, select **Custom SSL**.
- 547        4. Enter a name next to **VPN Connection Name**. In this sample implementation, **Great Seneca VPN** was used.
- 549        5. Next to **Identifier**, enter **com.paloaltonetworks.globalprotectvpn**.
- 550        6. Next to **Host name of the VPN Server**, enter the URL of the VPN endpoint without http or https.
- 551        7. Next to **VPN User Account**, enter **%username%**.
- 552        8. Next to **User Authentication Type**, select **Certificate**.
- 553        9. Next to **Identity Certificate**, select the name of the certificate profile created during the NDES configuration steps. In this sample implementation, **NDES** was used.
- 555        10. Next to **Custom Data 1**, enter **allowPortalProfile=0**
- 556        11. Next to **Custom Data 2**, enter **fromAspen=1**
- 557        12. Next to **Apps to use this VPN**, enter the application identifications (IDs) of applications to go through the VPN. This will be the applications deployed to the devices as work applications.
- 559        13. Next to **Provider Type**, select **Packet Tunnel**.
- 560        14. Click **Apps**.
- 561        15. Click **Add > iOS > iTunes App Store App**.
- 562        16. Search for **GlobalProtect**.
- 563        17. Select the **non-Legacy** version.
- 564        18. Click **Policies and Distribution**.
- 565        19. Check all three boxes next to **Remove App on**.
- 566        20. Select **All Devices** next to **Distribute to**.
- 567        21. Check the box next to **Instant Install**.
- 568        22. Click **Add**.
- 569        23. Navigate to **Security > Policies**.
- 570        24. Click the used iOS policy.
- 571        25. Click **Application Compliance**.

- 572        26. Click **Edit**.
- 573        27. Click the + next to the first row under **Configure Required Applications**.
- 574        28. Search for **GlobalProtect**.
- 575        29. Select the **non-Legacy** result.
- 576        30. Navigate to **Advanced Settings > Certificate Credentials**.
- 577        31. Check the box next to **Configure Credentials for Adding Certificates on the Device**.
- 578        32. Click **Add New**.
- 579        33. Give the certificate a name, such as Internal Root.
- 580        34. Click **Browse**, and navigate to the exported root CA certificate from earlier in the document.
- 581        35. Click **Save**.
- 582        36. Select **Internal Root** from the drop-down next to **CA Certificate**.
- 583        37. Click the + icon on the far right.
- 584        38. Repeat steps 33–35 with the internal sub CA certificate.
- 585        39. From the drop-down next to **Identity Certificate**, select the profile that matches the name con-  
586        figured on the MaaS360 Cloud Extender—for this example, **NDES**.
- 587        40. Click **Save And Publish**, and follow the prompts to publish the policy.

## 588      2.3 Zimperium

- 589      Zimperium was used as a mobile threat defense service via a MaaS360 integration.
- 590      Note: For Zimperium automatic enrollment to function properly, users **must** have an email address  
591      associated with their MaaS360 user account.

### 592      2.3.1 Zimperium and MaaS360 Integration

- 593      This section assumes that IBM has provisioned an application programming interface (API) key for  
594      Zimperium within MaaS360.
- 595      1. Log in to the zConsole.
- 596      2. Navigate to **Manage > MDM**.
- 597      3. Select **Add MDM > MaaS360**.

- 598        4. Fill out the MDM URL, MDM username, MDM password, and API key.
- 599        5. Note: For the MDM URL, append the account ID to the end. For example, if the account ID is  
600                  12345, the MDM URL would be https://services.fiberlink.com/12345.
- 601        6. Check the box next to **Sync users**.

602 **Figure 2-13 Zimperium MaaS360 Integration Configuration**

**Edit MDM**

**Step 1**  
Choose MDM Provider    **Step 2**  
Setup IBM MaaS360    **Step 3**  
Finish

**URL**  
Specify URL for this MDM provider.

**Username**  
Specify username for this MDM provider.

**Password**  
Specify password for this MDM provider.

**MDM Name**  
Specify a unique name for this MDM provider.

**Sync users**  
Specify if this MDM provider should synchronise users.

**Set synced users password**  
If you do not specify a password, a default value will be used

**Synced users password**  
Specify the password for users synched from the MDM

**Mask Imported User Information**  
By enabling this option, personally identifiable information will be masked (first name, last name and email) from the zConsole

**API key**  
Specify API KEY for this MDM provider.

**Send Device Activation email via zConsole for iOS Devices**  
By enabling this option, zConsole will send an activation email to a user for each iOS device which is  
synced from the MDM

**Send Device Activation email via zConsole for Android Devices**  
By enabling this option, zConsole will send an activation email to a user for each Android device  
which is synced from the MDM

**Next**

- 603        7. Click **Next**.
- 604        8. Select the MaaS360 groups to synchronize with Zimperium. In this case, **All Devices** was se-  
605                  lected.
- 606        9. Click **Finish**. Click **Sync Now** to synchronize all current MaaS360 users and devices.

607    **2.3.2 Automatic Device Activation**

608    Note: This requires contacting Zimperium support to get required application configuration values.

609    1. Log in to MaaS360.

610    2. Click **Apps** on the navigation bar.

611    3. Click **Add > iOS > iTunes App Store App**.

612    4. Search for **Zimperium zIPS**. Click the result that matches the name.

613    5. Click **Policies and Distribution**.

614    6. Check the three checkboxes next to **Remove App on**.

615    7. Next to **Distribute to**, select **All Devices**.

616    8. Click **Configuration**.

617    9. Set App Config Source to **Key/Value**.

618    10. The configuration requires three parameters: uuid, defaultchannel, and tenantid. uuid can be  
619       set to **%csn%**, but defaultchannel and tenantid must come from Zimperium support.

620    **Figure 2-14 Zimperium zIPS iOS Configuration**

MDMDeviceID	%csn%	(+)	(-)
defaultchannel		(+)	(-)
tenantid		(+)	(-)

621    11. Click **Add**.

622    12. Click **Add > Android > Google Play App**.

623    13. Select the radio button next to **Add via Public Google Play Store**.

624    14. Search for **Zimperium Mobile IPS (zIPS)**.

625    15. Click the matching result.

626    16. Click **I Agree** when prompted to accept permissions.

- 627        17. Click **Policies and Distribution**.
- 628        18. Check all three boxes next to **Remove App on**.
- 629        19. Check **Instant Install**.
- 630        20. Select **All Devices** next to **Distribute to**.
- 631        21. Click **App Configurations**.
- 632        22. Check **Configure App Settings**.
- 633        23. Enter the values provided by Zimperium next to **Default Acceptor** and **Tenant**.
- 634        24. Next to **MDM Device ID**, insert **%deviceid%**.
- 635        25. Adjust any other configuration parameters as appropriate for your deployment scenario.

636        **Figure 2-15 Zimperium zIPS Android Configuration**

Default Acceptor:	<input type="text"/>
Tenant:	<input type="text"/>
UUID:	<input type="text"/>
Display EULA:	<input type="text"/> No ▾
Tracking ID 1:	<input type="text"/>
Tracking ID 2:	<input type="text"/>
MDM Device ID:	<input type="text"/> %deviceid%

- 637        26. Click **Add**.

### 638        2.3.3 Enforce Application Compliance

639        From the IBM MaaS360 web portal:

- 640        1. Navigate to **Security > Policies**.
- 641        2. Select the default Android policy.

- 642        3. Navigate to **Android Enterprise Settings > App Compliance**.
- 643        4. Click **Edit**.
- 644        5. Check the box next to **Configure Required Apps** if not checked already. If it is, click the + icon.
- 645        6. Enter **com.zimperium.zips** as the App ID.
- 646        7. Click **Save And Publish**. This will prevent the user from uninstalling zIPS once it is installed.
- 647        8. Navigate to **Security > Policies**.
- 648        9. Select the default iOS policy.
- 649        10. Click **Application Compliance**.
- 650        11. Click **Edit**.
- 651        12. Check the box next to **Configure Required Applications** if not checked already. If it is, click the + icon.
- 652        13. Enter **Zimperium zIPS** for the Application Name.
- 653        14. Click **Save And Publish**, and follow the prompts to publish the policy.

#### 655      2.3.4 MaaS360 Risk Posture Alerts

- 656        1. From the MaaS360 home screen, click the + button that says **Add Alert**.

657      **Figure 2-16 Add Alert Button**



- 658        2. Next to **Available for**, select **All Administrators**.
- 659        3. For Name, enter **Zimperium Risk Posture Elevated**.
- 660        4. Under **Condition 1**, select **Custom Attributes** for Category.
- 661        5. Select **zimperium\_risk\_posture** for Attribute.
- 662        6. Select **Equal To** for Criteria.
- 663        7. For Value, select **Elevated** for the count of risk posture elevated devices or **Critical** for risk posture critical devices.

665 **Figure 2-17 Zimperium Risk Posture Alert Configuration**

666 8. Click **Update**.

## 2.4 Palo Alto Networks Virtual Firewall

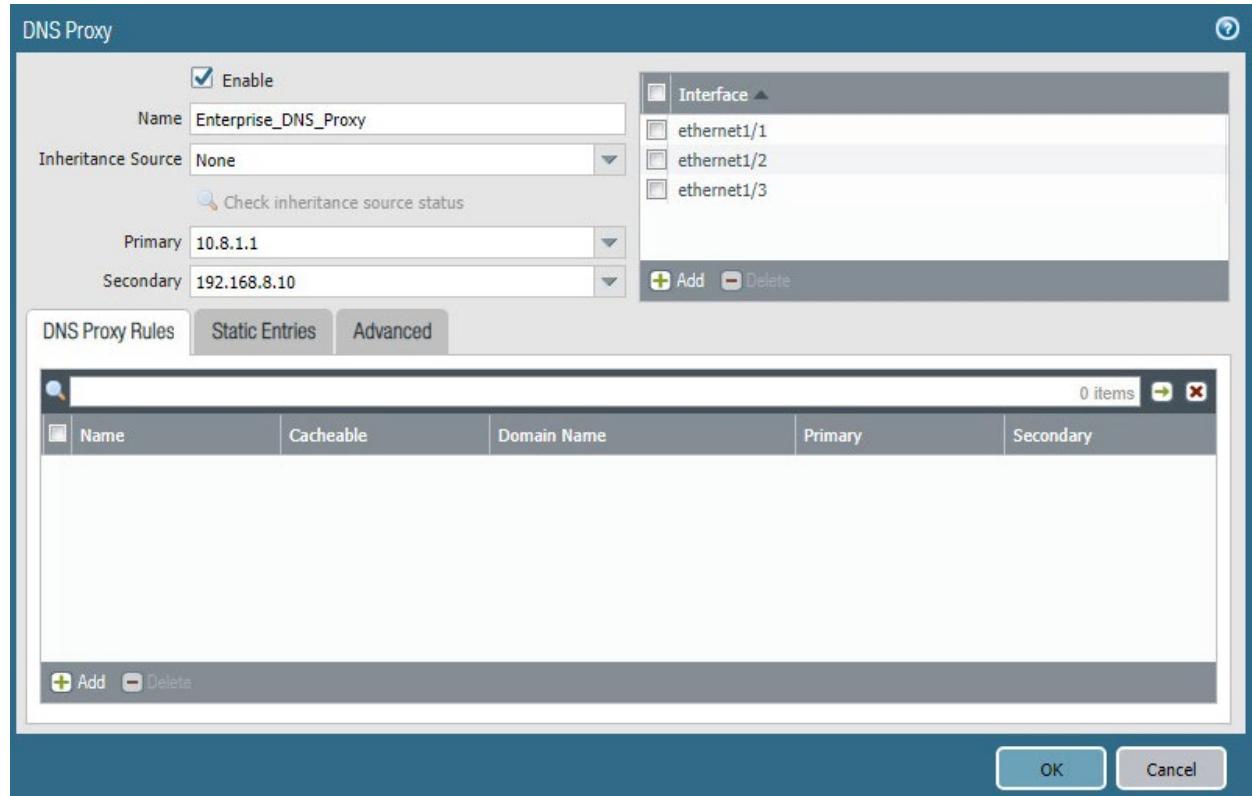
668 Palo Alto Networks contributed an instance of its VM-100 series firewall for use on the project.

### 2.4.1 Network Configuration

- 670 1. Ensure that all Ethernet cables are connected or assigned to the virtual machine and that the management web user interface is accessible. Setup will require four Ethernet connections: one for management, one for wide area network (WAN), one for local area network, and one for the demilitarized zone (DMZ).
- 674 2. Reboot the machine if cables were attached while running.
- 675 3. Navigate to **Network > Interfaces > Ethernet**.
- 676 4. Click **ethernet1/1**, and set the Interface Type to be **Layer3**.
- 677 5. Click **IPv4**, ensure that **Static** is selected under Type, and click **Add** to add a new static address.
- 678 6. If the appropriate address does not exist yet, click **New Address** at the bottom of the prompt.
- 679 7. Once the appropriate interfaces are configured, commit the changes. The Link State icon should turn green for the configured interfaces. The commit dialogue will warn about unconfigured zones. That is an expected dialogue warning.

- 682        8. Navigate to **Network > Zones**.
- 683        9. Click **Add**. Give the zone an appropriate name, set the Type to **Layer3**, and assign it an interface.
- 684        10. Commit the changes.
- 685        11. Navigate to **Network > Virtual Routers**.
- 686        12. Click **Add**.
- 687        13. Give the router an appropriate name, and add the internal and external interfaces.
- 688        14. Click **Static Routes > Add**. Give the static route an appropriate name, e.g., WAN. Set the destination to be **0.0.0.0/0**, set the interface to be the WAN interface, and set the next hop internet protocol (IP) address to be the upstream gateway's IP address.
- 691        15. (optional) Delete the default router by clicking the checkbox next to it and clicking **Delete** at the bottom of the page.
- 693        16. Commit the changes. The commit window should not display any more warnings.
- 694        17. Navigate to **Network > DNS Proxy**.
- 695        18. Click **Add**.
- 696        19. Give the proxy an appropriate name. Under **Primary**, enter the primary domain name system (DNS) IP address.
- 698        20. (optional) Enter the secondary DNS IP address.
- 699        21. Add the interfaces under **Interface**. Click **OK**.

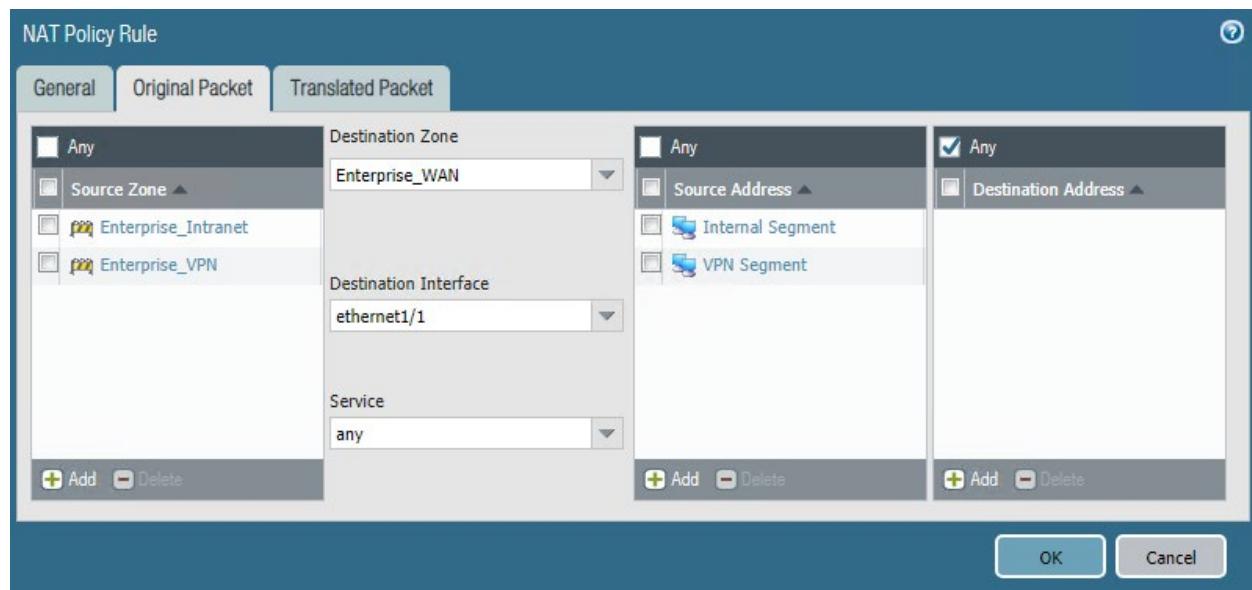
700 Figure 2-18 DNS Proxy Object Configuration



- 701 22. Navigate to **Device > Services**.
- 702 23. Click the **gear** in the top-right corner of the Services panel.
- 703 24. Under **DNS settings**, click the radio button next to **DNS Proxy Object**. Select the created DNS proxy object from the drop-down.
- 704
- 705 25. Click **OK** and commit the changes. This is where static DNS entries will be added in the future.
- 706 26. Navigate to **Objects > Addresses**.
- 707 27. For each device on the network, click **Add**. Give the device an appropriate name, enter an optional description, and enter the IP address.
- 708
- 709 28. Click **OK**.
- 710 29. Once all devices are added, commit the changes.
- 711 30. Navigate to **Policies > NAT**.
- 712 31. Click **Add**.

- 713        32. Give the network address translation rule a meaningful name, such as External Internet Access.
- 714        33. Click **Original Packet**.
- 715        34. Click **Add**, and add the zone representing the intranet—in this case, **Enterprise\_Intranet**.
- 716        35. Repeat step 34 for the secure sockets layer (SSL) VPN zone.
- 717        36. Under **Source Address**, click **Add**.
- 718        37. Enter the subnet corresponding to the intranet segment.
- 719        38. Repeat step 37 for the SSL VPN segment.
- 720        39. Click **Translated Packet**. Set the translation type to **Dynamic IP and Port**. Set Address Type to be **Interface Address**. Set Interface to be the WAN interface, and set the IP address to be the WAN IP of the firewall.
- 723        40. Click **OK** and commit the changes.

724        Figure 2-19 Original Packet Network Address Translation Configuration



#### 725        2.4.2 Demilitarized Zone Configuration

- 726        1. Navigate to **Network > Interfaces**.
- 727        2. Click the interface that has the DMZ connection.

- 728        3. Add a comment, set the Interface Type to **Layer3**, and assign it to the virtual router created ear-  
729        lier.
- 730        4. Click **IPv4 > Add > New Address**. Assign it an IP block, and give it a meaningful name. Click **OK**.
- 731        5. Navigate to **Network > Zones**.
- 732        6. Click **Add**. Give it a meaningful name, such as Enterprise\_DMZ.
- 733        7. Set the Type to **Layer3**, and assign it the new interface that was configured—in this case, ether-  
734        net1/3.
- 735        8. Click **OK**.
- 736        9. Navigate to **Network > DNS Proxy**. Click **Add** under **Interface**, and add the newly created inter-  
737        face. Click **OK**.
- 738        10. Commit the changes.
- 739        11. Navigate to **Network > Interfaces**, and the configured interfaces should be green.

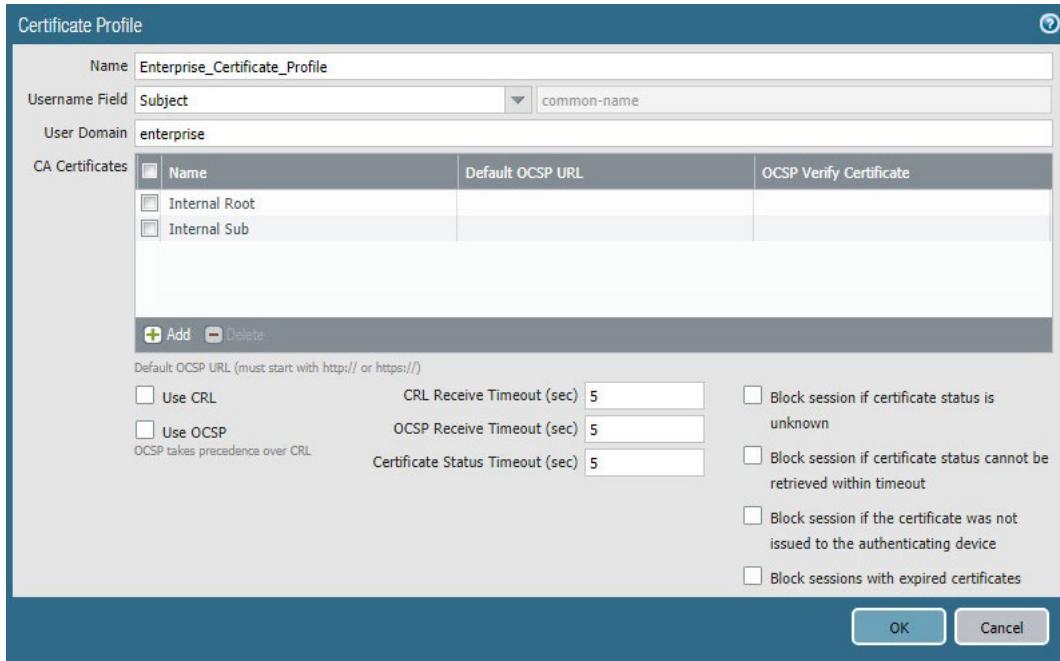
#### 740        2.4.3 Firewall Configuration

- 741        1. Navigate to **Policies > Security**.
- 742        2. Click **Add**.
- 743        3. Give the rule a meaningful name, such as Intranet Outbound.
- 744        4. Click **Source**. Click **Add** under source zone, and set the source zone to be the internal network.
- 745        5. Click **Destination**. Click **Add** under destination zone, and set the destination zone to be the WAN  
746        zone.
- 747        6. Click **Service/URL Category**. Under **Service**, click **Add**, and add **service-dns**. Do the same for ser-  
748        vice-http and service-https.
- 749        7. Click **OK**.
- 750        8. Click **Add**.
- 751        9. Click **Destination**. Add the IP address of the Simple Mail Transfer Protocol (SMTP) server.
- 752        10. Click **Application**. Click **Add**.
- 753        11. Search for **smtp**. Select it.
- 754        12. Click **OK**.

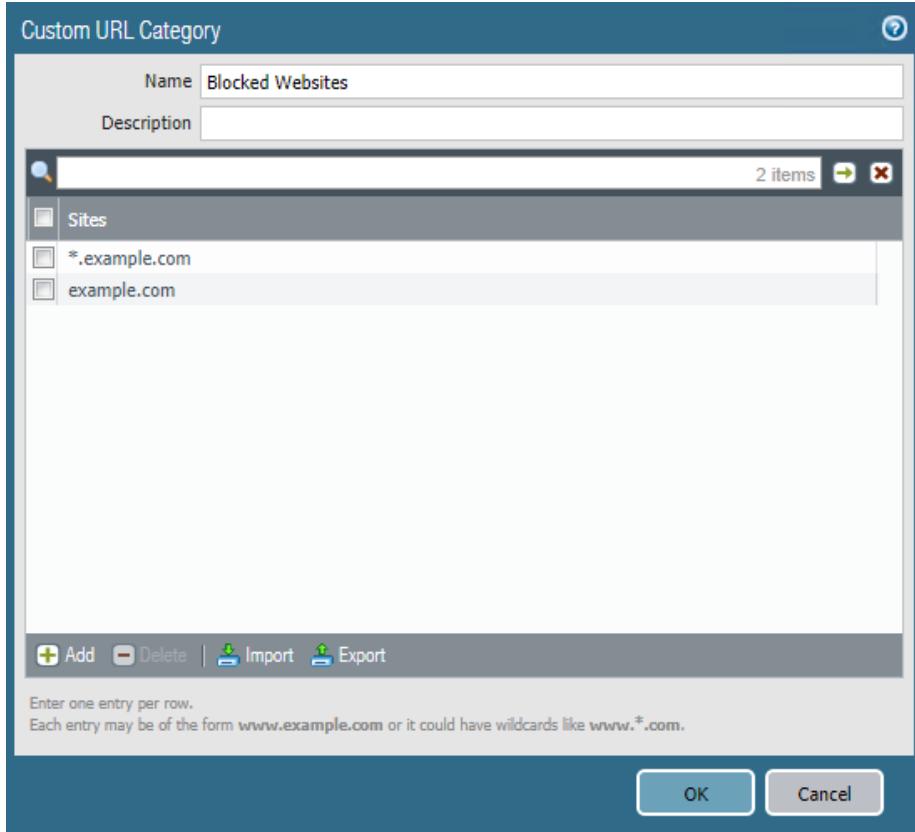
- 755        13. Commit the changes.  
756        14. Internal hosts should now be able to communicate on the internet.

757        **2.4.4 Certificate Configuration**

- 758        1. Navigate to **Device > Certificate Management > Certificate Profile**.  
759        2. Click **Add**.  
760        3. Give the profile a meaningful name, such as `Enterprise_Certificate_Profile`.  
761        4. Select **Subject** under **Username Field**.  
762        5. Select the radio button next to **Principal Name**.  
763        6. Enter the domain under **User Domain**—in this case, enterprise.  
764        7. Click **Add** under **CA Certificates**. Select the **internal root CA certificate**.  
765        8. Click **Add** under **CA Certificates**. Select the **internal sub CA certificate**. (Note: The entire certifi-  
766        cate chain must be included in the certificate profile.)  
767        9. Click **OK**.  
768        10. Commit the changes.

769 **Figure 2-20 Certificate Profile**770 **2.4.5 Website Filtering Configuration**771 **2.4.5.1 Configure Basic Website Blocking**

- 772 1. Navigate to **Objects > URL Category**.
- 773 2. Click **Add**.
- 774 3. Enter a name for the URL Category. Click **Add** on the bottom.
- 775 4. Add websites that should be blocked. Use the form `*.example.com` for all subdomains and `example.com` for the root domain.
- 776

777 **Figure 2-21 Custom URL Category**

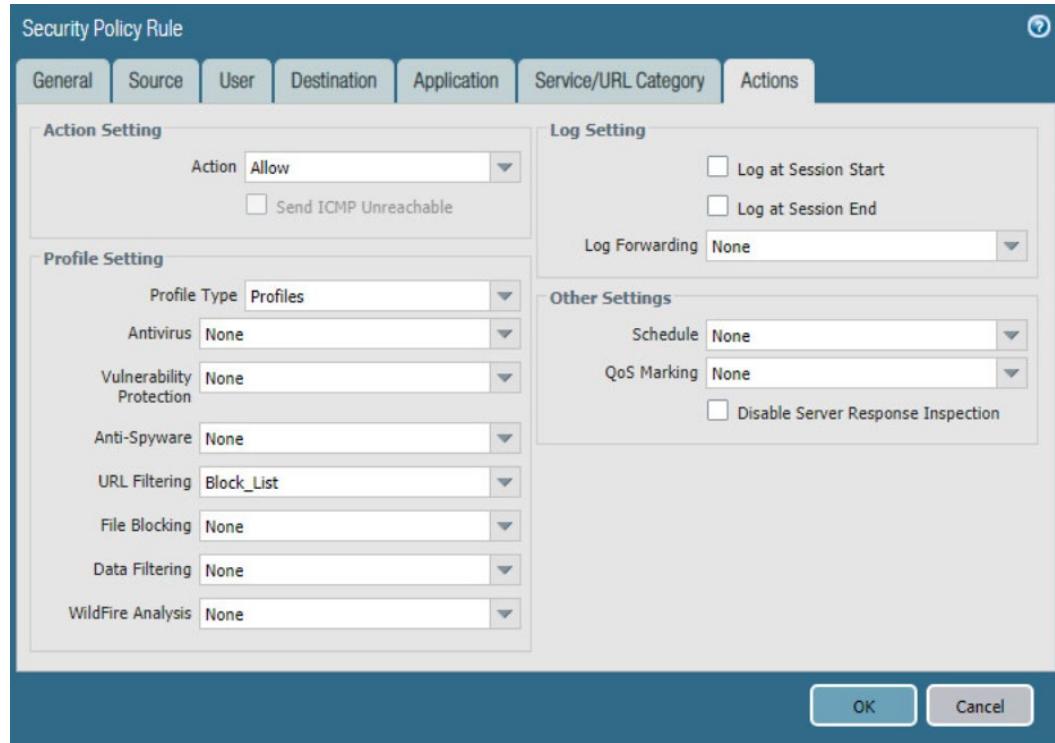
- 778 5. Click **OK**.
- 779 6. Navigate to **Objects > URL Filtering**.
- 780 7. Click **Add**.
- 781 8. Give the filtering profile a name.
- 782 9. Scroll to the bottom of the categories table. The profile created in step 4 should be the last item  
783 in the list, with an asterisk next to it. Click where it says **allow**, and change the value to **block**.
- 784 10. Configure any additional categories to allow, alert, continue, block, or override.

785    Figure 2-22 URL Filtering Profile

The screenshot shows the 'URL Filtering Profile' dialog box. At the top, there is a 'Name' field containing 'Block\_List' and a 'Description' field which is empty. Below these are five tabs: 'Categories' (selected), 'Overrides', 'URL Filtering Settings', 'User Credential Detection', and 'HTTP Header Insertion'. The main area displays a table titled 'Category' with columns for 'Site Access' and 'User Credential Submission'. The table contains 67 items. The rows include categories like 'adult-and-inappropriate', 'training-and-tools', 'translation', 'travel', 'unknown', 'weapons', 'web-advertisements', 'web-based-email', 'web-hosting', and 'Block List \*'. The 'Site Access' column shows values like 'allow' and 'block', and the 'User Credential Submission' column also shows 'allow' and 'block'. A note at the bottom left states: '\* indicates a custom URL category, + indicates external dynamic list'. At the bottom right are 'OK' and 'Cancel' buttons.

- 786    11. Click **OK**.
- 787    12. Navigate to **Policies > Security**.
- 788    13. Select a policy to which to apply the URL filtering.
- 789    14. Select **Actions**.
- 790    15. Next to **Profile Type**, select **Profiles**.
- 791    16. Next to **URL Filtering**, select the created URL filtering profile.

792 Figure 2-23 URL Filtering Security Policy

793 17. Click **OK**.

794 18. Repeat steps 13–17 for any policies to which to apply the filtering profile.

795 19. Commit the changes.

796 *[2.4.5.2 Configure SSL Website Blocking](#)*

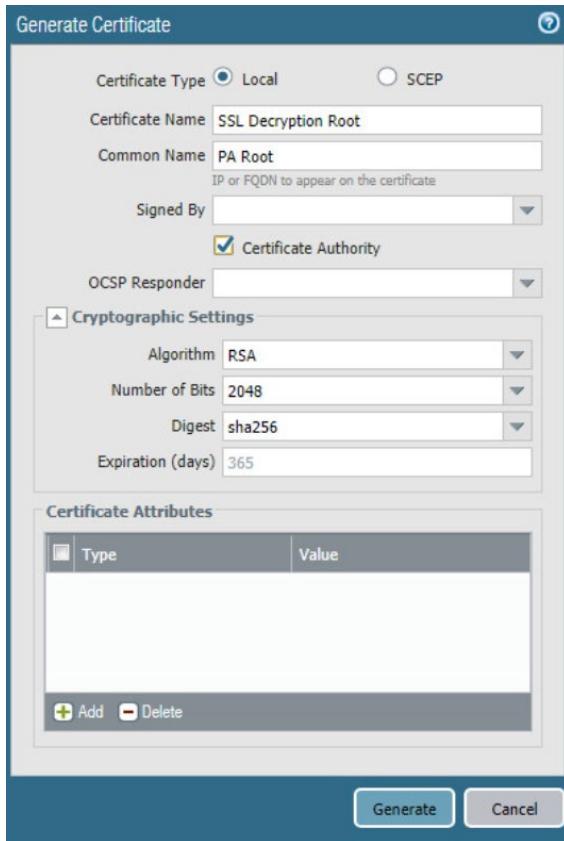
797 Note: This section is optional. Section [2.4.5.1](#) outlines how to configure basic URL filtering, which will  
 798 serve a URL blocked page for unencrypted (http [hypertext transfer protocol]) connections, and it will  
 799 send a transmission control protocol reset for encrypted (https [hypertext transfer protocol secure])  
 800 connections, which will show a default browser error page. This section outlines how to configure the  
 801 firewall so that it can serve the same error page for https connections as it does for http connections.  
 802 This is purely for user experience and has no impact on blocking functionality.

803 1. Navigate to **Device > Certificates**.804 2. Click **Generate** on the bottom of the page.

805 3. Give the root certificate a name, such as SSL Decryption Root; and a common name (CN) such as  
 806 PA Root.

807        4. Check the box next to **Certificate Authority**.

808        Figure 2-24 Generating the Root CA



809        5. Click **Generate**.

810        6. Click **Generate** at the bottom of the page.

811        7. Give the certificate a name, such as SSL Decryption Intermediate.

812        8. Give the certificate a CN, such as PA Intermediate.

813        9. Next to **Signed By**, select the generated root CA. In this case, SSL Decryption Root was selected.

814        10. Check the box next to **Certificate Authority**.

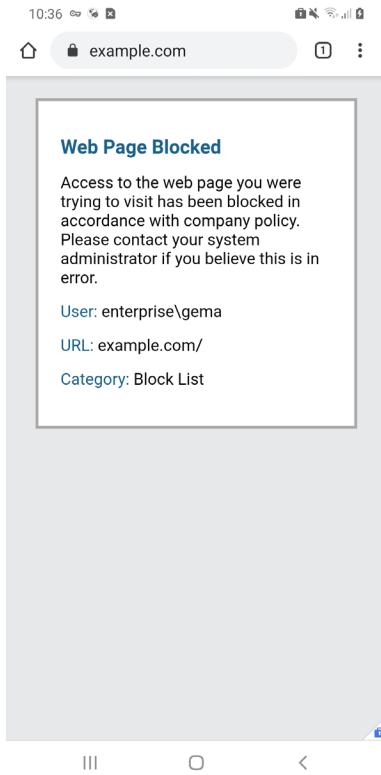
815        11. Click **Generate**.

816        12. Click the newly created certificate.

817        13. Check the boxes next to **Forward Trust Certificate** and **Forward Untrust Certificate**.

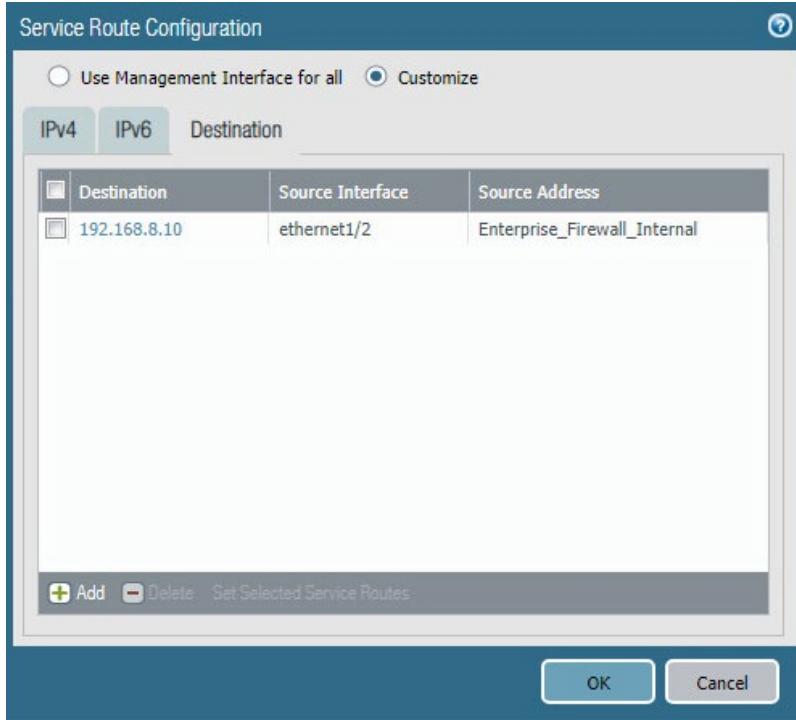
- 818        14. Click **OK**.
- 819        15. Navigate to **Policies > Decryption**.
- 820        16. Click **Add**.
- 821        17. Give the policy a name and description.
- 822        18. Click **Source**.
- 823        19. Under **Source Zone**, click **Add**.
- 824        20. Select the source zone(s) that matches the security policy that uses URL filtering. In this imple-  
825        mentation, the Intranet and SSL VPN zones were selected.
- 826        21. Click **Destination**.
- 827        22. Under **Destination Zone**, click **Add**.
- 828        23. Select the destination zone that matches the security policy that uses URL filtering. Most likely it  
829        is the WAN zone.
- 830        24. Click **Service/URL Category**.
- 831        25. Under **URL Category**, click **Add**.
- 832        26. Select the created block list. This ensures that only sites matching the block list are decrypted.
- 833        27. Click **Options**.
- 834        28. Next to **Action**, select **Decrypt**.
- 835        29. Next to **Type**, select **SSL Forward Proxy**.
- 836        30. Next to **Decryption Profile**, select **None**.
- 837        31. Click **OK**.
- 838        32. Commit the changes.

839 **Figure 2-25 Blocked Website Notification**



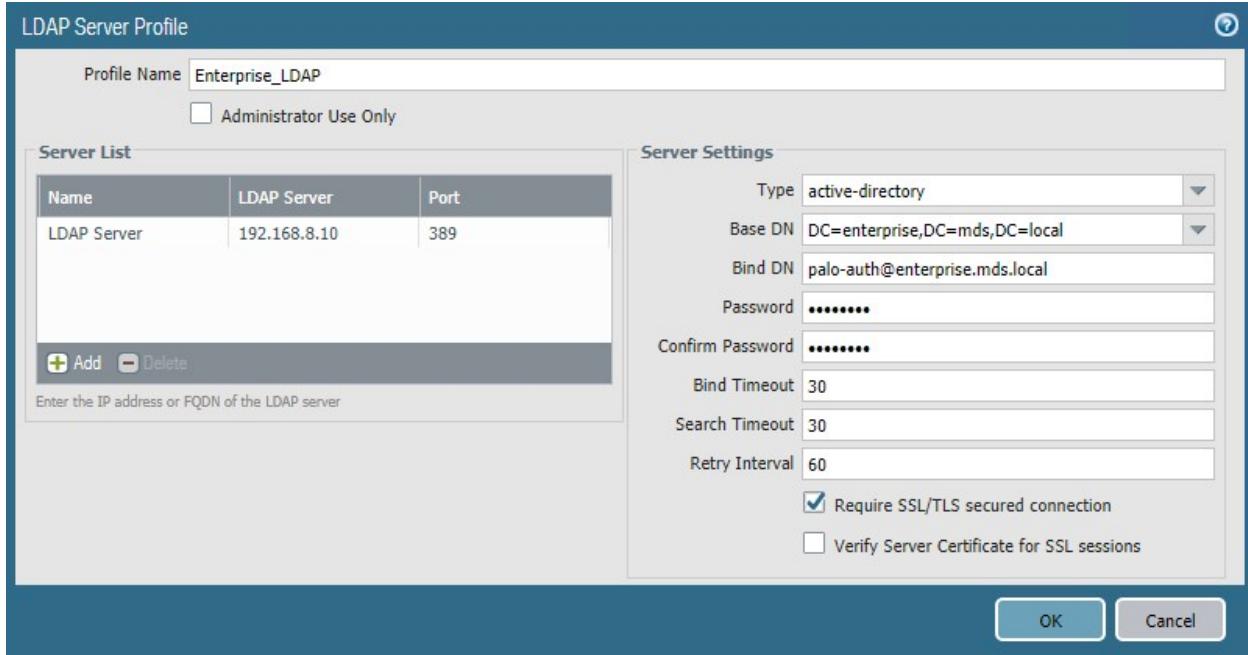
#### 840 **2.4.6 User Authentication Configuration**

- 841 1. Navigate to **Device > Setup > Services > Service Route Configuration**.
- 842 2. Click **Destination**.
- 843 3. Click **Add**.
- 844 4. Enter the IP address of the internal LDAP server for Destination.
- 845 5. Select the **internal network adapter** for Source Interface.
- 846 6. Select the **firewall's internal IP address** for Source Address.
- 847 7. Click **OK** twice, and commit the changes.

848 **Figure 2-26 Service Route Configuration**

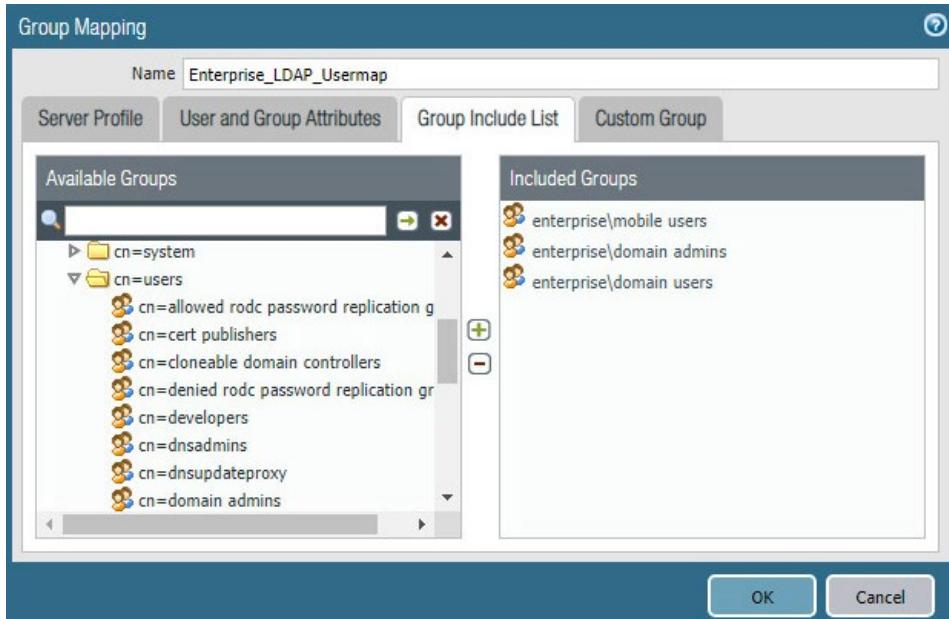
- 849     8. Navigate to **Device > Server Profiles > LDAP**.
- 850     9. Click **Add**.
- 851     10. Give the profile a meaningful name, such as **Enterprise\_LDAP\_Server**.
- 852     11. Click **Add** in the server list. Enter the name for the server and the IP.
- 853     12. Under **Server Settings**, set the Type to **active-directory**.
- 854     13. Enter the **Bind DN** and the password for the Bind DN.
- 855     Note: In this implementation, a new user, **palo-auth**, was created in Active Directory. This user does not require any special permissions or groups beyond the standard Domain Users group.
- 857     14. Ensure that **Require SSL/TLS secured connection** is checked.
- 858     15. Click the **down arrow** next to **Base DN**. If the connection is successful, the Base DN (Distinguished Name) should display.
- 860     16. Click **OK**.

861 Figure 2-27 LDAP Server Profile



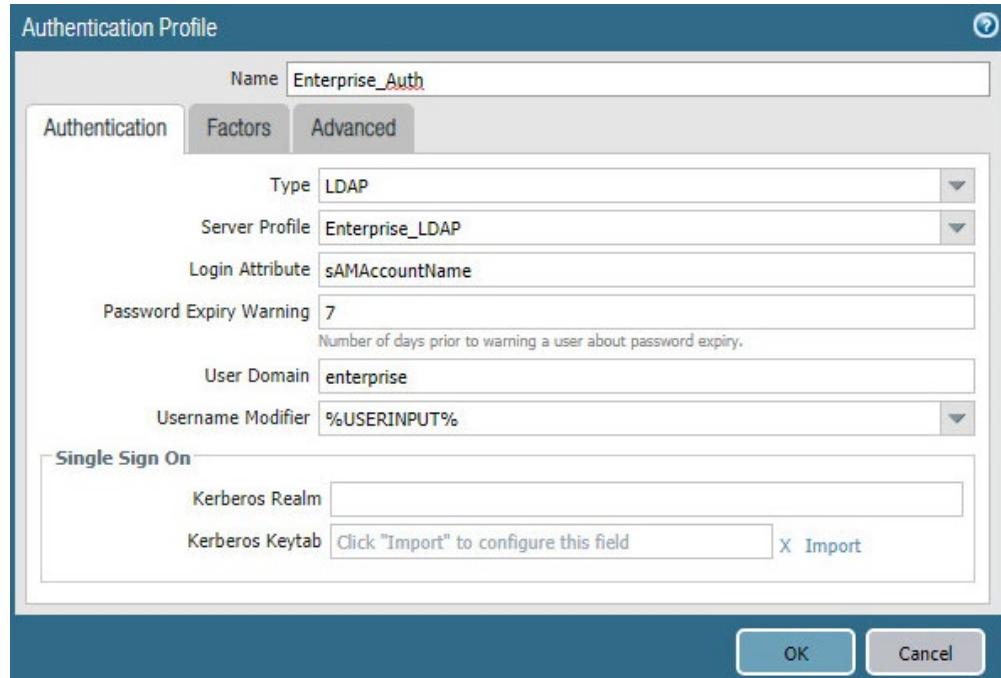
- 862 17. Navigate to **Device > User Identification > Group Mapping Settings**.
- 863 18. Click **Add**.
- 864 19. Give the mapping a name, such as Enterprise\_LDAP\_Usermap.
- 865 20. Select the **server profile**, and enter the **user domain**—in this case, Enterprise.
- 866 21. Click **Group Include List**.
- 867 22. Expand the arrow next to the **base DN** and then again next to **cn=users**.
- 868 23. For each group that should be allowed to connect to the VPN, click the proper **entry** and then  
869 the **+ button**. In this example implementation, mobile users, domain users, and domain admins  
870 were used.

871 Figure 2-28 LDAP Group Mapping



- 872 24. Click **OK**.
- 873 25. Navigate to **Device > Authentication Profile**.
- 874 26. Click **Add**.
- 875 27. Give the profile a meaningful name, such as **Enterprise\_Auth**.
- 876 28. For the Type, select **LDAP**.
- 877 29. Select the newly created LDAP profile next to **Server Profile**.
- 878 30. Set the Login Attribute to be **sAMAccountName**.
- 879 31. Set the User Domain to be the **LDAP domain name**—in this case, **enterprise**.

880 Figure 2-29 LDAP User Authentication Profile



- 881 32. Click on **Advanced**.
- 882 33. Click **Add**. Select **enterprise\domain users**.
- 883 34. Repeat step 33 for **mobile users** and **domain admins**.
- 884 35. Click **OK**.
- 885 36. Commit the changes.

#### 2.4.7 VPN Configuration

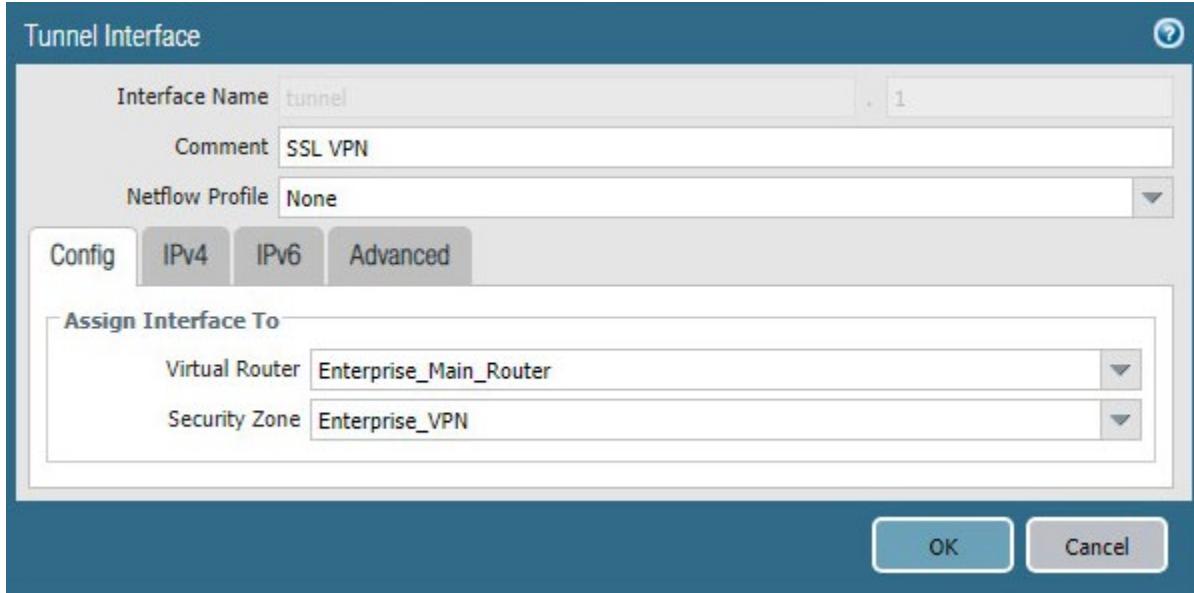
- 887 1. Navigate to **Network > Interfaces > Tunnel**.
- 888 2. Click **Add**.
- 889 3. Enter a tunnel number. Assign it to the main virtual router. Click **OK**.

890 Figure 2-30 Configured Tunnel Interfaces

Interface	Management Profile	IP Address	Virtual Router	Security Zone	Features	Comment
tunnel		none	none	none		
tunnel.1		none	Enterprise_Main_Ro...	Enterprise_VPN		SSL VPN

- 892        4. Click the **newly created tunnel**.  
893        5. Click the drop-down next to **Security Zone**. Select **New Zone**.  
894        6. Give it a name, and assign it to the newly created tunnel. Click **OK** twice.

895        Figure 2-31 SSL VPN Tunnel Interface Configuration



- 896        7. Commit the changes.  
897        8. Navigate to **Policies > Authentication**.  
898        9. Click **Add**.  
899        10. Give the policy a **descriptive name**. For this example, the rule was named **VPN\_Auth**.  
900        11. Click **Source**.  
901        12. Click **Add**, and add the VPN and WAN zones.  
902        13. Click **Destination**.  
903        14. Check the **Any** box above **Destination Zone**.  
904        15. Click **Service/URL Category**.  
905        16. Click **Add** under **Service**, and add **service-https**.  
906        17. Click **Actions**.

907        18. Next to **Authentication Enforcement**, select **default-web-form**.

908        19. Click **OK**.

909        *2.4.7.1 Configure the GlobalProtect Gateway*

910        1. Navigate to **Network > GlobalProtect > Gateways**.

911        2. Click **Add**.

912        3. Give the gateway a meaningful name. For this implementation, the name Enterprise\_VPN\_Gate-  
913        way was used.

914        4. Under **Interface**, select the **WAN Ethernet interface**.

915        5. Ensure that **IPv4 Only** is selected next to **IP Address Type**.

916        6. Select the **WAN IP of the firewall** next to **IPv4 Address**. Ensure that end clients can resolve it.

917        7. Click **Authentication**.

918        8. Select the created **SSL/TLS service profile** next to **SSL/TLS Service Profile**.

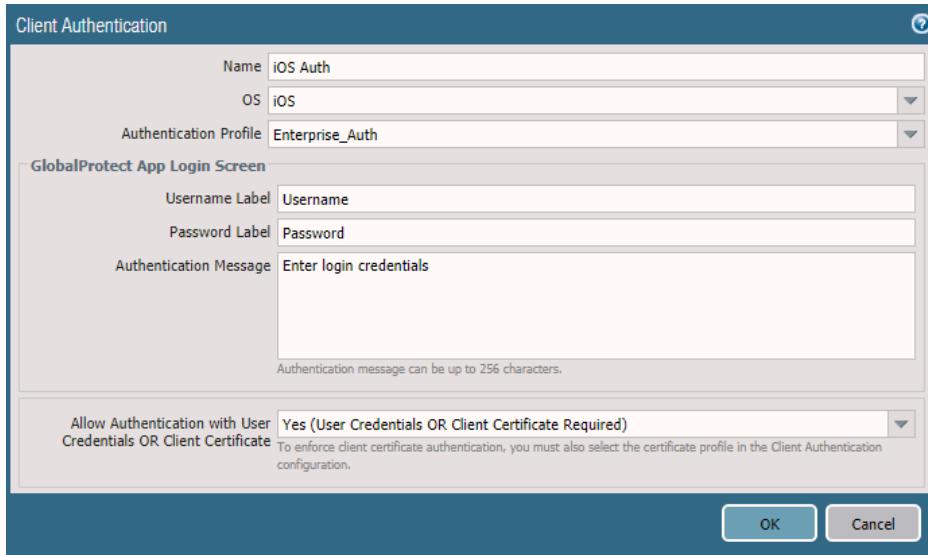
919        9. Click **Add** under **Client Authentication**.

920        10. Give the object a meaningful name, such as iOS Auth.

921        11. Next to **OS**, select **iOS**.

922        12. Next to **Authentication Profile**, select the **created Authentication Profile**.

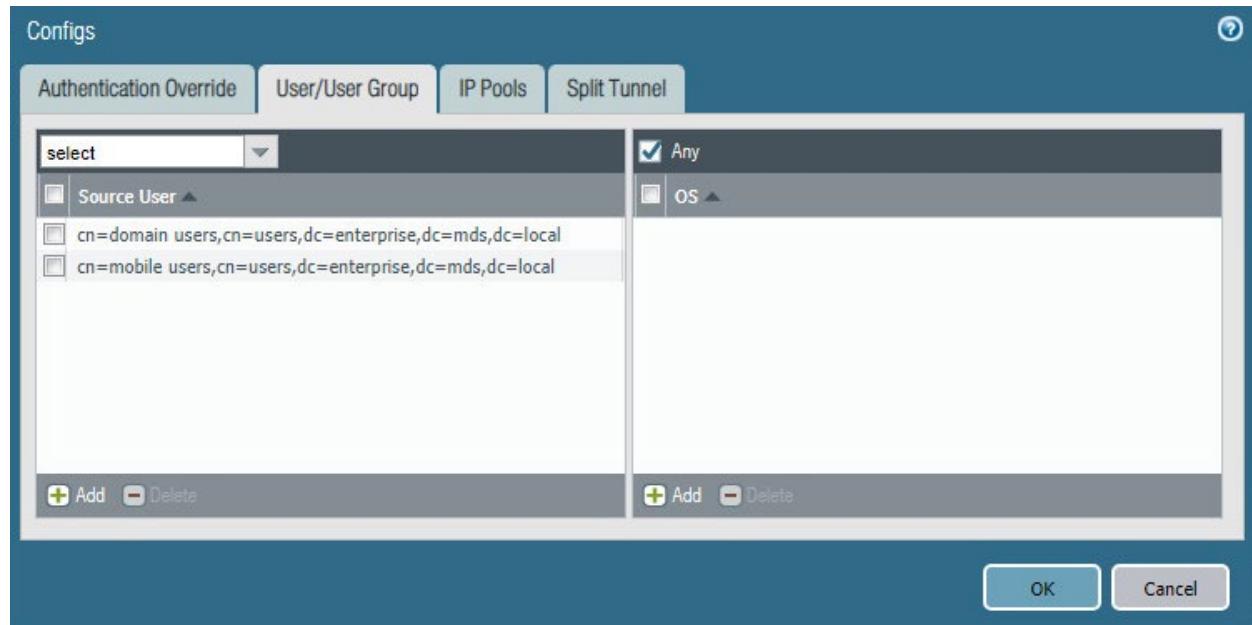
923        13. Next to **Allow Authentication with User Credentials OR Client Certificate**, select **Yes**.

924 **Figure 2-32 GlobalProtect iOS Authentication Profile**

- 925 14. Click **OK**.
- 926 15. Click **Add** under **Client Authentication**.
- 927 16. Give the object a meaningful name, such as **Android Auth**.
- 928 17. Next to **OS**, select **Android**.
- 929 18. Next to **Authentication Profile**, select the **created Authentication Profile**.
- 930 19. Next to **Allow Authentication with User Credentials OR Client Certificate**, select **No**.
- 931 20. Click **Agent**.
- 932 21. Check the box next to **Tunnel Mode**.
- 933 22. Select the **created tunnel interface** next to **Tunnel Interface**.
- 934 23. Uncheck **Enable IPSec**.
- 935 24. Click **Timeout Settings**.
- 936 25. Set **Disconnect On Idle** to an organization defined time.
- 937 26. Click **Client IP Pool**.
- 938 27. Click **Add**, and assign an IP subnet to the clients—in this case, **10.3.3.0/24**.
- 939 28. Click **Client Settings**.

- 940        29. Click **Add**.  
941        30. Give the config a meaningful name, such as Enterprise\_Remote\_Access.  
942        31. Click **User/User Group**.  
943        32. Click **Add** under **Source User**.  
944        33. Enter the **LDAP information** of the group allowed to use this rule. In this example, implementation, domain users, and mobile users were used.

946        **Figure 2-33 LDAP Authentication Group Configuration**

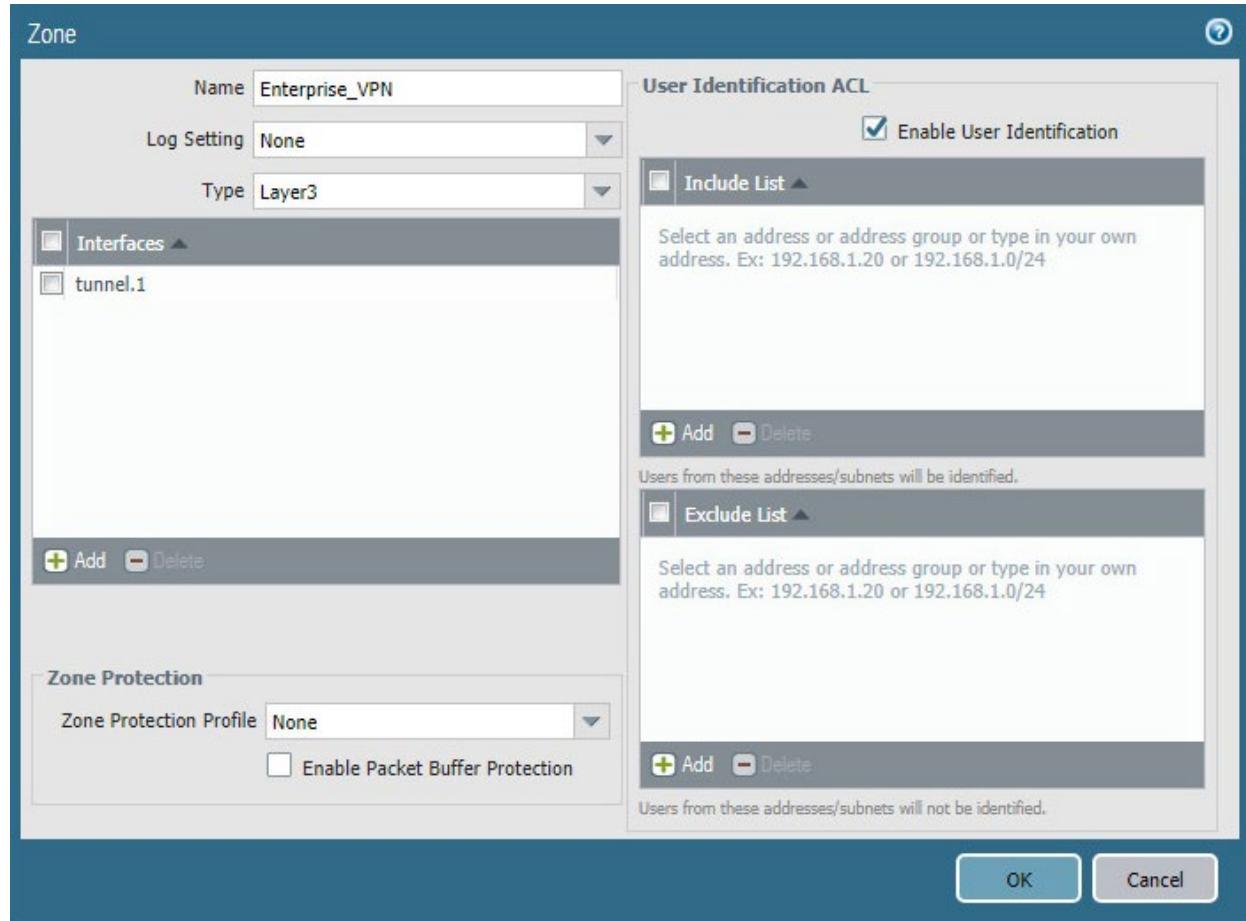


- 947        34. Click **Split Tunnel**.  
948        35. Click **Add** under **Include**.  
949        36. Enter **0.0.0.0/0** to enable full tunneling.  
950        37. Click **OK**.  
951        38. Click **Network Services**.  
952        39. Set **Primary DNS** to be the internal domain controller/DNS server—in this case, **192.168.8.10**.  
953        40. Click **OK**.  
954        41. Navigate to **Network > Zones**.

955        42. Click the created **VPN zone**.

956        43. Check the box next to **Enable User Identification**.

957        **Figure 2-34 VPN Zone Configuration**



958        44. Click **OK**.

959        45. Commit the changes.

#### *2.4.7.2 Configure the GlobalProtect Portal*

961        1. Navigate to **Network > GlobalProtect > Portals**.

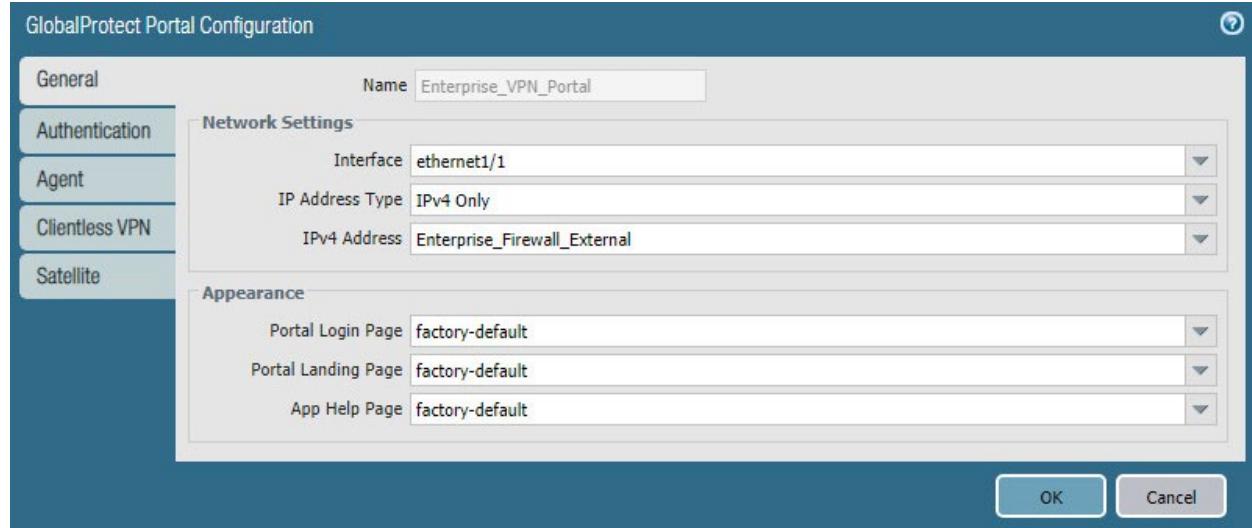
962        2. Click **Add**.

963        3. Give the profile a meaningful name, such as **Enterprise\_VPN\_Portal**.

964        4. For Interface, assign it the firewall's **WAN interface**.

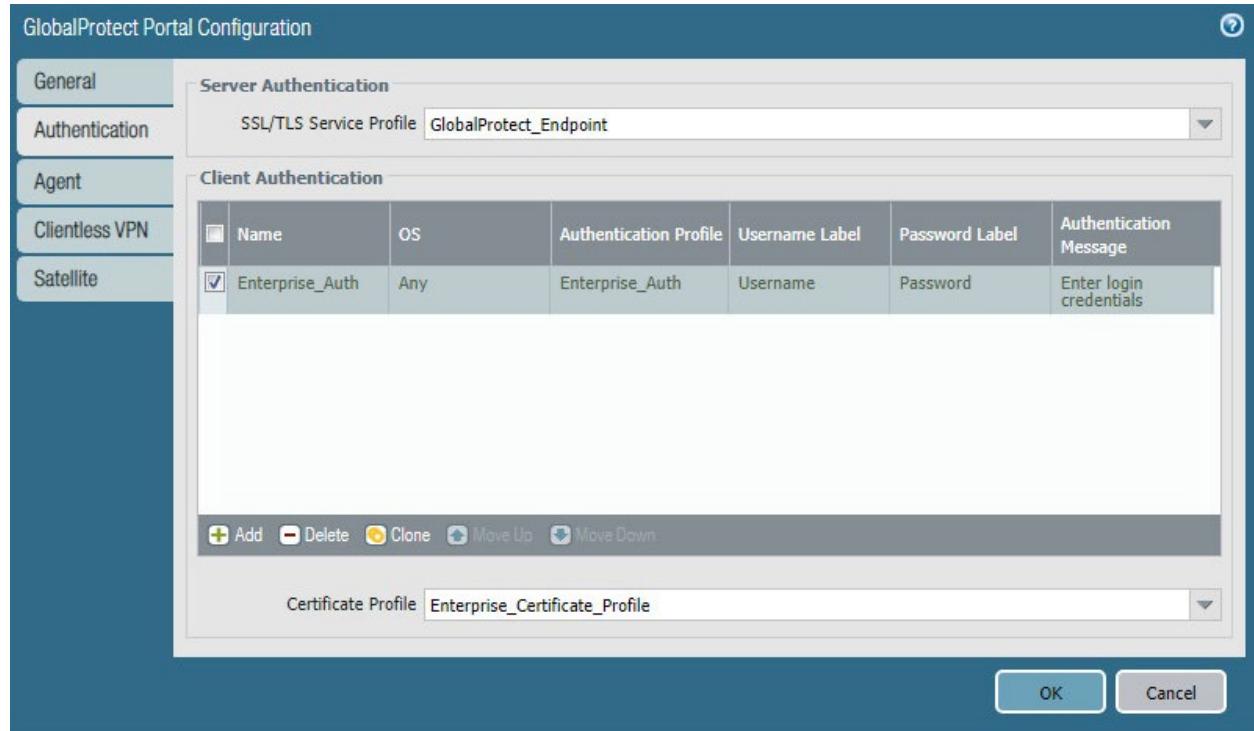
- 965        5. Set IP Address Type to **IPv4 Only**.  
966        6. Set the IPv4 address to the firewall's **WAN address**.  
967        7. Set all three appearance options to be **factory-default**.

968 **Figure 2-35 GlobalProtect Portal General Configuration**



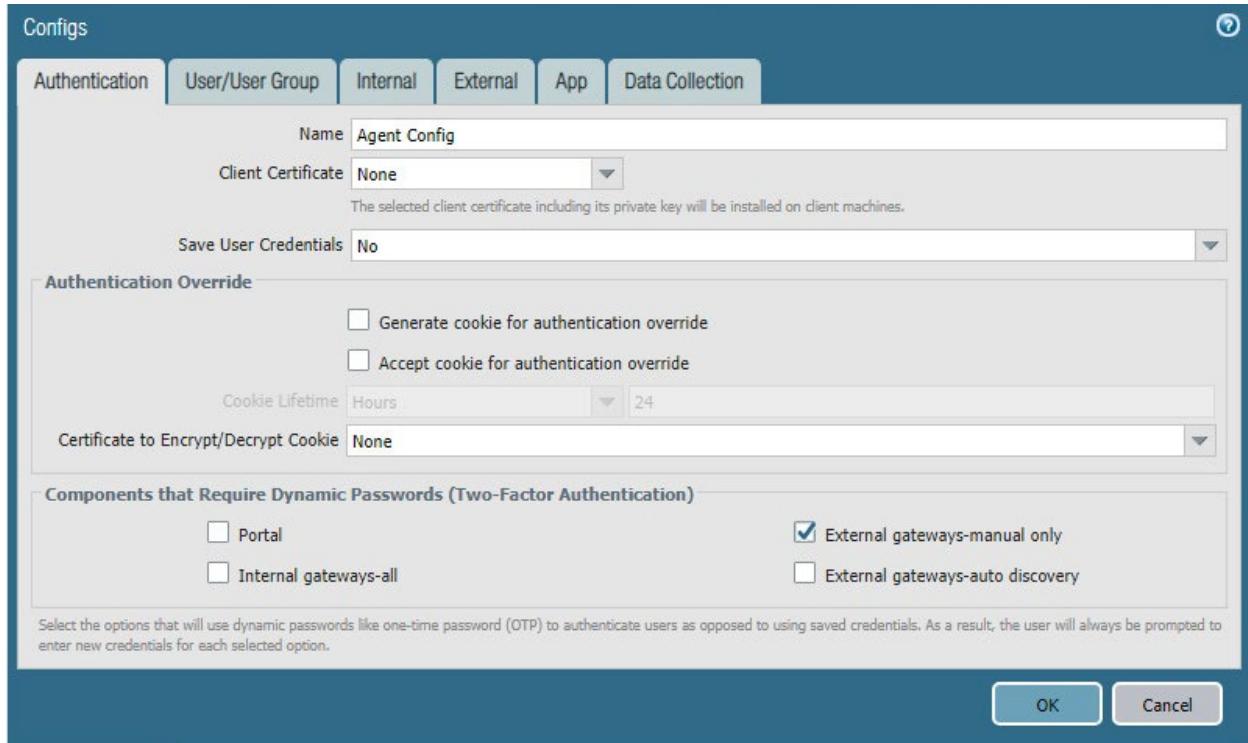
- 969        8. Click **Authentication**.  
970        9. Select the **created SSL/TLS service profile**.  
971        10. Click **Add** under **Client Authentication**.  
972        11. Give the profile a meaningful name, such as Enterprise\_Auth.  
973        12. Select the created **authentication profile** next to **Authentication Profile**.  
974        13. Click **OK**.

975 Figure 2-36 GlobalProtect Portal Authentication Configuration



- 976      14. Click **Agent**, and click **Add** under **Agent**.
- 977      15. Give the agent configuration a name.
- 978      16. Ensure that the **Client Certificate** is set to **None**, and **Save User Credentials** is set to **No**.
- 979      17. Check the box next to **External gateways-manual only**.

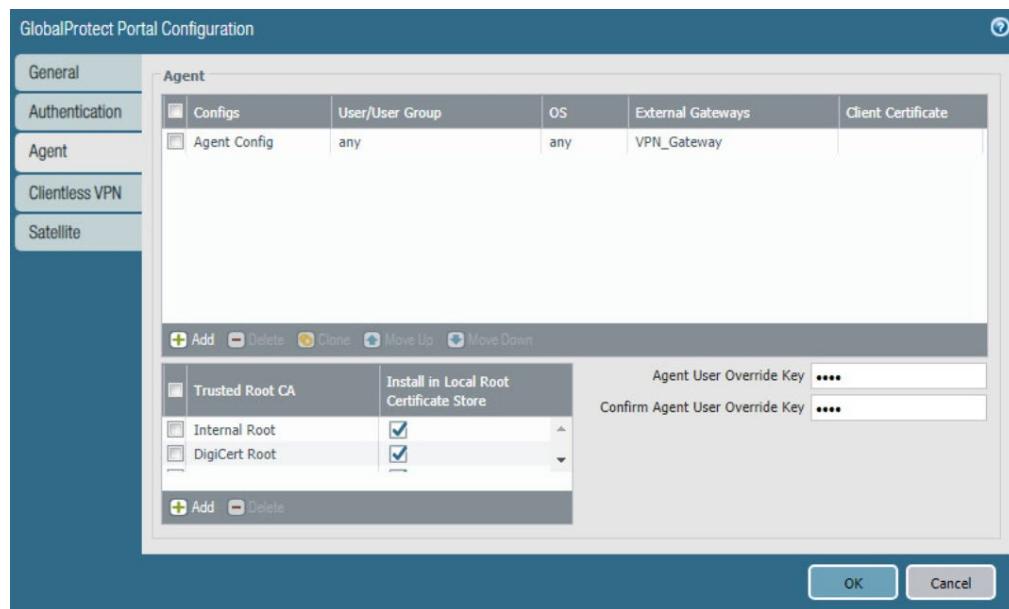
980 Figure 2-37 GlobalProtect Portal Agent Authentication Configuration



- 981 18. Click **External**.
- 982 19. Click **Add** under **External Gateways**.
- 983 20. Give the gateway a name, and enter the fully qualified domain name (FQDN) of the VPN end point.
- 984
- 985 21. Click **Add** under **Source Region**, and select **Any**.
- 986 22. Check the box next to **Manual**.
- 987 23. Click **OK**.
- 988 24. Click **App**.
- 989 25. Under **App Configurations > Connect Method**, select **On-demand**.
- 990 26. Next to **Welcome Page**, select **factory-default**.
- 991 27. Click **OK**.
- 992 28. Click **Add** under **Trusted Root CA**.

- 993        29. Select the **internal root certificate** used to generate device certificates.
- 994        30. Click **Add** again. Select the **root certificate** used to create the VPN end-point SSL certificate. For  
995        this implementation, it is a DigiCert root certificate.
- 996        31. Click **Add** again. Select the **root certificate** used for SSL URL filtering, created in a previous sec-  
997        tion.
- 998        32. Check the box next to **Install in Local Root Certificate Store** for all three certificates.

999 **Figure 2-38 GlobalProtect Portal Agent Configuration**

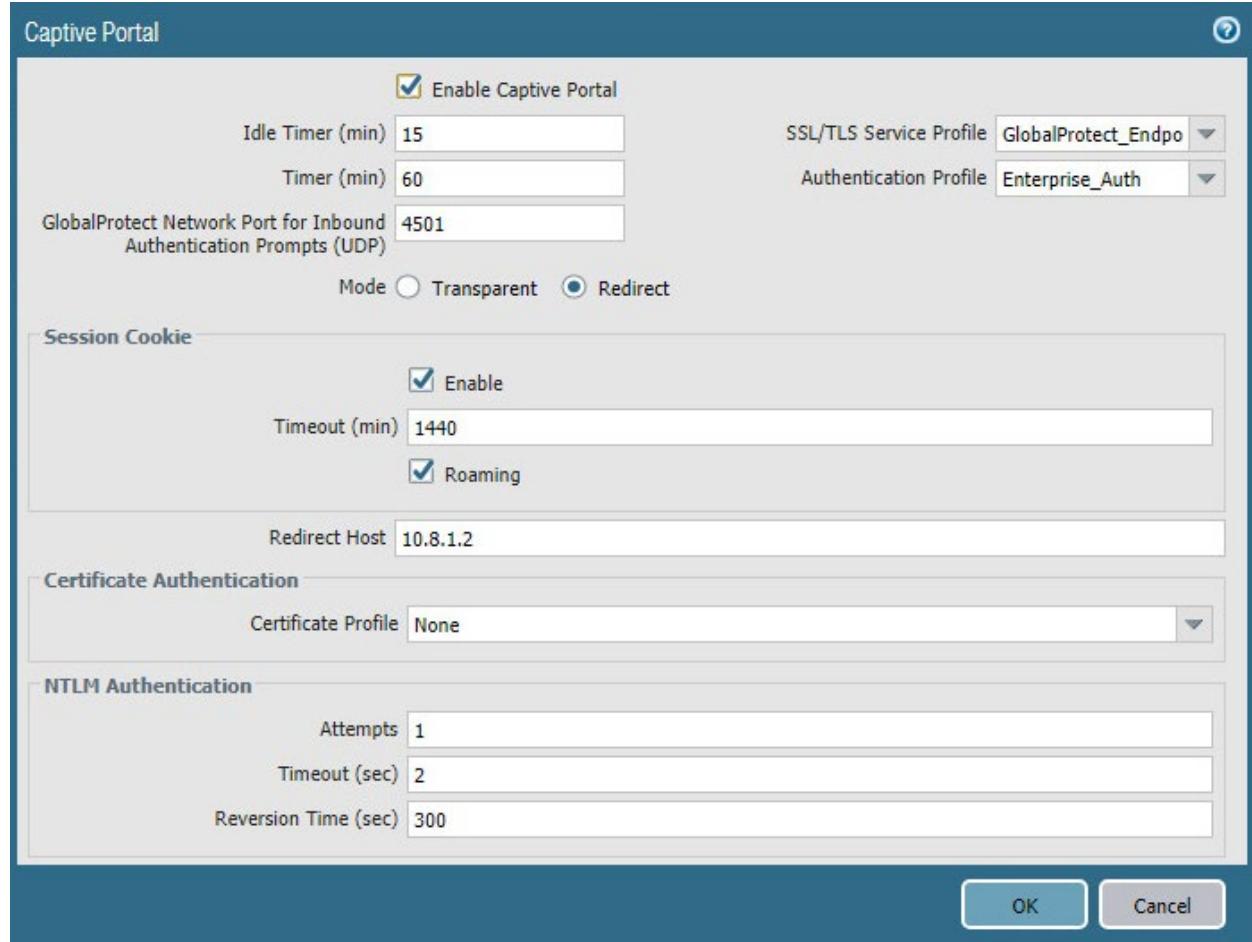


- 1000      33. Click **OK**.

#### 1001 ***2.4.7.3 Activate Captive Portal***

- 1002      1. Navigate to **Device > User Identification > Captive Portal Settings**.
- 1003      2. Click the **gear** icon on the top right of the Captive Portal box.
- 1004      3. Select the **created SSL/TLS service profile and authentication profile**.
- 1005      4. Click the radio button next to **Redirect**.
- 1006      5. Next to **Redirect Host**, enter the **IP address** of the firewall's WAN interface—in this case,  
1007      **10.8.1.2**.

1008 Figure 2-39 Captive Portal Configuration

1009 6. Click **OK**.

1010 7. Commit the changes.

1011 **2.4.7.4 Activate the GlobalProtect Client**1012 1. Navigate to **Device > GlobalProtect Client**.

1013 2. Acknowledge pop up messages.

1014 3. Click **Check Now** at the bottom of the page.1015 4. Click **Download** next to the **first release** that comes up. In this implementation, version 5.0.2ate-  
1016 was used.1017 5. Click **Activate** next to the **downloaded release**.

- 1018        6. Navigate to the FQDN of the VPN. You should see the Palo Alto Networks logo and the Glob-  
1019        alProtect portal login prompt, potentially with a message indicating that a required certificate  
1020        cannot be found. This is expected on desktops because there is nothing in place to seamlessly  
1021        deploy client certificates.

1022 **Figure 2-40 GlobalProtect Portal**



1023 Note: If you intend to use the GlobalProtect agent with a self-signed certificate (e.g., internal PKI), be  
1024 sure to download the SSL certificate from the VPN website and install it in the trusted root CA store.

#### 1025 [2.4.8 Enable Automatic Application and Threat Updates](#)

- 1026        1. In the **PAN-OS portal**, navigate to **Device > Dynamic Updates**.  
1027        2. Install the latest updates.  
1028            a. At the bottom of the page, click **Check Now**.

- 1029            b. Under **Applications and Threats**, click **Download** next to the last item in the list with the  
 1030            latest Release Date. This will take a few minutes.
- 1031            c. When the download completes, click **Close**.

1032 **Figure 2-41 Downloaded Threats and Applications**

Release Date	Downloaded	Currently Installed	Action	Documentation
2018/10/31 17:41:37 EDT	▼		<a href="#">Install</a> <a href="#">Review Policies</a> <a href="#">Review Apps</a>	<a href="#">Release Notes</a>

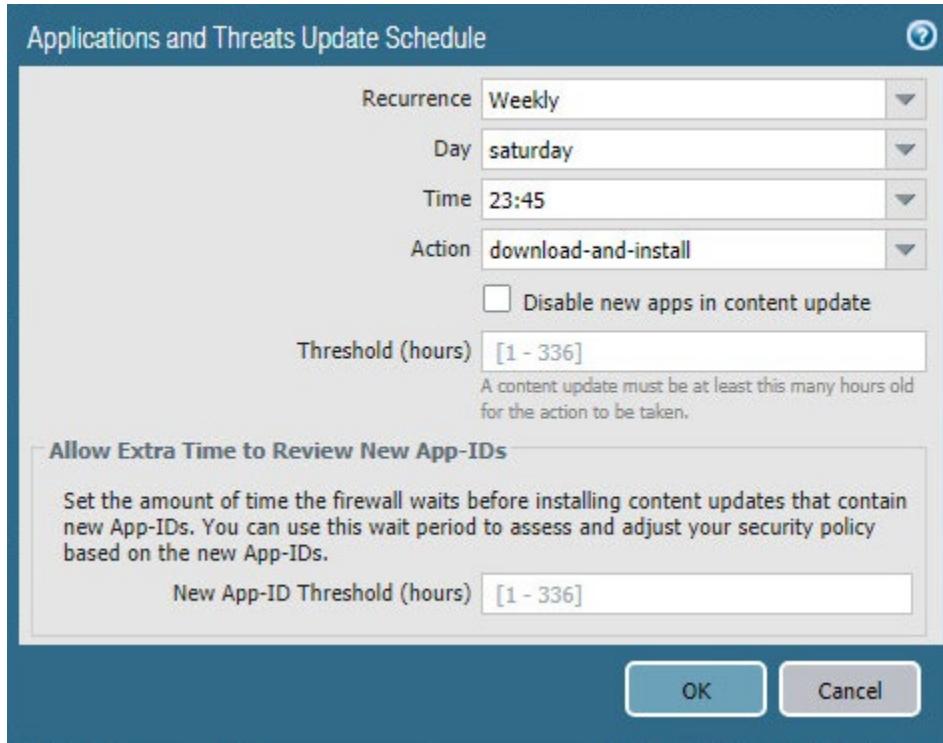
- 1033            d. Click **Install** on the first row.
- 1034            e. Click **Continue Installation**, leaving the displayed box unchecked. Installation will take a  
 1035            few minutes.
- 1036            f. When the installation completes, click **Close**.
- 1037            3. Enable automatic threat updates. (Note: Automatic threat updates are performed in the back-  
 1038            ground and do not require a reboot of the appliance.)
- 1039            a. At the top of the page, next to **Schedule**, click the hyperlink with the date and time, as  
 1040            shown in Figure 2-42.

1041 **Figure 2-42 Schedule Time Hyperlink**

Version ▲	File Name	Features	Type
▼ Applications and Threats	Last checked: 2018/11/29 12:25:15 EST	Schedule:	<a href="#">Every Wednesday at 01:02 (Download only)</a>

- 1042            b. Select the **desired recurrence**. For this implementation, weekly was used.
- 1043            c. Select the **desired day and time** for the update to occur. For this implementation, Saturday at 23:45 was used.
- 1045            d. Next to **Action**, select **download-and-install**.

1046 Figure 2-43 Application and Threats Update Schedule

1047 e. Click **OK**.

1048 f. Commit the changes.

1049 

## 2.5 Kryptowire

1050 Kryptowire was used as an application vetting service via a custom active directory-integrated web  
1051 application.1052 

### 2.5.1 Kryptowire and MaaS360 Integration

- 1053 1. Contact IBM support to provision API credentials for Kryptowire.
- 1054 2. Contact Kryptowire support to enable the MaaS360 integration, including the MaaS360 API cre-  
1055 dentials.
- 1056 3. In the Kryptowire portal, click the **logged-in user's email address** in the upper right-hand corner  
1057 of the portal. Navigate to **Settings > Analysis**.
- 1058 4. Set the **Threat Score Threshold** to the desired amount. In this sample implementation, 75 was  
1059 used.

- 1060        5. Enter an **email address** where email alerts should be delivered.
- 1061        6. Click **Save Settings**. Kryptowire will now send an email to the email address configured in step 5  
1062            when an analyzed application is at or above the configured alert threshold.

1063 **Appendix A List of Acronyms**

<b>AD</b>	Active Directory
<b>API</b>	Application Programming Interface
<b>CA</b>	Certificate Authority
<b>CN</b>	Common Name
<b>DC</b>	Domain Controller
<b>DMZ</b>	Demilitarized Zone
<b>DN</b>	Distinguished Name
<b>DNS</b>	Domain Name System
<b>FQDN</b>	Fully Qualified Domain Name
<b>HKEY</b>	Handle to Registry Key
<b>HKLM</b>	HKEY_LOCAL_MACHINE
<b>HTTP</b>	Hypertext Transfer Protocol
<b>HTTPS</b>	Hypertext Transfer Protocol Secure
<b>IBM</b>	International Business Machines
<b>IIS</b>	Internet Information Services
<b>IP</b>	Internet Protocol
<b>IPSec</b>	Internet Protocol Security
<b>IPv4</b>	Internet Protocol version 4
<b>LDAP</b>	Lightweight Directory Access Protocol
<b>MDM</b>	Mobile Device Management
<b>MDSE</b>	Mobile Device Security for Enterprise
<b>NCCoE</b>	National Cybersecurity Center of Excellence
<b>NDES</b>	Network Device Enrollment Service
<b>NIST</b>	National Institute of Standards and Technology

<b>OU</b>	Organizational Unit
<b>PKI</b>	Public Key Infrastructure
<b>SCEP</b>	Simple Certificate Enrollment Protocol
<b>SP</b>	Special Publication
<b>SSL</b>	Secure Sockets Layer
<b>TLS</b>	Transport Layer Security
<b>URL</b>	Uniform Resource Locator
<b>UUID</b>	Universally Unique Identifier
<b>VPN</b>	Virtual Private Network
<b>WAN</b>	Wide Area Network

1064 **Appendix B    Glossary**

**Bring Your Own Device (BYOD)** A non-organization-controlled telework client device. [\[2\]](#)

## 1065      **Appendix C    References**

- 1066 [1] International Business Machines. "Cloud Extender architecture." [Online]. Available:  
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- 1069 [2] M. Souppaya and K. Scarfone, *Guide to Enterprise Telework, Remote Access, and Bring Your Own  
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