NIST SPECIAL PUBLICATION 1800-8

Securing Wireless Infusion Pumps

In Healthcare Delivery Organizations

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

DRAFT

Gavin O'Brien
Sallie Edwards
Kevin Littlefield
Neil McNab
Sue Wang
Kangmin Zheng

National Institute of Standards and Technology
U.S. Department of Commerce

NCCoE
NATIONAL CYBERSECURITY CENTER OF EXCELLENCE

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Sallie Edwards
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Kangmin Zheng
The MITRE Corporation
McLean, VA

DRAFT

May 2017

U.S. Department of Commerce
Wilbur Ross, Secretary

National Institute of Standards and Technology
Kent Rochford, Acting Undersecretary of Commerce for Standards and Technology and Director

NIST SPECIAL PUBLICATION 1800-8A

Securing Wireless Infusion Pumps

In Healthcare Delivery Organizations

Volume A:
Executive Summary

DRAFT

Gavin O'Brien
National Cybersecurity Center of Excellence
Information Technology Laboratory

Sallie Edwards
Kevin Littlefield
Neil McNab
Sue Wang
Kangmin Zheng
The MITRE Corporation
McLean, VA

May 2017

Executive Summary

- Broad technological advancements have contributed to the Internet of Things (IoT) phenomenon, where physical devices now have technology that allow them to connect to the internet and communicate with other devices or systems.[i] With billions of devices being connected to the internet,[ii] many industries, including healthcare, have or are beginning to leverage IoT devices to improve operational efficiency and enhance innovation.
- Medical devices, such as infusion pumps[iii], were once standalone instruments that interacted only with the patient or medical provider. With technological improvements designed to enhance patient care, these devices now connect wirelessly to a variety of systems, networks, and other tools within a healthcare delivery organization (HDO) – ultimately contributing to the Internet of Medical Things (IoMT).
- As IoMT grows, cybersecurity risks have risen. According to the Association for the Advancement of Medical Instrumentation (AAMI) Technical Information Report 57 (TIR57), "this has created a new source of risk for [the] safe operation [of medical devices]."[iv] In particular, the wireless infusion pump ecosystem (the pump, the network, and the data stored in and on a pump) face a range of threats, including unauthorized access to protected health information (PHI), changes to prescribed drug doses, and interference with a pump's function.
- In addition to managing interconnected medical devices, HDOs oversee complex, highly technical environments, from back-office applications for billing and insurance services, supply chain and inventory management, and staff scheduling to clinical systems such as radiological and pharmaceutical support. In this intricate healthcare environment, HDOs and medical device manufacturers that share responsibility and take a collaborative, holistic approach to reducing cybersecurity risks of the infusion pump ecosystem can better protect healthcare systems, patients, PHI, and enterprise information.
- The National Cybersecurity Center of Excellence (NCCoE) at the National Institute of Standards and Technology (NIST) analyzed risk factors in and around the infusion pump ecosystem using a questionnaire-based risk assessment. With the results of that assessment, the NCCoE then developed an example implementation that demonstrates how HDOs can use standards-based, commercially available cybersecurity technologies to better protect the infusion pump ecosystem, including patient information and drug library dosing limits.

CHALLENGE

Technology improvements happen rapidly across all sectors. For organizations focused on streamlining operations and delivering high-quality patient care, it can be difficult to take advantage of the latest technological advances, while also ensuring new medical devices or applications are secure. For many HDOs, this can result in improperly configured information technology networks and components that increase cybersecurity risks.

Unlike prior medical devices that were once standalone instruments, today's wireless infusion pumps connect to a variety of healthcare systems, networks, and other devices. Although connecting infusion pumps to point-of-care medication systems and electronic health records (EHRs) can improve healthcare delivery processes, using a medical device's connectivity capabilities can create significant cybersecurity risk, which could lead to operational or safety risks. Tampering, intentional or otherwise, with the

wireless infusion pump ecosystem can expose a healthcare provider's enterprise to serious risks, such as:

- access by malicious actors
- loss or corruption of enterprise information and patient data and health records
- a breach of protected health information
- loss or disruption of healthcare services
- damage to an organization's reputation, productivity, and bottom-line revenue

As IoMT grows, with an increasing number of infusion pumps connecting to networks, the vulnerabilities and risk factors become more critical as they can expose the pump ecosystem to external attacks, compromises, or interference.

SOLUTION

The NCCoE has developed cybersecurity guidance, NIST Special Publication 1800-8 *Securing Wireless Infusion Pumps*, using standards-based commercially available technologies and industry best practices to help HDOs strengthen the security of the wireless infusion pump ecosystem within healthcare facilities.

This NIST cybersecurity publication provides best practices and detailed guidance on how to manage assets, protect against threats, and mitigate vulnerabilities by performing a questionnaire-based risk assessment. In addition, the security characteristics of wireless infusion pump ecosystem are mapped to currently available cybersecurity standards and the Health Insurance Portability and Accountability Act (HIPAA) Security Rule. Based on our risk assessment findings, we apply security controls to the pump's ecosystem to create a 'defense-in-depth' solution for protecting infusion pumps and their surrounding systems against various risk factors. Ultimately, we show how biomedical, networking, and cybersecurity engineers and IT professionals can securely configure and deploy wireless infusion pumps to reduce cybersecurity risk.

Although the NCCoE used a suite of commercially available tools and technologies to address wireless infusion pump cybersecurity challenges, this guide does not endorse any specific products, nor does it guarantee compliance with any regulatory initiatives. Your organization's information security experts can identify solutions that will best integrate with your organization's current tools and IT system infrastructure. Your organization may choose to adopt this solution, or one that adheres to these guidelines, or you may refer to this guide as a starting point for tailoring and implementing specific parts that best suit your organization's risk profile and needs.

BENEFITS

The NCCoE's practice guide to securing the wireless infusion pump ecosystem can help your organization:

- reduce cybersecurity risk, and potentially reduce impact to safety and operational risk, such as the loss of patient information or interference with the standard operation of a medical device
- develop and execute a defense-in-depth strategy that protects the enterprise with layers of security to avoid a single point of failure and provide strong support for availability

- implement current cybersecurity standards and best practices, while maintaining the performance and usability of wireless infusion pumps

SHARE YOUR FEEDBACK

You can view or download the guide at https://nccoe.nist.gov/projects/use_cases/medical_devices. Help the NCCoE make this guide better by sharing your thoughts with us. We recognize that technical solutions alone will not fully enable the benefits of a cybersecurity solution, so we encourage organizations to share their lessons learned and best practices for transforming the processes associated with implementing these guidelines. To provide comments or to learn more by arranging a demonstration of this reference solution, contact the NCCoE at hit_nccoe@nist.gov.

TECHNOLOGY PARTNERS/COLLABORATORS

Technology vendors who participated in this project submitted their capabilities in response to a call in the Federal Register. Companies with relevant products were invited to sign a Cooperative Research and Development Agreement with NIST, allowing them to participate in a consortium to build this example solution.

Certain commercial entities, equipment, products, or materials may be identified in this practice guide to adequately describe an experimental procedure or concept. Such identification is not intended to imply recommendation or endorsement by NIST or NCCoE, nor is it intended to imply that the entities, equipment, products, or materials are necessarily the best available for the purpose.

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

LEARN MORE

https://nccoe.nist.gov
nccoe@nist.gov
301-975-0200

[i] *Internet of Things*, Gartner IT Glossary, http://www.gartner.com/it-glossary/internet-of-things/ [accessed 4/5/2017].
[ii] *Popular Internet of Things Forecast of 50 Billion Devices by 2020 Is Outdated*, IEEE Spectrum, 2016. http://spectrum.ieee.org/tech-talk/telecom/internet/popular-internet-of-things-forecast-of-50-billion-devices-by-2020-is-outdated [accessed 4/5/2017].
[iii] Defined by the Food and Drug Administration (FDA) as "a medical device that delivers fluids into a patient's body in a controlled manner, either through the use of interconnected servers or via a standalone drug library-based medication delivery system." https://www.fda.gov/medicaldevices/productsandmedicalprocedures/generalhospitaldevicesandsupplies/infusionpumps/default.htm [accessed 4/5/2017].
[iv] *Principles of Medical Device Security,* Association for the Advancement of Medical Instrumentation (AAMI) Technical Information Report (TIR) 57, 2016, ix pp.

NIST SPECIAL PUBLICATION 1800-8B

Securing Wireless Infusion Pumps

In Healthcare Delivery Organizations

Volume B:
Approach, Architecture, and Security Characteristics

DRAFT

Gavin O'Brien
National Cybersecurity Center of Excellence
Information Technology Laboratory

Sallie Edwards
Kevin Littlefield
Neil McNab
Sue Wang
Kangmin Zheng
The MITRE Corporation
McLean, VA

May 2017

DISCLAIMER

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National Institute of Standards and Technology Special Publication 1800-8B Natl. Inst. Stand. Technol. Spec. Publ. 1800-8B, 90 pages, (May 2017), CODEN: NSPUE2

FEEDBACK

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

Comments on this publication may be submitted to: hit_nccoe@nist.gov.

Public comment period: May 8, 2017 through July 7, 2017

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

National Cybersecurity Center of Excellence
National Institute of Standards and Technology
100 Bureau Drive
Mailstop 2002
Gaithersburg, MD 20899
Email: nccoe@nist.gov

NATIONAL CYBERSECURITY CENTER OF EXCELLENCE

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

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

NIST CYBERSECURITY PRACTICE GUIDES

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

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

ABSTRACT

Medical devices, such as infusion pumps, were once standalone instruments that interacted only with the patient or medical provider. But today's medical devices connect to a variety of health care systems, networks, and other tools within a healthcare delivery organization (HDO). Connecting devices to point-of-care medication systems and electronic health records can improve healthcare delivery processes, however, increasing connectivity capabilities also creates cybersecurity risks. Potential threats include unauthorized access to patient health information, changes to prescribed drug doses, and interference with a pump's function.

The NCCoE at NIST analyzed risk factors in and around the infusion pump ecosystem using a questionnaire-based risk assessment to develop an example implementation that demonstrates how

HDOs can use standards-based, commercially available cybersecurity technologies to better protect the infusion pump ecosystem, including patient information and drug library dosing limits.

This practice guide will help HDOs implement current cybersecurity standards and best practices to reduce their cybersecurity risk, while maintaining the performance and usability of wireless infusion pumps.

KEYWORDS

authentication; authorization; digital certificates; encryption; infusion pumps; Internet of Things; IoT; medical devices; network zoning; pump servers; questionnaire-based risk assessment; segmentation; VPN; Wi-Fi; wireless medical devices

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The technology vendors who participated in this build submitted their capabilities in response to a notice in the Federal Register. Companies with relevant products were invited to sign a Cooperative

Research and Development Agreement (CRADA) with NIST, allowing them to participate in a consortium to build this example solution. We worked with:

Technology Partner/Collaborator	Build Involvement
Baxter Healthcare Corporation	• Sigma Spectrum LVP, version 8 • Sigma Spectrum Wireless Battery Module, version 8 • Sigma Spectrum Master Drug Library, version 8 • CareEverywhere Gateway Server, version 14
B. Braun Medical Inc.	• Infusomat® Space Infusion System/ Large Volume Pumps • DoseTrac® Infusion Management Software/ Infusion Pump Software
Becton, Dickinson and Company (BD)	• Alaris® 8015 PC Unit v9.19.2 • Alaris® Syringe Module 8110 • Alaris® LVP Module 8100 • Alaris® Systems Manager v4.2 • Alaris® System Maintenance (ASM) v 10.19
Cisco	• Access Point (AIR-CAP1602I-A-K9) • Wireless LAN Controller 8.2.111.0 • Cisco ISE • Cisco: ASA Catalyst 3650 Switch
Clearwater Compliance	Clearwater: IRM | Pro
DigiCert	CertCentral management account / Certificate Authority
Hospira Inc., a Pfizer Company (ICU Medical)	• Plum 360™ Infusion System, version 15.10 • LifeCare PCA™ Infusion System, version 7.02 • Hospira MedNet™, version 6.2

Technology Partner/Collaborator	Build Involvement
Intercede	MyID
MDISS	MDRAP
PFP Cybersecurity	Device Monitor
Ramparts	Risk Assessment
Smiths Medical	• Medfusion® 3500 V5 syringe infusion system • PharmGuard® Toolbox v1.5 • Medfusion 4000® Wireless Syringe Infusion Pump • CD, PHARMGUARD® TOOLBOX 2, V3.0 use with Medfusion® 4000 and 3500 V6 (US) • PharmGuard® Server Licenses, PharmGuard® Server Enterprise Edition, V1.1 • CADD®-Solis Ambulatory Infusion Pump • CADD™-Solis Medication Safety Software
Symantec Corporation	• Endpoint Protection (SEP) • Advanced Threat Protection: Network (ATP:N) • Server Advanced - DataCenter Security (DCS:SA):
TDi Technologies, Inc.	ConsoleWorks

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1 Summary

Medical devices, such as infusion pumps, were once standalone instruments that interacted only with the patient or medical provider [1]. With technological improvements designed to enhance patient care, these devices now connect wirelessly to a variety of systems, networks, and other tools within a healthcare delivery organization (HDO) – ultimately contributing to the Internet of Medical Things (IoMT).

In addition to managing interconnected medical devices, HDOs oversee complex, highly technical environments, from back-office applications for billing and insurance services, supply chain and inventory management, and staff scheduling to clinical systems such as radiological and pharmaceutical support. In this intricate healthcare environment, HDOs and medical device manufacturers that share responsibility and take a collaborative, holistic approach to reducing cybersecurity risks of the wireless infusion pump ecosystem can better protect healthcare systems, patients, PHI, and enterprise information.

The National Cybersecurity Center of Excellence (NCCoE) at the National Institute of Standards and Technology (NIST) developed an example implementation that demonstrates how HDOs can use standards-based, commercially available cybersecurity technologies to better protect the wireless infusion pump ecosystem, including patient information and drug library dosing limits.

The NCCoE's project has resulted in a NIST Cybersecurity Practice Guide, *Securing Wireless Infusion Pumps,* that addresses how to manage this challenge in clinical settings with a reference design and example implementation. Our example solution starts with two types of risk assessments: an industry analysis of risk and a questionnaire-based-risk assessment. With the results of that assessment, we then used a defense-in-depth strategy to secure the pump, server components, and surrounding network to create a better protected environment for wireless infusion pumps.

The solution and architectures presented here are built upon standards-based, commercially available products and represent one of many possible solutions and architectures. The example implementation can be used by any organization that is deploying wireless infusion pump systems and is willing to perform their own risk assessment and implement controls based on their risk posture.

For ease of use, here is a short description of the different sections of this volume.

Section 1: Summary presents the challenge addressed by the NCCoE project, with an in-depth look at our approach, the architecture, and the security characteristics we used; the solution demonstrated to address the challenge; benefits of the solution; and the technology partners that participated in building, demonstrating, and documenting the solution. The Summary also explains how to provide feedback on this guide.

Section 2: How to Use This Guide explains how readers like you—business decision makers, program managers, information technology (IT) professionals (e.g., systems administrators), and biomedical engineers—might use each volume of the guide.

Section 3: Approach offers a detailed treatment of the scope of the project, describes the assumptions on which the security platform development was based, the risk assessment that informed platform development, and the technologies and components that industry collaborators gave us to enable platform development.

Section 4: Risk Assessment and Mitigation highlights the risks we found, along with the potential response and mitigation efforts that can help lower risks for HDOs.

Section 5: Architecture describes the usage scenarios supported by project security platforms, including Cybersecurity Framework functions supported by each component contributed by our collaborators.

Section 6: Life Cycle Cybersecurity Issues discusses cybersecurity considerations from a product life cycle perspective including: procurement, maintenance, end of life.

Section 7: Security Characteristics Analysis provides details about the tools and techniques we used to perform risk assessments pertaining to wireless infusion pumps.

Section 8: Functional Evaluation summarizes the test sequences we employed to demonstrate security platform services, the Cybersecurity Framework functions to which each test sequence is relevant, and the NIST SP 800-53-4 controls that applied to the functions being demonstrated.

Section 9: Future Build Considerations is a brief treatment of other applications that NIST might explore in the future to further support wireless infusion pump cybersecurity.

Appendices provide acronym translations, references, a mapping of the wireless infusion pump project to the Cybersecurity Framework Core (CFC), and a list of additional informative security references cited in the CFC.

1.1 Challenge

The Food and Drug Administration (FDA) defines an *external infusion pump* as a medical device that delivers fluids into a patient's body in a controlled manner, using interconnected servers or via a standalone drug library-based medication delivery system [1]. In the past, infusion pumps were standalone instruments that interacted only with the patient and the medical provider. Now, connecting infusion pumps to point-of-care medication systems and electronic health records (EHRs) can help improve healthcare delivery processes, but using a medical device's connectivity capabilities can also create cybersecurity risk, which could lead to operational or safety risks.

Wireless infusion pumps are challenging to protect for several reasons. They can be infected by malware, which can cause them to malfunction or operate differently than originally intended. And traditional malware protection could negatively impact the pump's ability to operate efficiently. In

addition, most wireless infusion pumps contain a maintenance default passcode. If HDOs do not change the default passcodes when provisioning pumps, nor periodically change the passwords after pumps are deployed, this creates a vulnerability. This can make it difficult to revoke access codes when a hospital employee resigns from the job, for example. Furthermore, information stored inside infusion pumps also must be properly secured, including data from drug library systems, infusion rates and dosages, or protected health information (PHI) [2], [3], [4], [5], [6].

Additionally, like other devices with operating systems and software that connect to a network, the wireless infusion pump ecosystem creates a large *attack surface* (i.e., the different points where an attacker could get into a system, and where they could exfiltrate data out), primarily due to vulnerabilities in operating systems, subsystems, networks or default configuration settings that allow for possible unauthorized access [6], [7], [8]. Because many infusion pump models can be accessed and programmed remotely through a healthcare facility's wireless network, this vulnerability could be exploited to allow an unauthorized user to interfere with the pump's function, harming a patient through incorrect drug dosing or the compromise of that patient's PHI.

These risk factors are real, exposing the wireless pump ecosystem to external attacks, compromise or interference [6], [8], [9]. Digital tampering, intentional or otherwise, with a wireless infusion pump's ecosystem (the pump, the network, and data in and on the pump) can expose a healthcare delivery organization (HDO) to critical risk factors, such as malicious actors; loss of data; a breach of PHI; loss of services; loss of health records; the potential for downtime; and damage to an HDO's reputation, productivity, and bottom-line revenue.

This practice guide helps you address your assets, threats, and vulnerabilities by demonstrating how to perform a questionnaire-based risk assessment survey. After you complete the assessment, you can apply security controls to the infusion pumps in your area of responsibility to create a defense-in-depth solution to protect them from cybersecurity risks.

1.2 Solution

The NIST Cybersecurity Practice Guide *Securing Wireless Infusion Pumps* shows how biomedical engineers, networking engineers, security engineers and IT professionals, using commercially available, open source tools and technologies that are consistent with cybersecurity standards, can help securely configure and deploy wireless infusion pumps within HDOs.

In addition, the security characteristics of wireless infusion pump ecosystem are mapped to currently available cybersecurity standards and the Health Insurance Portability and Accountability Act (HIPAA) Security Rule. In developing our solution, we used standards and guidance from:

- NIST Framework for Improving Critical Infrastructure Cybersecurity (commonly known as the NIST CSF) [10]
- NIST Risk Management Framework (RMF) [11], [12], [13]

- NIST SP 800-53rev4 Security and Privacy Controls for Federal Information Systems and Organizations [14]
- Association for the Advancement of Medical Instrumentation (AAMI) Technical Information Report (TIR) 57 [9]
- International Electrotechnical Commission (IEC) 80001 and 80002 risk management for IT networks incorporating medical devices [15], [16], [17], [18], [19]
- Food and Drug Administration's (FDA) Postmarket Management of Cybersecurity in Medical Devices for building block standards for any medical device cybersecurity solution.

Ultimately, this practice guide:

- maps security characteristics to standards and best practices from NIST and other standards organizations, to the Health Insurance Portability and Accountability Act of 1996 (HIPAA) Security Rule [10], [14], [20], [21], [22]
- provides a detailed architecture and capabilities that address security controls
- provides a how-to for implementers and security engineers to recreate the reference design
- is modular and uses products that are readily available and interoperable with existing IT infrastructure and investments.

Your organization may choose to adopt this example solution, or one that adheres to these guidelines, or you may refer to this guide as a starting point for tailoring and implementing specific parts that best suit your organization's needs. Although the NCCoE used a suite of commercially available tools and technologies to address wireless infusion pump cybersecurity challenges, this guide does not endorse any specific products, nor does it guarantee compliance with any regulatory initiatives. Refer to your organization's information security experts to identify solutions that will best integrate with your organization's current tools and IT system infrastructure.

1.3 Benefits

The example solution presented in this practice guide offers several benefits, including:

- illustrating cybersecurity standards and best practice guidelines to better secure the wireless infusion pump ecosystem, such as the hardening of operating systems, segmenting the network, white listing, code-signing, and using certificates for both authorization and encryption, maintaining the performance and usability of wireless infusion pumps
- reducing risks from the compromise of information, including the potential for breach or loss of protected health information (PHI), as well as not allowing these medical devices to be used for anything other than the intended purposes
- documenting a defense-in-depth strategy to introduce layers of cybersecurity controls that avoid a single point of failure and provide strong support for availability. This strategy may include a variety of tactics: using network segmentation to isolate business units and user

138 access; applying firewalls to manage and control network traffic; hardening and enabling device
139 security features to reduce zero-day exploits; and implementing strong network authentication
140 protocols and proper network encryption, monitoring, auditing and intrusion detection and
141 prevention services (IDS/IPS).

142 - highlighting best practices for procurement of wireless infusion pumps by including the need for
143 cybersecurity features at the point of purchase

144 - calling upon industry to create new best practices for healthcare providers to consider when on-
145 boarding medical devices, with a focus on elements such as asset inventory, certificate
146 management, device hardening and configuration, and a clean-room environment to limit the
147 possibility of zero-day vulnerabilities.

148 2 How to Use This Guide

149 This NIST Cybersecurity Practice Guide demonstrates a standards-based reference design and provides
150 users with the information they need to replicate NCCoE's questionnaire-based risk assessment and
151 deployment of a defense in depth strategy. This reference design is modular and can be deployed in
152 whole or in parts.

153 This guide contains three volumes:

154 - NIST SP 1800-8A: *Executive Summary*

155 - NIST SP 1800-8B: *Approach, Architecture, and Security Characteristics* – what we built and why
156 **(you are here)**

157 - NIST SP 1800-8C: *How-To Guides* – instructions for building the example solution.

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

159 - **Business decision makers, including chief security and technology officers** will be interested in
160 the *Executive Summary (NIST SP 1800-8A)*, which describes the:

161 - challenges enterprises face in securing the wireless infusion pump ecosystem

162 - example solution built at the NCCoE

163 - benefits of adopting the example solution.

164 - **Technology or security program managers** concerned with how to identify, understand, assess,
165 and mitigate risk will be interested in this part of the guide, *NIST SP 1800-8B,* which describes
166 what we did and why. The following sections will be of particular interest:

167 - Section 4, Risk Assessment and Mitigation, describes the risk analysis we performed

168 - Section 4.3, Security Characteristics and Controls Mapping, maps the security
169 characteristics of this example solution to cybersecurity standards and best practices.

You might share the *Executive Summary, NIST SP 1800-8A,* with your leadership team to help them understand the significant risk of unsecured IoMT and the importance of adopting standards-based, commercially available technologies that can help secure the wireless infusion pump ecosystem.

IT professionals who want to implement an approach like this will find the whole practice guide useful. You can use the How-To portion of the guide, *NIST SP 1800-8C*, to replicate all or parts of the example implementation that we built in our lab. The How-To guide provides specific product installation, configuration, and integration instructions for implementing the example solution. We do not recreate the product manufacturers' documentation, which is generally widely available. Rather, we show how we incorporated the products together in our environment to create an example solution.

This guide assumes that IT professionals have experience implementing security products within the enterprise. While we have used a suite of commercial products to address this challenge, this guide does not endorse any products. Your organization can adopt this solution or one that adheres to these guidelines in part or in whole. Your organization's security experts should identify the products that will best integrate with your existing tools and IT system infrastructure. We hope you will seek products that are congruent with applicable standards and best practices. Section 4.4, Technologies lists the products we used and maps them to the cybersecurity controls provided by this reference solution.

A NIST Cybersecurity Practice Guide does not describe *the* solution, but rather a *possible* solution. This is a draft guide. We seek feedback on its contents and welcome your input. Comments, suggestions, and success stories will improve subsequent versions. Please contribute your thoughts by sending them to hit_nccoe@nist.gov.

2.1 Typographical Conventions

The following table presents typographic conventions used in this volume.

Typeface/Symbol	Meaning	Example
Italics	filenames and pathnames references to documents that are not hyperlinks, new terms, and placeholders	For detailed definitions of terms, see the *NCCoE Glossary.*
Bold	names of menus, options, command buttons and fields	Choose **File > Edit**.
`Monospace`	command-line input, on-screen computer output, sample code examples, status codes	`mkdir`

Typeface/Symbol	Meaning	Example
`Monospace Bold`	command-line user input contrasted with computer output	`service sshd start`
blue text	link to other parts of the document, a web URL, or an email address	All publications from NIST's National Cybersecurity Center of Excellence are available at https://nccoe.nist.gov.

3 Approach

Medical devices have grown increasingly powerful, offering patients improved, safer healthcare options with less physical effort for providers. To accomplish this, medical devices now contain operating systems and communication hardware that allow them to connect to networks and other devices. The connected functionality responsible for much of the improvement of medical devices poses challenges not formerly seen with standalone instruments.

Clinicians and patients rely on infusion pumps for safe and accurate administration of fluids and medications. However, the FDA has identified problems that can compromise the safe use of external infusion pumps [2], [3], [7]. These issues can lead to over- or under-infusion, missed treatments, or delayed therapy. The NCCoE initiated this project to help healthcare providers develop a more secure wireless infusion pump ecosystem, which can be applied to similarly connected medical devices. The wireless infusion pump was selected as a representative medical device. Throughout the remainder of this guide, the focus will be on the secure operation of the wireless infusion pump ecosystem. Both the architecture and security controls may be applied to increase the security posture for other types of medical devices. However, any application should be reviewed and tailored to the specific environment in which the medical device will operate.

Throughout the wireless infusion pump project, we collaborated with our Healthcare Community of Interest (COI) and cybersecurity vendors to identify infusion pump threat actors, define interactions between the actors and systems, review risk factors, develop an architecture and reference design, identify applicable mitigating security technologies, and design an example implementation. This practice guide highlights the approach used to develop the NCCoE reference solution. Elements include risk assessment and analysis, logical design, build development, test and evaluation and security control mapping. The practice guide seeks to help the healthcare community evaluate the security environment surrounding infusion pumps deployed in a clinical setting.

3.1 Audience

This guide is primarily intended for professionals implementing security solutions within an HDO. It may also be of interest to anyone responsible for securing non-traditional computing devices (i.e., the Internet of Things, or IoT).

More specifically, Volume B of the practice guide is designed to appeal to a wide range of job functions. This volume offers cybersecurity or technology decision makers within HDOs a view into how they can make the medical device environment more secure to help improve their enterprise's security posture and reduce enterprise risk. It offers technical staff guidance on architecting a more secure medical device network and instituting compensating controls.

3.2 Scope

The NCCoE project focused on securing the environment of the medical device and not re-engineering the device itself. To do this, we reviewed known vulnerabilities in wireless infusion pumps and examined how the architecture and component integration could be designed to increase the security of the device. The approach considered the life cycle of a wireless infusion pump from planning the purchase, to decommissioning, with a concentration on the configuration, use, and maintenance phases.

3.2.1 Assumptions

Considerable research, investigation, and collaboration went into the development of the reference design in this guide. The actual build and example implementation of this architecture occurred in a lab environment at the NCCoE. Although the lab is based on a clinical environment, it does not mirror the complexity of an actual hospital network. It is assumed that any actual clinical environment would represent additional complexity.

3.2.2 Security

We assume that those of you who plan to adopt this solution or any of its components have some degree of network security already in place. As a result, we focused primarily on new vulnerabilities that may be introduced if organizations implement the example solution. Section 4, Risk Assessment and Mitigation, contains detailed recommendations on how to secure the core components highlighted in this practice guide.

3.2.3 Existing Infrastructure

This guide may help you design an entirely new infrastructure. However, it is geared toward those with an established infrastructure, as that represents the largest portion of readers. Hospitals and clinics are likely to have some combination of the capabilities described in this reference solution. Before applying

any measures addressed in this guide, we recommend that you review and test them for applicability to your existing environment. No two hospitals or clinics are the same, and the impact of applying security controls will differ.

3.2.4 Technical Implementation

The guide is written from a how-to perspective. Its foremost purpose is to provide details on how to install, configure, and integrate components, and how to construct correlated alerts based on the capabilities we selected.

3.2.5 Capability Variation

We fully understand that the capabilities presented here are not the only security options available to the healthcare industry. Desired security capabilities may vary considerably from one provider to the next.

4 Risk Assessment and Mitigation

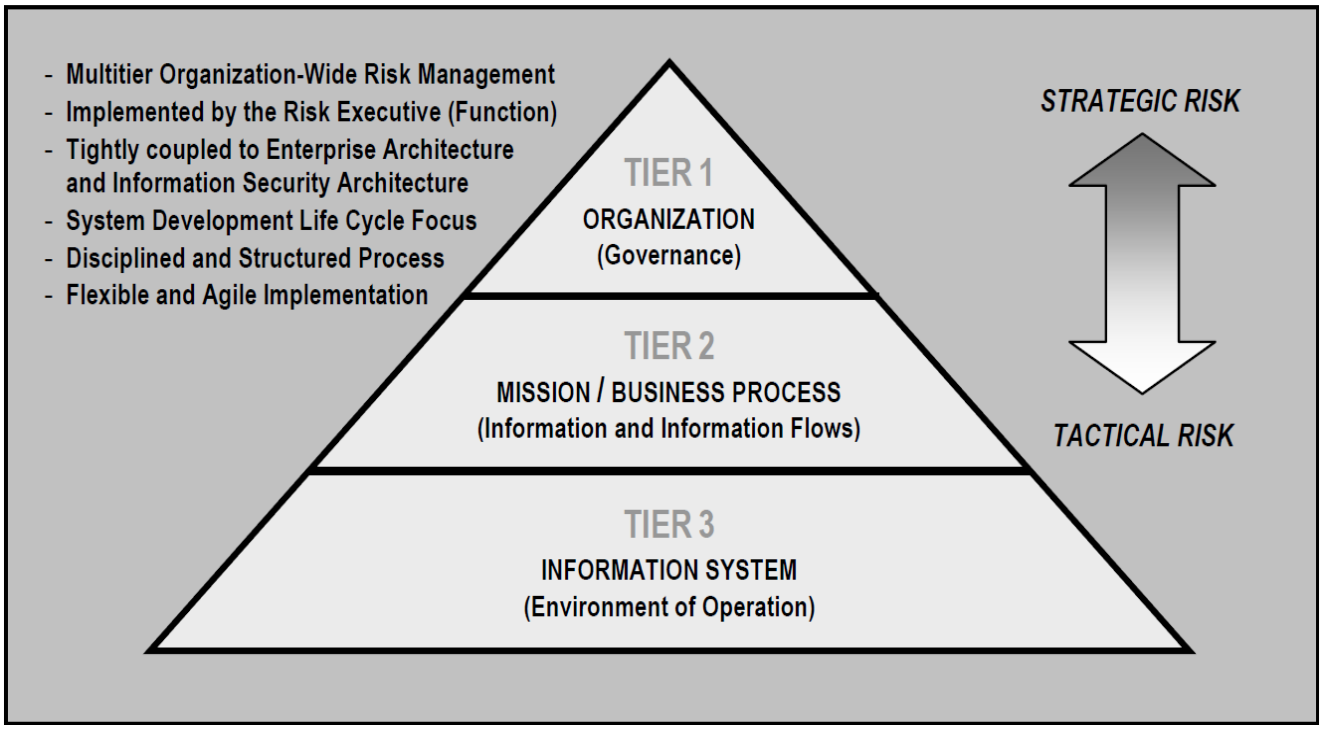
NIST SP 800-30, *Risk Management Guide for Information Technology Systems*, states, "Risk is the net negative impact of the exercise of a vulnerability, considering both the probability and the impact of occurrence. Risk management is the process of identifying risk, assessing risk, and taking steps to reduce risk to an acceptable level" [11].

We recommend that any discussion of risk management, particularly at the enterprise level, begin with a comprehensive review of NIST SP 800-37, *A Guide for Applying the Risk Management Framework to Federal Information Systems* [12].NIST's Risk Management Framework (RMF) guidance has provided invaluable advice in providing a baseline to assess risks, from which the NCCoE developed the project, the security characteristics of the solution, and this guide.

It is important to understand what constitutes the definition of risk as it relates to non-traditional information systems such as wireless infusion pumps. NIST SP 800-37 presents three tiers in the risk management hierarchy (Figure 4-1):

1. Organization
2. Business Processes
3. Information Systems

275 **Figure 4-1: Tiered Risk Management Approach (NIST SP 800-37)**



276

277 This guide focuses on the Tier 3 application of risk management but incorporates other industry risk
278 management and assessment standards and best practices for the context of networked medical
279 devices in HDOs. Relevant standards and best practices include:

280 ▪ International Electrotechnical Commission (IEC) 80001-1 (2010): Application of risk
281 management for IT-networks incorporating medical devices—Part 1: Roles, responsibilities, and
282 activities [23]

283 ▪ International Electrotechnical Commission/ Technical Report (IEC/TR) 80001-2: Application of
284 risk management for IT networks incorporating medical devices [16], [17], [18], [19]

285 ▪ International Standards Organization (ISO) 14971:2007 Medical devices—Application of risk
286 management to medical devices [24]

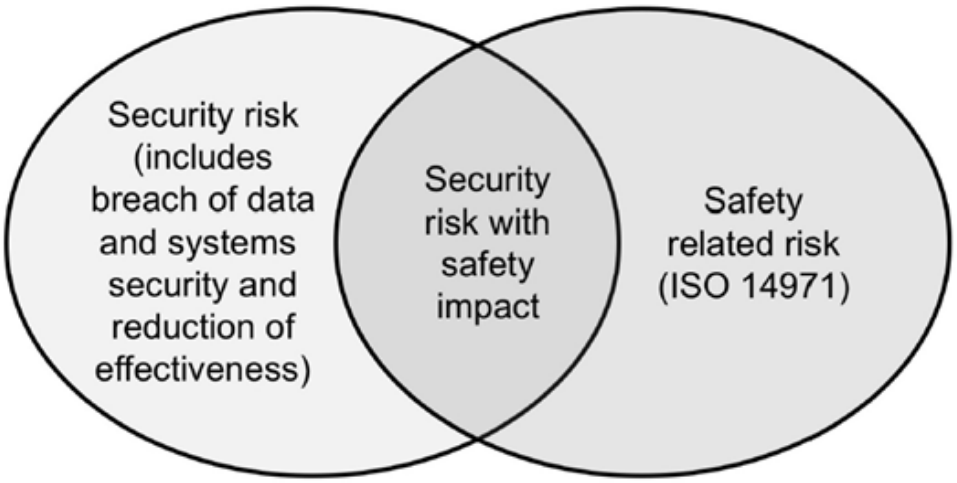
287 ▪ Association for the Advancement of Medical Instrumentation (AAMI) Technical Information
288 Report (TIR) 57: 2016 Principles for medical device security—risk management [9]

289 ▪ Food and Drug Administration (FDA) Postmarket Management of Cybersecurity in Medical
290 Devices [3].

291 For this NCCoE project, it was extremely important to understand the complexity of networked medical
292 devices in a system-of-systems environment. Additionally, we felt it necessary to understand where
293 security risks may have safety implications. The AAMI TIR57 was particularly useful in this regard, as it

specified elements of medical device security using NIST's RMF, IEC 80001-1, IEC/TR 80001-2 and ISO 14971 [9], [11], [12], [13], [15], [16], [17], [18], [19], [23], [24]. Also, the Venn diagram in Figure 4-2 illustrates the relationship between security and safety risks (AAMI TIR57). As seen in this diagram, there are cybersecurity risks that may have safety impacts. For HDOs, these risks should receive special attention from both security and safety personnel.

Figure 4-2: Relationship between Security and Safety Risks (AAMI TIR 57) [7]



4.1 Risk Assessments

For this NCCoE project, we performed two types of risk assessments: (1) industry analysis of risk and (2) questionnaire-based risk assessment.

4.1.1 Industry Analysis of Risk

The first assessment was an industry analysis of risk performed while developing the initial use case. This industry analysis provided insight into the challenges of integrating medical devices into a clinical environment containing a standard IT network. Completion of the industry analysis narrowed the objective of our use case to helping HDOs secure medical devices on an enterprise network, with a specific focus on wireless infusion pumps.

Activities involved in our industry analysis included reaching out to our COI and other industry experts through workshops and focus group discussions. After receiving feedback on the NCCoE's use case publication through a period of public comment, NCCoE adjudicated the comments and clarified a project description. These activities were instrumental to identifying primary risk factors as well as

educating our team on the uniqueness of cybersecurity risks involved in protecting medical devices in healthcare environments.

4.1.2 Questionnaire-based Risk Assessment

For the second type of risk assessment, we conducted a formal questionnaire-based risk assessment, using tools from two NCCoE Cooperative Research and Development Agreement (CRADA) collaborators. We conducted this questionnaire-based risk assessment to gain greater understanding of the risks surrounding the wireless infusion pump ecosystem. The tool identifies the risks and maps them to the security controls. This type of risk assessment is considered appropriate for Tier 3: Information Systems, per NIST's RMF. One tool focuses on medical devices and the surrounding ecosystem. The other tool focuses on the HDO enterprise. Both questionnaire-based risk assessment tools leverage guidance and best practices including the NIST RMF and CSF and focus on built-in threats, vulnerabilities, and controls [10], [11], [12], [13]. The assessment results measure likelihood, severity, and impact of potential threats.

All risk assessment activities provide an understanding of the challenges and risks involved when integrating medical devices, in this case wireless infusion pumps, into a typical IT network. Based on this analysis, this project has two fundamental objectives for this project:

- to protect the wireless infusion pumps from cyberattacks;
- to protect the healthcare ecosystem, should a wireless infusion pump be compromised.

Per AAMI's TIR57, "To assess security risk, several factors need to be identified and documented," (Hoyme & Geoff, 2016) [9].

Based on our risk assessments and additional research, we identified primary threats, vulnerabilities, and risks that should be addressed when using wireless infusion pumps in HDOs.

4.1.3 Assets

Defining the asset is the first step in establishing the asset-threat-vulnerability construct necessary to properly evaluate or measure risks, per NIST's RMF [11], [12], [13]. An information asset is typically defined as a software application or information system that uses devices or third-party vendors for support and maintenance. For the NCCoE's purposes, the information asset selected is a *Wireless Infusion Pump System.* A risk assessment of this asset would include an evaluation of the cybersecurity controls for the pump, pump server, end-point connections, network controls, data storage, remote access, vendor support, inventory control, and any other associated elements.

4.1.4 Threats

Below are some potential known threats in HDOs that use network-connected medical devices, such as wireless infusion pumps. Refer to Appendix A for a description of each threat.

- Targeted attacks
- Advanced Persistent Threats (APTs)
- Disruption of Service – Denial of Service (DoS) and Distributed Denial of Service (DDoS) attacks
- Malware infections
- Theft or loss of assets
- Unintentional misuse
- Vulnerable systems or devices directly connected to the device (e.g., via USB or other hardwired, non-network connections).

It is important to understand that the threat landscape is constantly evolving and unknown threats exist and may be unavoidable, which need to be identified and remediated as they are found.

4.1.5 Vulnerabilities

Vulnerabilities afflict wireless infusion pump devices, pump management applications, network applications and even the physical environment and personnel using the device or associated systems. Within a complex system-of-systems environment, vulnerabilities may be exploited at all levels. There are multiple information resources available to keep you informed about potential vulnerabilities. This guide recommends that security professionals turn to the National Vulnerability Database (NVD). The NVD is the U.S. government repository of standards-based vulnerability management data [https://nvd.nist.gov].

Here is a list of typical vulnerabilities that may arise when using wireless infusion pumps. Refer to Appendix B for a description of each vulnerability.

- Lack of asset inventory
- Long useful life
- Information/Data Vulnerabilities
  - Lack of encryption on private/sensitive data-at-rest
  - Lack of encryption on transmitted data
  - Unauthorized changes to device calibration or configuration data
  - Insufficient data backup
  - Lack of capability to de-identify private/sensitive data
  - Lack of data validation
- Device/Endpoint (Infusion Pump) Vulnerabilities
  - Debug-enabled interfaces

- Use of removable media
- Lack of physical tamper detection and response
- Misconfiguration
- Poorly protected and patched devices

- User or Administrator Accounts Vulnerabilities
  - Hard-coded or factory default passcodes
  - Lack of role-based access and/or use of principles of least privilege
  - Dormant accounts
  - Weak remote access controls
- IT Network Infrastructure Vulnerabilities
  - Lack of malware protection
  - Lack of system hardening
  - Insecure network configuration
  - System complexity.

To mitigate risk factors, HDOs should also strive to work closely with medical device manufacturers and follow FDA's post-market guidance, as well as instructions from the U.S. Department of Homeland Security's Industrial Control System-Cyber Emergency Response Team (ICS-CERT).

4.1.6 Risks

NIST SP 800-30, *A Guide for Conducting Risk Assessments,* defines *risk* as, "a measure of the extent to which an entity is threatened by potential circumstance or event, and is typically a function of: (i) the adverse impacts that would arise if the circumstance or event occurs; and (ii) the likelihood of occurrence" [11]

NIST SP 800-30 further notes within a definition of *risk assessment* that, "assessing risk requires careful analysis of threat and vulnerability information to determine the extent to which circumstances or events could adversely impact an organization and the likelihood that such circumstances or events will occur."

Based on the above guidance from NIST SP 800-30, several risks endanger medical devices:

- Infusion pumps and server components may be leveraged for APTs and serve as pivot points to cause adverse conditions throughout a hospital's infrastructure.
- Infusion pumps may be manipulated to prevent the effective implementation of safety measures, such as the drug library.

- Infusion pump interfaces may be used for unintended or unexpected purposes, with those conditions leading to degraded performance of the pump.
- PHI may be accessed remotely by unauthorized individuals.
- PHI may be disclosed to unauthorized individuals should the device be lost, stolen, or improperly decommissioned.
- Improper third party vendor connections.

Although these risks may persist in infusion pumps and server components, HDOs should perform appropriate due diligence in determining the extent of the business impact and likelihood of each risk factor.

Vulnerabilities may be present in infusion pumps and their server components since these devices often include embedded operating systems on the endpoints. Infusion pumps are designed to maintain a prolonged period of useful life, and, as such, may include system components (e.g., an embedded operating system) that may either reach end-of-life or reach a period of degraded updates prior to the infusion pump being retired from service. Patching and updating may become difficult over the course of time.

Infusion pumps may not allow for the addition of third-party mechanisms, such as antivirus or anti-malware controls. Should limitations be identified in embedded operating systems used by an infusion pump, vulnerabilities, weaknesses, and deficiencies may become known to malicious actors who may seek to leverage those deficiencies to install malicious or unauthorized software on those devices.

Malicious software, or malware, may cause adverse conditions on the pump, degrading the performance of the pump, or rendering the device unable to perform its function (e.g., ransomware). Malware may also be used to convert the infusion pump into an access point for malicious actors to subsequently access or disrupt the operations of other hospital systems.

As noted above, infusion pumps may allow for the manipulation of configurations or safety measures implemented through the drug library (e.g., adjusting dosage or flow rates). This risk may be instantiated through local access, such as an interface or port on the device with either no or weak authentication or access control in place. Further, infusion pumps may be reachable across a hospital's network, which provides an avenue for a malicious actor to cause an adverse event.

Pumps may implement local ports, such as USB ports serial interfaces, Bluetooth, radio frequency, or other mechanisms that allow for close proximity connection to the pump. These ports may be implemented with the intent to facilitate technical support; however, they also pose a risk by providing a pathway for actors to cause adverse conditions to the pump.

Modern infusion pumps and server components may include PHI, such as a patient's name, medical record number (MRN), procedure coding, and medication or treatment. Through similar deficiencies that would allow configuration or use manipulation as noted above, this PHI may then be viewed,

accessed, or removed by unauthorized individuals. Also, individuals who have direct access to the infusion pump may be able to extract information through unsecured ports or interfaces [2], [3], [7], [17], [25].

Common vulnerabilities and control deficiencies that enable these risks may include:

- **The implementation of default credentials and passwords:** Weak authentication, and default passwords, or not implementing authentication or access control, may be discovered by malicious actors who would seek to cause adverse conditions. Malicious actors may leverage this control deficiency for risk factors that span from installing malware on the infusion pump, to manipulating configuration settings, or to extract information such as PHI from the device.
- **The use of unsecured network ports, such as Telnet or FTP:** Telnet and FTP are internet protocols that do not secure or encrypt network sessions. Telnet and FTP may be used nominally for technical support interfaces; however, malicious actors may attempt to leverage these to access the infusion pump. Telnet and FTP may include deficiencies that allow for compromise of the protocol itself, and, since the network session is not encrypted, malicious actors may implement mechanisms to capture network sessions, including any authentication traffic, or to identify sensitive information such as credentials, configuration information, or any PHI stored on the device.
- **Local interfaces with limited security controls:** Local interfaces, such as USB ports, serial ports, Bluetooth, radio frequency, or other ports may be used for device technical support. These ports, however, allow for malicious actors within close proximity to the device to access the device, manipulate configuration settings, access or remove data from the device, or install malware on the device. These ports may exist on the pump for support purposes, but use of the ports for unauthorized or unexpected purposes, such as recharging a mobile device such as a smart phone or tablet, may cause a disruption to the pump's standard operation.

4.1.7 Recommendations and Best Practices

The recommendations in Appendix C address additional security concerns which, although not as pressing as those listed above, are worthy of consideration. If applied, these additional recommendations will likely reduce risk factors or prevent them from becoming greater risks. Associated best practices for reducing the overall risk posture of infusion pumps are also included in Recommendations and Best Practices list.

4.2 Risk Response Strategy

Risk mitigation is often confused with *risk response*. Per NIST SP 800-30, risk mitigation is defined as "prioritizing, evaluating, and implementing the appropriate risk-reducing controls/countermeasures recommended from the risk management process."

Risk mitigation is a subset of risk response. Risk response is defined by NIST SP 800-30 as: accepting; avoiding; mitigating; sharing, or transferring risks. When considering risk response, your organization should recommend to a corporate risk management board ways that the Information Risk Manager or equivalent should treat risk.

4.2.1 Risk Mitigation

Organizations must determine their tolerance or appetite for risk, the response to which will drive risk remediation or risk mitigation for identified risks. This tolerance should be codified in a Risk Management Plan. Such a plan will include regulatory requirements and guidance, industry best practices, and security controls. Organizations should set an appropriate risk tolerance based on the factors noted above with the intent to remediate those risks above the established risk tolerance (i.e., critical or high risks.)

These remediation responses can take the form of administrative, physical, and technical controls, or an appropriate mix. Section 4.1.7 of this guide identifies several mitigation recommendations regarding specific risk. Additional compensating safeguards, countermeasures, or controls are noted below:

- Physical security controls, including standard tamper-evident physical seals, which can be applied to hardware to indicate unauthorized physical access [10], [26].
- Ensuring implementation of a physical asset management program that manages and tracks unique, mobile media such as removable flash memory devices (e.g., SD cards, thumb drives) used by pump software hosted on an endpoint client. Consider encryption of all portable media used in such a fashion [10], [26], [27], [28].
- Following procedures for clearing wireless network authentication credentials on the endpoint client if the pump is to be removed or transported from the facility. These procedures can be found in pump user manuals but should be referenced in official HDO policies and procedures [29], [30], [31], [32].
- Changing wireless network authentication credentials regularly and, if there is evidence of unauthorized access to a pump system, immediately changing network authentication credentials [10], [26].
- Ensuring all wireless network access is minimally configured for WPA2 PSK encryption and authentication. All pumps should be set to WPA2 encryption [33], [34], [35], [36].
- All pumps and pump systems should include cryptographic modules that have been validated as meeting NIST FIPS 140-2 [37].
- All ports are disabled except when in use, and the device has no listening ports [3], [9], [10], [25], [26].
- Employing mutual transport layer security (TLS) encryption in transit between the client and server [38].

- Employing individual pump authentication with no shared key for all pumps [10], [26].
- Certificate-based authentication for a pump server [29], [30], [31], [32].

4.3 Security Characteristics and Controls Mapping

As described in the previous sections, we derived the security characteristics by analyzing risk in collaboration with our healthcare sector stakeholders as well as our participating vendor partners. In the risk analysis process, we used IEC/TR 80001-2-2 as our basis for wireless infusion pump capabilities in healthcare environments [16]. Table 4-1 presents the desired security characteristics of the use case in terms of the CSF subcategories [10], [14]. Each subcategory is mapped to relevant NIST standards, industry standards, controls, and best practices. In our example implementation, we did not observe any security characteristics that mapped to the Respond or Recover subcategories of the CSF.

Table 4-1: Security Characteristics and Controls Mapping - NIST Cyber Security Framework

Cybersecurity Framework (CSF) v1.1				Sector-Specific Standards & Best Practices		
Function	**Category**	**Subcategory**	**SP800-53R4**	**IEC TR 80001-2-2**	**HIPAA Security Rule 45 [39]**	**ISO/IEC 27001:2013**
IDENTIFY (ID)	Asset Management (ID.AM)	ID.AM-1: Physical devices and systems within the organization are inventoried	CM-8	CNFS	C.F.R. §§ 164.308(a)(1)(ii)(A), 164.310(a)(2)(ii), 164.310(d)	A.8.1.1, A.8.1.2
		ID.AM-5: Resources (e.g., hardware, devices, data, time, and software) are prioritized based on their classification, criticality, and business value	CP-2, RA-2, SA-14	DTBK	C.F.R. § 164.308(a)(7)(ii)(E)	A.8.2.1
	Business Environment (ID.BE)	ID.BE-4: Dependencies and critical functions for delivery of critical services are established	CP-8, PE-9, PE-11, PM-8, SA-14	DTBK	C.F.R. §§ 164.308(a)(7)(i), 164.308(a)(7)(ii)(E), 164.310(a)(2)(i), 164.312(a)(2)(ii), 164.314(a)(1), 164.314(b)(2)(i)	A.11.2.2, A.11.2.3, A.12.1.3
	Risk Assessment (ID.RA)	ID.RA-1: Asset vulnerabilities are identified and documented	CA-2, CA-7, CA-8, RA-3, RA-5, SA-5, SA-11, SI-2, SI-4, SI-5	RDMP	C.F.R. §§ 164.308(a)(1)(ii)(A), 164.308(a)(7)(ii)(E), 164.308(a)(8), 164.310(a)(1), 164.312(a)(1), 164.316(b)(2)(iii)	A.12.6.1, A.18.2.3

Cybersecurity Framework (CSF) v1.1				Sector-Specific Standards & Best Practices		
Function	**Category**	**Subcategory**	**SP800-53R4**	**IEC TR 80001-2-2**	**HIPAA Security Rule 45 [39]**	**ISO/IEC 27001:2013**
PROTECT (PR)	Identity Management and Access Control (PR.AC)	(note: not directly mapped in CSF)	AC-1, AC-11, AC-12	ALOF		
		PR.AC-1: Identities and credentials are issued, managed, revoked, and audited for authorized devices, users, and processes	AC-2, IA Family	AUTH, CNFS, EMRG, PAUT	C.F.R. §§ 164.308(a)(3)(ii)(B), 164.308(a)(3)(ii)(C), 164.308(a)(4)(i), 164.308(a)(4)(ii)(B), 164.308(a)(4)(ii)(C), 164.312(a)(2)(i), 164.312(a)(2)(ii), 164.312(a)(2)(iii), 164.312(d)	A.9.2.1, A.9.2.2, A.9.2.4, A.9.3.1, A.9.4.2, A.9.4.3
		PR.AC-2: Physical access to assets is managed and protected	PE-2, PE-3, PE-4, PE-5, PE-6, PE-9	PLOK, TXCF, TXIG	C.F.R. §§ 164.308(a)(1)(ii)(B), 164.308(a)(7)(i), 164.308(a)(7)(ii)(A), 164.310(a)(1), 164.310(a)(2)(i), 164.310(a)(2)(ii), 164.310(a)(2)(iii), 164.310(b), 164.310(c), 164.310(d)(1), 164.310(d)(2)(iii)	A.11.1.1, A.11.1.2, A.11.1.4, A.11.1.6, A.11.2.3
		PR.AC-3: Remote access is managed	AC-17, AC-19, AC-20	NAUT, PAUT	C.F.R. §§ 164.308(a)(4)(i), 164.308(b)(1), 164.308(b)(3), 164.310(b), 164.312(e)(1), 164.312(e)(2)(ii)	A.6.2.2, A.13.1.1, A.13.2.1
		PR.AC-4: Access permissions and authorizations are managed, incorporating the principles of least privilege and separation of duties	AC-2, AC-3, AC-5, AC-6, AC-16	AUTH, CNFS, EMRG, NAUT, PAUT	C.F.R. §§ 164.308(a)(3), 164.308(a)(4), 164.310(a)(2)(iii), 164.310(b), 164.312(a)(1), 164.312(a)(2)(i), 164.312(a)(2)(ii)	A.6.1.2, A.9.1.2, A.9.2.3, A.9.4.1, A.9.4.4

Cybersecurity Framework (CSF) v1.1				Sector-Specific Standards & Best Practices		
Function	**Category**	**Subcategory**	**SP800-53R4**	**IEC TR 80001-2-2**	**HIPAA Security Rule 45 [39]**	**ISO/IEC 27001:2013**
		PR.AC-5: Network integrity is protected, incorporating network segregation where appropriate	AC-4, SC-7	NAUT	C.F.R. §§ 164.308(a)(4)(ii)(B), 164.310(a)(1), 164.310(b), 164.312(a)(1), 164.312(b), 164.312(c), 164.312€	A.13.1.1, A.13.1.3, A.13.2.1
	Data Security (PR.DS)	PR.DS-1: Data-at-rest is protected	SC-28	IGAU, STCF	C.F.R. §§ 164.308(a)(1)(ii)(D), 164.308(b)(1), 164.310(d), 164.312(a)(1), 164.312(a)(2)(iii), 164.312(a)(2)(iv), 164.312(b), 164.312(c), 164.314(b)(2)(i), 164.312(d)	A.8.2.3
		PR.DS-2: Data-in-transit is protected	SC-8	IGAU, TXCF	C.F.R. §§ 164.308(b)(1), 164.308(b)(2), 164.312(e)(1), 164.312(e)(2)(i), 164.312(e)(2)(ii), 164.314(b)(2)(i)	A.8.2.3, A.13.1.1, A.13.2.1, A.13.2.3, A.14.1.2, A.14.1.3
		PR.DS-4: Adequate capacity to ensure availability is maintained	AU-4, CP-2, SC-5	AUDT, DTBK	C.F.R. §§ 164.308(a)(1)(ii)(A), 164.308(a)(1)(ii)(B), 164.308(a)(7), 164.310(a)(2)(i), 164.310(d)(2)(iv), 164.312(a)(2)(ii)	A.12.3.1
		PR.DS-6: Integrity checking mechanisms are used to verify software, firmware, and information integrity	SI-7	IGAU	C.F.R. §§ 164.308(a)(1)(ii)(D), 164.312(b), 164.312(c)(1), 164.312(c)(2), 164.312(e)(2)(i)	A.12.2.1, A.12.5.1, A.14.1.2, A.14.1.3

Cybersecurity Framework (CSF) v1.1				Sector-Specific Standards & Best Practices		
Function	**Category**	**Subcategory**	**SP800-53R4**	**IEC TR 80001-2-2**	**HIPAA Security Rule 45 [39]**	**ISO/IEC 27001:2013**
	Information Protection Processes and Procedures (PR.IP)	PR.IP-1: A baseline configuration of information technology/industrial control systems is created and maintained incorporating appropriate security principles (e.g. concept of least functionality)	CM-2, CM-3, CM-4, CM-5, CM-6, CM-7, CM-9, SA-10	CNFS, CSUP, SAHD, RDMP	C.F.R. §§ 164.308(a)(8), 164.308(a)(7)(i), 164.308(a)(7)(ii)	A.12.1.2, A.12.5.1, A.12.6.2, A.14.2.2, A.14.2.3, A.14.2.4
		PR.IP-4: Backups of information are conducted, maintained, and tested periodically	CP-4, CP-6, CP-9	DTBK	C.F.R. §§ 164.308(a)(7)(ii)(A), 164.308(a)(7)(ii)(B), 164.308(a)(7)(ii)(D), 164.310(a)(2)(i), 164.310(d)(2)(iv)	A.12.3.1, A.17.1.2, A.17.1.3, A.18.1.3
		PR.IP-6: Data is destroyed according to policy	MP-6	DIDT	C.F.R. §§ 164.310(d)(2)(i), 164.310(d)(2)(ii)	A.8.2.3, A.8.3.1, A.8.3.2, A.11.2.7
		PR.MA-2: Remote maintenance of organizational assets is approved, logged, and performed in a manner that prevents unauthorized access	MA-4	CSUP	C.F.R. §§ 164.308(a)(3)(ii)(A), 164.310(d)(1), 164.310(d)(2)(ii), 164.310(d)(2)(iii), 164.312(a), 164.312(a)(2)(ii), 164.312(a)(2)(iv), 164.312(b), 164.312(d), 164.312(e), 164.308(a)(1)(ii)(D)	A.11.2.4, A.15.1.1, A.15.2.1

Cybersecurity Framework (CSF) v1.1				Sector-Specific Standards & Best Practices		
Function	**Category**	**Subcategory**	**SP800-53R4**	**IEC TR 80001-2-2**	**HIPAA Security Rule 45 [39]**	**ISO/IEC 27001:2013**
DETECT (DE)	Anomalies and Events (DE.AE)	DE.AE-1: A baseline of network operations and expected data flows for users and systems is established and managed	AC-4, CA-3, CM-2, SI-4	AUTH, CNFS	C.F.R. §§ 164.308(a)(1)(ii)(D), 164.312(b)	none
	Security Continuous Monitoring (DE.CM)	DE.CM-1: The network is monitored to detect potential cybersecurity events	AC-2, AU-12, CA-7, CM-3, SC-5, SC-7, SI-4	AUTH, CNFS, EMRG, MLDP	C.F.R. §§ 164.308(a)(1)(ii)(D), 164.308(a)(5)(ii)(B), 164.308(a)(5)(ii)(C), 164.308(a)(8), 164.312(b), 164.312(e)(2)(i)	none
		DE.CM-3: Personnel activity is monitored to detect potential cybersecurity events	AC-2, AU-12, AU-13, CA-7, CM-10, CM-11	AUTH, CNFS, EMRG, MLDP	C.F.R. §§ 164.308(a)(1)(ii)(D), 164.308(a)(3)(ii)(A), 164.308(a)(5)(ii)(C), 164.312(a)(2)(i), 164.312(b), 164.312(d), 164.312€	A.12.4.1
		DE.CM-4: Malicious code is detected	SI-3	IGAU, MLDP, TXIG	C.F.R. §§ 164.308(a)(1)(ii)(D), 164.308(a)(5)(ii)(B)	A.12.2.1
		DE.CM-6: External service provider activity is monitored to detect potential cybersecurity events	CA-7, PS-7, SA-4, SA-9, SI-4	RDMP	C.F.R. § 164.308(a)(1)(ii)(D)	A.14.2.7, A.15.2.1
	Detection Processes (DE.DP)	DE.DP-3: Detection processes are tested	CA-2, CA-7, PE-3, PM-14, SI-3, SI-4	IGAU	C.F.R. § 164.306€	A.14.2.8
RESPOND (RS)						
RECOVER (RC)						

4.4 Technologies

Table 4-2 lists all of the technologies used in this project and map the generic application term to the specific product we used and the security control(s) we deployed. Refer to Table 4-1 for an explanation of the CSF Subcategory codes [10].

The reference architecture design in Section 5 is vendor agnostic such that any Wireless Infusion Pump (WIP) system can be integrated safely and securely into a hospital's IT infrastructure. Therefore, for the infusion pump device, infusion pump server and wireless infusion pump ecosystem, we captured the most common security features among all the products we tested in this use case. A normalized view of the list of functions and NIST CSF Subcategories are presented in the table below.

Please note, some of the CSF Subcategory codes require people, and process controls, not solely technical controls.

Table 4-2: Products and Technologies

Component	Specific Product	Function	CSF Subcategories
Infusion Pump Device	Baxter: Sigma Spectrum LVP, Version 8 Baxter: Sigma Spectrum Wireless Battery Module, version 8 BBraun: Space Infusomat Infusion Pump (LVP) – s/w U BD: Alaris® 8015 PC Unit v9.19.2 BD: Alaris® Syringe Module 8110	• requires passcode to access the bio-medical engineering mode (on device or connect to device) for configuring and setting up the devices • provides the capability to change the manufacture default passcode • supports IEEE 802.11i enterprise wireless encryption/authentication standards, including WPA2-EAP-TLS for protecting data exchange • restricted access to the server, application and stored data • closes/disables all communication ports that are not required for the intended use	PR.AC-1, PR.AC-2, PR.DS-2, PR.DS-6, PR.IP-1, PR.IP-6

Component	Specific Product	Function	CSF Subcategories
	BD: Alaris® LVP Module 8100	• closes/disables all services that are not required for intended use • provides an integrity checking mechanism to verify information • supports baseline configuration • supports removing/destroying data from the device • few models have a tamper-resist switch, with tamper-evident seals	
	Hospira: Plum 360 version15.10		
	Hospira: PCA version 7.02		
	Smiths Medical: Medfusion® 3500 V5 syringe infusion system		
	Smiths Medical: Medfusion 4000® Wireless Syringe Infusion Pump		
	Smiths Medical: CADD®-Solis Ambulatory Infusion Pump		
Infusion Pump Server	Baxter: CareEverywhere Gateway Server, version 14	• with appropriate configuration, discovers and identifies devices connected to the pump server via wired, wireless, and virtual private networks, to aid in building and maintaining accurate physical device inventories • supports role-based authentication and password rules and policies • supports the use of a HDO's Active Directory/LDAP solution • supports auto-logoff, data encryption/obscuration	ID.AM-1, PR.AC-1, PR.AC-3, PR.AC-4, PR.DS-1, PR.DS-2, PR.MA-2
	BBraun: Space Online Suite Software, version AP 2.0.1		
	BD: Alaris® Systems Manager v4.2		
	Hospira: MedNet 6.2		

Component	Specific Product	Function	CSF Subcategories
	Smiths Medical: PharmGuard® Server Enterprise Edition, V1.1	• can be accessed remotely via VPN (or like) tools • a few models support FIPS 140-2 • operates on manufacturer-supported OS, DB Server and Web Server (allows software patches) • supports secure protocols, such as TLS • supports co-existence with firewall, anti-virus, backup software, and other types of security safeguard products • maintains different types of audit/log records for preventing • unauthorized access	
Infusion Pump Ecosystem	Baxter: Sigma Spectrum Master Drug Library, version 8		
	BBraun: Space DoseTrace and Space DoseLink software – Eng version available for testing		
	BD: Alaris® System Maintenance (ASM) v 10.19		
	Smiths Medical: PharmGuard® Toolbox v1.5		
	Smiths Medical: CADD™-Solis Medication Safety Software		
Access Point (AP)	Cisco: Access Point (AIR-CAP1602I-A-K9	• authenticates and connects infusion pumps to the Wi-Fi • supports Wireless Network Standards: IEEE 802.11a/b/g/n/ac • supports Security Protocols: IEEE 802.11i (WPA2), EAP-TLS • AP joins a WLC to form a Control and Provisioning of Wireless Access Points protocol (CAPWAP) tunnel	PR.AC-5, PR.DS-1, PR.DS-2, DE.CM-1, DE.CM-3
Wireless LAN Controller (WLC)	Cisco: Wireless LAN Controller 8.2.111.0		

Component	Specific Product	Function	CSF Subcategories
		• uses ISE as the authentication service • provides message authentication and encryption in data transmission	
Identity Services Engine (ISE)	Cisco ISE	• discovers and identifies devices connected to wired, wireless, and virtual private networks. It gathers this information based on what's accurate connecting to the network, a key step toward building and maintaining accurate physical device inventories • provides advanced network access controls by connecting user identity with device profiling and access policy • provides log audit of events which can be monitored for the network traffic	ID.AM-1, PR.AC-1, PR.AC-4, PR.DS-1, PR.DS-2, DE.CM-1, DE.CM-3
Firewall/Router	Cisco: ASA	• delivers network integrity protection • used as external firewall for connecting to the internet for guest network • used as internal firewall for all other network zones with rules and policies	PR.AC-5, PR.DS-1, PR.DS-2, DE.CM-1, DE.CM-3
Switch	Cisco: Catalyst 3650 Switch	• provides port-level controls, port blocking, VLAN segmentation	PR.AC-5, PR.DS-1, PR.DS-2, DE.CM-1, DE.CM-3
Endpoint Protec-tion	Symantec: Endpoint Protection (SEP)	• provides intrusion prevention, URL, and firewall policies • provides application behavioral controls • provides device control to restrict access • provides anti-virus file protection	DE.CM-1, DE.CM-3, DE.CM-4, PR.DS-1, PR.DS-2, DE.AE-1

Component	Specific Product	Function	CSF Subcategories
		• Provides behavioral monitoring • Provides file reputation analysis	
Network Advanced Threat Protection	Symantec: Advanced Threat Protection: Network (ATP:N)	• monitors internal inbound and outbound internet traffic • uncovers advanced attacks • automatically prioritizes critical events • searches for known indicators-of-compromise (IoC) across the entire environment • blacklists or whitelists files and URLs once they are identified as malicious • can be integrated with third-party security information and events management (SIEM) tool	DE.CM-1, DE.CM-4, PR.DS-1, PR.DS-2, DE.AE-1
DataCenter Security	Symantec: Server Advanced - DataCenter Security (DCS:SA):	• out-of-the-box host intrusion detection system (IDS) and intrusion prevention systems (IPS) policies • provides sandboxing and Process Access Control (PAC) to prevent a new class of threats • hosts firewall to control inbound and outbound network traffic to and from servers • compensating host intrusion prevention system (HIPS) controls restrict application and operating system behavior using policy-based least privilege access control • prevents file and system tampering	DE.CM-1, DE.CM-4, PR.DS-1, PR.DS-2, DE.AE-1

Component	Specific Product	Function	CSF Subcategories
		• provides application and device control by locking down 'configuration' settings, file systems, and use of removable media	
Secure Remote Management and Monitoring	TDi Technologies: ConsoleWorks	• authenticates system managers • provides role-based access control of system management functions • implements a protocol break between the system manager and the managed assets • records all system management actions • performs remote configuration management and monitoring of devices	PR.AC-3, PR.AC-4, PR.MA-2, PR.PT-1, PR.PT-3, DE.CM-1, DE.CM-3, DE.CM-4, DE.CM-6
Physics-based integrity assessment	PFP: Device Monitor	• detects device behavior • detects cyberattacks in hardware and software • detects tiny anomalies in power patterns to instantly catch attacks, thereby providing an early warning that a device has been tampered with • integrity assessment uses side channel	
Certificate Authority Service	DigiCert: Certificate Authority	• provides certificate authority service	Access Control (PR.AC) PR.DS-2
Certificate Management / Provisioning	Intercede: MyID	• serves as device provisioner	

Component	Specific Product	Function	CSF Subcategories
Risk Assessment	Clearwater: IRM | Pro	• provides tool for conducting risk assessments that focus on healthcare compliance and cyber risk management	ID.RA-1
	MDISS: MDRAP	• provides tool for conducting risk assessments that focus on medical devices	

535

5 Architecture

Wireless infusion pumps are no longer standalone devices; they now also include pump servers for managing the pumps, drug libraries, networks allowing for interoperability with other hospital systems, and VPN tunnels to outside organizations for maintenance. While interconnectivity, enhanced communications, and safety measures on the pump have added complexity to infusion pumps, these components can help improve patient outcomes and safety.

As infusion pumps have evolved, one safety mechanism development was the invention of the "drug library." The drug library is a mechanism that is applied to an infusion pump that catalogs medications, fluids, dosage, and flow rates. While hospital pharmacists may be involved in the maintenance of the drug library, continuous application of the drug library to the infusion pump environment tends to be managed through a team of biomedical engineers. Initially, the drug library file may be loaded onto the pump through a communication port. When the drug library file is updated, all infusion pumps need to be updated to ensure that they adhere to the current rendition of that drug library. Drug library distribution, which may require that staff manually adjust individual pumps, may become onerous for the biomedical staff in HDOs that use thousands of pumps [1], [40].

Manufacturers provide wireless communications on some pumps and use a pump server to manage the drug library file, capture usage information on the pumps, and provide pump updates.

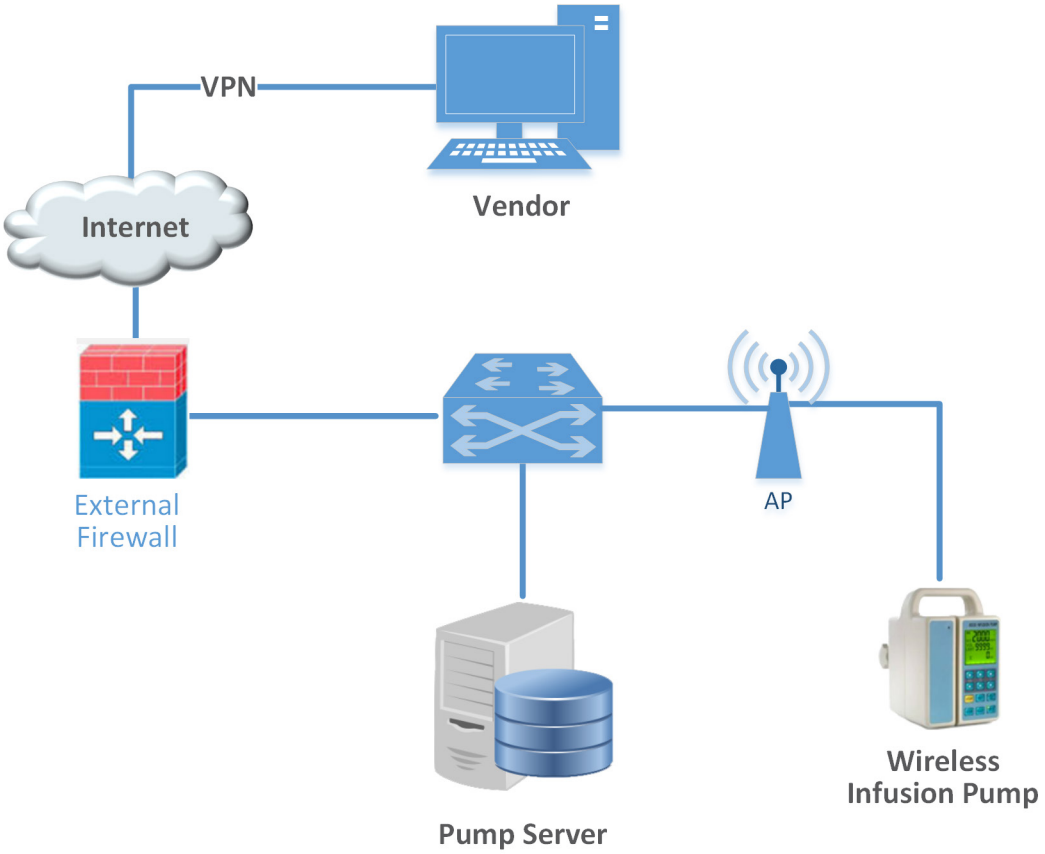
Medical devices manufacturers are subject to regulatory practices by the Food & Drug Administration (FDA), and may tend to focus on the primary function of the pump (i.e., assurance that the pump delivers fluids of a certain volume and defined flow rates, consistent with needs that providers may have to ensure safe and appropriate patient care). Technology considerations, such as cybersecurity controls, may not be primarily addressed in the device design and approval process. As such, infusion pumps may include technology that does not lend itself to the same controls that an HDO may implement on standard desktops, laptops, or workstations used for productivity [9], [18].

As technology has evolved, cybersecurity risk has expanded, both in visibility and in the number of threats and vulnerabilities. This expansion has led to a heightened concern, from manufacturers, as well as the FDA, and work has been established to identify measures to better respond to cybersecurity risk [7], [9], [25]. In Section 5.1, we describe the wireless infusion pump ecosystem by defining the components. Section 5.2 discusses the data flow, and Section 5.3 explains the set of controls we use in our example implementation, including those for networks, pumps, pump servers, and enterprise. Section 5.4 describes the target architecture for our example implementation.

5.1 Basic System

A basic wireless infusion pump ecosystem includes a wireless infusion pump, a pump server, a network consisting of an access point, a wireless LAN controller, a firewall, and a VPN to a manufacturer.

570 **Figure 5-1: Basic System**



571

572 5.2 Data Flow

573 The flow of data between a wireless infusion pump and its corresponding server falls into the following
574 transaction categories:

575 - modifying the drug library
576 - performing software updates
577 - remotely managing the devices
578 - auditing the data flow processes.

579 Infusion pumps may also include other advanced features such as auto-programming to receive patient
580 prescription information and record patient treatment information to the patient's electronic health
581 record.

5.3 Cybersecurity Controls

This section discusses security controls by their location, either on the network, pump, or pump server. We also describe controls implemented in the NCCoE lab, and depict the controls implemented in our final architecture.

In general, we recommend that a clinically focused network be designed to protect information used in HDOs, whether that information is at-rest or in-transit. As described in *Cisco Medical-Grade Network (MGN) 2.0-Wireless Architectures* (Higgins & Mah, 2012), no single architecture can be designed to meet the security requirements of all organizations [41]. However, many cybersecurity best practices can be applied by HDOs to meet regulatory compliance standards.

Our reference architecture uses Cisco's solution architecture as the baseline. This baseline demonstrates how the network can be used to provide multi-tiered protection for medical devices when exchanging information via a network connection. The goal of our reference architecture is to provide countermeasures to deal with challenges identified in the assessment process. For our use case solution, we use segmentation and defense-in-depth as security models to build and maintain a secure device infrastructure. This section provides additional details on how to employ security strategies to achieve specific targeted protections when securing wireless infusion pumps.

We used the following cybersecurity controls:

- network controls
- pump controls
- pump server controls
- enterprise level controls

5.3.1 Network Controls

Proper network segmentation or network zoning is essential to developing a strong cybersecurity posture [33], [34], [35], [36], [42]. Segmentation uses network devices such as switches and firewalls to split a large computer network into subnetworks, each referred to as a *network segment* [41]. Network segmentation not only enhances network management, but also improves cybersecurity, allowing the separation of networks based on network security requirements driven by business needs or asset value.

The architecture designed for this build uses Cisco's solution architecture as the baseline for demonstrating how the network can be used to provide a multi-tiered protection for medical devices when exchanging information with the outside world during the operation involving network communication. The goal of this architecture design is to provide countermeasures to mitigate challenge areas identified in the assessment process. In our use case solution, *segmentation* and *defense-in-depth* are the security models we used as security measures to build and maintain secure

device infrastructure. This section provides additional details on how to employ security strategies to achieve the target security characteristics for securing wireless infusion pumps.

5.3.1.1 Segmentation/Zoning

Our network architecture uses a zone-based security approach. By using different local networks for designated purposes, networked equipment identified for a specific purpose can be put together on the same network segment and protected with an internal firewall. The implication is that there is no inherent trust between network zones and that trust limitations are enforced by properly configuring firewalls to protect equipment in one zone from other, less trusted zones. By limiting access from other, less trusted areas, firewalls can more effectively protect the enterprise network.

For discussion purposes, we include some generic components of a typical HDO in our network architecture examples. A given healthcare facility may be simpler or more complex and may contain different subcomponents. The generic architecture contains several functional segments, including the following elements:

- core network
- guest network
- business office
- database server
- enterprise services
- clinical server
- biomedical engineering
- medical devices with wireless LAN
- remote access for external vendor support

At a high level, each zone is implemented as a virtual local area network (VLAN) with a combination firewall/router Cisco Adaptive Security Appliance (ASA) device connecting it to the rest of the enterprise through a backbone network, referred to as the core network [43], [44], [45]. Segments may consist of physical or virtual networks. We implemented sub-nets that correspond exactly to VLANs for simplicity and convenience. The routing configuration is the same for each, but the firewall configuration may vary depending on each zone's specific purpose. An external router/firewall device is used to connect the enterprise and guest network to the internet. Segmentation is implemented via a VLAN using Cisco switches. A short description of each segment and the final network architecture follow.

5.3.1.1.1 Core Network

Our reference architecture implements a core network zone that consists of the equipment and systems used to establish the backbone network infrastructure. The external firewall/router also has an

interface connected to the core enterprise network, just like other firewall/router devices in the other zones. This zone serves as the backbone of the enterprise network and consists only of routers connected by switches. The routers automatically share internal route information with each other via authenticated Open Shortest Path First (OSPF) to mitigate configuration errors as zones are added or removed.

5.3.1.1.2 Guest Network Zone

Hospitals often implement a guest network that allows visitors or patients to access internet services during their visit. As shown in Figure 5-2, network traffic here tends not to be clinical in nature but is offered as a courtesy to hospital visitors and patients to access the internet. Refer to Section 5.3.1.5, External Access for additional technical details.

5.3.1.1.3 Business Office Zone

A business office zone is established for systems dedicated to hospital office productivity and does not include direct patient-facing systems. This zone consists of traditional clients on an enterprise network, such as workstations, laptops, and possibly mobile devices. Within the enterprise, the business office zone will primarily interact with the enterprise services zone. This zone may also include Wi-Fi access.

5.3.1.1.4 Database Server Zone

A database server zone is established to house server components that support data persistence. The database server zone may include data stores that aggregate potentially sensitive information, and, given the volume, require safeguards. Databases may include PHI, so HIPAA privacy and security controls are applicable. This zone consists of servers with databases. Ideally, applications in the enterprise services zone and biomedical engineering zone use these databases instead of storing information on application servers. This type of centralization allows for simplified management of security controls to protect the information stored in databases.

5.3.1.1.5 Enterprise Services Zone

The enterprise services zone consists of systems that support hospital staff productivity. Enterprise services may not be directly patient specific systems, but rather support core office functions found in a hospital. This zone consists of traditional enterprise services, such as DNS, Active Directory, Identity Service System, and asset inventory that probably lives in a server room or data center. These services must be accessible from various other zones in the enterprise.

5.3.1.1.6 Clinical Services Zone

The clinical services zone consists of systems that pertain to providing patient care. Examples of systems that would be hosted in this zone include the electronic health record (EHR) system, pharmacy systems, health information systems, and other clinical systems to support patient care.

5.3.1.1.7 Biomedical Engineering Zone

The biomedical engineering zone establishes a separate area that enables a biomedical engineering team to manage and maintain systems such as medical devices as shown in Figure 5-2. This zone consists of all equipment needed to provision and maintain medical devices. In the case of wireless infusion pumps, this is where the pump management servers are hosted on the network.

5.3.1.1.8 Medical Device Zone

The medical device zone provides a network space where medical devices may be hosted. Infusion pumps would be deployed in this zone. Infusion pump systems are designed so that all external connections to EHR systems or vendor maintenance operations can be completed through an associated pump server that resides in the biomedical engineering network zone. Access to the rest of the network and internet is blocked. This zone contains a dedicated wireless network to support the wireless infusion pumps, as explained in Section 5.3.1.2, Medical Device Zone's Wireless LAN.

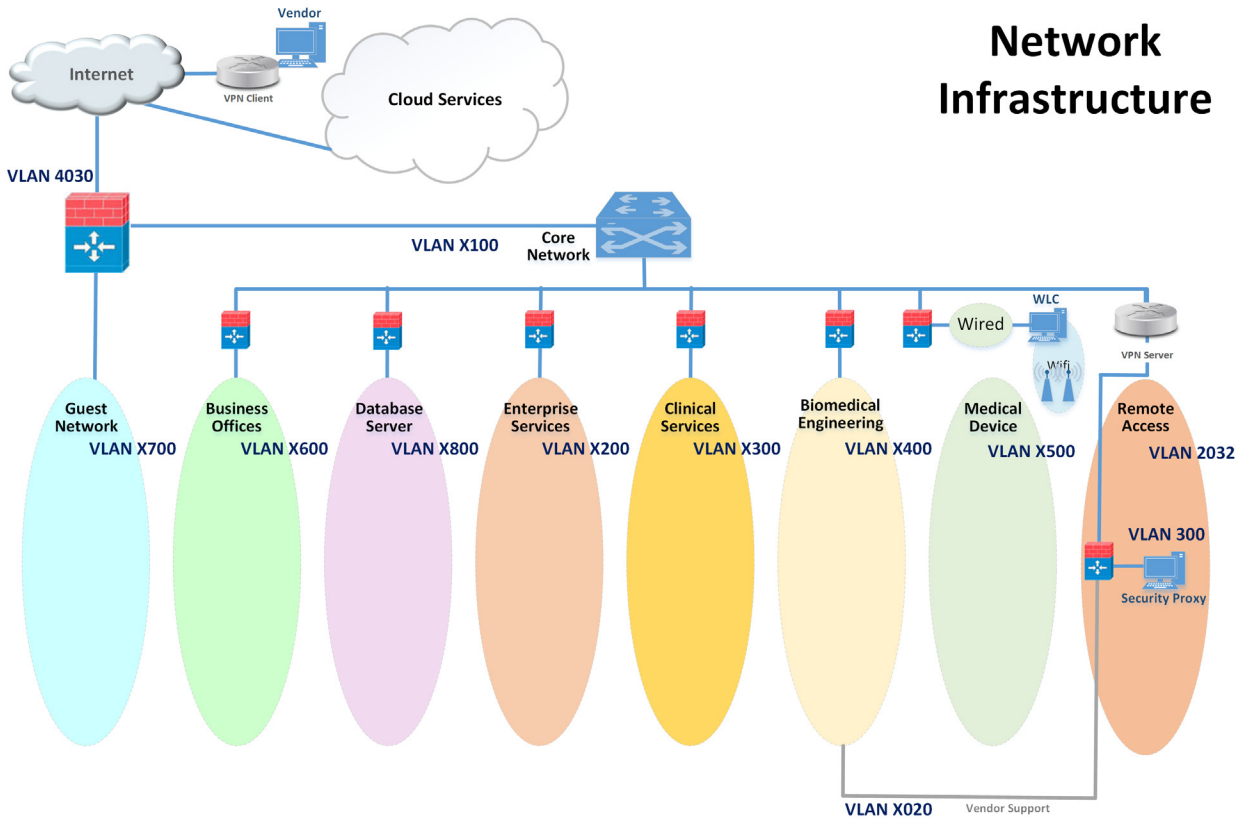
5.3.1.1.9 Remote Access Zone

The remote access zone provides a network segment that extends external privileged access so that vendors may access their manufactured components and systems on the broader HDO network. Refer to Section 5.3.1.4, Remote Access for additional technical details.

5.3.1.1.10 Final Network Architecture

Figure 5-2 shows the interconnection of all components and zones previously described. It also illustrates the connection to vendor and cloud services via the internet. VLAN numbers shown are VLAN identifiers used in the lab, but may vary on actual healthcare enterprise networks.

Figure 5-2: Network Architecture with Segmentation



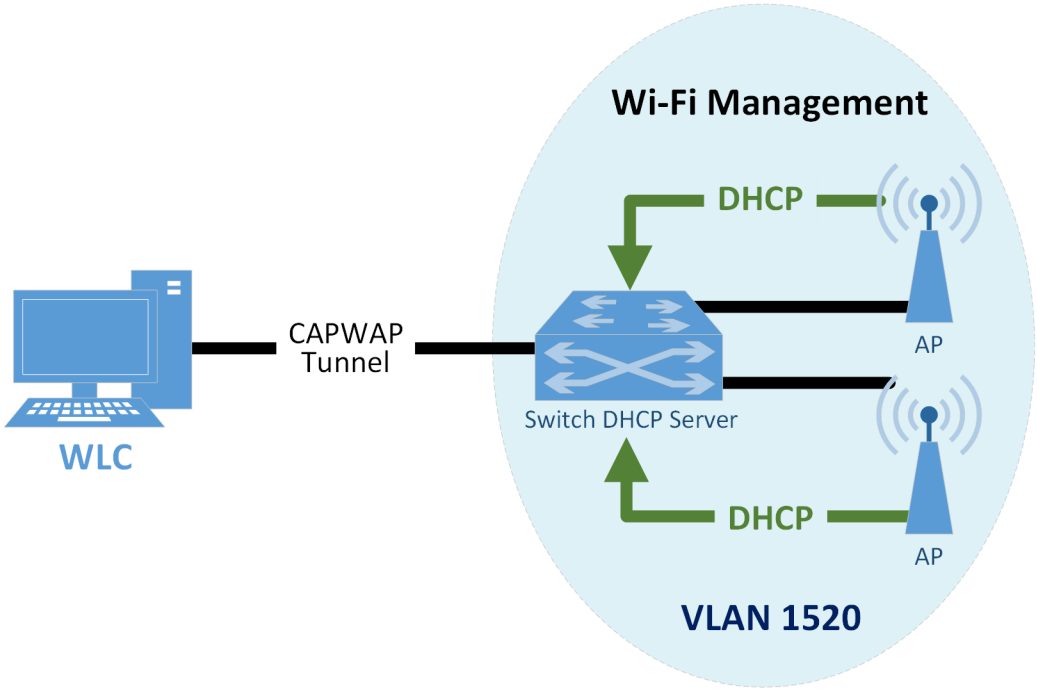
5.3.1.2 Medical Device Zone's Wireless LAN

The Wi-Fi management network is different in that it does not have a firewall/router that connects directly to the core network as shown in Figure 5-3. This is a completely closed network used for the management and communication between the Cisco Aironet wireless Access Point (AP) and the Cisco Wireless LAN Controller (WLC). The WLC is the central point where wireless Service Set Identifiers (SSIDs), Virtual LANs (VLANs), and Wi-Fi Protected Access version 2 (WPA2) security settings are managed for the entire enterprise [8], [17], [33], [34], [35], [36], [42], [46], [47], [48], [49].

Two SSIDs were defined, IP_Dev and IP_Dev Cert. IP_Dev uses WPA2-PSK, and IP_Dev Cert uses WPA2-Enterprise protocols. In an actual HDO, two WLCs should be configured for redundancy. Initially, the wireless access points configure themselves for network connectivity like any other device using Dynamic Host Configuration Protocol (DHCP) from the switch DHCP server (see the green line in Figure 5-3). The switch also sends DHCP option 43, which provides the IP address of the WLC. The AP then connects to the WLC to automatically download firmware updates and wireless configuration information. Finally, the Control and Provisioning of Wireless Access Points (CAPWAP) tunnel and

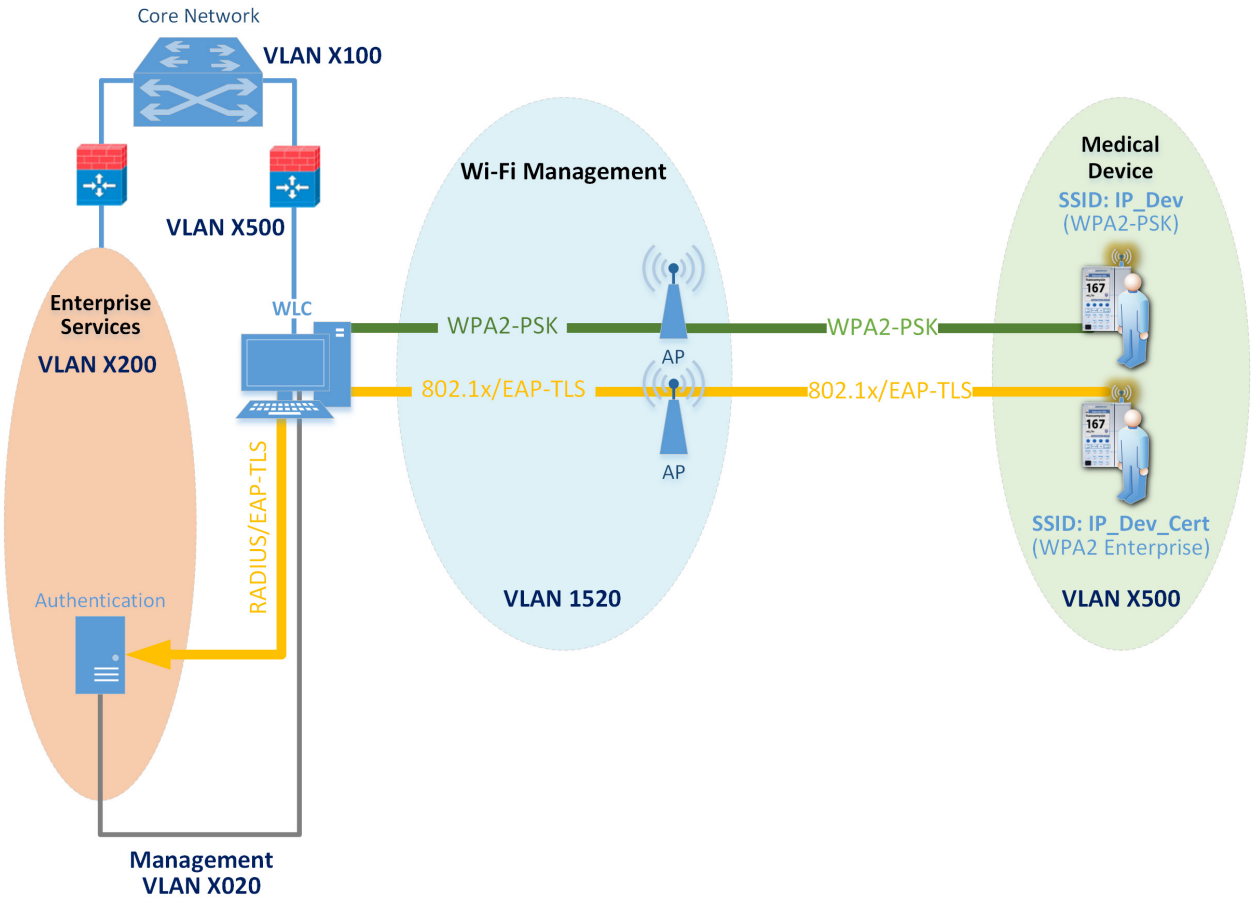
encrypt wireless traffic (see the black line in Figure 5-3). The traffic is then routed to the enterprise network via the WLC [28], [37], [44], [50].

Figure 5-3: Wi-Fi Management



When a device first connects to the Wi-Fi network, it needs to authenticate with either the agreed-upon pre-shared key or certificate. The authentication process is tunneled from the AP back to the WLC as shown in Figure 5-4. In the case of a pre-shared key, the WLC verifies that the client key matches (see green line). In the case of a certificate, the authentication process is passed from the WLC to the Cisco identity service engine (ISE) for validation using remote authentication dial-in user service (RADIUS) protocol (yellow line). Upon successful authentication, the device negotiates an encryption key and is granted link layer network access.

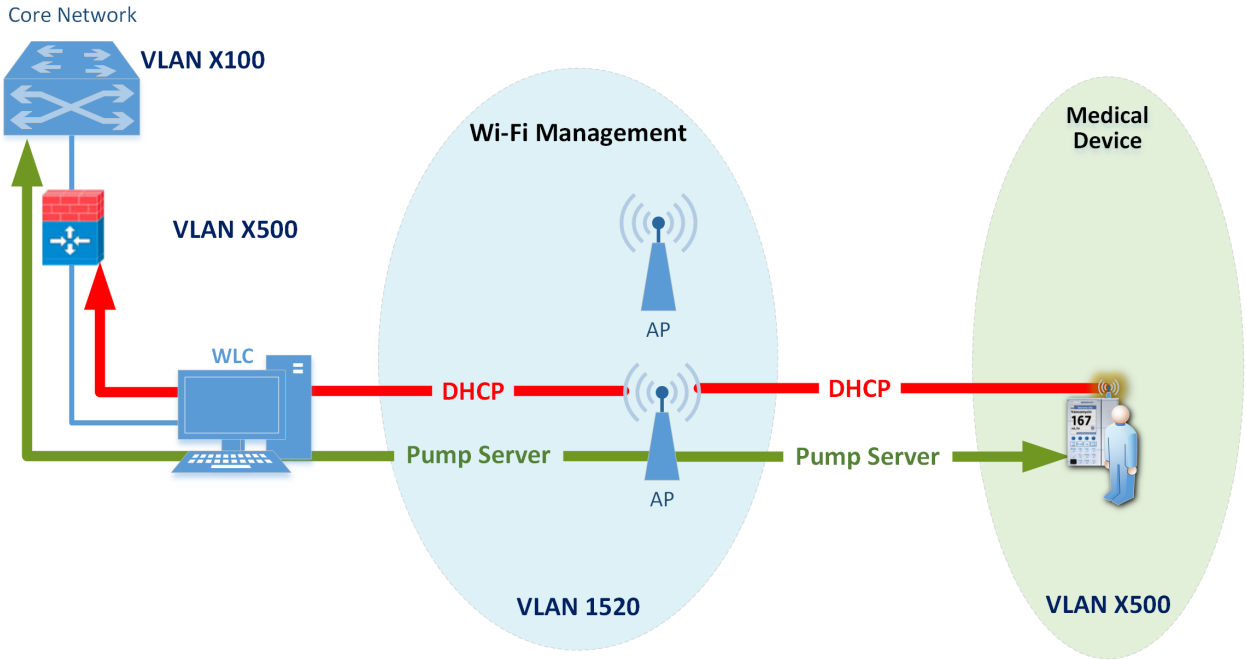
729 **Figure 5-4: Wi-Fi Authentication**



730

731 Once authentication is complete, typical network client activity is allowed. Figure 5-5 shows how Dy-
732 namic Host Configuration Protocol (DHCP) is used to contact the router to obtain network configuration
733 information for the device (see red line). Once the network is configured, the infusion pump will at-
734 tempt to connect to its provisioned pump server address on the enterprise network in the biomedical
735 zone (see green line).

736 **Figure 5-5: Wi-Fi Device Access**



737

738 Using an enterprise-grade Wi-Fi system can simplify transitions to more secure protocols by decoupling
739 Wi-Fi SSIDs and security parameters from the Wi-Fi spectrum and physical Ethernet connections. First,
740 every AP only needs to broadcast on a single Wi-Fi channel (in each band) and can broadcast multiple
741 SSIDs. This helps avoid interference due to multiple independent wireless systems trying to use the
742 same frequencies. Second, each SSID can be tied to its own VLAN. This means logical network
743 separation can be maintained in Wi-Fi without having to use additional spectrum. Third, multiple SSIDs
744 can be tied to the same VLAN or standard Ethernet network. Each SSID can have its own security
745 configuration as well. For example, in our use case, we have two different authentication mechanisms
746 for granting access to the same network, one configured for WPA2-PSK and another for so-called
747 *enterprise certificates.* This can be particularly useful for gradual transitions from old security
748 mechanisms (e.g., WEP, WPA) or old Pre-Shared Keys (PSKs) to newer ones instead of needing to
749 transition all devices at one time. In our case, to determine which devices may need reconfiguration to
750 use certificates, we used the WLC to identify exactly which devices are using old PSK SSIDs. Once this
751 number is reduced to an acceptable level, the old PSK SSID can be turned off and only certificate-based
752 authentication will be allowed.

753 *5.3.1.3 Network Access Control*

754 This section describes how network access control using a wireless LAN, as shown above, is applied to
755 the wireless infusion pumps.

Before we describe network access controls, it's important to discuss each pump's wireless protection protocol. There are three available wireless protection protocols (WEP, WPA, and WPA2). We also describe in-depth options for WPA2-PSK. Finally, we describe options for WPA2 across the HDO enterprise. Many of the infusion pumps used in this NCCoE project are newer models, capable of supporting various wireless protocols. For HDOs, WPA2 is the recommended wireless protocol to use. WEP and WPA are considered insufficient for appropriately securing wireless network sessions. Our architecture is designed to support multiple levels of access control for different groups of users. The architecture is configured to use WPA2-PSK and WPA2-Enterprise security protocols for secure wireless connections to accommodate the best available security mechanisms depending on which vendor products your organization uses. Please note that a wireless infusion pump manufactured prior to 2004 may not be able to support these newer wireless security protocols [41].

The WPA2-PSK is often referred to as *pre-share key mode.* This protocol is designed for small office networks and does not require an external authentication server. Each wireless network device encrypts the network traffic using a 256-bit key. All pumps used in our example implementation support this wireless security mode, and each pump performed properly using this mode. However, because all devices share the same key in a pre-shared key mode using WPA2-PSK, if credentials are compromised, significant manual reconfiguration and change management will be required.

WPA2 enterprise security uses 802.1x/EAP. By using 802.1x, an HDO can leverage the existing network infrastructure's centralized authentication services such as remote authentication dial-in use service, or RADIUS, authentication server to provide a strong client authentication. Cisco recommends that WPA2 Enterprise, which uses the AES (Advanced Encryption Standard) cypher for optimum encryption, be used for wireless medical devices, if available. We implemented WPA2-Enterprise with EAP-TLS security mode on several of our pumps to demonstrate that these pumps can leverage the public key infrastructure (PKI) to offer strong endpoint authentication and the strongest encryption possible for highly secure wireless transmissions. In this mode, pumps were authenticated to the wireless network with a client certificate issued by DigiCert Certificate Authority. During the authentication process, the pump's certificates are validated against a RADIUS authentication server using Cisco ISE. Automatic logoff features allow the system to terminate the endpoints from the network after a predetermined time of inactivity. Organizations manage and control the client certificates via the certificate authority. With this capability, organizations may revoke and renew certificates as needed.

Once WPA2 is selected as the appropriate wireless protection protocol, certificates may be issued to authenticate infusion pumps using 802.1x/EAP-TLS mode, as illustrated Figure 5-6 [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [42], [46], [47], [48], [49], [50].

Certificate issuance involves the following three stages, denoted by shaded boxes in Figure 5-6:

1. Certificate Registration

Step 1: Request a certificate from the DigiCert Certificate Authority, which is a Certificate Register Manager. Request pump certificates through a standalone computer connected to the internet using DigiCertUtil, a certificate request tool, on behalf a pump.

Step 2: The approved certificates are exported to the pumps using the specific tools provided by pump vendors. Typically, this activity is performed by a biomedical engineer.

Step 3: Install the certificate into the Cisco ISE application.

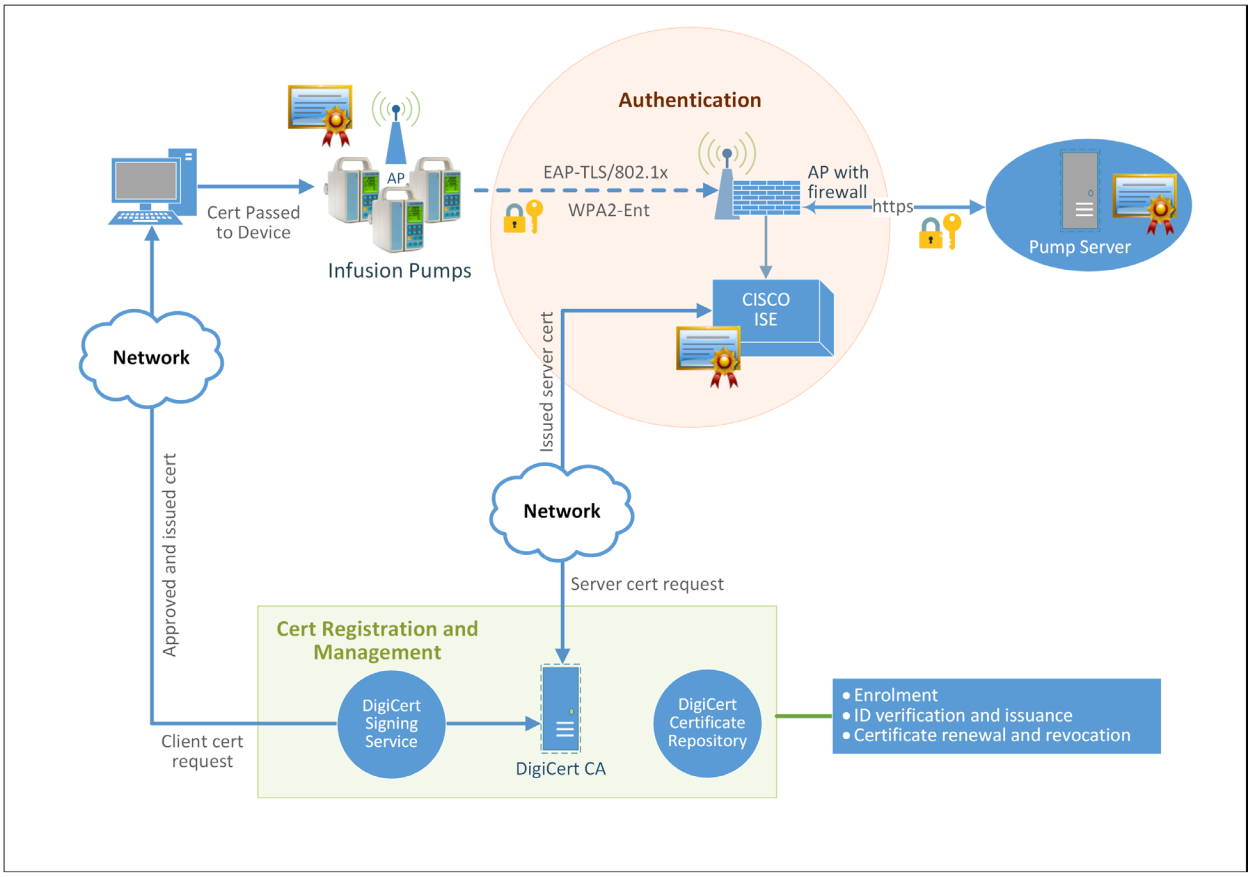
2. Authentication

Authentication is performed by the Cisco ISE application to validate the pump certificate under the 802.1x/EAP-TLS. During the network access authentication procedure, the AP will pass the certification information to ISE server for validation. Once passed, the connection between the pump and the pump server will be established, and the data transmitted between the pump and AP is encrypted.

3. Certificate Management

Certificate management will provide services to revoke certificates when they are no longer in use, and will also manage the certificate revocation list, along with any related processes for renewing old certificates.

807 **Figure 5-6: Network Access Control**



808

809 The detailed process for setting up the 802.1x network authentication for pump and pump server
810 communication is documented in Volume C of the How-to guide.

811 ### *5.3.1.4 Remote Access*

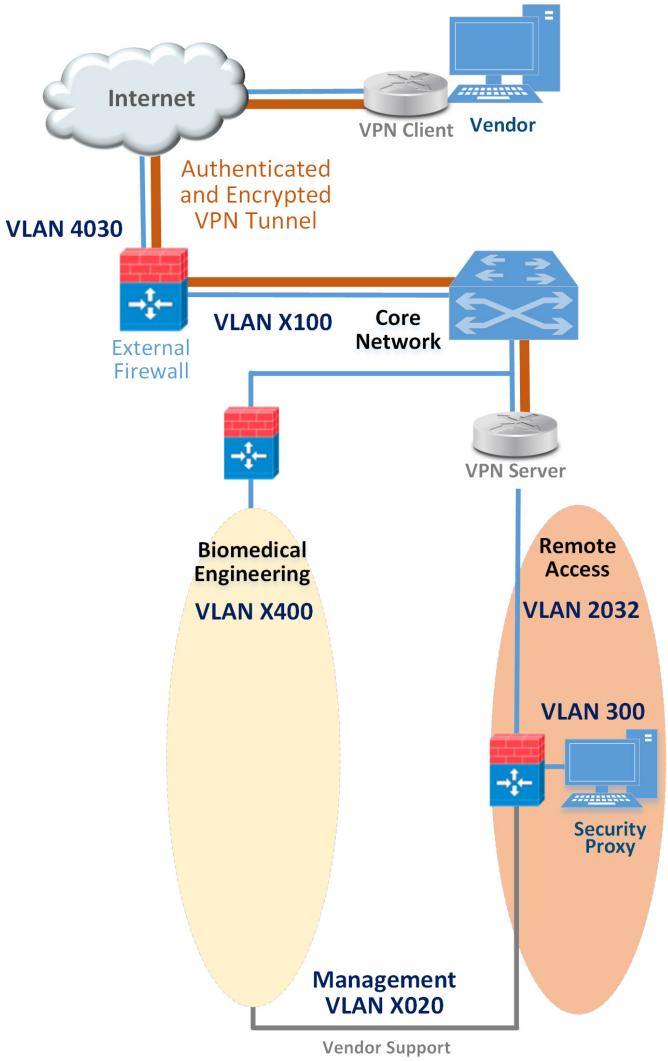
812 Many medical devices and their back-end management systems required access by manufacturers for
813 device repairs, configuration, software, and firmware patching and updates, or maintenance. A vendor
814 network segment (VendorNet) is designed to provide external privileged access for vendors to their
815 manufactured components and systems that reside within an HDO's architecture. In the NCCoE lab, a
816 VendorNet is implemented using TDi ConsoleWorks. ConsoleWorks is a vendor-agnostic interface that
817 gives organizations the ability to manage, monitor, and record virtually any activities in the IT
818 infrastructure that come from external vendors.

819 Communication using TDi ConsoleWorks for vendor access to products does not require the installation
820 of software agents to establish connections for managing and monitoring targeted components.

Established connections are persistent to facilitate IT operations, enforce security, and maintain comprehensive audit trails. All information collected by ConsoleWorks is time-stamped and digitally signed to ensure information accuracy, empower oversight, and meet compliance requirements. Through a standard web browser, ConsoleWorks can be securely accessed from any geographical location, eliminating the need for administrators and engineers to be locally present to perform their work.

Remote access is only allowed through a specific set of security mechanisms. This includes using a VPN at the network layer as shown in Figure 5-7 client, for vendors to authenticate to the VPN server [43], [44], [51].

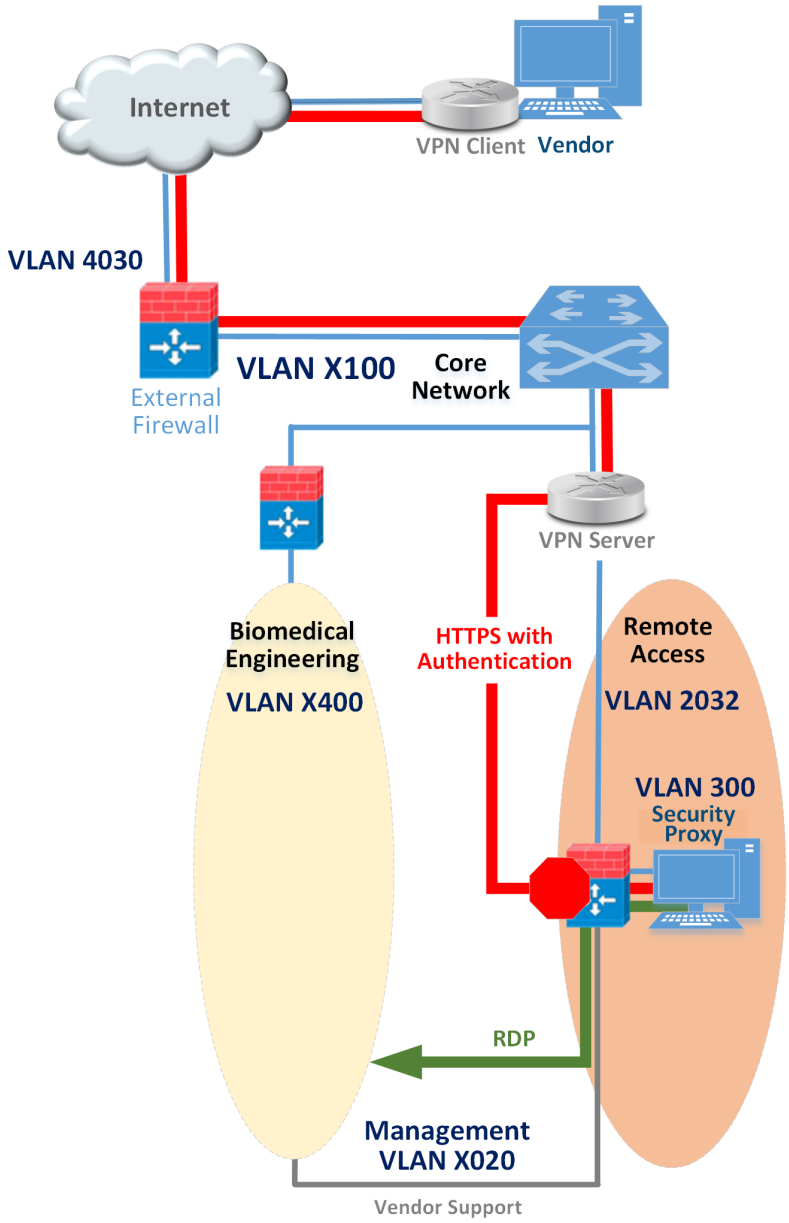
Figure 5-7: Remote Access VPN



After the VPN connection is established at the application layer, the security proxy will restrict who can access certain resources within the enterprise network, as depicted in Figure 5-8. Vendors also authenticate to the HTTPS-based security proxy (see red line). Based on the vendor's role, the security proxy will facilitate a Remote Desktop Protocol (RDP) connection to equipment in the biomedical engineering zone via the vendor support network (see green line). The credentials used to authenticate the RDP connection are stored by the security proxy and not disclosed to the vendor.

The remote access firewall/router is configured so that direct access between the VPN and vendor support is denied and the only allowed path is through the security proxy (see stop sign). Additionally, the firewall/router can further restrict what is accessible at the network layer from the security proxy. The security proxy is granted access to the internet to support patching and email alerts. The public IP address of the external firewall is configured to forward VPN traffic to the IP address of the VPN server [43], [44], [46], [47], [49], [51], [52], [53].

844 **Figure 5-8: Remote Access**



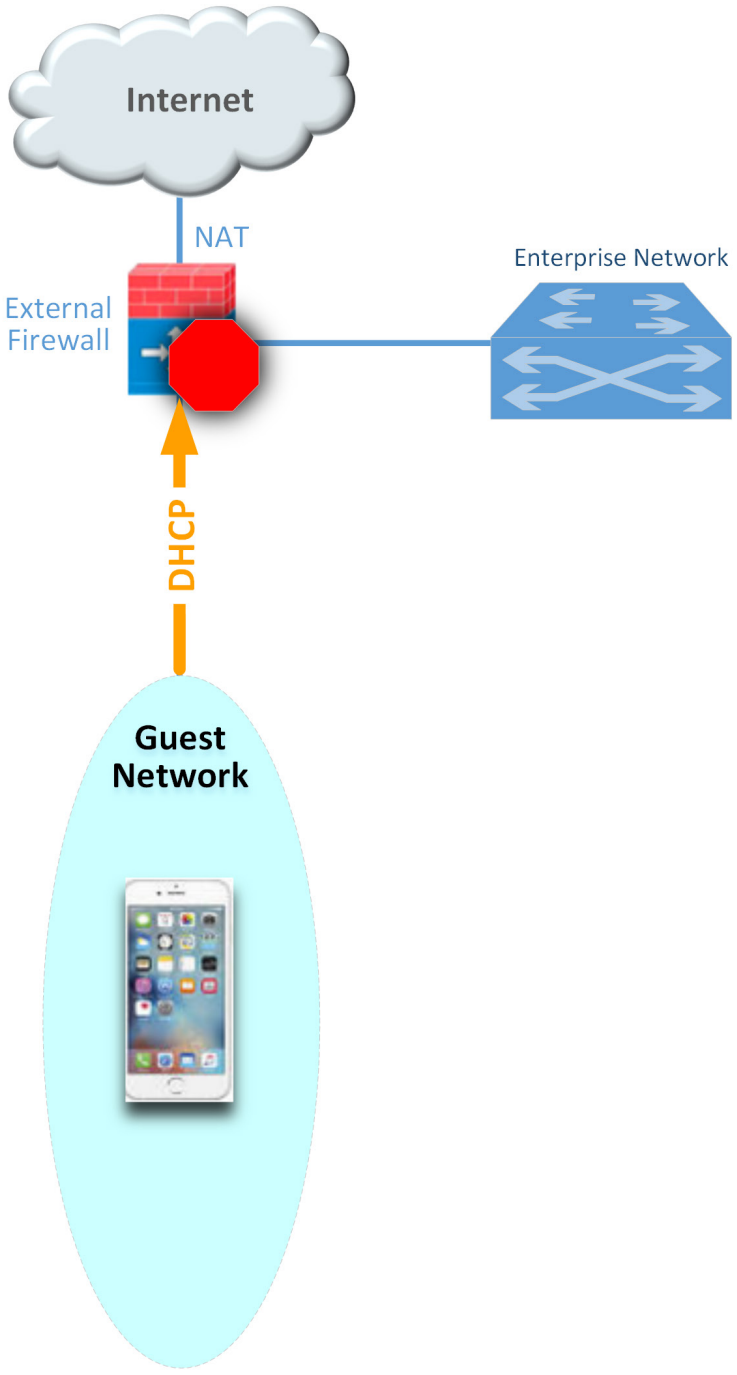
845

846 *5.3.1.5 External Access*

847 A guest network allows visitors or patients to access internet services during their visit. As explained in
848 the previous section (Guest Network Zone), the work traffic tends not to be of a clinical nature, but is
849 offered as a courtesy to hospital visitors and patients to access the internet. The external firewall marks
850 the boundary between the enterprise and the internet. As shown in Figure 5-9, this is the only point in

the network where network address translation (NAT) is used. Additionally, the guest network for personal devices connects to the internet though the external firewall. The guest network is configured such that traffic cannot go between the enterprise and guest networks – only out to the internet. This is denoted by the stop sign. The external firewall is configured to provide the necessary services for guest users to use the internet, such as DHCP, which allows dynamic addressing for anyone. Typically, consumer equipment is connected here, such as smart phones, tablets, and personal entertainment systems (Figure 5-9) [52].

858 **Figure 5-9: External**



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5.3.2 Pump Controls

Wireless infusion pumps have the following controls:

- endpoint protection
- hardening
- data protection.

5.3.2.1 Endpoint Protection

Traditional security relies on the network border to provide security protection to its internal nodes, using security technologies such as application firewalls, proxy gateways, centralized virus scan, network intrusion detection, and prevention systems. This is no longer considered a best practice. The nodes, such as networked medical devices, should participate in their own security. Otherwise, the device can become the weakest element in the enterprise and present a risk to the entire HDO network.

To avoid the single point of failure caused by an unsecured node, every system should have an appropriate combination of local protections applied to it. These protections include code signing, anti-tampering, encryption, access control, white listing, and others.

5.3.2.2 Hardening

Wireless infusion pumps and their servers are considered computing endpoints when it comes to hardening the software contained within these devices. Medical devices usually contain third-party commercial, off-the-shelf (COTS) products, including proprietary or commercial embedded operating systems, network communication modules, runtime environments, web services, or databases. Because these products can contain vulnerabilities, medical devices may also inherit these vulnerabilities just by using the products [2], [3], [7], [9], [25]. Therefore, it is important to identify all software applications used on medical devices, implement securing and hardening procedures recommended by the manufacturers, and apply timely patches and updates to guard against any newly discovered threats.

Hardening may include the following:

- disabling unused or unnecessary communication ports and services
- changing manufacturer default administrative passwords
- securing remote access points if there are any
- confirming the firmware version is up to date
- ensuring hashes or digital signatures are valid

However, please note that most infusion pumps do not have the same level of storage resources and CPU processing capability as those provided for personal computers and servers.

5.3.2.3 Data Protection

The two primary reasons for data protection are confidentiality and integrity. Medical devices may contain patient data such as patient name, medical record number, gender, age, height, weight, procedure number, medication and treatment information, or other identifiers that may constitute PHI. PHI must be appropriately protected, for example, through encryption or other safeguard measures that would prevent unauthorized disclosure of such information.

Infusion pumps may also contain configuration data such as drug libraries specifying dosage and threshold limits. This data must be protected against compromises as well. Our defense-in-depth approach for data integrity involves sandboxing the critical system files stored in pump servers using Symantec Advanced Data Center Security and encrypting messages when communicating between a medical infusion pump and the backend infusion management system, via Internet Protocol Security or secure sockets layer encryption (e.g., https, TLS).

5.3.3 Pump Server Controls

Pump server features vary. Usually, a pump server can be used to distribute firmware, the drug library, other software updates used inside the devices, or as a tool for providing services such as reporting and device asset management. Data collected by the infusion pump server is valuable for further analysis to provide reports on trends, compliance checking, and to measure infusion safety.

Because pump servers connect to infusion pumps to deliver and receive infusion-related information, it is also important to secure the infusion pump server, its associate applications, databases and communication channels as well.

5.3.3.1 User Account Controls

Access to the pump server typically implements user name/password authentication. After the pump server is installed, an initial step is to define the password policy that applies to users accessing the pump server. When managing user accounts for a pump server, common cybersecurity hygiene should include the following:

- changing factory default passwords
- enforcing password policies
- assigning each user's access level using the least privilege principle
- if supported, using centralized access management, such as LDAP for user account, management at the enterprise level
- configuring auto logout

5.3.3.2 Communication Controls

Pump servers interface with many other systems or components such as: databases, web services, and web portals. Communications between different systems can be configured. Pump servers might provide choices for selecting unsecure or secure TCP/IP ports for communication. We recommend using secure (e.g., stateful, encrypted network sessions) ports for message communication or for package download.

There may be a default setting for the communication interval, in number of seconds, for communication attempts between the server and the pump. Be sure to set this idle time-out setting properly.

5.3.3.3 Application Protection

Application protection refers to software applications running on the pump servers. Most of the software application security concerns and security controls used on traditional personal computers and servers may also be applied to pump servers to protect data integrity and confidentiality. These control measures may include:

- trusted applications
- stronger access control mechanisms for pumps and pump servers
- better key management
- application white listing
- sandboxing applications
- performing code-signing verification for newly installed software
- applying the latest patches and software updates
- encrypting message data in-transit, or at rest

Server security baseline integrity is achieved via the use of three Symantec cybersecurity products on an enterprise network with a specific focus on wireless infusion pumps:

- Symantec Data Center Security: Server Advanced (DCS:SA)
- Symantec Endpoint Protection (SEP)
- Symantec Advanced Threat Protection: Network (APT:N)

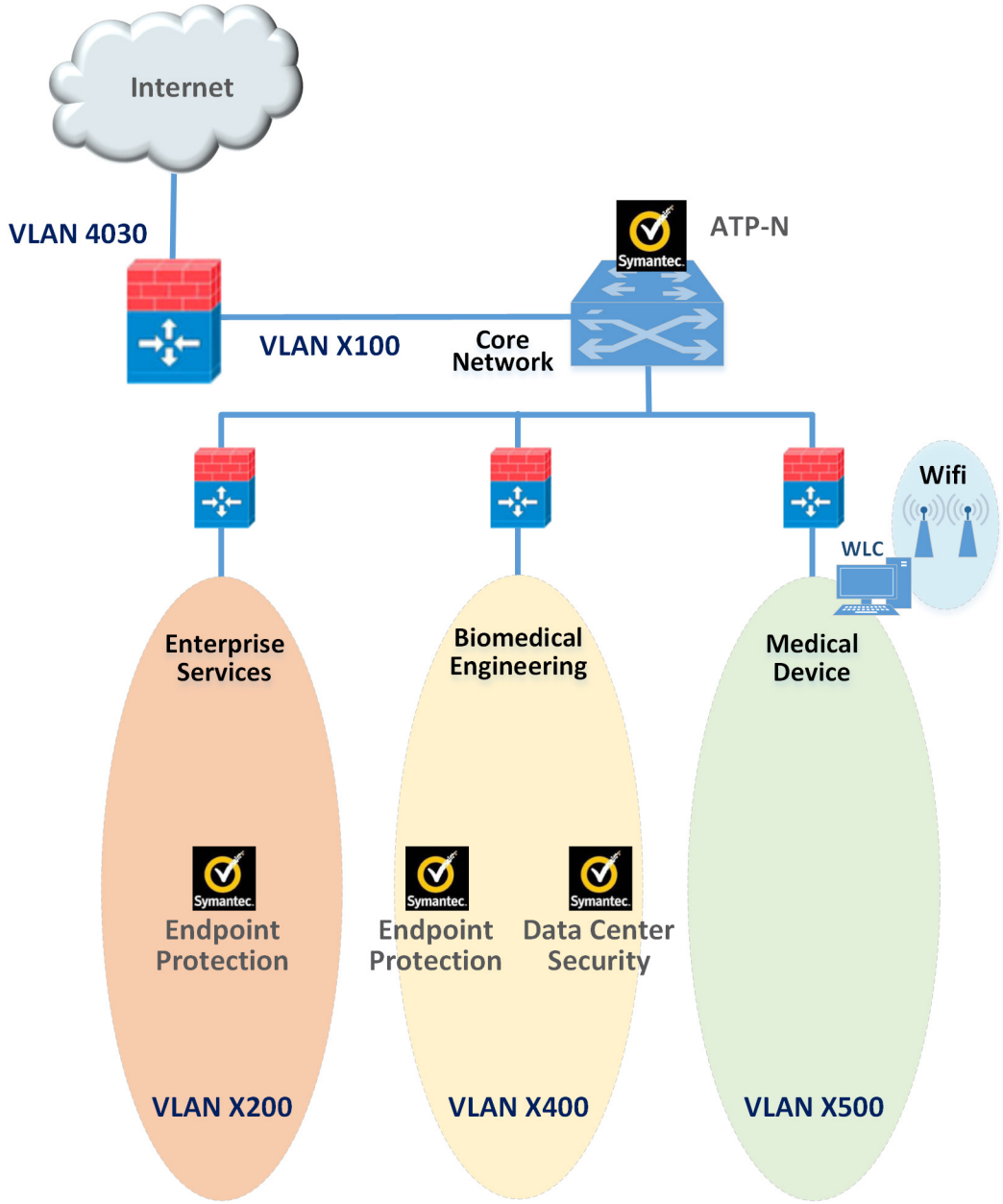
Each of these products provide protections for components in the enterprise systems in different levels. With pre-built policies, the Data Center Security Server installed can provide out-of-the-box host Intrusion IDS and IPS by monitoring and preventing suspicious server activities on pump servers. The use of DCS also provides the host firewall service for controlling inbound and outbound network traffic to and from a protected server. Using DCS, the configuration settings, file, and file systems in the pump

server can be locked down using policy-based least privilege access controls to restrict application and operating system behavior and prevent file and system tampering.

Like DCS, Symantec's Endpoint Protection (SEP) provides similar protection for endpoint devices and servers. SEP features in-memory exploit mitigation and anti-virus file protection to block malware from infecting protected endpoint servers. This will reduce the possibility of zero-day exploits on popular software that may not have been properly patched or updated. To protect endpoint servers, an SEP agent must be installed on servers.

Advanced Threat Protection: Network (ATP:N) can provide network-based protection of medical device subnets by monitoring internal inbound and outbound internet traffic. It can also be used as a dashboard to gain visibility to all devices and all network protocols. In addition, if ATP:N is integrated with the SEP, ATP can then monitor and manage all network traffic from the endpoints and provide threat assessments for dangerous activity to secure medical devices on an enterprise network. The use of these Symantec security products is depicted in Figure 5-10 below.

967 **Figure 5-10: Pump Server Protection**



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5.3.4 Enterprise Level Controls

5.3.4.1 Asset Tracking and Inventory Control

Medical asset management includes asset tracking and asset inventory control. Asset tracking is a management process used to maintain oversight of the equipment, using anything from simple methods such as pen and paper to record equipment, to more sophisticated IT asset management platforms. HDOs can use asset tracking to verify that a device is still in the possession of the assigned, authorized users. Some more advance tracking solutions may provide service for locating missing or stolen devices.

Inventory management is also important throughout a medical device's life cycle. Inventory tracking should not be limited to hardware inventory management. It should also be expanded to include software, software versions, data stored and accessed in the devices, for security purpose. HDOs can use this type of inventory information to verify compliance with security guidelines and check for exposure of confidential information to unauthorized entities.

5.3.4.2 Monitoring and Audit Controls

Logging, monitoring, and auditing procedures are essential security measures that can be used to help HDOs prevent incidents and provide an effective response when a security breach occurs. Logging records events to various logs; monitoring oversees the events for abnormal activities, such as scanning, compromises, malicious code, and denial of services in real time; and auditing reviews and checks these recorded events to find abnormal situations or evaluate if the applied security measures are effective. By combining the logging, monitoring, and auditing features, an organization will be able to track, record, review and respond to abnormal activities and provide historical records when needed.

Many malware and virus infections can be almost completely avoided by using properly configured firewalls or proxies with regularly updated knowledge databases and filters to prevent connections to known malicious domains. It is also important to review your firewall logs for blocked connection attempts so that you can identify the attached source and remedy infected devices if needed.

In our example implementation, user audit controls—simple audits—are in place. Although additional security incident and event managers (SIEM) and centralized log aggregation tools are recommended to maximize security event analysis capabilities, aggregation and analytics tools like these are considered out of scope for this project iteration.

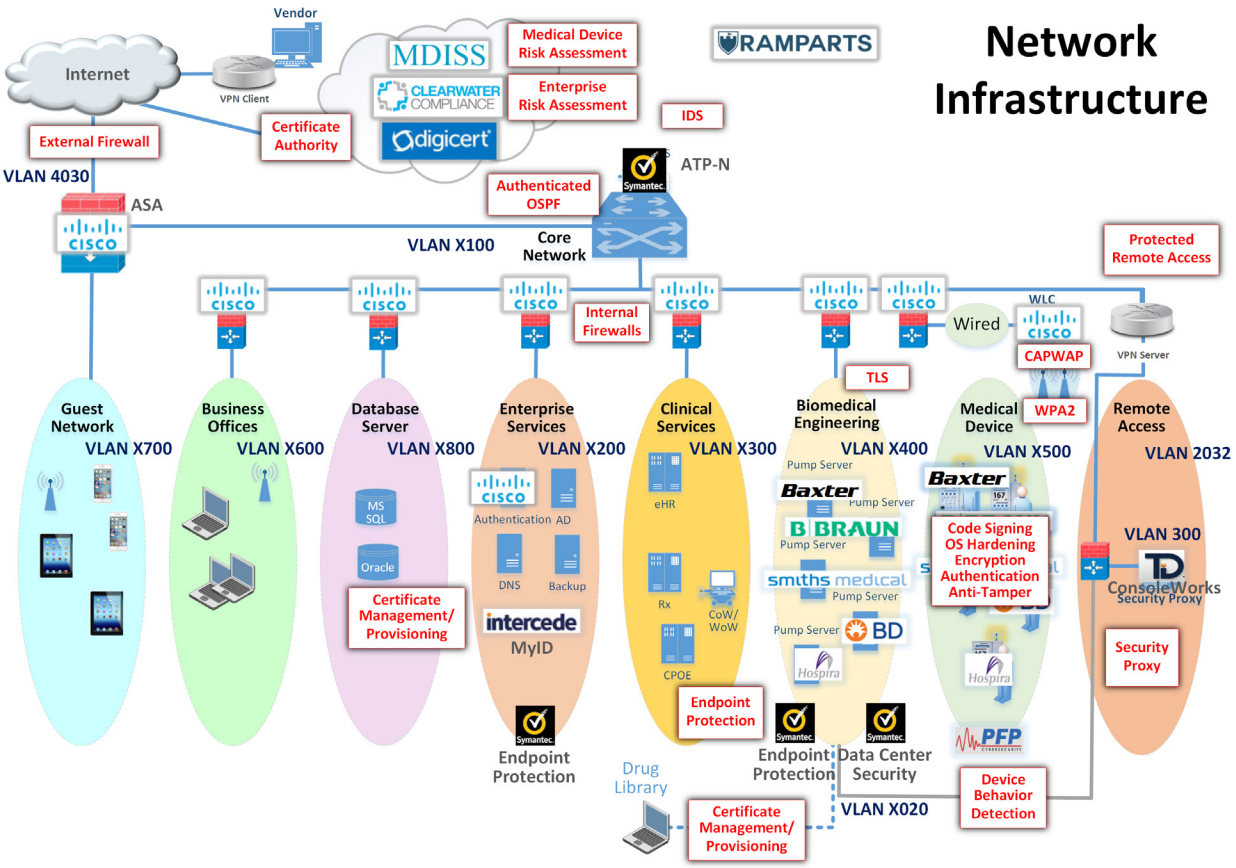
Each system is monitored for compliance with a secure configuration baseline. Each system is also monitored for risks to known good, secure configurations by vulnerability scanning tools. In our project, the AP provided by Cisco, the Cisco ISE as Radius authentication server, VendorNet provided by TDI, and the pump servers from each vendor are all equipped with proper monitoring and logging capabilities. Real-time monitoring for events happening within these systems can be analyzed and compared to the baseline. If any abnormal behavior occurs, it can be detected. The auditing of data was considered out

of scope for this reference design because the absence of an actual data center made auditing behavior impractical.

5.4 Final Architecture

The target architecture, depicted in Figure 5-11, indicates the implementation of network segmentation and controls as described by this practice guide. Segmentation identified nine zones, ranging from the guest network to the medical device zone, and includes zones for Wi-Fi infrastructure, and core network infrastructure. The zoned concept implements firewall/router devices to enforce segmentation, with the firewall enforcing limited trust relationships between each zone. Noted in the diagram are processes that have impact on the overall architecture. Security controls are implemented to enforce encryption on network sessions. For Wi-Fi, leveraging standard protocols such as WPA2- PSK and WPA2-Enterprise created a secure channel for the pumps to communicate with the (AP)s, and to use TLS to secure the communication channel from the pumps to the server.

Figure 5-11: Target Architecture

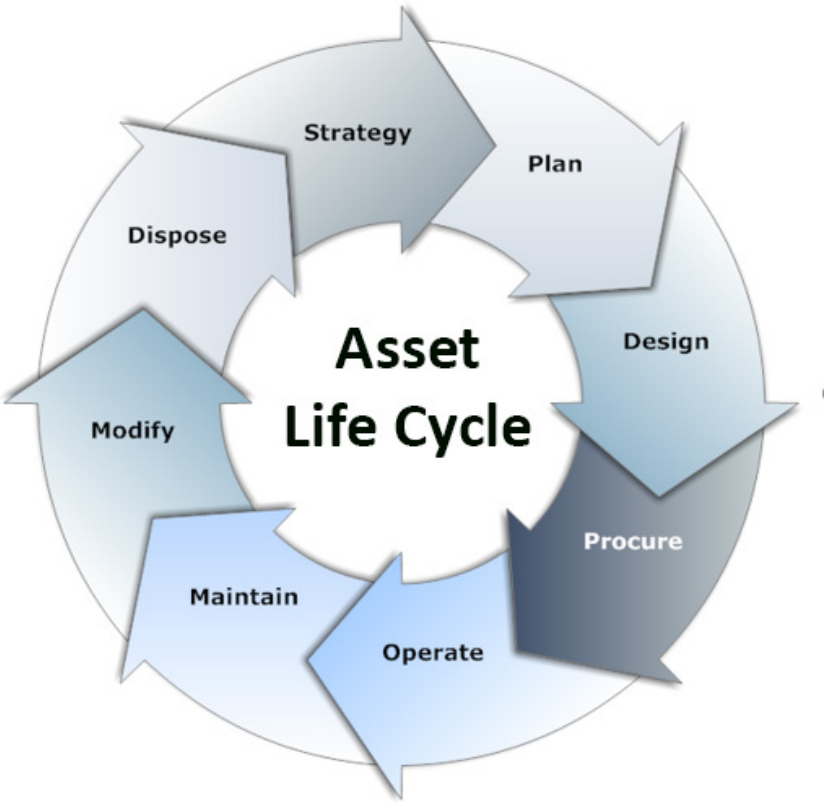


6 Life Cycle Cybersecurity Issues

Configuration management throughout a device's life cycle is a key process that is necessary for the support and maintenance of medical devices [3]. *NIST SP 1800-5: IT Asset Management for the Financial Services Sector* discusses IT Asset Management (ITAM), and, although the focus of the document pertains to financial services, similar challenges exist in healthcare [54]. Establishing a product life cycle management program addresses a few of the risks noted in previous sections of this guide, and should be considered as part of a holistic program for managing risks associated with infusion pump deployments.

Figure 6-1 illustrates a typical life cycle for an asset, and this model can be applied to medical devices. The sections below will take specific phases of the asset life cycle and discuss essential cybersecurity activities that should occur during those phases.

Figure 6-1: Asset Life Cycle [55]



6.1 Procurement

Asset life cycle management typically begins with Strategy, Plan, and Design phases, which lead into procurement. These phases are opportunities for hospitals to define requirements and identify where security controls may be implemented on infusion pumps or other devices that the hospital intends to acquire.

Phases leading into procurement enable the HDO, reseller, or manufacturer to ensure that the equipment that the HDO will deploy offers the appropriate combination of security and functionality required to render patient care. These phases also enable the hospital to implement appropriate security controls to safeguard the device and the information that it may store or process.

Purchasers at HDOs may request manifests or architectural guidance on secure deployment of the equipment and may perform research on products and the manufacturers that they have selected. While performing the research, HDOs may begin a risk assessment process to ensure that risks are mitigated.

Manufacturers maintain a document referred to as the MDS2 (Manufacturer Disclosure Statement for Medical Devices) that an HDO may review, enabling the HDO to determine possible vulnerabilities and risks [56]. Hospital purchasers may also determine if vulnerabilities exist in the proposed equipment by reviewing the FDA-hosted MAUDE database (Manufacturer and User Facility Device Experience).

Hospitals should also obtain any necessary training, education, and awareness material from the manufacturer and educate staff about the deployment, operation, maintenance, and security features available on their equipment. HDOs might consider writing user-friendly documentation to ensure that staff can use the equipment with confidence and competence.

Performing research and risk analysis during the phases leading into procurement will allow HDOs to make informed decisions. For further reference, we note that the Mayo Clinic has produced a best practice document that discusses procurement.

6.2 Operation

After procuring their equipment, hospitals onboard it during the Operation and Maintenance phases. Equipment purchasers should apply asset management processes (e.g., asset tagging and entry into a configuration management database or some other form of inventory tracking), and have standard baseline configurations implemented. Wireless infusion pumps may need to be configured to connect to a hospital's Wi-Fi network (Medical Device zone, as depicted in the architecture section of this document; see Section 5.3.1.2, Medical Device Zone's Wireless LAN and implement digital certificates to allow for device authentication.)

As noted above, hospitals should implement some type of configuration management database or asset inventory that captures granular information about the device. Implementing an ITAM mechanism

enables the hospital to have visibility into their infusion pump deployment, with captured information that describes the make/model, firmware, OS, and software versions, a general description of the applied configuration along with change history, and physical location within the hospital. Regular maintenance of the ITAM would reduce risks, for example, that may emerge based on loss/theft, as well as provide a central knowledge repository that allows the hospital to coordinate any required maintenance or refresh.

As part of deployment, hospitals should apply practices noted by the manufacturer (e.g., regarding access control and authentication). As noted above, digital certificates should be installed to allow for device authentication to Wi-Fi, but engineers should implement access control and auditing mechanisms where applicable.

6.3 Maintenance

Pump manufacturers have two types of systems that require updating: the pumps and the pump servers. Pumps may implement control systems in firmware (writeable, non-volatile storage that may include an embedded operating or other control system). Control systems may be maintained through an update process that involves replacing all or parts of the operating or control system. Server components may be implemented on more conventional IT systems, using commercial operating systems (e.g., Windows or Linux variants).

Another aspect of configuration management that HDOs will want to pursue is that of patching. Patching, known colloquially as *bug fixing*, does not require a full replacement of software and is generally performed on pump servers. The patch frequency that manufacturers generally adhere to is monthly for patches and yearly for updates. This observation on timing comes from industry, not NIST—and is considered standard practice, rather than advice.

In addition to identifying patch frequency, organizations must be aware of likely vulnerabilities and the risks they introduce into the enterprise, and then decide whether a patch should be applied. NIST SP 800-40 *Guide to Enterprise Patch Management Technologies* discusses the importance of patch management and the challenges.

6.4 Disposal

The *Dispose* phase of the ITAM life cycle comes into play when products reach their end of life and are removed from hospital service. Wireless infusion pumps have increased in sophistication and information that each device may use, process, or store. The information found on pumps and related equipment may include sensitive information or information that may be regarded as PHI. As such, hospitals should seek to implement mechanisms to ensure that any sensitive information is removed from all storage areas that a pump or its system components may maintain. Practices to remove that information may be found in NIST SP 800-88 *Guidelines for Media Sanitation* [27].

7 Security Characteristics Analysis

We identified the security benefits of the reference design, how they map to NIST Cybersecurity Framework (CSF) subcategories, and the mitigating steps to secure the reference design against potential new vulnerabilities [10], [14].

7.1 Assumptions and Limitations

Our security analysts reviewed the reference architecture and considered if the integration described in this guide would meet security objectives. The analysts purposely avoided testing products, and readers should not assume any endorsement or diminution of the value of any vendor products. Although we have aimed to be thorough, we counsel those following this guide to evaluate their own implementation to adequately gauge risks particular to their organizations.

7.2 Application of Security Characteristics

Using the CSF subcategories to organize our analysis allowed us to systematically consider how well the reference design supports specific security activities and provides additional confidence that the reference design addresses our use case security objectives. The remainder of this subsection discusses how the reference design supports each of the identified CSF subcategories [10].

7.2.1 Supported CSF Subcategories

The reference design focuses primarily on the *Identify* and *Protect* function areas (i.e., subcategories) of the CSF. Specifically, the reference design supports:

- three activities in the CSF *Identify* function area: Asset Management, Business Environment, and Risk Assessment
- activities from each category of the CSF *Protect* function area, except for Awareness and Training

We discuss these CSF subcategories in the following subsections.

7.2.1.1 ID.AM-5: Resources (e.g., Hardware, Devices, Data, Time, and Software) are Prioritized Based on Their Classification, Criticality, and Business Value

To address this subcategory of the *Identify* function, we conducted an asset inventory as part of the risk management process. For this project, we identified assets and entered them into the Clearwater Compliance IRM|Analysis™ tool. This risk analysis tool categorized project resources into types of assets. Additionally, it characterized the system, enabling us to address the criticality of our resources. Our project only partially satisfies the *Resources* subcategory as we focused on technical solutions and did not write a business impact assessment or business continuity plan.

7.2.1.2 ID.BE-1: The Organization's Role in the Supply Chain is Identified and Communicated

Organizations who may be using this guide are the end users of medical devices. NIST SP 800-53, control SA-12, most directly applies to such end users because it directs users to define which security safeguards to employ to protect against supply chain threats [14]. Our implementation uses network segmentation to limit exposure to the wireless infusion pump from other areas within a hospital network. This is done because if a vulnerability is identified in a device, segmentation and access control will help safeguard the medical device until the vulnerability can be properly addressed.

7.2.1.3 ID.RA-1: Asset Vulnerabilities are Identified and Documented

Given a reasonably long life cycle, even the best designed electronic asset will eventually be impacted by a vulnerability. Medical devices can have a long product life cycle, per TIR57, "Device or platform used for decades" [9], [25]. Identifying vulnerabilities in an asset may occur via various means. Some may be identified through onsite testing; however, often the manufacturer or a researcher will find the vulnerability. An effective risk management program is essential to reduce the likelihood that an identified vulnerability will be exploited. This implementation uses a combination of risk analysis tools and methods to help reduce the impact a vulnerability may have on the build.

7.2.1.4 PR.AC-1: Identities and Credentials are Issued, Managed, Revoked, and Audited for Authorized Devices, Users, and Processes

Following the segmentation approach used to separate hospital networks into zones, our implementation employs role-based security, which limits access based on who actually need to access the pump. HDO users with no business need are not permitted access to pumps, pump servers, or related components. Most users, including biomedical staff, are granted access via active directory. Although our NCCoE lab did not use single-sign-on (SSO), using SSO can make pump access seamless to an end user. How to manage credentials of clinicians who operate the pump directly is beyond the scope of this guide.

Remote access is necessary to maintain proper functionality of infusion pumps, but the mechanism for gaining and controlling remote access varies depending on the user type. Hospital staff such as biomedical engineers remotely access pumps through a VPN and hardened gateway at the application layer. Such users are considered trusted HDO staff with access to other network resources throughout the enterprise.

Pump manufacturers who may need to reach a device for maintenance or troubleshooting can gain access into a VendorNET zone only, from which they can access pumps and pump servers, but not other zones in the enterprise. Our example implementation uses ConsoleWorks for authentication, role-based access control, and recording system management actions of remote vendor activity.

7.2.1.5 PR.AC-4: Access Permissions and Authorizations are Managed, Incorporating the Principles of Least Privilege and Separation of Duties

This CSF subcategory is supported for the pumps and pump servers with Data Center Security (DCS). The configuration settings, file, and file systems in the pump server are restricted, thereby implementing policy-based least privilege access control. DCS restricts application and operating system behavior and prevents unauthorized users from tampering with files and systems.

Least privilege is also addressed via the network design itself. By limiting user access to the zones where a user has a business need for access, the architecture seeks to enforce the concept of least privilege and separation of duties.

7.2.1.6 PR.AC-5: Network Integrity is Protected, Incorporating Network Segregation Where Appropriate

Network segmentation is a key function of this reference design. Segregating Guest, Business Office, Database, Enterprise Services, Clinical Server, and Biomedical Engineering networks from the Medical Device zone reduces the risk of medical devices being negatively impacted from malware or an exploit in another zone. Using a combination firewall/router device to segregate the zones also limits risk to the enterprise should a vulnerability be exploited within the medical device zone.

7.2.1.7 PR.DS-2: Data-In-Transit is Protected

Data-in-transit occurs when data travels from the drug library on a pump server to an infusion pump. The information being passed most frequently will be types of drugs and dosage range. This information is not PHI; however, the availability and integrity of this information are important. This project uses WPA2-AES, which authenticates pumps to the wireless network with client certificate issued by DigiCert Certificate Authority.

7.2.1.8 PR.DS-6: Integrity Checking Mechanisms are Used to Verify Software, Firmware, and Information Integrity

This CSF subcategory is supported with server and agent products to monitor and lock-down configuration settings, files, and file systems in the pump server using the policy-based least privilege access control. This limits application and operating system to expected behavior and reduces the likelihood of system from digital tampering.

7.2.1.9 PR.IP-1: A Baseline Configuration of Information Technology/Industrial Control Systems is Created and Maintained Incorporating Appropriate Security Principles (e.g., Concept of Least Functionality)

A mature cybersecurity program follows a documented secure baseline for traditional information technology components and medical devices. This NCCoE project has implemented hardening for each

component used in the build and documented the steps taken. This initial step produces a secure baseline configuration. Because this project uses five different types of wireless infusion pumps, the baseline is of limited use; however, in a healthcare organization with many medical devices and multiple biomedical and information technology professionals, it is essential to develop and implement a baseline configuration for vulnerability management.

7.2.1.10 PR.MA-2: Remote Maintenance of Organizational Assets is Approved, Logged, and Performed in a Manner that Prevents Unauthorized Access

We controlled remote access to pump vendors by implementing ConsoleWorks, a software tool that records all the actions performed over a connection; thereby providing an audit trail that documents vendor activity.

7.2.1.11 PR.PT-1: Audit/Log Records are Determined, Documented, Implemented, and Reviewed in Accordance with Policy

Our example implementation supports this CSF subcategory by enabling logging on all devices in two ways: with a logging capability and with a process of identifying which events the log will record. Although our project employs auditing and recognizes its importance in a cybersecurity program, log aggregation and implementing a log review process, albeit vital activities, are beyond this project's scope.

7.2.1.12 DE.AE-1: A Baseline of Network Operations and Expected Data Flows for Users and Systems is Established and Managed

As we did with systems and medical devices, we took a least functionality approach when configuring the network. We followed best practices for configuring firewalls based on a default deny, restricted SSID broadcast, and limiting the power of wireless signals.

This CSF subcategory is supported by the Symantec Intrusion Detection System (IDS) component of the reference design. This tool identifies, monitors, and reports anomalous network traffic that may indicate a potential intrusion. Endpoint protection implements policies for expected behavior and alerts when activities occur outside the usual patterns.

7.3 Security Analysis Summary

Our reference design's implementation of security surrounding wireless infusion pumps helps reduce risk from a pump, even if a vulnerability is identified in a pump, by creating a more secure environment for medical devices. The key feature is network segmentation. Supporting this zone approach, our project build follows security best practices to harden devices, monitor traffic, and limit access via the wireless network to only authorized users. Any organization following this guide must conduct its own analysis of how to employ the elements we've discussed here in their environment. It is essential that

organizations follow security best practices to address potential vulnerabilities and minimize any risk to the operational network.

8 Functional Evaluation

We conducted a functional evaluation of our example implementation to verify that several common provisioning functions used in our laboratory test worked as expected. We also needed to ensure that the example solution would not alter normal pump and pump server functions. The test plan in Section 8.1 outlines our test cases, the purposes, and desired outcomes.

The subsequent sections explain the functional tests in more details and list the procedures for each of the functional tests.

8.1 Functional Test Plan

Test Case	Purpose	Desired Outcomes
WIP-1: Network Segmentation	Test the effectiveness of network segmentation	All firewall rules for each segment are implemented correctly, as designed.
WIP-2: Data Center Security	Test the effectiveness of Data Center Security (DCS:SA) to see that it follows defined policies	The inbound and outbound network traffic to and from servers is controlled per host firewall rules.
WIP-3: Endpoint Protection	Test the effectiveness of the Symantec (SEP) to ensure that it follows defined policies	A bad file is detected and the planned installation action is blocked.
WIP-4: Advanced Threat Protection	Test the effectiveness of Advanced Threat Protection: Network (ATP:N) to ensure it follows defined policies	The URLs in the blacklist are blocked. Also, the URLs in the whitelist are allowed.
WIP-5: Protected Remote Access	Test the effectiveness of the remote access controls	The vendor can only access to what's been granted for access with the correct privileges.
WIP-6: Pump and Pump server network connection	Confirm the installation and configuration of pumps and pump server are fully completed	Pumps and pump servers are connected to the network and pumps communicate to the corresponding pump servers.

Test Case	Purpose	Desired Outcomes
WIP-7: Pump and Pump server basic functions	Test a set of operational events between pumps and pump servers	Pumps are connected to the corresponding pump server, able to perform a set of operational events.

8.1.1 Test Case: WIP-1

Test Case Name	Network Segmentation
Description	• Show that the WIP solution allows the inbound and outbound traffic of a given zone as per design • Show the WIP solution blocks the inbound and outbound traffic of a given zone as per design
Preconditions	• WIP network segmentation is implemented • Internal firewall rules of each zone are defined and implemented • The ASAs are configured to use stateful filtering, so return traffic is automatically allowed if the initial connection is allowed. Everything not explicitly allowed in a rule is denied
Procedure	1. Use Medical Device and Biomedical Segment zones as a test example. 2. Review the port and communication protocol requirements from each tested pump vendor, for pump and corresponding pump server 3. Configure the ASA firewall access list to open only the needed ports and allow access only to necessary protocols 4. Everything not explicitly allowed in a rule is denied.
Result	1. Review the ASA configuration file to verify that the ASA firewall is configured to only allow communication with a specific protocol and port as specified by the pump vendors. All other communication between these two segments will be denied and blocked using a command such as: 2. “show access-list | include eq” to see the opened ports 3. Use network discovery scanning tools such as nmap to check the open, closed, or filtered ports

8.1.2 Test Case: WIP-2

Test Case Name	Data Center Security
Description	• Show that the WIP solution detects files that are defined in policy and apply the file and system tampering prevention methods by locking down files
Preconditions	• DCS:SA is installed and configured • File and System Tamper Prevention policy is set

Test Case Name	Data Center Security
	• Windows_Baseline_detect_TEST is used as the baseline for server hardening
Procedure	There are two admin applications for the DCS, the console admin and the portal admin. The console admin is the thick client and the portal is the thin client. The console is used to create and modify the policy, and the portal is used to publish the policy. Portal URL is https://192.168.120.167:8443/webportal/#/ • Log in to the DCS Console • Select the Policy->Work Space->Pump Server folder • Select Detection tab to show the detection polices • You should see a preinstalled policy-Windows_Baseline_detect_Test, double click it to open a detailed policy editing window for configuration • Create a policy for hardening the server, such as “do not allow any file to be installed on the server” • Enable the policy • Publish the policy
Result	Test to verify that no file is allowed to be installed on the protected server

1242 ### 8.1.3 Test Case: WIP-3

Test Case Name	Endpoint Protection/Advance Threat Protection
Description	• Show that the WIP solution has the capability to detect a bad file and act (i.e., stop installing that bad file)
Preconditions	• Symantec Endpoint Protection (SEP) is installed and configured • Define the antivirus signature rule • Create a ‘bad’ file that is part of the antivirus signature rule
Procedure	1. Make sure the test server has a Symantec End Protection agent installed and enabled. 2. From the server machine, open an IE browser and type: http://test.symantecatp.com. This is a test site provided by Symantec containing some unharmful links for testing purposes 3. Click some links such as ‘antivirus test’ from the list to install some suspicious software on the test server 4. The installation should be blocked by the server’s SEP and the violation incident should be reported in the ATP 5. To view the violation in ATP: login to the ATP Server from a browser in a server that can access the 192.168.120.x network, such as the Active Directory server (192.168.120.162) 6. Type this URL in the browser: https://192.168.120.168

Test Case Name	Endpoint Protection/Advance Threat Protection
	7. View any violation incidents from the ATP to verify that the bad link is blocked. • If wanted, one can dive into the details to see which bad sites it tried to connect. • Then for an open incident, need to close it.
Result	To verify that the ATP:N and Symantec deployment and configuration offers needed security protection to prevent malware installed in a server. To view the violation, in ATP: login to the ATP Server from a browser in a server that can access the network, where the tested server is located. 1. View any violation incidents from the ATP to verify that the bad link is blocked. 2. Check the details to see which bad sites it tried to connect. 3. Close open incidents

8.1.4 Test Case: WIP-4

Test Case Name	Advanced Threat Protection
Description	• Show that the WIP solution has effective network threat protection based on network intrusion prevention, URL, and firewall policies.
Preconditions	• Advanced Threat Protection: Network (ATP:N) is installed and configured • Firewall and browser protection rules are defined
Procedure	1. Logon to a vm server with APT:N installed 2. Access to a malicious website 3. Check the results
Result	See Test Case WIP-3

8.1.5 Test Case: WIP-5

Test Case Name	Protected Remote Access
Description	• Show that the WIP solution has the protected remote access capability. The VendorNet concept was created out of a need to give vendors more restricted remote access to a lab than NIST/NCCoE/MITRE staff. VendorNet is an NCCoE network created for each lab that is tied to an active directory group. This group of people is then allowed to access the lab through VendorNet. VendorNet hosts controlled access mechanisms such as ConsoleWorks, file transfer servers, or other remote access proxy services.
Preconditions	• VendorNet is created • TDi ConsoleWorks is installed and configured

Test Case Name	Protected Remote Access
	• ConsoleWorks profile and user are created
Procedure	1. Using public Internet, remotely logon to the NCCoE VPN 2. Logon to ConsoleWorks using the IP address: https://consoleworks.nccoe.nist.gov 3. From the graphical menu, select the View to view graphical connections 4. Each external vendor can only view the resources assigned to them 5. Access the granted hosts 6. Perform the allowed operations as specified 7. Check the results
Result	1. Verify that the vendor can access associated pump server using VendorNet and ConsoleWorks 2. Verify that they can perform the preassigned operational activities 3. Verify that they cannot perform unauthorized operations, such as some administration task, such as adding a new user account 4. Verify that all activities performed by the external vendor are logged and can be audited as needed

8.1.6 Test Case: WIP-6

Test Case Name	Pump and Pump Server Network Connection
Description	• Show that the WIP solution establish the wireless network connection between each vendor's pumps and their corresponding pump server
Preconditions	• Wireless router with pre-share password SSID has been set up • Infusion pump servers have been installed and configured • Infusion pumps have been installed and configured using WPA2-PSK or WPA2-ENT/EAP-TLS for secure wireless network connection • Cisco ISE is installed and configured with root CA installed
Procedure	1. Turn on the pump 2. Check the wireless indicator 3. Check the Access Point and ISE administration portals for device connection and authentication status 4. Check the Infusion Pump server management tool for discovered pumps
Result	Both the access point portal should indicate that the pumps are successfully connected to the network The pump server admin portal should indicate the pump is online and in use. (Note: the way the pump server portal displays these messages is vendor dependent.)

Test Case Name	Pump and Pump Server Network Connection
	In the case of WPA2-Ent/EAP TLS wireless access mode, the Cisco ISE should display that the pumps are successfully authenticated

8.1.7 Test Case: WIP-7

Test Case Name	Pump and Pump Server Basic Functions
Description	• Show that the WIP solution supports the basic operational events for each vendor's pumps and their corresponding pump server
Preconditions	• Successful test results of WIP-6 • The drug library for a specific pump has been created by a pharmacist and validation has been performed. • The drug library has been successfully published or loaded to the infusion pump server to be tested
Procedure	1. From the pump server, send the new version of drug library to its pumps. Following is an example procedure used by Hospira to send Drug Library to its pump using the MedNet Software Server: • Log in to a Metnet software server • Request the download of the drug library to one or more pump • MedNet displays the drug library download status as "Pending" • MedNet using MedNet Service forwards the drug library to infusion pump selected • Pump infuser downloads the drug library from the MedNet Server • Pump Infuser sends a download status update to Hospira MedNet server to indicate the drug library is successfully downloaded and wait for installation • The pump server displays a download status as "On Pump" • The operator of the pump powers down the pump and choose to install the new drug library when prompted by the infuser • The pump sends the update status to MedNet to indicate that the drug library was successfully installed and a "Completed" status is displayed. 2. From the pump server, send the new version of software updates to its pumps (Using Smiths Medical pump as an example). Using the PharmGuard pump server, packages containing data such as device configuration data or firmware, specific to an installed Smiths Medical device model can be installed. The package tested is provided by Smiths Medical. • Log in to a PharmGuard server

Test Case Name	Pump and Pump Server Basic Functions
	• Select Package Deployment from the Asset Management drop-down menu, all previously-deployed packages, if any, are listed • Click Add Package • Click Browse to navigate to and select the package file • Click Upload to upload the package. After package file is read, information about the package is displayed in the package table • Select the package you like to deploy and click View/Deploy, the package detailed information is displayed • Click Deploy to deploy the new package • Enter the name for the deployment and specify a start deploy • Enter the required password and click Continue • After you confirm the package deployment, the name of the newly-deployed package displays in the Deployment list with the Status of Active • To check if a package has been received by the individual pump associated with the package deployment, you need to check the device itself
Result	Using the device or the corresponding pump server portal to verify that the intended package has been successfully deployed. How this information is displayed is device- and manufacturer-specific. Please consult documentation for specific devices for more information.

9 Future Build Considerations

During our development of this project and practice guide, we did not implement several components; however, they should be considered. We did not implement a commercially available electronic health record (EHR) system. EHRs are often regarded as central within a hospital.

Other solutions that were not implemented in the lab were a central asset inventory management tool, or mechanisms to perform malware detection or network monitoring in the Medical Device zone. An update to this practice guide could evaluate these components and other control mechanisms that may become available in the future.

Appendix A Threats

Below are some potential known threats in the healthcare environments that use network-connected medical devices, such as wireless infusion pumps.

- **Targeted attacks:** threats involving actors that attempt to compromise the pump and system components directly affecting pump operations, including the pump, the pump server, drug library, or drug library management systems. Actors who perform such targeted attacks may be external, in other words those who attempt to access the pump system through the public Internet, or via vendor support networks or VPNs. There may also be internal actors, such as those on staff who may be involved in accidental misconfiguration or who possess provisioned access and abuse their granted privileges, or patients or other visitors who attempt to modify the behavior of a pump.
- **Advanced Persistent Threats:** APTs occur when the threat actor attempts to place malicious software on the pump or pump system components, which may enable that threat actor to perform unauthorized actions, either on the pump system itself, or as a pivot point to cause adverse conditions for hospital internal systems that may have reachability from the pump network environment. Placement of malicious software may or may not cause adverse scenarios on the pump or its system components.
- **Disruption of Service – Denial of Service (DoS) and Distributed Denial of Service (DDoS) attacks:** DoS or DDoS attacks may be components found in a broader APT scenario. Such attacks are intended to cause the unavailability of the pump or pump system components, thus rendering providers with degraded capability to fulfill patient care.
- **Malware infections:** In this type of attack, a threat actor places malicious software on the pump, likely as part of an APT campaign, or to cause an adverse situation on the pump or pump systems. One example of a malware infection is that of ransomware, in which malicious software would cause a disruption of the availability of the pump for standard operations, and may affect patient safety by preventing providers from leveraging system functionality (e.g., the ability to associate the pump with a patient and deliver medications), or by preventing the pump from effectively using safety measures such as the drug library.
- **Theft or loss of assets:** This threat type applies when the pump or pump system components are not accounted for in an inventory, thereby leading to degraded availability of equipment, and a possible breach of PHI.
- **Unintentional misuse:** This threat considers the possibility that the pump or its components may be unintentionally misconfigured or used for unintended purposes, including errors introduced through the misapplication of updates to operating systems or firmware, misconfiguration of settings that allow the pump to achieve network connectivity or communication to the pump server, misapplication or errors found in the drug library, or errors associated with fluids applied to pumps.

- **Vulnerable systems or devices directly connected to the device (e.g., via USB, or other hardwired non-network connections):** Extending from the unintentional misuse of the device, this threat considers scenarios in which individuals may expose devices or server components using external ports or interfaces for purposes outside the device's intended use, for example, to extract data to portable storage media, or to connect a mobile device to recharge that device's battery. In leveraging ports for unintended purposes, threat actors may enable malicious software to migrate to the pump or server components, or to create adverse conditions based on unexpected connections.

Appendix B Vulnerabilities

Here's a list of typical vulnerabilities that may arise when using wireless infusion pumps:

- **Lack of asset inventory:** Deficient or out-of-date inventories represent a cybersecurity control deficiency that may lead to the loss/theft of devices or equipment, with little chance for the hospital to recover or take recourse against losses. Deficient asset inventory controls, when paired with a credible threat, such as the loss or theft of a device or equipment, raises risks associated with a provider's ability to render patient care, and may expose PHI to unauthorized individuals.
- **Long useful life:** Infusion pumps are designed to perform clinical functions for several years, and they tend to have long-term refresh rates. One vulnerability associated with infrequent refresh is that each device's technological attributes may become obsolete or insufficient to support patching, updating, or the support of cyber security controls that may become available in the future.
- Information/Data Vulnerabilities
  - **Lack of encryption on private/sensitive data at rest**: Pump devices may have local persistent storage, but they may not have a means to encrypt data stored on the device. Locally stored data may include sensitive configuration information, or patient information, including possible PHI.
  - **Lack of encryption on transmitted data:** Sensitive data should be safeguarded in transit as well as at rest. Where capabilities exist, pumps and server components should employ encryption on the network or when transmitting sensitive information. An inability to safeguard data in transit using appropriate encryption capabilities may expose sensitive information or allow malicious actors to determine how to connect to a pump or server to perform unauthorized activities.
  - **Unauthorized changes to device calibration or configuration data:** Modifications made to pump or server components that are not accurately approved, deployed, or tracked may lead to adverse operation of the equipment. Hospitals should ensure that changes to device calibration, configuration, or modification of safeguard measures such as the drug library are performed and managed using appropriate measures.
  - **Insufficient data backup:** Providing backup and recovery capability is a common cybersecurity control to ensure HDOs can restore services in a timely fashion after an adverse event. Hospitals should perform appropriate pump system backup and restore functions.
  - **Lack of capability to de-identify private/sensitive data:** As a secondary cybersecurity control to data encryption, hospitals may wish to consider the ability to de-identify or obfuscate sensitive information or PHI.

- **Lack of data validation:** Data used and captured by infusion pumps and associated server components may require data integrity assurance to support proper functioning and patient safety. Mechanisms should be used to provide assurance that data cannot be altered inappropriately.

- Device/Endpoint (Infusion Pump) Vulnerabilities
  - **Debug-enabled interfaces:** Interfaces required to support or troubleshoot infusion pump functions should be identified, with procedures noted to indicate when interfaces are available, and how interfaces may be disabled when not required for troubleshooting or system updates/fixes.
  - **Use of removable media:** Infusion pumps that include external or removable storage should be identified. Cybersecurity precautions are necessary because the use of removable media may lead to inappropriate information disclosure, and may provide a viable avenue for malicious software to migrate to the pump or server components.
  - **Lack of physical tamper detection and response:** Infusion pumps may involve physical interaction, including access to interfaces used for debugging. HDOs should enable mechanisms to prevent physical tampering with infusion pump devices, including alerting appropriate personnel whenever a pump or its server components are manipulated or altered.
  - **Misconfiguration:** Mechanisms should be used to ensure that pump configurations are well managed and may not be configured to produce adverse conditions.
  - **Poorly protected and patched devices:** Like the misconfiguration vulnerability, HDOs should implement processes to protect/patch/update pumps and server components. This may involve including controls on the device, or provisions that allow for external controls that would prevent exposure to flaws or weaknesses.
- User or Administrator Accounts Vulnerabilities
  - **Hard-coded or factory default passcodes:** Processes or mechanisms should be added to prevent the use of so-called hard coded or default passcodes. This would overcome a common IT systems deficiency in the use of authentication mechanisms for privileged access to devices in terms of using weak passwords or passcodes protection. Weak authentication mechanisms that are well known or published degrade the effectiveness of authentication control measures. HDOs should implement a means to update and manage passwords.
  - **Lack of role-based access and/or use of principles of least privilege:** When access management roles and principles of least privilege are poorly designed, they may allow the use of a generic identity (e.g., a so-called admin account) that enables greater access capability than necessary. Instead, HDOs should implement processes to limit access to privileged accounts, infusion pumps and server components, and use accounts or identities

that tie to specific functions, rather than providing/enabling the use of super user, root, or admin privileges.

- **Dormant accounts:** Accounts or identities that are not used may be described as *dormant.* Dormant account information should be disabled or removed from pumps and server components.
- **Weak remote access controls:** When remote access to a pump and or server components is required, access controls should be appropriately enforced to safeguard each network session and ensure appropriate authentication and authorization.

- IT Network Infrastructure Vulnerabilities
  - **Lack of malware protection:** Pumps and server components should be protected using processes or mechanisms to prevent malware distribution. When malware *protection* cannot be implemented on end-point devices, malware *detection* should be implemented to protect network traffic.
  - **Lack of system hardening:** Pumps and server components should incorporate protective measures that limit functionality only to the specific capabilities necessary for infusion pump operations.
  - **Insecure network configuration:** HDOs should employ a least privilege principle when configuring networks that include pumps and server components, limiting network traffic capabilities, and enforcing limited trust between zones identified in hospital environments.
  - **System complexity:** When implementing network infrastructure controls, hospitals should seek device models and communications paths/patterns that limit complexity where possible.

Appendix C Recommendations and Best Practices

Associated best practices for reducing the overall risk posture of infusion pumps are also included in the following list:

- Consider forming a Medical Device Security Committee composed of staff members from biomedical services, IT, and InfoSec that would report to C-suite governance.
  - Enable this committee to manage the security of all network-connected medical devices. Too often, for example, the biomedical services team is solely responsible for cradle-to-grave maintenance of all aspects of medical devices, including cybersecurity, leaving IT and InfoSec staff out-of-the-loop.
  - Develop a committee charter with roles and responsibilities and reporting requirements to the C-suite and Board of Directors.
- Consider the physical security of mobile medical devices including wireless infusion pumps.
  - Designate a secure and lockable space for storing these devices when they are not in use.
  - Ensure that only personnel with a valid need have access to these spaces. Ideally, a proximity system with logging should be used and audited frequently.
- Create a comprehensive inventory of medical devices and actively manage it.
  - Consider the use of Radio-frequency identification (RFID) or Real-time locating systems (RTLS) technologies to assist with inventory processes and help staff locate devices that have been moved without documentation.
- Ensure that any Cybersecurity Incident Response Plan includes medical devices.
  - Recently, the FDA and Industrial Control System – Computer Emergency Response Team (ICS-CERT) have both issued cybersecurity vulnerability advisories for medical devices. This was the first major warning to covered entities regarding medical device vulnerabilities. Most covered entities have not incorporated medical device response into their planning.
- Ensure that pumps cannot step down to a Wireless Encryption Protocol (WEP) encrypted network.
  - WEP is a compromised encryption protocol and should NEVER be used in operational wireless networks.
  - Operating any form of IT equipment including medical devices over a WEP network will result in the potential for data compromise and a regulatory breach.
  - Any wireless network should be using, at a minimum, Wi-Fi Protected Access 2 (WPA2). This protocol implements NIST-recommended Advanced Encryption Standard (AES).
- Put in place an Information Security department and functionally separate it from the IT department. This is necessary to ensure operational IT personnel are not responsible for any

information security measures, which may otherwise lead to a fox-guarding-the-hen-house situation.

- Enable a separate InfoSec department to report to the Chief Information Security Officer (CISO) rather than to the Chief Information Officer (CIO.)
- Make this organization part of the Medical Device Security Committee.

- Create an operational information security program. This can take the form of an in-house Security Operations Center (SOC) to monitor information systems and initiate cybersecurity incident response, to include monitoring of potential exploits of medical devices, as necessary. Alternatively, organizations may wish to consider a Managed Security Service Provider (MSSP) to perform these duties.
- Ensure that vendor management includes the evaluation of information security during the due diligence phase of any related procurement processes. Too often, the Information Security team is not brought in until after contracts have been signed.
  - When purchasing medical devices, ensure that devices incorporate the latest cybersecurity controls and capabilities.
  - Understand roles and responsibilities related to upgrades, patching, password management, remote access, etc., to ensure the cybersecurity of products or services.
- Consider media access control (MAC) address filtering to limit exposure of unauthorized devices attempting to access the network. This would identify a bad actor attempting access a medical device from within the network through an exposed wired Ethernet port.
- Develop or update policies and procedures to ensure a holistic approach to deployment, sanitization, and reuse of medical devices; include the Medical Device Security Committee.

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[53] NIST SP 800-95, Guide to Secure Web Services. Accessed 6 April 2017: http://csrc.nist.gov/publications/nistpubs/800-95/SP800-95.pdf

[54] NIST SP 1800-5A, IT Asset Management. Accessed 10 April 2017: https://nccoe.nist.gov/sites/default/files/library/sp1800/fs-itam-nist-sp1800-5-draft.pdf

[55] http://wc1.smartdraw.com/cmsstorage/exampleimages/44b341d1-a502-465f-854a-4e68b8e4bf75.png

[56] Manufacturer Disclosure Statement for Medical Device Security (MDS2) http://www.himss.org/resourcelibrary/MDS2

NIST SPECIAL PUBLICATION 1800-8C

Securing Wireless Infusion Pumps

In Healthcare Delivery Organizations

Volume C:
How-to Guides

DRAFT

Gavin O'Brien
National Cybersecurity Center of Excellence
Information Technology Laboratory

Sallie Edwards
Kevin Littlefield
Neil McNab
Sue Wang
Kangmin Zheng
The MITRE Corporation
McLean, VA

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Certain commercial entities, equipment, products, or materials may be identified in this document to describe an experimental procedure or concept adequately. Such identification is not intended to imply recommendation or endorsement by NIST or NCCoE, nor is it intended to imply that the entities, equipment, products, or materials are necessarily the best available for the purpose.

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FEEDBACK

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

Comments on this publication may be submitted to: hit_nccoe@nist.gov.

Public comment period: May 8, 2017 through July 7, 2017

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

National Cybersecurity Center of Excellence
National Institute of Standards and Technology
100 Bureau Drive
Mailstop 2002
Gaithersburg, MD 20899
Email: nccoe@nist.gov

NATIONAL CYBERSECURITY CENTER OF EXCELLENCE

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

To learn more about the NCCoE, visit https://nccoe.nist.gov. To learn more about NIST, visit https://nist.gov.

NIST CYBERSECURITY PRACTICE GUIDES

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

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

ABSTRACT

Medical devices, such as infusion pumps, were once standalone instruments that interacted only with the patient or medical provider. But today's medical devices connect to a variety of health care systems, networks, and other tools within a healthcare delivery organization (HDO). Connecting devices to point-of-care medication systems and electronic health records can improve healthcare delivery processes, however, increasing connectivity capabilities also creates cybersecurity risks. Potential threats include unauthorized access to patient health information, changes to prescribed drug doses, and interference with a pump's function.

The NCCoE at NIST analyzed risk factors in and around the infusion pump ecosystem using a questionnaire-based risk assessment to develop an example implementation that demonstrates how HDOs can use standards-based, commercially available cybersecurity technologies to better protect the infusion pump ecosystem, including patient information and drug library dosing limits.

This practice guide will help HDOs implement current cybersecurity standards and best practices to reduce their cybersecurity risk, while maintaining the performance and usability of wireless infusion pumps.

KEYWORDS

authentication; authorization; digital certificates; encryption; infusion pumps; Internet of Things; IoT; medical devices; network zoning; pump servers; questionnaire-based risk assessment; segmentation; VPN; Wi-Fi; wireless medical devices

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The technology vendors who participated in this build submitted their capabilities in response to a notice in the Federal Register. Companies with relevant products were invited to sign a Cooperative Research and Development Agreement (CRADA) with NIST, allowing them to participate in a consortium to build this example solution. We worked with:

Technology Partner/Collaborator	Build Involvement
Baxter Healthcare Corporation	• Sigma Spectrum LVP, version 8 • Sigma Spectrum Wireless Battery Module, version 8 • Sigma Spectrum Master Drug Library, version 8 • CareEverywhere Gateway Server, version 14
B. Braun Medical Inc.	• Infusomat® Space Infusion System/ Large Volume Pumps • DoseTrac® Infusion Management Software/ Infusion Pump Software
Becton, Dickinson and Company (BD)	• Alaris® 8015 PC Unit v9.19.2 • Alaris® Syringe Module 8110 • Alaris® LVP Module 8100 • Alaris® Systems Manager v4.2 • Alaris® System Maintenance (ASM) v 10.19
Cisco	• Access Point (AIR-CAP1602I-A-K9) • Wireless LAN Controller 8.2.111.0 • Cisco ISE • Cisco: ASA • Catalyst 3650 Switch
Clearwater Compliance	Clearwater: IRM | Pro
DigiCert	CertCentral management account / Certificate Authority
Hospira Inc., a Pfizer Company (ICU Medical)	• Plum 360™ Infusion System, version 15.10 • LifeCare PCA™ Infusion System, version 7.02 • Hospira MedNet™, version 6.2
Intercede	MyID
MDISS	MDRAP

Technology Partner/Collaborator	Build Involvement
PFP Cybersecurity	Device Monitor
Ramparts	Risk Assessment
Smiths Medical	• Medfusion® 3500 V5 syringe infusion system • PharmGuard® Toolbox v1.5 • Medfusion 4000® Wireless Syringe Infusion Pump • CD, PHARMGUARD® TOOLBOX 2, V3.0 use with Medfusion® 4000 and 3500 V6 (US) • PharmGuard® Server Licenses, PharmGuard® Server Enterprise Edition, V1.1 • CADD®-Solis Ambulatory Infusion Pump • CADD™-Solis Medication Safety Software
Symantec Corporation	• Endpoint Protection (SEP) • Advanced Threat Protection: Network (ATP:N) • Server Advanced - DataCenter Security (DCS:SA):
TDi Technologies, Inc.	ConsoleWorks

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1 Introduction

The following guidelines show IT professionals and security engineers how the NCCoE implemented this example solution. We discuss every product that we employed in this reference design. We do not, however, recreate the product manufacturers' documentation, which is widely available. Rather, these guidelines show how we integrated the products in our environment on your behalf.

Note: These guidelines are not comprehensive tutorials. Many possible service and security configurations for these products exist but are out of scope for this reference design.

1.1 Practice Guide Structure

This NIST Cybersecurity Practice Guide demonstrates a standards-based reference design and gives users the information they need to replicate all or parts of the example implementation that we built in our lab. This reference design is modular and can be deployed in whole or in part.

This guide contains three volumes:

- NIST SP 1800-8A: Executive Summary
- NIST SP 1800-8B: Approach, Architecture, and Security Characteristics – what we built and why
- NIST SP 1800-8C: How-To Guides – instructions for building the example solution **(you are here)**

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

Business decision makers, including chief security and technology officers will be interested in the *Executive Summary (NIST SP 1800-8A)*, which describes the:

- challenges enterprises face in securing the wireless infusion pump ecosystem
- example solution built at the NCCoE
- benefits of adopting the example solution

Technology or security program managers who are concerned with how to identify, understand, assess, and mitigate risk will be interested in *NIST SP 1800-8B,* which describes what we did and why. The following sections will be of particular interest:

- Section 4, Risk Assessment and Mitigation, describes the risk analysis we performed
- Section 4.3, Security Characteristics and Control Mapping, maps the security characteristics of this example solution to cybersecurity standards and best practices

You might share the *Executive Summary, NIST SP 1800-8A,* with your leadership team members to help them understand the importance of adopting standards-based, commercially available technologies that can help secure the wireless infusion pump ecosystem.

IT professionals who want to implement an approach like this will find the entire practice guide useful. You can use the How-To portion of the guide, *NIST SP 1800-8C*, to replicate all or parts of the build created in our lab. The How-To guide provides specific product installation, configuration, and integration instructions for implementing the example solution. We do not recreate the product manufacturers' documentation, which is generally widely available. Rather, we show how we incorporated the products in our environment to create an example solution.

This guide assumes that IT professionals have experience implementing security products within their enterprise. Although we have used a suite of commercial products to address this challenge, this guide does not endorse these products. Your organization can adopt this solution or one that adheres to these guidelines in part or in whole. Your organization's security experts should identify the products that will best integrate with your existing tools and IT system infrastructure. We hope you will seek products that are congruent with applicable standards and best practices. Vol B. section 4.4, Technologies, lists the products we used and maps them to the cybersecurity controls provided by this reference solution.

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

1.2 Typographical Conventions

The following table presents typographic conventions used in this volume.

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

1.3 How-to Overview

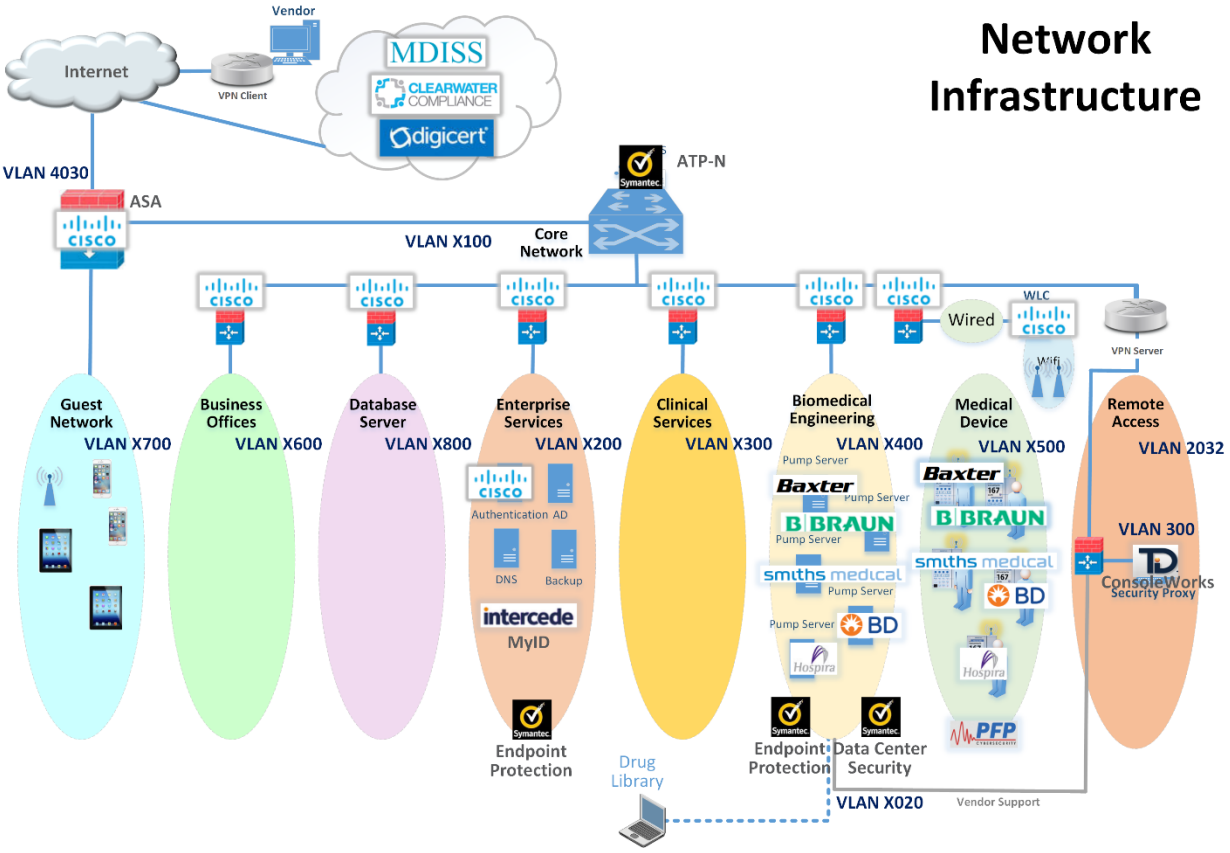
Refer to NIST SP 1800-8B: *Approach, Architecture, and Security Characteristics* for an explanation of why we used each technology.

1.4 Logical Architecture Summary

Below depicts a reference network architecture that performs groupings that would translate to network segments or zones. The rationale behind segmentation and zoning is to limit trust between

areas of the network. In considering a hospital infrastructure, NCCoE identified devices and usage, and grouped them by usage. The grouping facilitated the identification of network zones. Once zones are defined, infrastructure components may be configured such that those zones do not inherently have network access to other zones within the hospital network infrastructure. Segmenting the network in this fashion limits the overall attack surface posed to the infusion pump environment, and considers the network infrastructure configuration as part of an overall defense in depth strategy. Figure 1-1 is included from the architecture for your reference.

Figure 1-1: Logical Architecture Summary



2 Product Installation Guides

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

2.1 The Core Network

The NCCoE's example architecture implements a core network zone which is used to establish the backbone network infrastructure. The external firewall/router also has an interface connected to the core enterprise network, just like other firewall/router devices in the other zones. This zone serves as the backbone of the enterprise network and consists only of routers connected by switches. The routers automatically share internal route information with each other via authenticated Open Shortest Path First (OSPF) [1] to mitigate configuration errors as zones are added or removed.

Several functional segments may be part of this core network:

- guest network
- business office (example only)
- database server (example only)
- enterprise services
- clinical services (example only)
- biomedical engineering
- medical devices with wireless LAN
- remote access for external vendor support

The NCCoE build uses Cisco Adaptive Security Appliances (ASA) as virtual router and firewall devices within the network. Each defined zone in the hospital network we built has its own ASA, with two interfaces to protect the zone. As we considered how many ASAs to use, we opted for a tradeoff between the complexity of the configuration and the number of interfaces on a single ASA.

2.1.1 Cisco ASA Baseline Configuration

In our environment, all ASAs are virtualized and are based on Cisco's Adaptive Security Virtual Appliance (ASAv) product. In your environment, the responsible person would complete installation by following Cisco's *Adaptive Security Virtual Appliance (ASAv) Quick Start Guide, 9.6* [2].

We imported the virtual appliance called *asav-vi.ovf*, assigning the first interface to the management network, the second to the wide area network (WAN), and the third to the local area network (LAN). For an unknown reason, the '`show version`' command did not work in the console; as a workaround, we configured secure shell (SSH) [3] access and ran the command via SSH instead.

Then we configured the ASA with a baseline configuration template that allows all outbound traffic, but only related traffic inbound as allowed by the stateful firewall. Internet Control Message Protocol (ICMP) [4] enables troubleshooting with ping and traceroute tools. Authenticated OSPF automates routing tables as we added or removed ASAs in the network. In your production environment, you may wish to make different decisions in your baseline configuration. All ASAs have an additional management interface on 192.168.29.0/24. We opted to configure Simple Network Management Protocol (SNMP) [5] and SSH for management use on this interface, but not on the other interfaces. See Section A.1 for the ASA configuration for this zone.

2.1.2 External Firewall and Guest Network

We configured the build network to use network address translation (NAT) at the external firewall. This is the only point in the network where NAT is used. The upstream provider uses 10.0.0.0/8 addresses on the WAN interface. We also defined a LAN interface on 192.168.100.0/24 as the core network where other ASAs connect. Another interface is defined as *GUEST* on 192.168.170.0/24. We assigned the GUEST and LAN interfaces equal security levels higher than those for the WAN interface. When ASAs interfaces are configured with equal security levels, by default they cannot communicate with each other, but they will both have WAN access. Dynamic Host Configuration Protocol (DHCP) [6] is enabled on the GUEST interface for addressing.

See Section A.2 for the ASA configuration for this zone.

2.1.3 Enterprise Services

We defined a LAN interface on 192.168.120.0/24 as the LAN for all enterprise services. Ports are open for domain name system (DNS) from the Biomedical Engineering network to the DNS servers. Port 8114 is open for all hosts to the Symantec Endpoint Protection server. Several ports are open for any host to the Symantec Data Center Security server.

See Section A.3 for the ASA configuration for this zone.

2.1.4 Biomedical Engineering Network

This zone contains a dedicated wireless network to support the wireless infusion pumps. We defined a LAN interface on 192.168.140.0/24 for all biomedical equipment, including infusion pump servers. Each manufacturer has a custom set of ports opened to their server. These ports are only accessible from the medical device network.

Generally, the firewall is configured in this way:

All pump servers -> internet/intranet (all destinations)

All intranet -> all pump servers Ping and Traceroute (primarily for debugging)

All pumps -> *Smiths Medical Pump Server* on port 1588

All pumps -> *Carefusion Pump Server* on port 3613

All pumps -> *Baxter Pump Server* on port 51244

All pumps -> *Hospira Pump server* on ports 443, 8443, 8100,9292,11443, 11444

All pumps -> *B. Braun Pump server* on ports 443, 80, 8080, 1500, 4080

See Section A.4 for the ASA configuration for this zone.

2.1.5 Medical Devices

We defined a LAN interface on 192.168.150.0/24 as the LAN for all medical devices. The infusion pump systems are designed such that all external connections to the pumps, such as an EHR system or vendor maintenance, is completed with the associated pump server on the Biomedical Engineering network. This enables us to disallow all outbound traffic not destined for the Biomedical Engineering network. In addition, because some pump servers initiate connections to open ports on the pumps, we added vendor-specific rules to allow this. A DNS server is not useful in this case, but, if you needed one, we recommend that the ASA act as a forwarder. The DHCP server on the ASA is enabled for LAN addressing. In our lab, we discovered that at least one brand of infusion pump would not recognize network setup as complete unless at least one DNS server address was set. In this case, the DNS server address only needed to be included in the configuration; a DNS server did not actually need to be present at that address.

Generally, the firewall is configured in this way:

All pumps -> all pumps servers

All intranet -> all pumps Ping and Traceroute (primarily for debugging)

Hospira Pump Server -> All pumps ports 8100, 9292, 443, 8443

Baxter Pump Server-> All pumps port 51243

B. Braun Pump Server -> All pumps ports 80, 443, 8080, 1500

See Section A.5 for the ASA configuration for this zone.

2.1.6 Cisco Catalyst Switch Configuration

The Catalyst 3650 switch is configured with four virtual LANs (VLANs) [7]. One port is assigned to a management VLAN, with subnet 192.168.20.0/24. Wireless access points are connected to a Wi-Fi management VLAN, which also is trunked back to the virtual WLAN controller software. Additionally, the Biomedical and Device networks have some physical ports configured for testing, both of which are also trunked back to the virtualization hardware and ASAs. DHCP is enabled for the wireless access points. SNMP and SSH are enabled for management. The switch also supports Power over Ethernet (PoE), allowing for a single Ethernet cable, with both data and power for the APs.

To set up your organization's configuration, follow the instructions in Cisco's *Catalyst 3650 Switch Getting Started Guide:* http://www.cisco.com/c/en/us/td/docs/switches/lan/catalyst3650/hardware/quick/guide/cat3650_gsg.html.

See Section A.6 for the switch configuration.

2.1.7 Cisco Enterprise Wi-Fi Infrastructure

The Wi-Fi management network is different in that it does not have a firewall/router that connects directly to the core network. A completely closed network, this is used for management and communication between the Cisco Aironet wireless access points (AP) and the Cisco Wireless LAN Controller (WLC). The WLC is the central point where wireless service set identifiers (SSID), virtual LANs (VLAN), and Wi-Fi-protected access version 2 (WPA2) [8] security settings are managed for the entire enterprise. We defined two SSIDS: *IP_Dev* and *IP_Dev_Cert*. IP_Dev uses *WPA2-PSK* and *IP_Dev_Cert* uses *WPA2-Enterprise* protocols.

2.1.7.1 Installation

In our environment, the Cisco WLC is virtualized. In your environment, the responsible person would complete installation by following *Cisco's Virtual Wireless LAN Controller Deployment Guide 8.2:* http://www.cisco.com/c/en/us/td/docs/wireless/technology/mesh/8-2/b_Virtual_Wireless_LAN_Controller_Deployment_Guide_8-2.html.

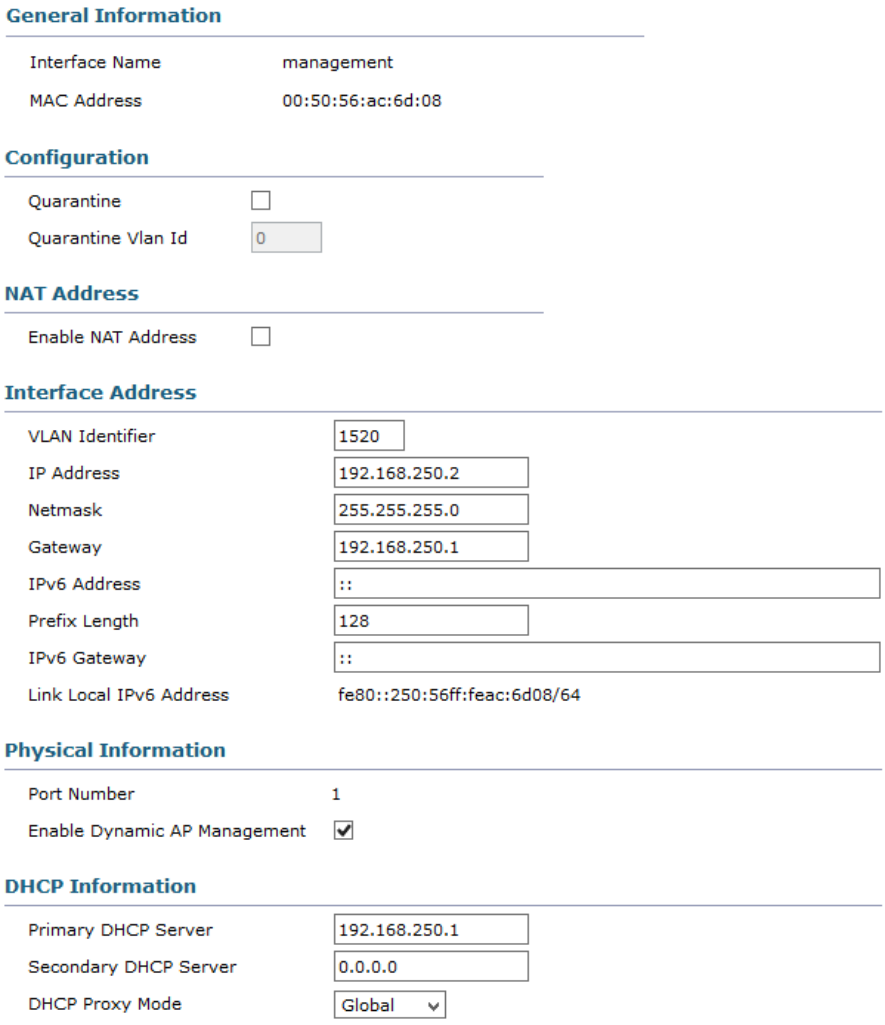
We imported the virtual appliance called *AIR_CTVM_K9_8_2_111_0.ova*, assigning the first interface to the management network, referred to as *service-port* in the web interface. The second interface is used as a trunk port, with VLAN tags for all user and Wi-Fi management traffic. In the web interface, the built-in *management* interface refers to the wireless system control traffic network that the APs are connected to.

The primary management mechanism for the WLC is the web interface. To configure an IP address for the web interface, we first needed to use the console and complete the setup wizard that sets the *service-port* address. What follows is our process, which your organization can adapt to your needs.

2.1.7.2 Controller Configuration

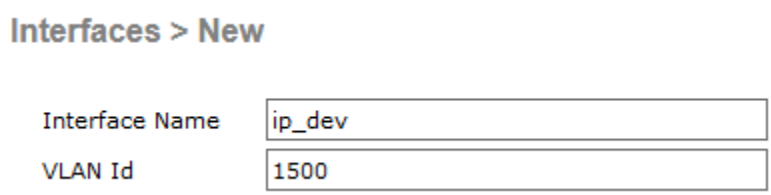
Configure Network Interfaces:

1. Configure the interface for AP management traffic at **Controller** -> **Interfaces** -> **Management**.

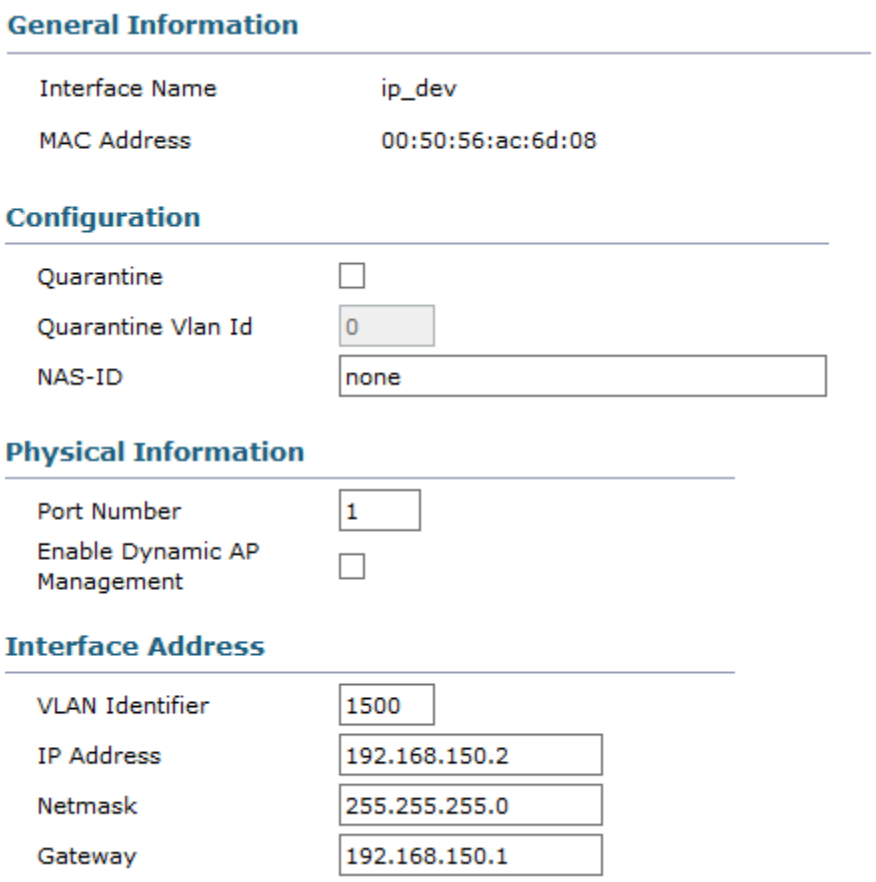


2. Configure interfaces for user Wi-Fi traffic, by first mapping the interface to an Ethernet port and setting the VLAN and IP address, and then mapping to wireless SSIDs.

Create the new interface at **Controller -> Interfaces -> New.**



Configure the new interface by using the form below. Refer to the completed interface for the values that we used in the lab.



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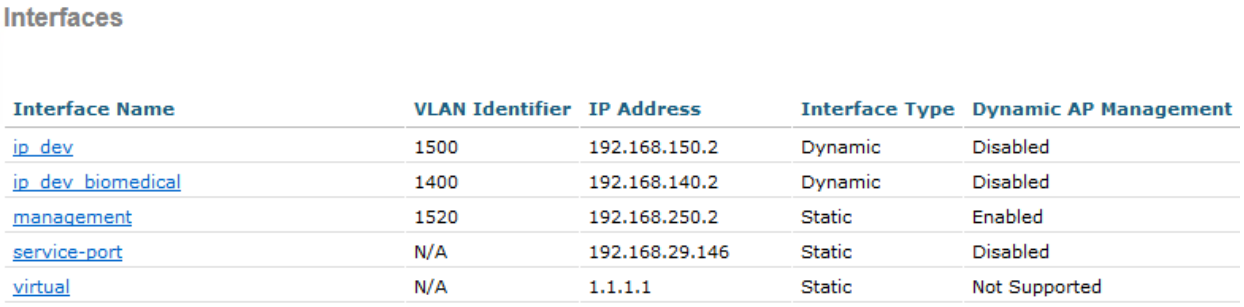
198 Our completed Interfaces list looks like the following:



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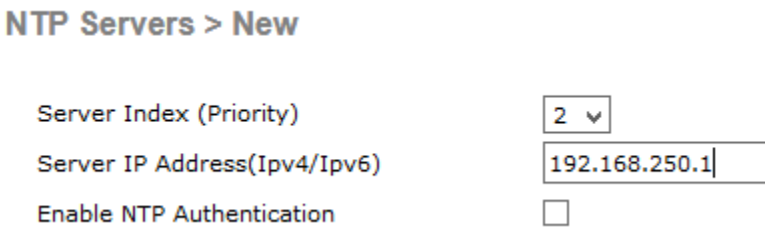
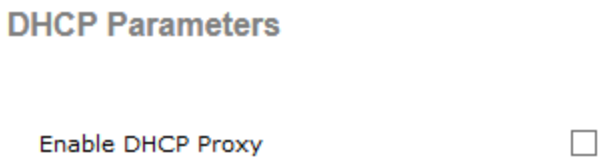
200 Configure NTP [9] at **Controller -> NTP -> Server -> New**:



201

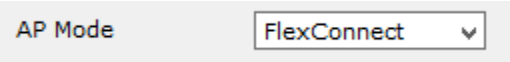
202 To configure the DHCP server, disable the DHCP Proxy at **Controller -> Advanced -> DHCP.**



2.1.7.3 Wireless AP Connection and Setup

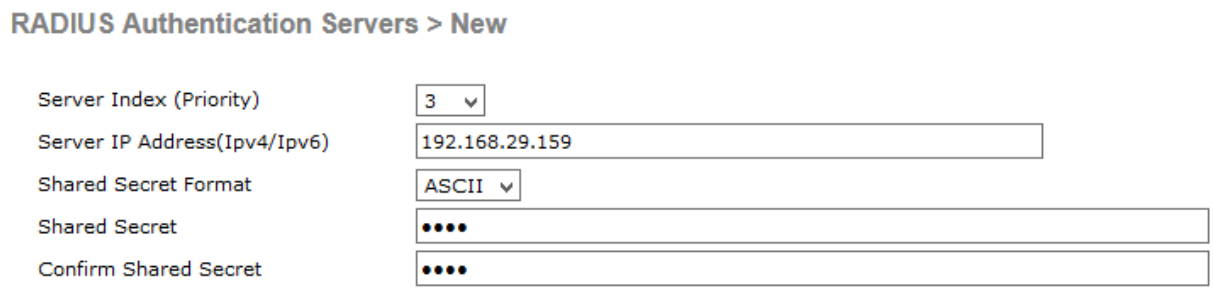
Connect the APs to the Ethernet ports configured for untagged VLAN 1520. They will obtain their addresses and the WLC address automatically via DHCP from the switch (see Cisco Catalyst Switch Configuration in Section 2.1.6). No other VLANs should to be configured for the APs because we are using a centralized switching model where Wi-Fi traffic VLANs are connected to the Enterprise network through the WLC.

As each AP is connected, it should show up in the *Wireless* tab on the WLC. For each AP, the *AP Mode* needs to be set to *FlexConnect* (see below).



2.1.7.4 Authentication Configuration

To use certificate-based authentication, the WLC must consult a RADIUS server. Configure Cisco ISE RADIUS server IP Address and Shared Secret at **Security -> RADIUS -> Authentication -> New**.



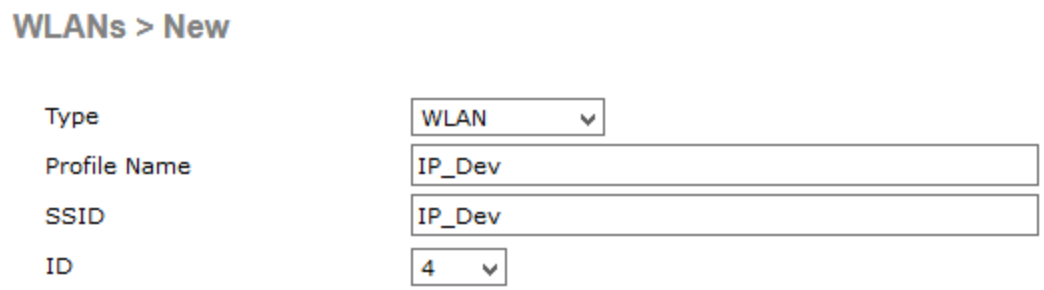
2.1.7.5 WLANs Configuration

At this point, we configured two SSIDs for medical devices: *IP_Dev* is configured for WPA2 (AES [10]) PSK, and *IP_Dev_Cert* is configured for WPA2 (AES) Enterprise. They both use the same interface and therefore connect to the same network VLAN; the only difference is the Wi-Fi security.

To create a new SSID, follow these steps:

1. Use the WLAN tab.

2. Enter your new SSID information.



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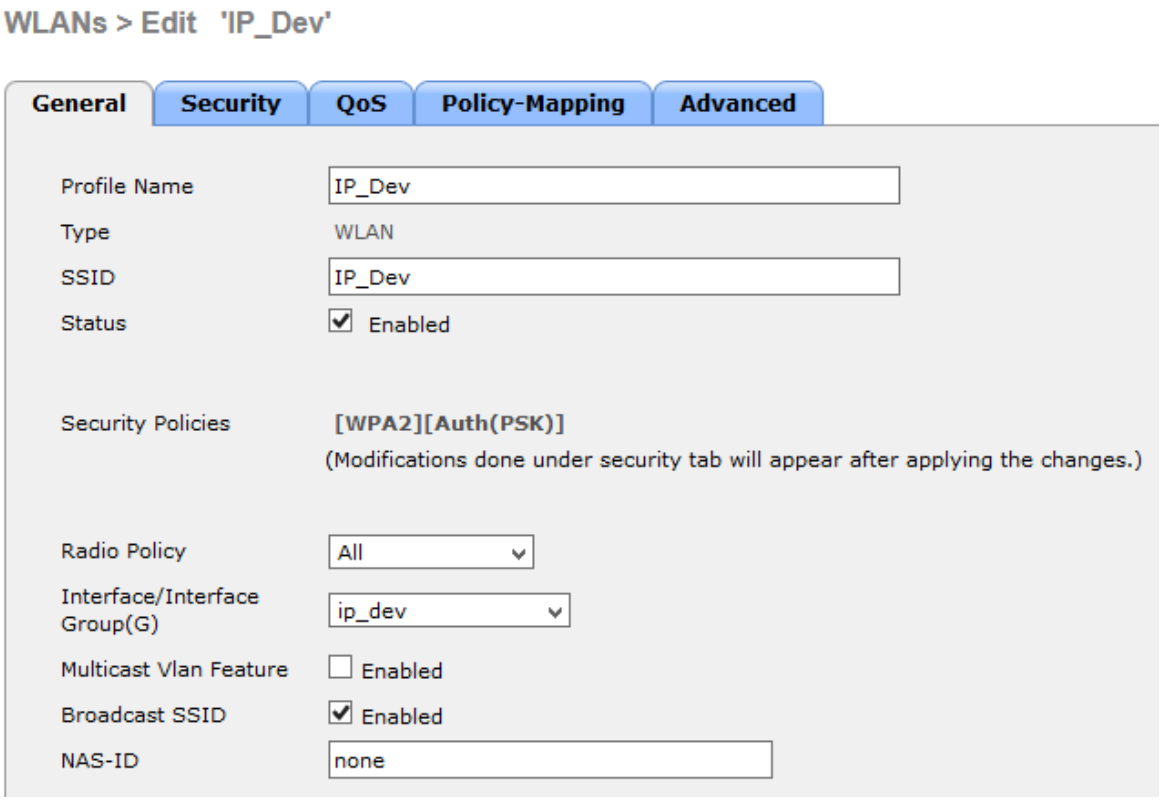
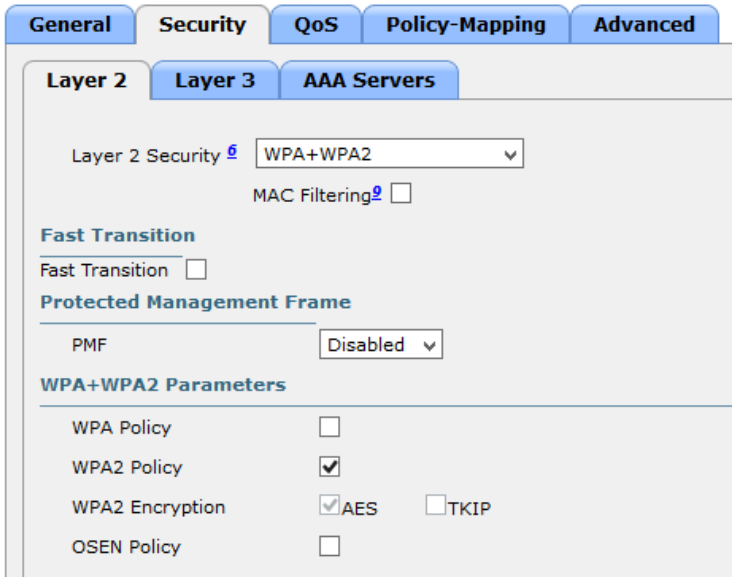
226 3. In **WLANs > WLANs -> WLANs**, select the WLAN ID number of the newly created SSID. Set *Status* to
227 *Enabled* and Interface/Interface Group(G) to *ip_dev*.



228

229 4. On the **Security tab** under **Authentication Key Management**, uncheck *802.1X*, check *PSK,* and set
230 the PSK field.



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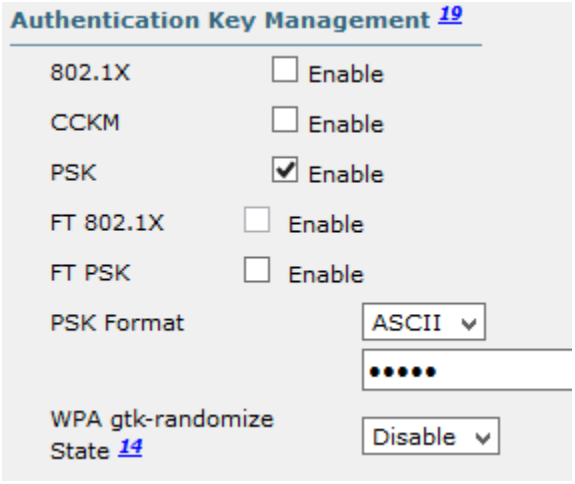
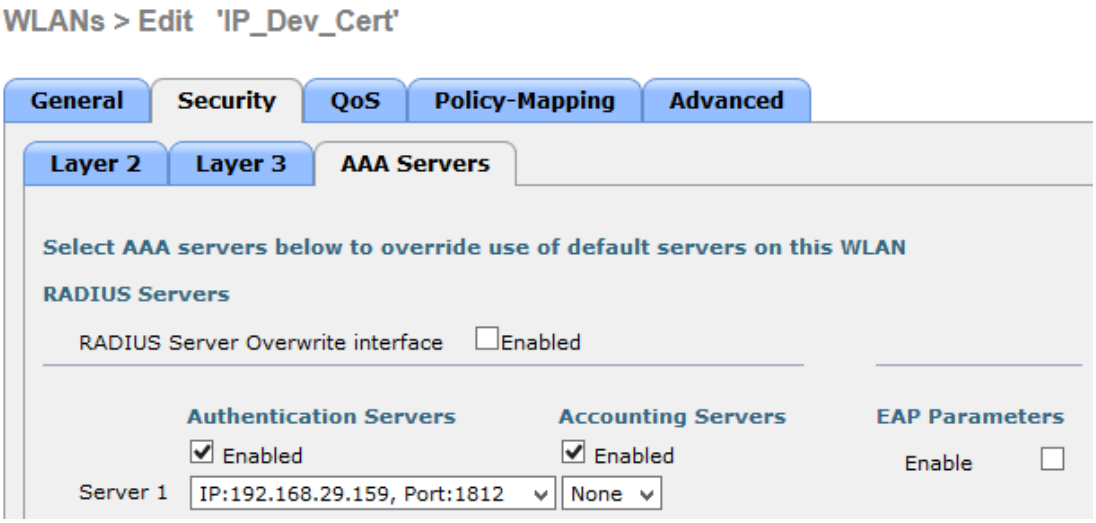


232

233 5. For the SSID *IP_Dev_Cert*, repeat the steps above, but do not change the Security Settings for
234 Authentication Key Management; leave *802.1X* checked, and leave *PSK* unchecked.

235 6. On the **Security, AAA Servers** tab, select the *RADIUS* server to authenticate with.



236

237 *2.1.7.6 Monitoring*

238 By using **Monitor -> Clients**, you will find the list of currently connected clients, which SSID they are
239 connected to, and the User Name used to authenticate (Common Name from Certificate).

Client MAC Addr	IP Address(Ipv4/Ipv6)	WLAN Profile	WLAN SSID	User Name
00:17:23:e1:8e:32	192.168.250.116	IP_Dev_Cert	IP_Dev_Cert	BBraun
00:17:23:f3:9f:db	192.168.250.123	IP_Dev	IP_Dev	Unknown
00:17:23:f4:f5:4e	192.168.250.118	IP_Dev_Cert	IP_Dev_Cert	Carefusion
00:18:e7:8f:cd:1f	192.168.250.126	IP_Dev	IP_Dev	Unknown
00:40:9d:96:04:0c	192.168.250.125	IP_Dev	IP_Dev	Unknown
00:40:9d:96:06:06	192.168.250.124	IP_Dev	IP_Dev	Unknown
00:80:92:68:62:26	192.168.250.117	IP_Dev_Cert	IP_Dev_Cert	Hospira
28:ed:6a:f2:4e:37	192.168.250.122	IP_Dev_Cert	IP_Dev_Cert	Baxter

240

241 *2.1.7.7 Final Configuration*

242 See Section A.7 for the WLC configuration, accessing details about additional configuration options at
243 *Cisco Wireless Controller Configuration Guide, Release 8.0,*
244 http://www.cisco.com/c/en/us/td/docs/wireless/controller/8-0/configuration-guide/b_cg80.html.

245 2.1.8 TDi ConsoleWorks External Remote Access

246 The NCCoE lab implemented a VendorNet using TDi ConsoleWorks, which is a browser interface that
247 enables healthcare organizations to manage, monitor, and record activities from external vendors in the
248 IT infrastructure.

249 System Environment:

250 The NCCoE lab set up a fully updated (as of 4/20/2016) CentOS 7 Operating System, with the following
251 hardware specifications:

252 - 8GB RAM
253 - 40 GB HDD
254 - 1 Network Interface

Other requirements:

- ConsoleWorks install media (we built from a CD)
- ConsoleWorksSSL-<version>.rpm
- ConsoleWorks_gui_gateway-<version>.rpm
- ConsoleWorks license keys (*TDI_Licenses.tar.gz*)
- Software installation command
- yum install uuid libbpng12 libvncserver

Installation:

As Root:

1. Place ConsoleWorks Media into the system
2. `mount` /dev/sr0 /mnt/cdrom
3. `mkdir` /tmp/consoleworks
4. `cp` /mnt/cdrom/consolew.rpm /tmp/consoleworks/consolew.rpm
5. `rpm -ivh` /tmp/consoleworks/ConsoleWorksSSL-<version>.rpm
6. `mkdir` /tmp/consoleworkskeys/
7. Copy ConsoleWorks keys to */tmp/consoleworkskeys/*
8. `cd` /tmp/consoleworkskeys/
9. `tar xzf` TDI_Licenses.tar.gz
10. `cp` /tmp/consoleworkskeys* /etc/TDI_licenses/
11. `/opt/ConsoleWorks/bin/cw_add_invo`
12. Accept the License Terms.
13. Press Enter to continue.
14. Name the instance of ConsoleWorks.
15. Press Enter to accept default port (5176).
16. Press N to deny SYSLOG listening.
17. Press Enter to accept parameters entered.
18. Press Enter to return to /opt/ConsoleWorks/bin/cw_add_invo.
19. `rpm -ivh` /tmp/consoleworks/ConsoleWorks_gui_gateway-version>.rpm
20. `/opt/gui_gateway/install_local.sh`
21. `/opt/ConsoleWorks/bin/cw_start` <invocation name created early>
22. `service gui_gatewayd start`

Usage:

1. Open a browser and navigate to *https://<ConsoleWorksIP>:5176*.
2. Log in with Username*: console_manager*, Password: *Setup.*
3. Change the default password.
4. Choose Register Now.

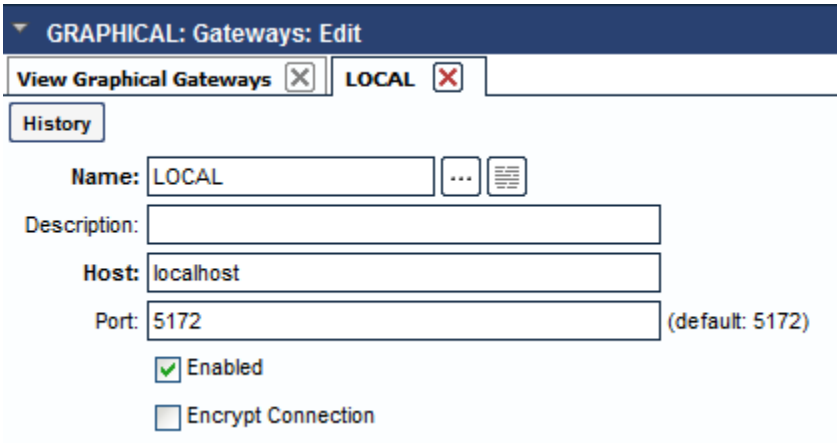
NCCoE chose ConsoleWorks to segregate and limit vendor access to our labs. Our data model groups consoles and graphical connections together into a tag. The *tag* is a collection of equipment that you need to connect to, although a vendor typically owns the equipment. This tag allows us to operate on a group of *consoles* and *graphical connections*. We group users from the same vendor into a *profile* that allows us to operate on the users. An Access Control Rule associates a profile with a tag and defines permissions for a particular component type (typically consoles or graphical connections).

Initial Configuration of Graphical Gateway

Use the menu in the sidebar to access all instructions below.

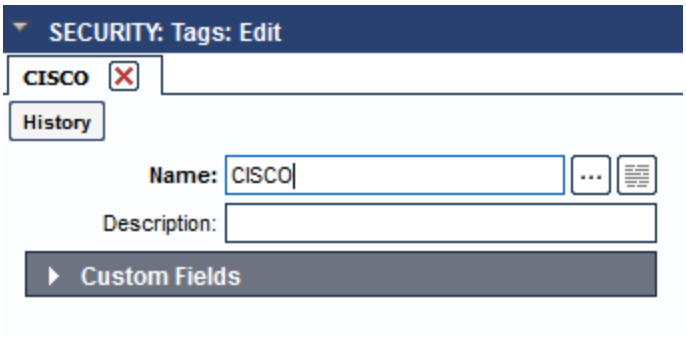
Configure Graphical Gateway (only required for graphical connections such as virtual network computing, VNC; and remote desktop protocol, RDP):

1. Click on Graphical->Gateways->Add.
2. Set a name: LOCAL, then set Host as Localhost and port as 5172.
3. Check the Enabled box and click Save.
4. Verify that it works by clicking Test in the top-left corner.



Create one tag for each vendor company:

1. Click on Security->Tags->Add.
2. Set Name*,* usually the company name.
3. Click *Save.*



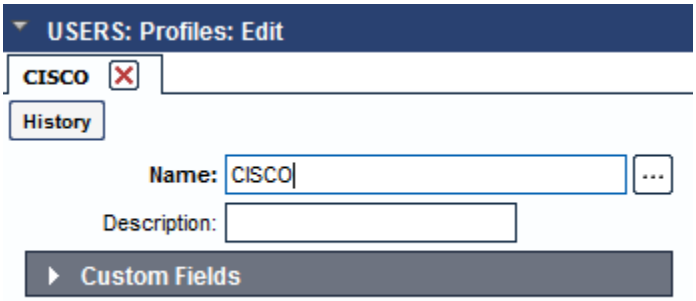
310

311 Create one profile for each vendor company.

312 1. Click on Users->Profiles->Add.

313 2. Set Name, usually the company name.

314 3. Click *Save.*



315

316 Establish graphical access controls. (Repeat this section for each vendor company.)

317 1. Click on Security->Access Control->Add.

318 2. Set Name to Vendor_Company_Graphical.

319 3. Check *Enabled.*

320 4. Set *Order.*

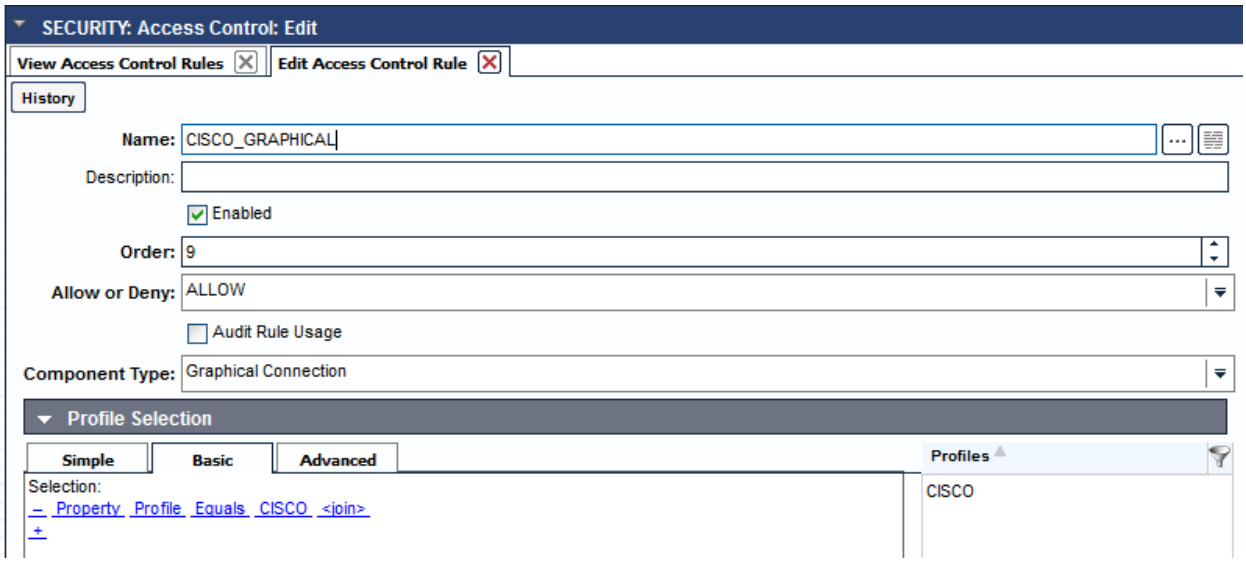
321 5. Set *Allow.*

322 6. Set Component Type to Graphical Connection.

323 7. Look under *Profile Selection*; you should see:

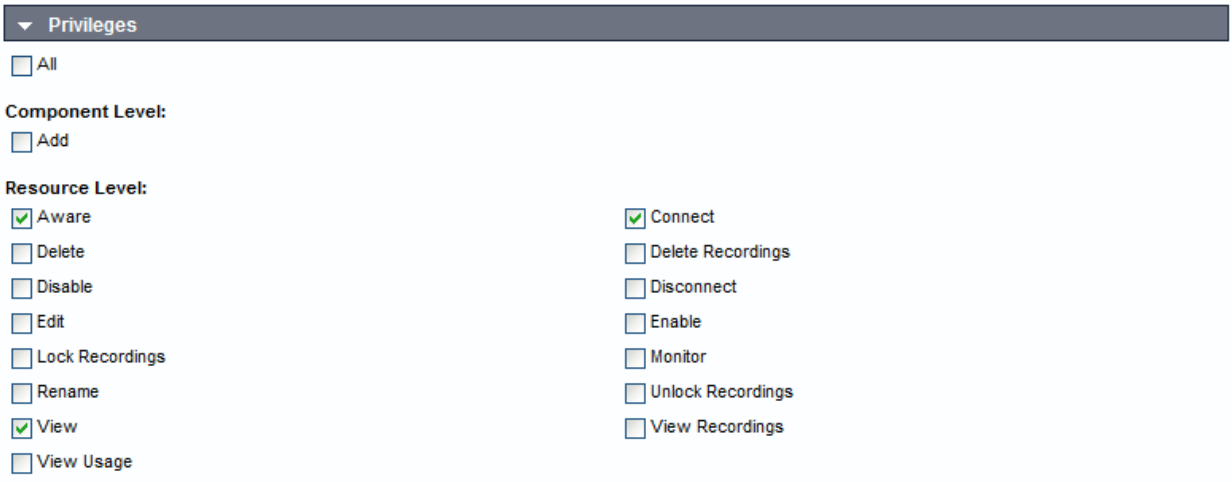
324 - Property Profile Equals *Vendor Company Profile Name* <join>.

325 - Vendor company profile should appear in the box on right.



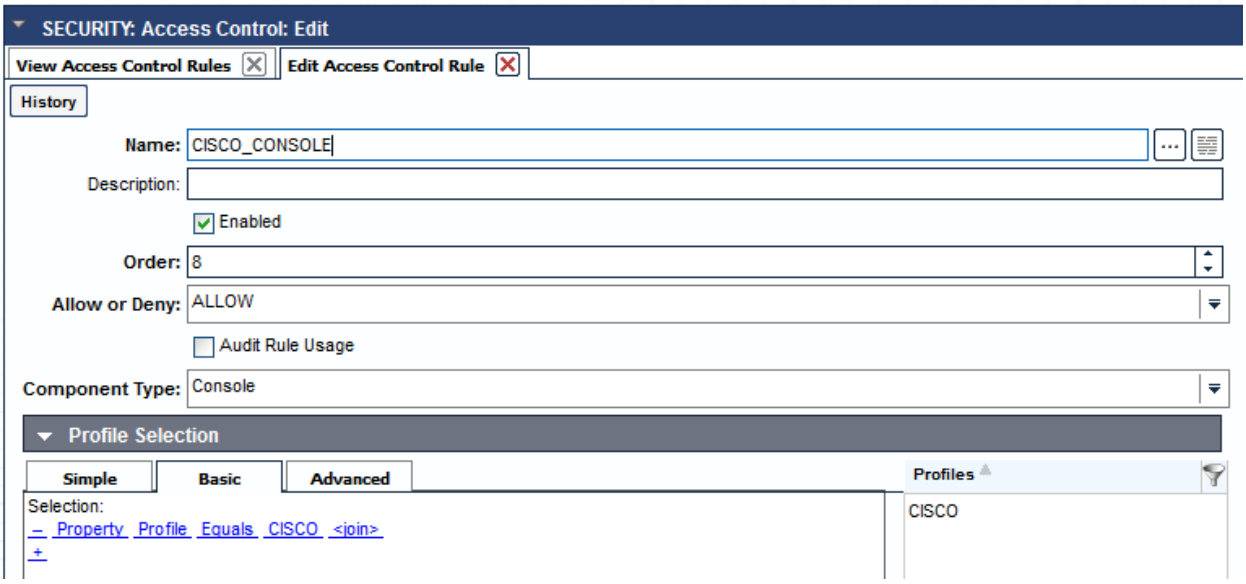
8. Look under *Resource Selection*; you should see:
   - Associated with a Tag that
   - Property Tag Equals *Vendor Company Tag name* <join>.

9. Matching Graphical Consoles should then appear in the box on right. Under Privileges, check:
   - Aware
   - View
   - Connect



Console Access Controls (repeat this section for each vendor company):

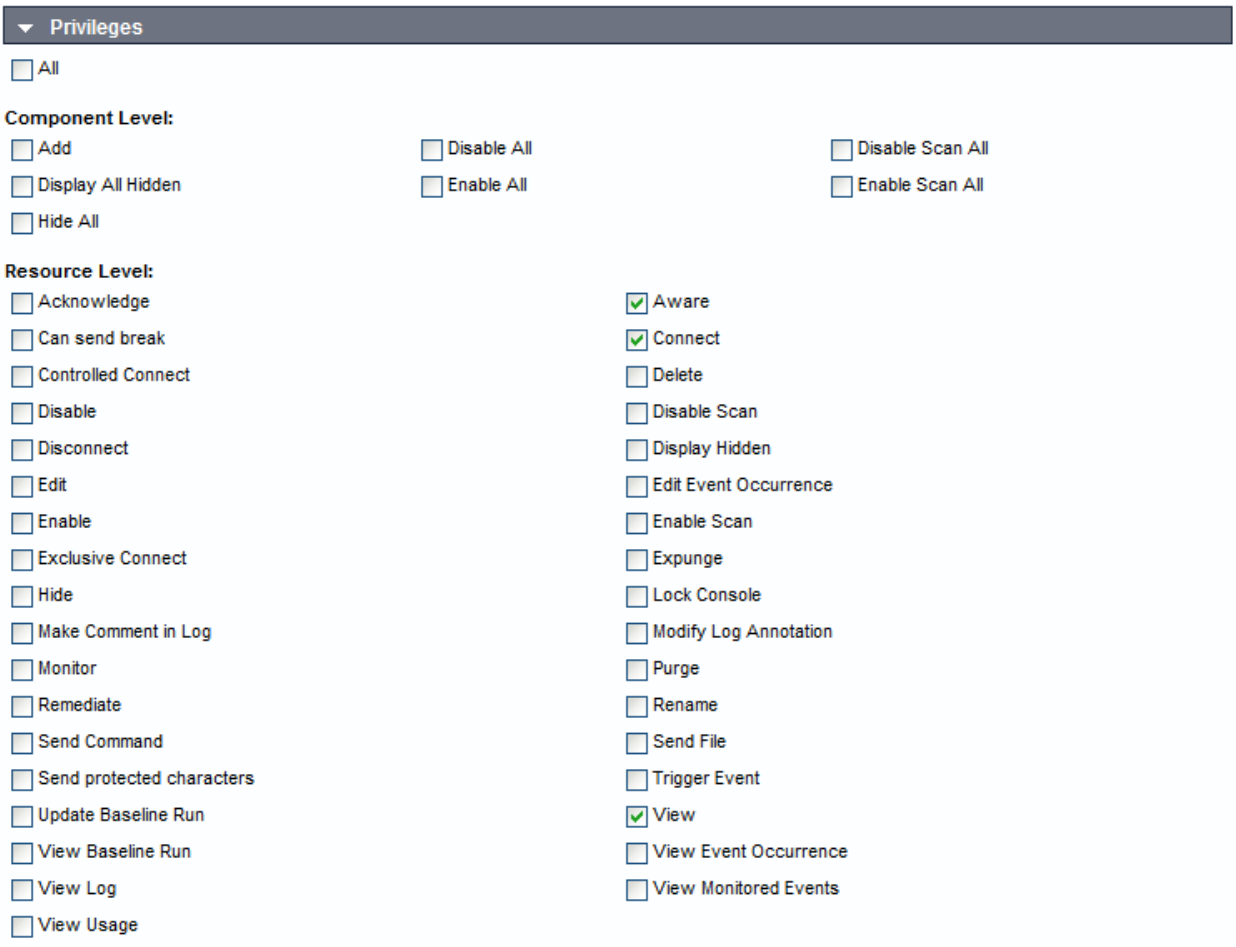
1. Security->Access Control->Add
2. Set Name to Vendor_Company_Console.
3. Check *Enabled.*
4. Set *Order.*
5. Set *Allow.*
6. Set Component Type to Console.
7. Look at *Profile Selection*. You should see:
   - Property Profile Equals **Vendor Company Profile Name** <join>.
   - Vendor company Profile should appear in the box on right.



8. Look under *Resource Selection*; you should see:
   - Associated with a Tag that
     - Property Tag Equals **Vendor Company Tag name** <join>

9. Matching consoles should appear in the box on right. Under Privileges, check:

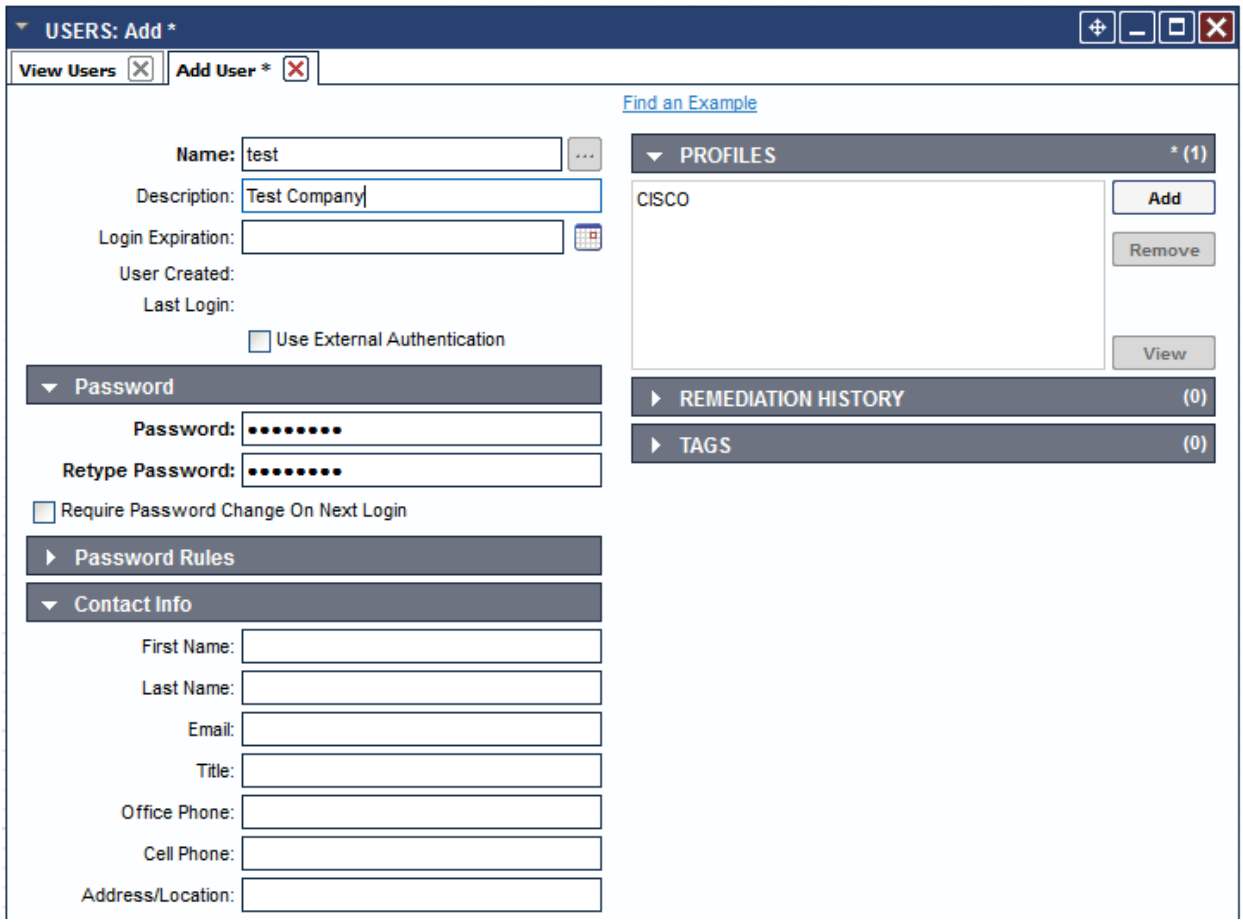
- Aware
- View
- Connect



Users:

Users->Add:

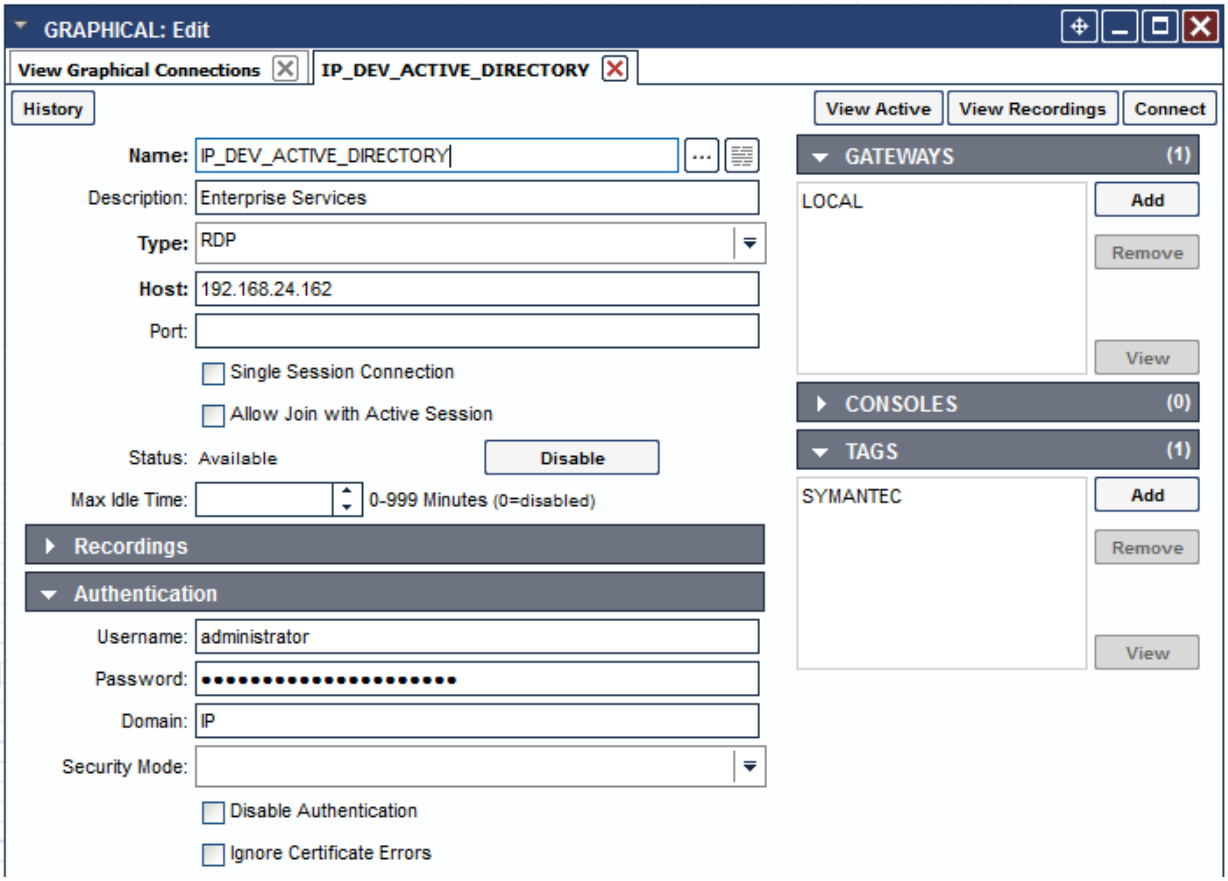
1. Set *Name.*
2. Set *Password* and retype password to confirm.
3. Fill in contact information.
4. Set *Profile* to the one defined for this user's company.
5. Click *Save.*



RDP Graphical Connections

Follow these steps to add a *RDP* graphical connection:

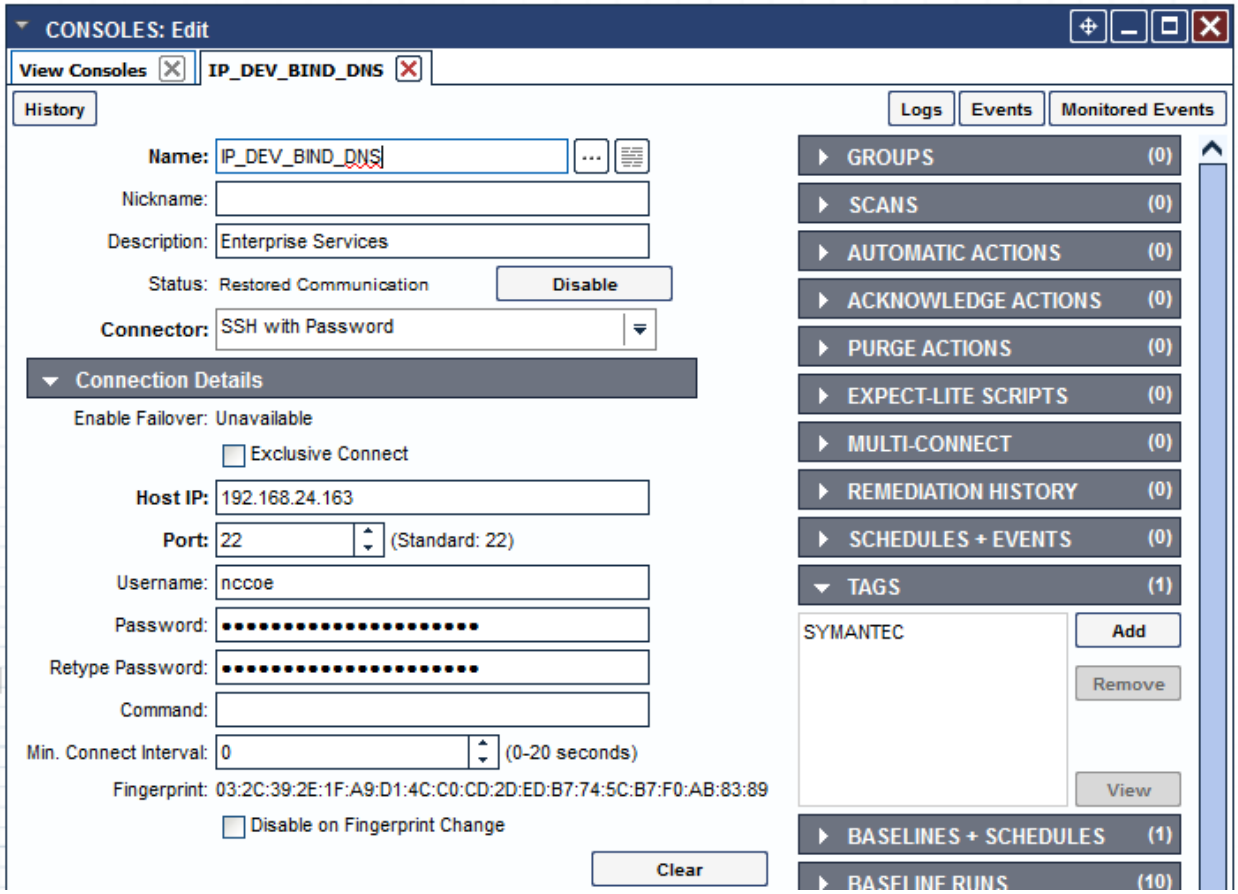
1. Graphical->Add
2. Set *Name* for the device you are connecting to.
3. Set *Type* to *RDP.*
4. Set *Hostname/IP* for the device you are connecting to.
5. Set Authentication:
   - Username
   - Password
   - *Domain* (optional).
6. Add Graphical Gateway named Local.
7. Add Tags for all vendor companies that should have access.
8. Click *Save.*



SSH Console Connections

Follow these steps to add a *SSH* console connection:

1. Consoles->Add
2. Set *Name* for the device you are connecting to.
3. Set the *Connector* to SSH Session with *Password Connection Details.*
4. Set the Host IP for the device you are connecting to by doing the following:
    a. Set Port to 22.
    b. Set Username.
    c. Set Password.
    d. Retype the password.
5. Add tags for all vendor companies that should have access.
6. Click *Save.*



2.2 Infusion Pump and Pump Server

2.2.1 Infusion Pumps

Vendors collaborating with the NCCoE in this use case donated the following pump products.

Table 2-1: Infusion Pump List

Vendor Name	Product Name	Product Type	Description
B. Braun	SpaceStation	Station for hosting individual pump	Provides centralized power and network connection for pumps stacked on the station
	Infusomat® Space large volume infusion pump	Wireless infusion pump	Designed for acute-care facilities for adults and children
	Perfusor® Space Syringe Pump	Syringe infusion pump	Can be stacked in SpaceStation and uses SpaceStation for network communication

Vendor Name	Product Name	Product Type	Description
Baxter	Baxter Sigma Spectrum	Wireless infusion pump	Provides large-volume infusion capability for patients.
BD	Alaris PC 8015	Infusion pump core system	Provides a common user interface for programming infusion, network connection, and monitoring modules. The Alaris® 8015 PC Unit is the core of the Alaris® System and provides a common user interface for programming infusion and monitoring modules.
	Alaris Syringe 8110	Syringe infusion pump	Provides syringe infusion capability for patients and it works with Alaris PC unit.
	Alaris Pump 8100	Large-volume infusion pump	Provides large-volume infusion capability for patients and it works with Alaris PC unit.
Hospira	Plum 360	Infusion system	Builds on the air management and secondary delivery features of Plum A+, while expanding its drug library and wireless capability to enable streamlined electronic medical record integration
	Hospira PCA	PCA syringe infusion system	Complements Infusion pump to manage pain
Smiths Medical	MediFusion 4000	Syringe infusion pump	Delivers medication to patients in critical care units
	CADD Solis 2000	Ambulatory infusion pump	Delivers medication to patients in hospital, home care, and alternative care facilities

2.2.1.1 Infusion Pump Setup

In our example solution, we generalized the infusion pump vendors' products and systems as infusion pump devices, infusion pump servers, and infusion pump ecosystems. Our first goal was to connect each vendor's infusion pump(s) to their corresponding pump server for performing the basic operational

events, such as registering the devices to the server; pushing/installing the new drug library to the pumps; pushing/updating the new version of software to the pumps, and keeping the log of the pump usage.

Each pump vendor has a basic setup that includes configuring the pump to connect to the network and the pump server wirelessly. We used *WPA2* security with Advanced Encryption Standard (AES) for encryption. In the case of *WPA2-PSK* mode, we assigned all infusion pumps the same access password for wireless network authentication. In the case of *WPA2-Enterprise/EAP-TLS* [11], we configured the pumps to use an individual certificate issued by DigiCert for wireless network authentication, using Cisco ISE, the enterprise authentication server.

Because each pump vendor has its own way of connecting, configuring, and setting up its pumps, we describe high-level steps in a generic way. The following table summarizes these key configuration steps. See Appendix B for the sample configuration files.

Table 2-2: Summary of Infusion Pump Configuration Methods

Vendors	Infusion Pump Model	Configuration Tool	Connection Methods
Baxter	Sigma Spectrum	Uses a PC with an IrDA interface to program multiple pumps with the same configuration Edits the network configuration file (a simple text file) on a PC and send it via the IrDA to a pump	Uses the IrDA Serial Infrared Link to a PC under the IrDA Serial Infrared Link Management Protocol v1.1
B. Braun	Space Station	Connects PC with HiBaSeD Service program to the Space Station using a B. Braun interface cable for pump configuration setting	Uses special B. Braun interface cable
	Infusomat® Space large volume infusion pump	Connects PC with HiBaSeD Service program to the Space Station using a B. Braun interface cable for pump configuration setting	Uses special B. Braun interface cable
	Perfusor® Space Syringe Pump	Connects PC with HiBaSeD Service program to the Space Station using a B. Braun interface cable for pump configuration setting	Uses special B. Braun interface cable
BD	The Alaris® 8015 PC	Uses management system to do the configuration. The Alaris® 8015 PC Unit is	Uses series cable to connect pump to a local computer.

Vendors	Infusion Pump Model	Configuration Tool	Connection Methods
		the core of the Alaris® System and provides a common user interface for programming infusion and monitoring modules.	
Hospira	Hospira PCA	Accesses Web Config utility on Pump through a web browser using the Local IP address of the pump	Uses pump's Ethernet Jack to connect to a LAN or to interface with host computer
	Plum 360	Accesses Web Config utility on Pump through a web browser using the Local IP address of the pump	Uses pump's Ethernet Jack to connect to a LAN or to interface with host computer
Smiths Medical	MediFusion 4000	Pushes configuration text file to pump using the Telnet from a PC connected to the pump with the known IP address	Connects a PC to pump using micro USB-USB cable
	CADD Solis 2000	Uses Smiths Medical Network Configuration Utility to update the pump's configuration parameters	Connects a PC to pump using micro USB-USB cable

2.2.1.2 Infusion Pump Configuration

Pre-Conditions:

- You have set up wireless AP with pre-share password SSID
- You have installed and configured infusion pump servers
- You have made available the infusion pump configuration and setup manual available

Post-Conditions:

- You have connected the infusion pumps to AP
- You have estimated the pump server to discover the pumps to the corresponding pump server

NCCoE followed the pump vendors' instructions to access to the pump in maintenance/biomedical model. We configured the pump as follows:

- For wireless properties
  - Enable wireless
  - Use DHCP

- Set SSID (IP_Dev or IP_Dev_Cert)
- For wireless security properties
  - Set Security Mode (WPA2-PSK or WPA2-Ent)
  - Set Encryption Protocol to AES/CCMP
  - Enter PSK password or install a PKI certificate
- For pump server properties
  - Set Server IP/port
  - Set Device Name or ID
  - Set Device Type
- To verify connectivity for each infusion pump and the corresponding pump server:
  - Connect pumps to AP (*IP_Dev* with PSK or *IP_Dev_Cert* with *EAP-TLS*)
  - Confirm that pump receives an IP address from the DHCP server from the AP
  - Confirm that the pump server can discover the pumps and display the pump status such connected, in use, or offline.

2.2.1.3 Infusion Pump Hardening

Hardening may include the following:

- disabling unused or unnecessary communication ports and services
- changing manufacture default administrative passwords
- securing the remote access points if there are any
- confirming the firmware version is up-to-date.

2.2.2 Infusion Pumps Server Systems

Table 2-3: Pump Servers used in this Example Implementation

Vendor Name	Product Name	Operating Platform	Description
B. Braun	DoseTrac® Infusion Management	Microsoft Windows	Drug library and infusion management system that provides real-time, infusion data reporting and analysis to add safety, efficiency and value
Baxter	Care Everywhere Infusion Pump Management System	Microsoft Windows	Provides interface capability to help hospital biomedical engineering department manage their infusion pump fleet

Vendor Name	Product Name	Operating Platform	Description
			effectively. Drug Library publishing module helps hospital pharmacy distribute and enforce medication safety rules effectively.
BD	Alaris Systems Manager	Compatible with VMWare ESX and VMWare vSphere environment	Virtual server platform that provides two-way wireless communication with Alaris PC units
Hospira	Hospira MetNet Server	Microsoft Windows	Manages drug libraries, firmware updates, and configurations of intravenous pumps
Smiths Medical	PharmGuard Server	Microsoft Windows	Manages drug libraries, firmware updates, and configurations of Hospira intravenous pumps for Smiths Medical Pumps

NCCoE installed the pump servers in the network in the VLAN 1400. To do so, we prepared a virtual machine in the VMWare with the operating system and network as specified in the vendor installation manual. Because one or more database is associated with the infusion pump server for storing the data, installation and configuration of the database is part of the pump server installation procedure. After the installation, we implemented basic configuration: the user account setup, reporting template configuration, security hardening, license installation, pump metadata installation.

We have not included the pump server setup because the vendor performs this activity.

2.3 Identity Services

2.3.1 Cisco Identity Service Engine (ISE)

The Cisco Identity Services Engine (ISE) enables your organization to:

- Centralize and unify identity and access policy management
- Have visibility and more assured device identification during certificate challenges
- Use business rules to segment access to sections of the network
- Make the user experience seamless during the challenge process, even with more assured and stronger authentication

System requirements

- Virtual Hypervisor (VH) capable of housing virtual machines (VMs)
- VM with CPU: Single Quad-core; 2.0 GHz or faster
- VM with minimum 4 GB memory
- VM with minimum 200 GB disk space

NCCoE installed the Cisco ISE 2.1 on a virtual machine using the OVA image provided by Cisco.

For your organization, follow the guidance from your VM vendor to import the OVA and start the install process. Once the system boots up, follow the console display to select one of the installation options. The configuration parameter selected for this use case is shown below:

```
! hostname
ise
!ip domain-name
nccoe.lab
! ipv6
enable
!interface
GigabitEthernet 0 ip address 192.168.29.159 255.255.255.0 ipv6 address autoconfig ipv6 enable
! interface
GigabitEthernet 1 ip address 192.168.120.159 255.255.255.0 ipv6 address autoconfig ipv6 enable
!interface
GigabitEthernet 2 shutdown ipv6 address autoconfig ipv6 enable
! interface
GigabitEthernet 3 shutdown ipv6 address autoconfig ipv6 enable
! ip name-server
8.8.8.8 8.8.4.4
! ip default-gateway
192.168.120.1
!
! clock timezone
EST
! ntp server
```

```
time.nist.gov
! username admin password hash
$5$jNPleEb4$YxDZH6oDF2Y4.02OqE/jBWxXFumRvtpe8JdNNZm1yj0 role admin
! max-ssh-sessions
5
! service sshd
enable
! password-policy
lower-case-required
upper-case-required
digit-required
no-username
no-previous-password
password-expiration-enabled
password-expiration-days 45
password-expiration-warning 30
min-password-length 4
password-lock-enabled
password-lock-timeout 15
password-lock-retry-count 3
! logging loglevel
6
! conn-limit 10
port 9060
! cdp timer
60 cdp holdtime 180 cdp run GigabitEthernet 0
! icmp echo
on
!
```

2.3.1.1 Configure ISE to Support EAP-TLS Authentication

Execute your management of the Cisco ISE with a web browser unless you intend to administer via command line. Using a web browser and the Cisco ISE host address, log on to the Cisco ISE Administration Portal. You will use the credentials (username and password) you created during the installation procedure.

2.3.1.2 Set ISE to Support RADIUS Authentication

Use the following steps to set up a communication connection from Cisco ISE to the network device (Access Point) you use as the authentication server during RADIUS [12] authentication:

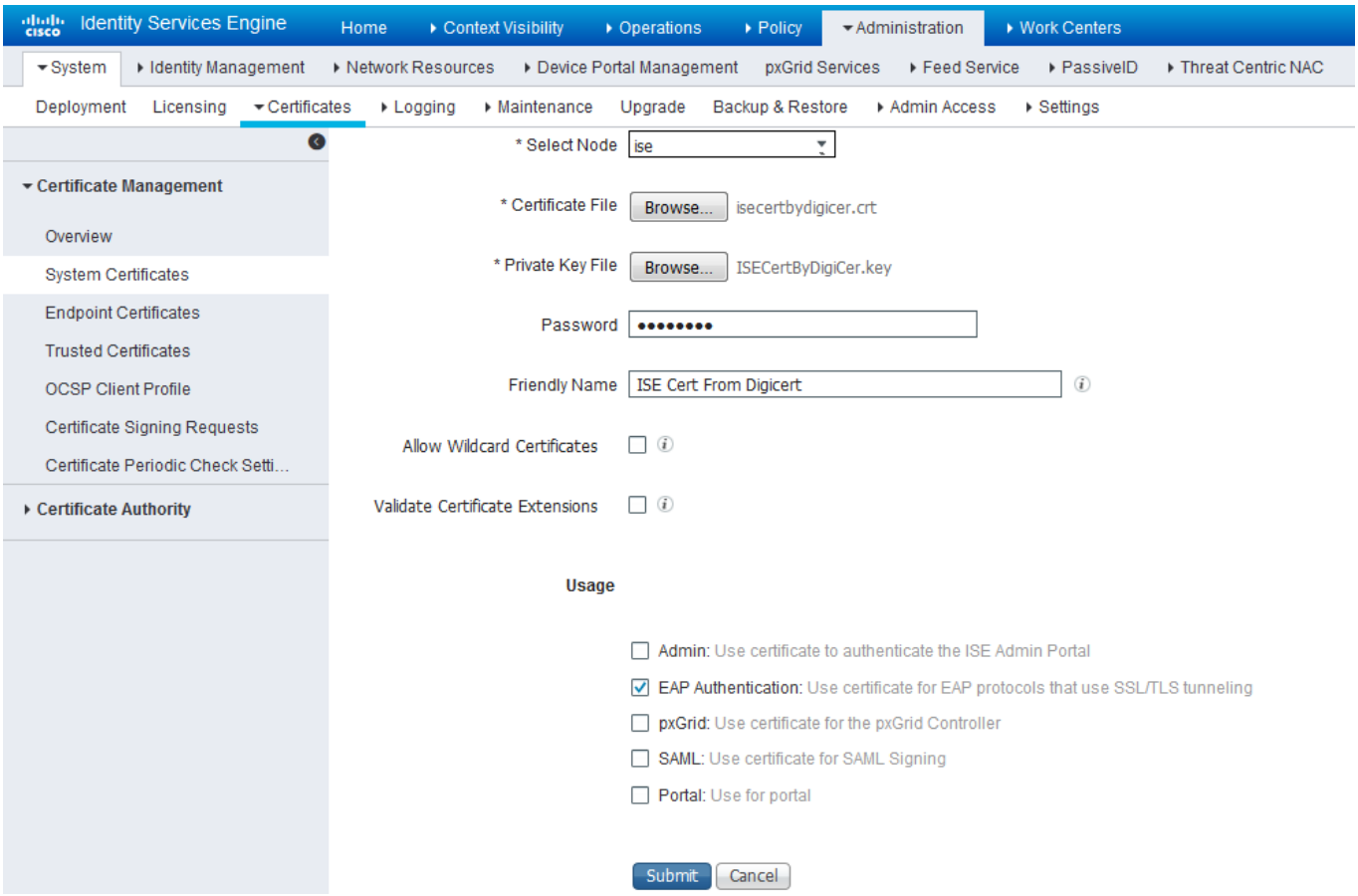
1. Add a Network Recourse

From the ISE Admin Portal, navigate to the path: ***Administration > Network Resources > Network Devices***. Then select ***Add***. Fill out the required parameters as indicated in the form:

- The name of the network device
- The IP Address of the device with its subnet mask.

2. Select the RADIUS protocol as the selected protocol, and enter the shared secret that is configured on the network device.
3. Populate the system certificate with CA-signed certificates. We replaced the Cisco ISE default self-signed certificate with the CA-signed certificate issued through DigiCert Certificate Authority. The steps for acquiring the signing certificate from DigiCert are described in the next Section 2.3.2, DigiCert Certificate Authority.
4. Once the CA-signed certificate for ISE and the Root CA are issued, use the following steps to install the certificates to the System.
5. From the ISE Administration Portal, use the navigation path **Administration > System > Certificates > System Certificate** to show the installed certificates. Then select Import to open a screen for importing Server certificate. Fill in the required information as shown in the following screen shot.

547 **Figure 2-1: Importing Server Certificate**



548

549

550 6. Check the EAP Authentication to enable the imported certificate to be used for EAP Authentication.
551 Then click the **Submit** button to complete the certificate importing.

552 7. Import the DigiCert Root CA and signing CA to ISE Trusted Certificates. From the ISE Administration
553 Portal, use the navigation path **Administration > System > Certificates > Trusted Certificate** to show
554 the installed certificates. Then select Import to open a screen for importing DigiCert Root CA and the
555 signing CA individually.

556 a. After importing, make sure the certificate status is Enabled.

557 b. Establish the OCSP [13] client profile from the OCSP Client Profile page under the
558 **Administration > System > Certificates > OCSP Client Profile**.

559 c. If OCSP (Online Certificate Status Protocol) is used for Certificate Status Validation, check
560 Validate against OCSP Service and enter the OCSP service name.

561 8. Set *Identity Source for Client Certificate Authentication.* When using the trusted certificate for EAP-
562 TLS certificate-based authentication validation, set up the Certificate Authentication Profile in the
563 ISE as the external identity source. Instead of authenticating via the traditional username and
564 password, Cisco ISE compares the client certificate received from the Access Point to verify the
565 authenticity of a device, in this case, the infusion pump.

To create a Certificate Authentication Profile:

- Use the Administration Portal to navigate to the path Administration > Identity Management > External Identity Sources > Certificate Authentication Profile and click *Add.*
- Name the profile as, for example, "Cert_Auth_Profile", then fill out the form with proper parameters. Be sure to select *Subject Name* as the Principal Username X509 attribute because it is the field that will be used to validate the authenticity of the client.
- Select the *Identity Resource Sequences* tab, in the Certificate Based Authentication, check *Select Certificate Authentication Profile* and choose the *Cert_Auth_Profile* from the dropdown list.

9. Set *Authentication Protocols.* Cisco ISE uses authentication protocols to communicate with external identity sources. Cisco ISE supports many authentication protocols such as the Password Authentication Protocol (PAP), Protected Extensible Authentication Protocol (PEAP), and the Extensible Authentication Protocol-Transport Layer Security (EAP-TLS). For this build, we used the EAP-TLS protocol for user and machine authentication. To specify the allowed protocols services in Cisco ISE:
   - From the Administration Portal navigate to the path Policy >Policy Elements > Results >Authentication > Allowed Protocols > Add
   - Select the preferred protocol or list of protocols. In this build, the EAP_TLS is selected as the allowed authentication protocol.
10. Set up *Authentication Policy.* Define the authentication policy by selecting the protocols that ISE should use to communicate with the network devices, and the identity sources that it should use for authentication. To specify the authentication policy:
    - From the Administration Portal navigate to the path **Policy >Authentication Policy > Type > Rule Based**.
    - Set "if Protocol is Wireless 802.1x, use the Network Device as defined in Step 1 and the Identity Sequences as defined in Step 8.

2.3.2 DigiCert Certificate Authority

DigiCert is a cloud-based platform designed to provide a full line of SSL Certificates, tools, and platforms for optimal certificate life cycle management. After you set up an account with DigiCert, you can use a DigiCert dashboard and its built-in certificate management tools to issue PKI certificates for network authentication and encryption for data-at-rest or in-transition if needed.

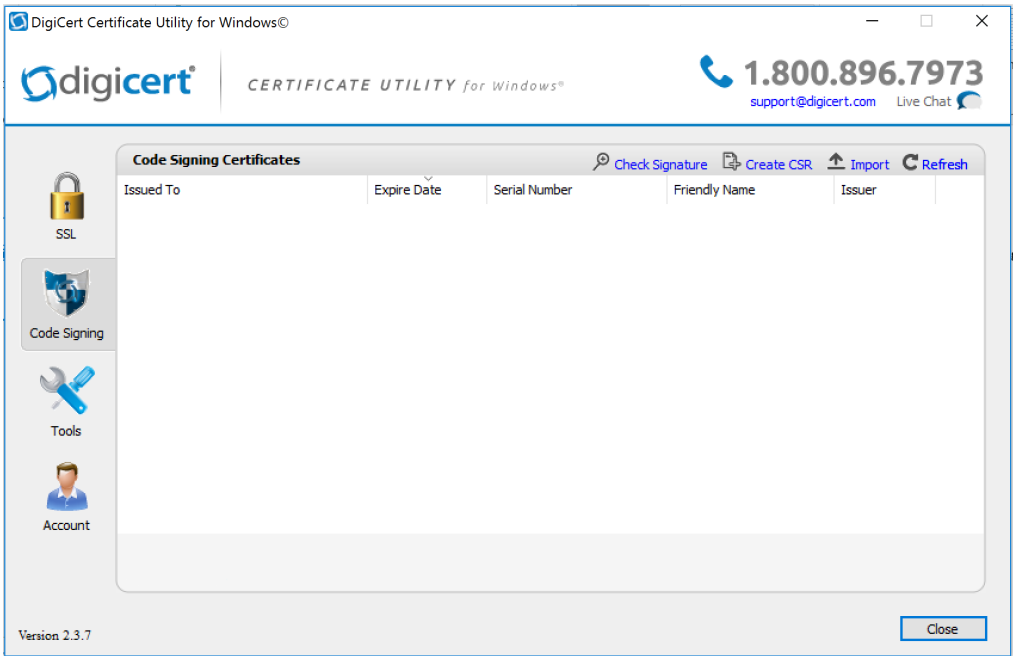
The follow instruction describes the process we used to request a PKI certificate on behalf a wireless infusion pump using the DigiCert PKI services:

2.3.2.1 Create a Certificate Signing Request (CSR)

A CSR can be represented as a Base64 encoded PKCS#10 binary format. Many tools and utilities are available to help to generate a CSR, and the key pair containing the private key and public key is generated in the same time. The CSR identifies the applicant's distinguished name, which must be digitally signed using the applicant's private key and the information for the public key chosen for the applicant. In this build, Certificate Utility for Windows (DigiCertUtil.exe) provided by DigiCert is used to generate CSRs for infusion pumps.

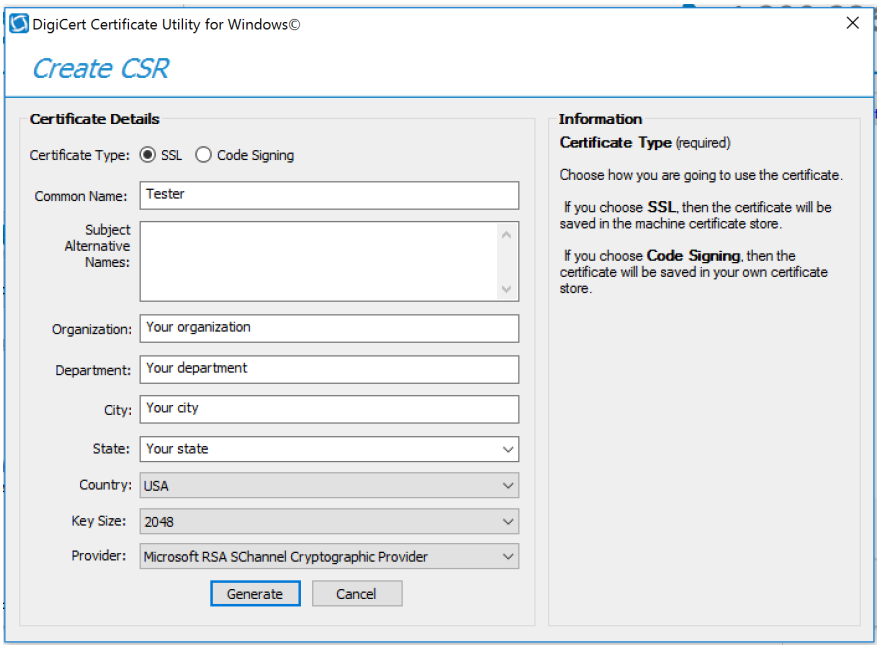
605 Download and save the DigiCertUtil.exe from https://www.digicert.com/util/csr-creation-microsoft-
606 servers-using-digicert-utility.htm.

607 1. Double-click *DigiCertUtil.exe* to start the utility:



608

609 2. Click the *Create CSR* link to open a CSR request window.



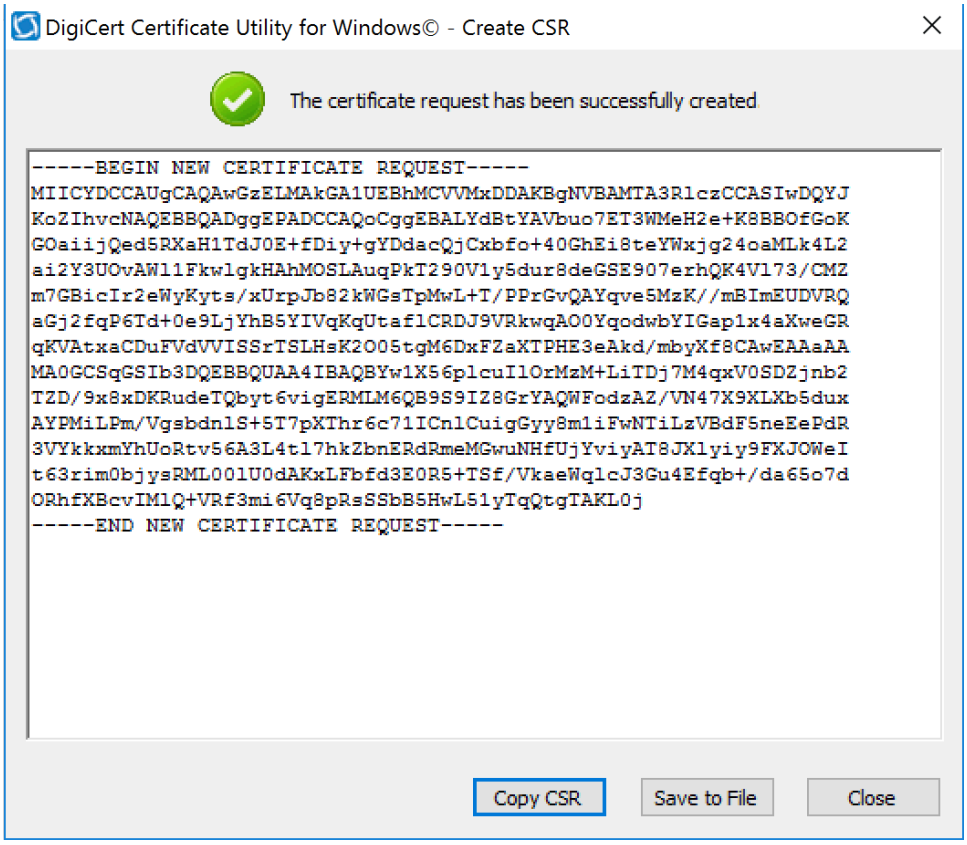
610

611 3. On the Create CSR window, fill in the key information (some is optional):

612 - Certificate Type: Select *SSL*
613 - Common Name: Enter the entity name
614 - Organization: Enter your company's legally registered name

- City: Enter the city where your company is legally located
- State: Select the state where your company is legally located
- Country: Select the country where your company is legally located
- Key Size: In the drop-down list, select *2048*
- Provider: Select *Microsoft RSA SChannel Cryptographic Provider* (unless you have a specific cryptographic provider)

4. Click ***Generate*** to generate a CSR:



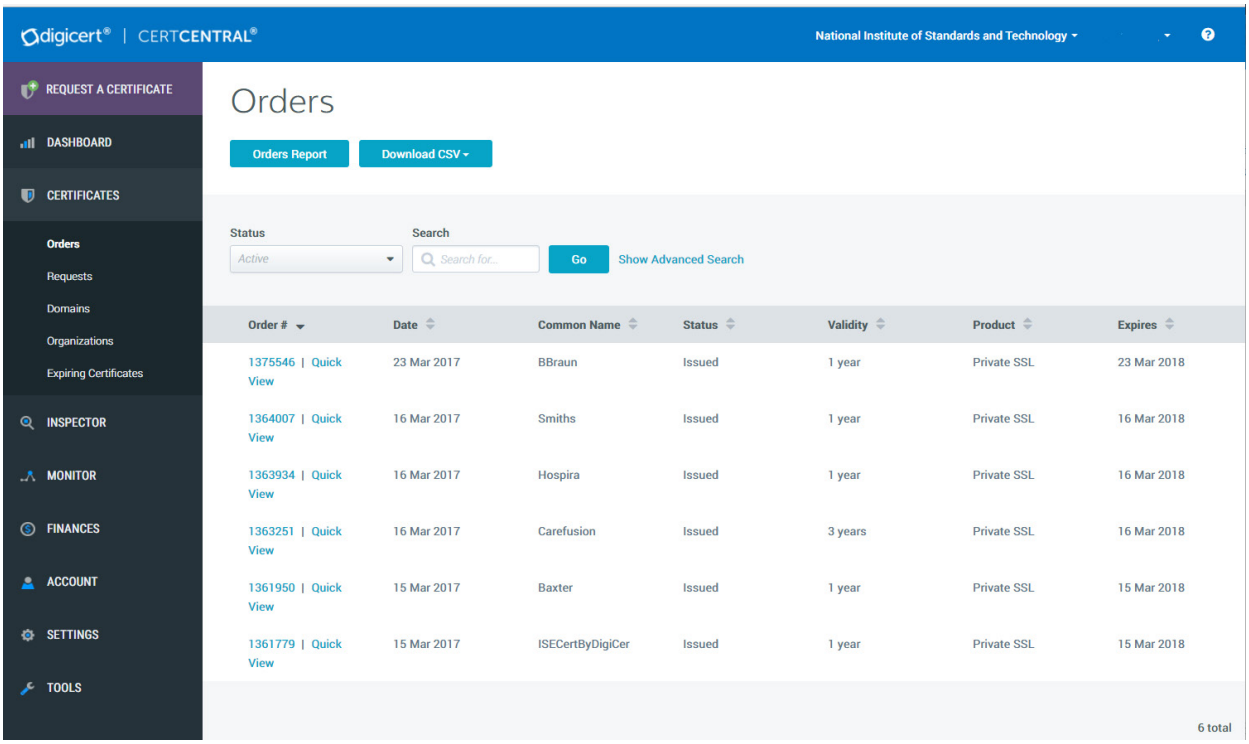
This will also generate a corresponding private key in the Windows computer from which the CSR is requested. The Certificate Enrollment Request is stored under: (*Console Root**Certificates(Local Computer)**Certificate Enrollment Requests**Certificates*).

2.3.2.2 Issue Signed Certificates

5. With a created applicant CSR, request a signed certificate using DigiCert CertCentral portal.
   - Login to a DigiCert Dashboard <https://www.digicert.com/account/login.php> with your account user name and password.
   - Once in the portal, go to **Request a Certificate**, then select ***Private SSL*** to open a certificate request form. Fill in the certificate settings in the fields shown in the form which includes pasting the CSR information to the area called *Paste your CSR.*

6. After filling in all the required information and scroll down to the bottom of the page and click on the "I agree to the Certificate Services Agreement above" check box, click the ***Submit Certificate Request*** button at the bottom of the form to submit the certificate for signing approval. The administrator of the CA authority will use the same portal with different privilege to prove the request after reviewing and verifying the submitted request information if needed.

7. To download the signed certificate, go to ***CERTIFICATES->Orders*** to list the ordered signed certificates:



8. Click a specific order number to display the certificate details with a list of actions for you to perform. Click the ***Download Certificate*** *As* to download certificates with signed CA and Root CA certificates. A variety of certificate formats can be downloaded, such as .crt, .p7b, or .PEM, etc.

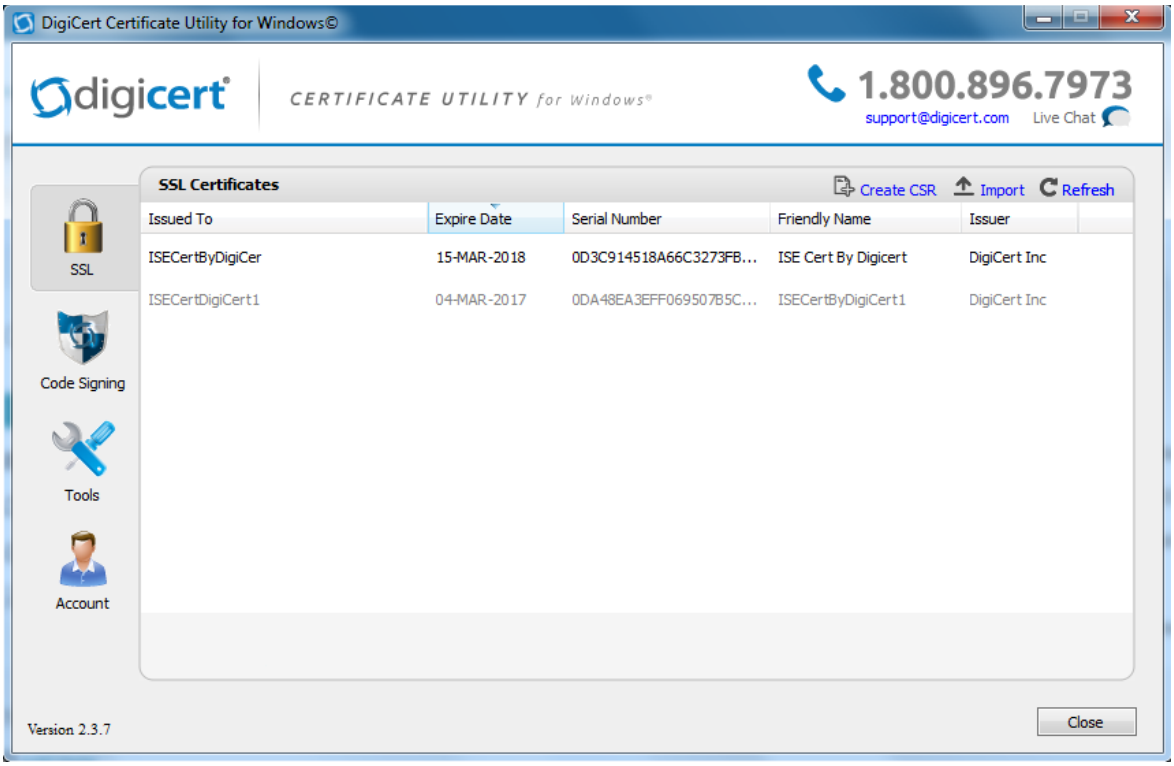
9. Save the downloaded certificate in a location where it can be used for further processing if needed.

2.3.2.3 Import and Export the Signed Certificate

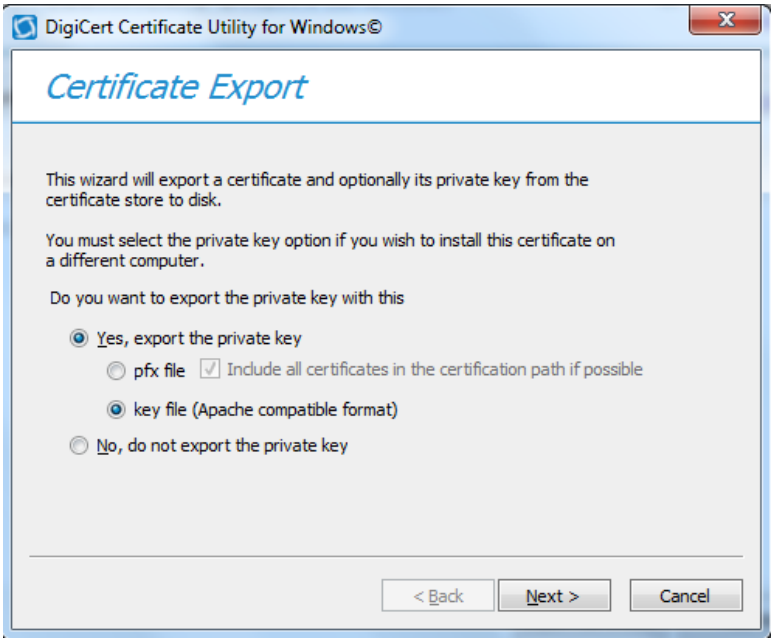
Using the DigiCert Utility and OpenSSL tool, you can further manipulate the certificates to combine with the private key and export the signed certificate, or you can convert certificates or keys to the formats specified for your organization's devices.

10. To import a signed certificate, use DigiCert Utility to click the *Import* button to load a downloaded file to the utility. The download file was saved in Step 9 above. Click the *Next* button to import.

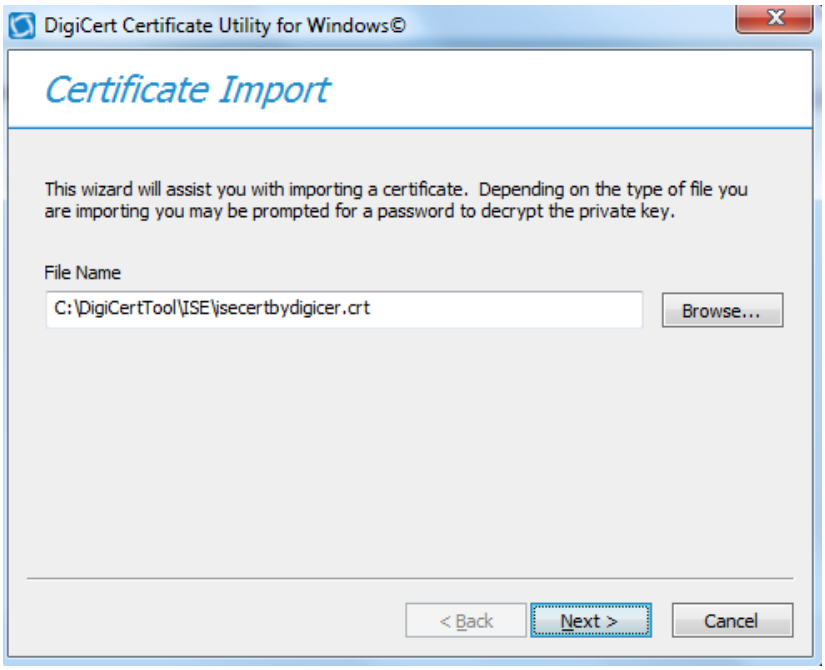
11. From the DigiCert Certificate utility for Windows, click *SSL* to list all the imported files.



12. To export the certificate, select the certificate that you want to export as a combined certificate file and key file in a *.pfx* file or separated as a certificate file and key file, and then click *Export Certificate.*



13. Click the *Next* button and follow the wizard instruction to save the certificate file and private key file to a location you desire.



2.3.2.4 Certificate and Key File Format Conversion

PKI certificates and key files can be in different formats. When PKI certificates are used in medical devices, device manufacturer user guides specify which formats are acceptable in their devices. Fortunately, many tools can perform format conversion. One utility tool that NCCoE used is the OpenSSL for Windows. It is open source and can be downloaded from https://www.openssl.org/community/binaries.html. Here are some of the useful convert commands:

- To convert .crt to .pem:
  - **openssl** *x509* **-in** mycert.crt **-outform** *PEM* **-out** mycert.pem.
- To convert a private key into PEM format:
  - **openssl rsa -in** yourdomain.key **-outform** *PEM* **-out** yourdomain_pem.key.
- Separate a pfx file into two different .key/.crt files:
  - For a key file: **openssl pkcs12 -in** *yourfile*.pfx **-nocerts -out** keyfile-*encrypted*.key.
  - For cert file: **openssl pkcs12 -in** [*yourfile*.pfx] **-clcerts -nokeys -out** [*certificate*.crt].
- To convert a Cert PEM file to DER:
  - **openssl x509 -outform der -inform** *DEM* **-in** *certificate.pem* **-out** *certificate.der.*
- To convert a key PEM file to DER:
  - **openssl rsa -inform** *DEM* **-in** infile.key **-out** outfile.der-**outform** *DER.*

2.4 Symantec Endpoint Protection and Intrusion Detection

NCCoE protected the pump server application in the notional Biomedical Engineering network by using three Symantec cybersecurity products on an enterprise network, with a specific focus on wireless infusion pumps:

- Symantec Data Center Security- Server Advanced
- Symantec Endpoint Protection Manager Server
- Symantec Advanced Threat Protection Server.

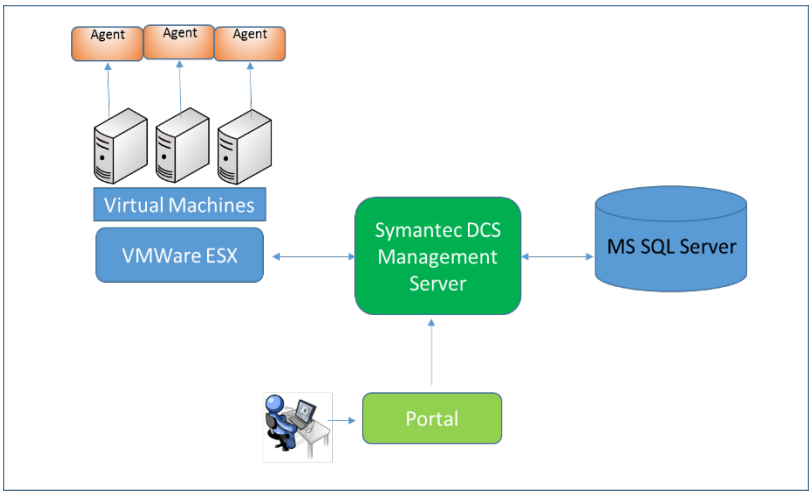
Each product protects components in the enterprise systems at different levels.

2.4.1 Symantec Data Center Security: Server Advanced

For data center security, Server Advanced provides a policy-based approach to endpoint security and compliance. It includes the management server, the agents, the unified management console, the database, and DCS Security Virtual Appliance (SVA). The agent components working with the server management provide intrusion prevention and detection on endpoint devices; the database is used for storing the policies, agent information, and real time actionable events; and the SVA provides agentless anti-malware protection for VMWare guest VMs running Windows.

The management server and the console can be installed on one system, and the agents are generally deployed to every supported host or endpoint devices. Figure 2-2 displays the Data Center Security: Server Advanced Environment.

Figure 2-2: Data Center Security: Server Advanced Environment



2.4.1.1 Installing Data Center Security: Server Advanced Manager

Minimum Hardware Requirement: Server Advanced includes hardware support x86, EM64T, and AMD64 with 60 GB free disk space (all platforms) 8 GB RAM 4 CPUs.

Minimum Software Requirement: Windows Installer 2.0 or higher, Microsoft SQL Server 2008, .NET Framework 4.0 or 4.5.1, PowerShell 2.0, and Windows 2008 or later.

Operating the Symantec Data Center Security: Server Advanced installation requires to link to an instance of SQL Server locally or remotely. All installations allocate approximately 60 GB of space for the database on SQL Server Enterprise edition. We first installed a new instance of SQL Server that conforms to the Symantec installation requirements. The SQL Server was installed on the same machine as that for the Data Center Security: Server Advanced Manager.

Follow these steps to install the SQL Server software.

1. Use *SCSP* as the default instance name
2. Set authentication configuration to Mixed Mode (Windows authentication and SQL Server authentication)
3. Set the "*sa*" with a password when you set Mixed Mode authentication. You will need this password when you install Data Center.
4. After installing the instance of SQL Server, select to authenticate using SQL Server credentials.
5. Register the instance. Registering the instance also starts the instance.

Follow these steps to install Data Center Security: Server Advanced:

1. Double click *server.exe*, then in the Welcome panel, click *Next* and accept the license agreement
2. In the Installation Type panel, click Evaluation Installation, then click Use an Existing MSSQL Instance, and then click Next.
3. Follow the instructions and select the parameters suitable for your organization to complete the installation.

See *Symantec™ Data Center Security: Server, Monitoring Edition, and Server Advanced 6.7 MP1 Planning and Deployment Guide* for further details: https://symwisedownload.symantec.com//resources/sites/SYMWISE/content/live/DOCUMENTATION/9000/DOC9394/en_US/DCSSA_Planning_Deployment_Guide.pdf?__gda__=1494398285_572b0ff349979359e0cc9342b337f3bb

2.4.1.2 Configuration of Data Center Security: Server Advanced Manager

After you install the Management Server, the Server Configuration Wizard lets you configure various parameters of the installation.

One purpose of these configuration settings is to use the policy-based least privilege access control provided by DCS to lock down the configuration settings, files, and file systems in the pump for restricting application and operating system behavior and protecting the files and systems from tampering.

To enable a policy in DCS Management Server, follow these steps:

1. Login to the DCS console.
2. Create a policy folder.
3. In the Java console, click *Policies.*
4. Under the *Policies* tab, click *Prevention* or *Detection.*
5. On the Policies page, in the *Workspace Folders*, select the *Workspace* folder and then right-click *Add Folder.* Look for a new policy folder with the name *New Folder.* Rename this folder as *Pump Server*.
6. Copy an existing policy to the Pump Server folder.
7. From the default Symantec folder, find a proper policy example and copy it to the Pump Server.
8. Using the *Move To* command. In the *Workspace* pane, select a policy (e.g., "windows-baseline-detection" policy in *Symantec folder* for *Detection*), and then right-click *Move To.* In the *MoveFolder* dialog box, select *Pump Server* to receive the policy, and then click *MoveTo.*

9. To edit a policy, right-click a policy, and then click *Edit Policy.* Configure the setting based on your security protection needs.

DCS Advanced Server provides a variety of configurable protection from application data protection, application protection to network protection. For example, the Windows prevention policies have a Protected Whitelisting strategy that lets you specify an application to which you always want to allow access or give permission to run. When you whitelist a process or an application, all the other processes and applications that are not included in the list are denied access.

To allow a program to run by using the Protected Whitelisting strategy, follow these steps:

10. In the management console, click the *Policies* tab and then click *Prevention.*
11. In the *Policies* workspace, click *Add.*
12. In the Select a Prevention Policy Builder wizard, in the New Policy Builder section, click Launch.
13. In the *Policy Name* panel, from the *Policy Pack* drop-down list, select the policy pack that you want to use as the baseline for the new custom policy.
14. In the *Name* text box, enter a name for the policy that you create. In this build, we use "Windows Prevention Policy 6.0 Reference 31 Protected Whitelisting strategy."
15. Check Create a custom prevention policy, and then click Next.
16. In the *Protection Strategy* panel, use the slider to select *Protected Whitelisting.*
17. In the *Trusted Updaters* panel, click *Add,* and then in the *Select Type* dialog box, select the type of updater that you want to add. The Trusted Updaters list is populated through the agent data retriever. You can edit or delete an updater that you have already added to the list.
18. Click *Next.*
19. In the *Application Rules* panel, click *Add,* and then in the *Select Type* dialog box, select the type of rules that you want to add. You can edit or delete a rule that you have already added to the list.
20. In the *Global Policy Options* panel, click *Configure* to configure the global policy settings, and then click *Next.*
21. In the *Summary* panel, click *Save.*

2.4.1.3 Installing Data Center Security: Server Advanced Agent

Use agent.exe to install the agent software on computers that run supported Windows operating systems. To install the Windows agent software, follow these steps:

1. On the installation package, double-click *agent.exe.*
2. In the *Welcome* panel, click *Next.*
3. In the License Agreement panel, select I accept the terms in the license agreement, and then click Next.
4. In the *Destination Folder* panel, change the folders if necessary, and then click Next.
5. In the *Agent Configuration* panel, accept or change the default settings, and then click *Next.* Ensure that *Enable Intrusion Prevention* is checked.

6. In the *Management Server Configuration* panel, in the Primary Management Server box, type the fully qualified host name or IP address of the primary server that is used to manage this agent. If you changed the Agent Port setting during management server installation, in the Agent Port box, type a port number that matches.
7. (Optional) In the *Management Server Configuration* panel, in the Alternate Management Servers box, type the fully qualified host name or IP address of the alternate servers that are used for failover for this agent. Type the servers in a comma-separated list.
8. In the *Management Server Configuration* panel, accept the directory for the SSL certificate *Agent-cert.ssl*, or click *Browse* to browse to and locate *Agent-cert.ssl*. Access to a copy of the SSL certificate *Agent-cert.ssl* is required to connect to the management server. All primary and alternate management servers must use the same certificate.
9. In the Management Server Configuration panel, click Next.
10. (Optional) In the *Agent Group Configuration* panel, in the group boxes, type the group names that you created with the Java console. You may add multiple detection policy group names separated with commas. You may include the name of an existing detection policy domain in the group path/name.
11. In the *Agent Group Configuration* panel, click *Next.*
12. In the *Service User Configuration* panel, accept the default Local System account, and then click *Next.*
13. In the *Ready to Install the Program* panel, confirm the installation parameters, and then click Install.
14. When the installation completes, click *Finish.*

Agent installation configures the appropriate networking for the environment. The agent installation configuration includes which Data Center Security: Server Advanced Management Servers to communicate with, which ports to use, and how often to poll for changes. The initial Data Center Security: Server Advanced installation also determines whether key product features are enabled or not. Particular key agent features can be installed, and each provides different protection:

- Enabling the intrusion prevention feature
- Enabling the real-time file integrity monitoring feature in intrusion detection
- Enabling the real-time file integrity monitoring feature in intrusion detection
- Creating agent registration groups.

See the Symantec Data Center Security: Server, Monitoring Edition, and Server Advanced 6.7 MP1 Planning and Deployment Guide for details: http://help.symantec.com/cs/DCS6.7/DCS6_7/v118490468_v110163010/Installing-Data-Center-Security:-Server-Advanced-6.7-or-6.7-MP1/?locale=EN_US.

2.4.2 Symantec Endpoint Protection Manager

Minimum Hardware Requirement: 2 GB RAM as minimum; 8 GB or more available recommended. Hard drive should be 40 GB as minimum (200 GB recommended) for the management server and database with a remote SQL Server database.

Minimum Software Requirement: Windows Installer 2.0 or higher, Microsoft SQL Server 2008, .NET Framework 4.0 or 4.5.1, PowerShell 2.0, and Windows 2008 Server or later. Intel Pentium Dual-Core or equivalent minimum, 8-core or greater is recommended.

The Symantec Endpoint Protection Manager includes an embedded database. You may instead choose to use a database from one of the following versions of Microsoft SQL Server: SQL Server 2008, SP4 up to SQL Server 2016.

2.4.2.1 Installing Symantec Endpoint Manager

1. Download the product, extract the entire installation file to a physical disk, such as a hard disk. Run *Setup.exe.* The installation should start automatically.
2. Follow the screen instruction and accept the license agreement.
3. Continue the installation until it is finished. After the initial installation completes, configure the server and database.
4. Click *Next.* The Management Server Configuration Wizard starts.
5. Select *Default Configuration,* and then click *Next.*
6. Enter company name, a password for the default administrator admin, and an email address.
7. If you run *LiveUpdate* as part of a new installation, content is more readily available for the clients you deploy.
8. If you want Symantec to receive anonymous data, click *Next* to begin the database creation.
9. When the database creation completes, click *Finish* to complete the Symantec Endpoint Protection Manager configuration.

2.4.2.2 Installing the Client

After installing Symantec Endpoint Protection Manager, install the Symantec Endpoint Protection client to the endpoint host with the Client Deployment Wizard. Of the several installation methods, we recommend using the *Save* package. This installation option creates an executable installation package that you save on the management server and then distribute to the client computers. Follow these steps:

1. Make your configuration selections as you install the Symantec Endpoint Protection Manager and then create the client installation packages.
2. Save the installation package to a folder on the computer that runs Symantec Endpoint Protection Manager.
3. Copy this package to a client machine where you have an administrator privilege.
4. The installation package comprises one setup.exe file. Click the executable file to start the installation. Follow the wizards to complete the installation.

2.4.3 Symantec Advanced Threat Protection: Advanced Threat Protection: Network

With Advanced Threat Protection: Network (ATP:N) installed on the network, it can provide Network-based protection of medical device subnets via monitor internal inbound and outbound internet traffic.

We integrate Symantec Advanced Threat Protection (ATP) with Symantec Endpoint Protection, it will allow ATP to monitor and manage all network traffic from the endpoints and provide threat assessment for dangerous activity to secure the medical devices on an enterprise network.

Minimum Hardware Requirement: 32 GB RAM; 4 CPUs. Hard drive should be at least 500 GB.

Minimum Software Requirement: ESXi 5.5 and 6.0, ATP virtual appliance includes an Integrated Dell Remote Access Controller (iDRAC). The iDRAC console requires the latest version of the Java Runtime Environment (JRE) installed on the administrative client.

2.4.3.1 ATP-N Installation

The installation of the ATP-N involves the deployment of the OVA template on the VMware ESXi Server. A sample installation steps are shown below:

1. Deploy the OVA. During the Deploying procedure, the Deploy OVA Template wizard prompts you to map the Source Network adapters, which are built into the APT OVA with Destination Networks that you already configured on your network.
2. In VMware vSphere Client, start the newly-created virtual appliance.
3. Open a console to the appliance and logon with the user name admin and the proper password to start the bootstrap.
4. From a computer that is on the same subnet as the appliance management port, use a browser to connect to the APT Manager using the ATP IP address. The user name is setup and the password is *Symantec*.

2.4.3.2 Integrating APT with Symantec Endpoint Protection

To integrate the Symantec Advanced Threat Protection (ATP) with Symantec Endpoint Protection allows us to Correlation of event data from Symantec Endpoint Protection Manager to ATP. To do the integration, follow these steps:

1. On Symantec Endpoint Protection Manager, prepare the database for log collection to allow ATP to access the database using DB administrator (sa) credentials.
2. Enable Symantec Endpoint Protection Correlation option by checking in the Settings > Global > Synapse area of ATP Manager.
3. In ATP Manager, configure the connection to Symantec Endpoint Protection Manager instances.
4. In Symantec Endpoint Protection Manager, configure host integrity and quarantine firewall policies, if not already enabled.
5. In Symantec Endpoint Protection Manager, configure endpoints to send information to the ATP management node.
6. In ATP Manager, add SSL certificates for secure communication between endpoints and ATP, if needed.

More detail about integrating ATP and Symantec Endpoint Protection can be found from the following reference: http://help.symantec.com/cs/ATP_2.2/ATP/v102658999_v117970559/About-integrating-ATP-with-Symantec-Endpoint-Protection?locale=EN_US.

2.5 Risk Assessment Tools

2.5.1 Clearwater IRM|Analysis™ Software

We used Clearwater IRM|Analysis™ Software-as-a-Service (SaaS) application, a control-based risk tool for conducting a risk assessment with a focus on the Healthcare Delivery Organization (HDO) enterprise. In our environment, we built the enterprise network to simulate a typical HDO environment. Clearwater Compliance created an account for NCCoE under their cloud based tool, IRM|Analysis™. The software is based on the construct of an "Information Asset" which creates, maintains, receives or transmits electronically Protected Health Information (ePHI.) This can be a software application, information system, medical device system, etc.

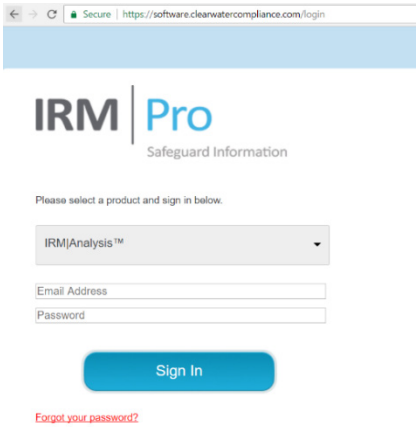
This section does not show you how to conduct a risk assessment. Instead, we present some basic steps for using the IRM|Analysis™ tool to conduct the risk assessment:

1. Login to IRM|Analysis™.
2. Import Inventory of Information Assets or enter the data through the Asset Inventory Form.
3. Establish conformance with the NIST-based Security Controls.
4. Determine the Risk Rating predicated on a 5x5 matrix of likelihood x impact.
5. Identify those risks that are exceed the established "risk threshold."
6. Document "Risk Response" and associated tasks necessary to mitigate, transfer, avoid or accept the risk in the IRM|Analysis™ software.
7. Leverage Dashboard and Reporting functionality to provide documentation and evidence of a credible and bona fide risk analysis.

2.5.1.1 Login to IRM|Analysis™

1. From a browser, type https://software.clearwatercompliance.com/login.
2. On the Login page (see Figure 2-3), enter the appropriate email and password.
3. Click on Sign In.

Figure 2-3: IRM|Analysis™ Login Page



2.5.1.2 Enter Asset Inventory

We used the *New Asset* page to add the assets to the system and the *Edit Asset* page to update the record. After all assets are entered, an analysis is conducted to determine if media (i.e., devices) associated with different assets can be grouped together based on a similar risk profile. For instance: all servers are virtual machines using the same Storage Area Network and identical Operating Systems. If you have 10 assets that have server selected and they are all the same, they can be grouped and evaluated as one. The Media/Asset Group is the logic group for organizing media into classes to reduce the number of identical security control assessments.

To add a new asset:

1. On the IRM|Analysis™ tool, expand *Assets* on the left menu bar.
2. Under Assets, click on Asset Inventory List.
3. On the *Asset Inventory List* page (see Figure 2-4), click on the *New* button.
4. On the *New Asset* form (see Figure 2-5), enter the required information and click on the *Save* button.

Figure 2-4: Asset Inventory List

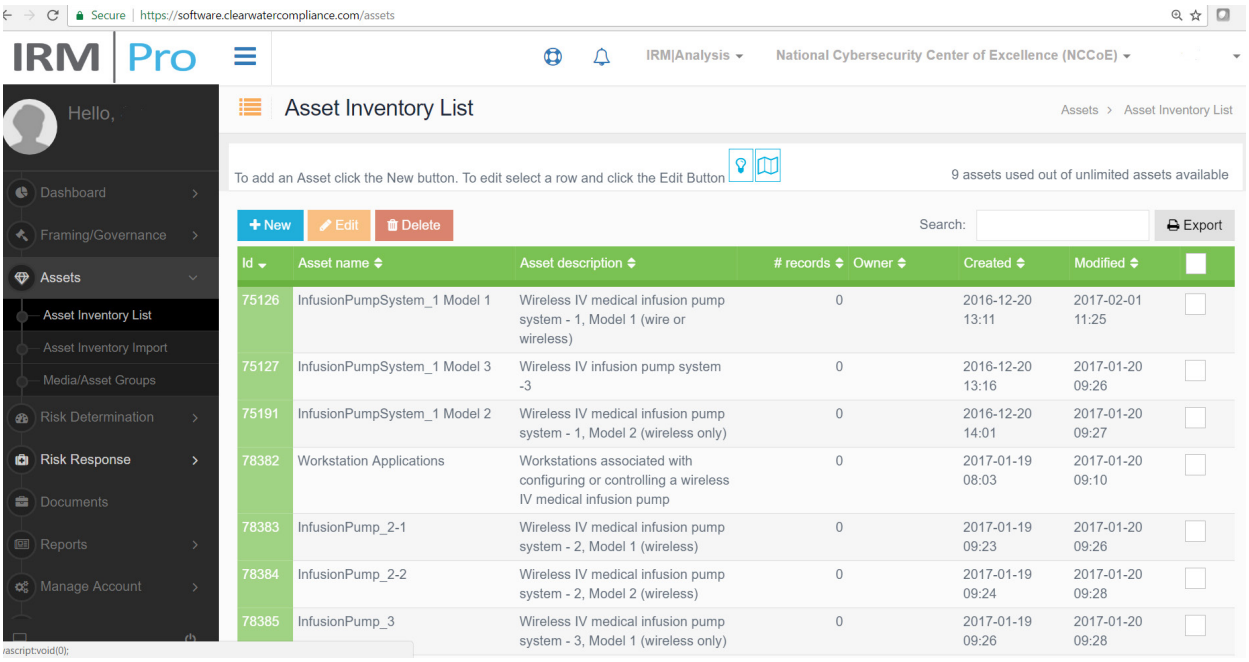
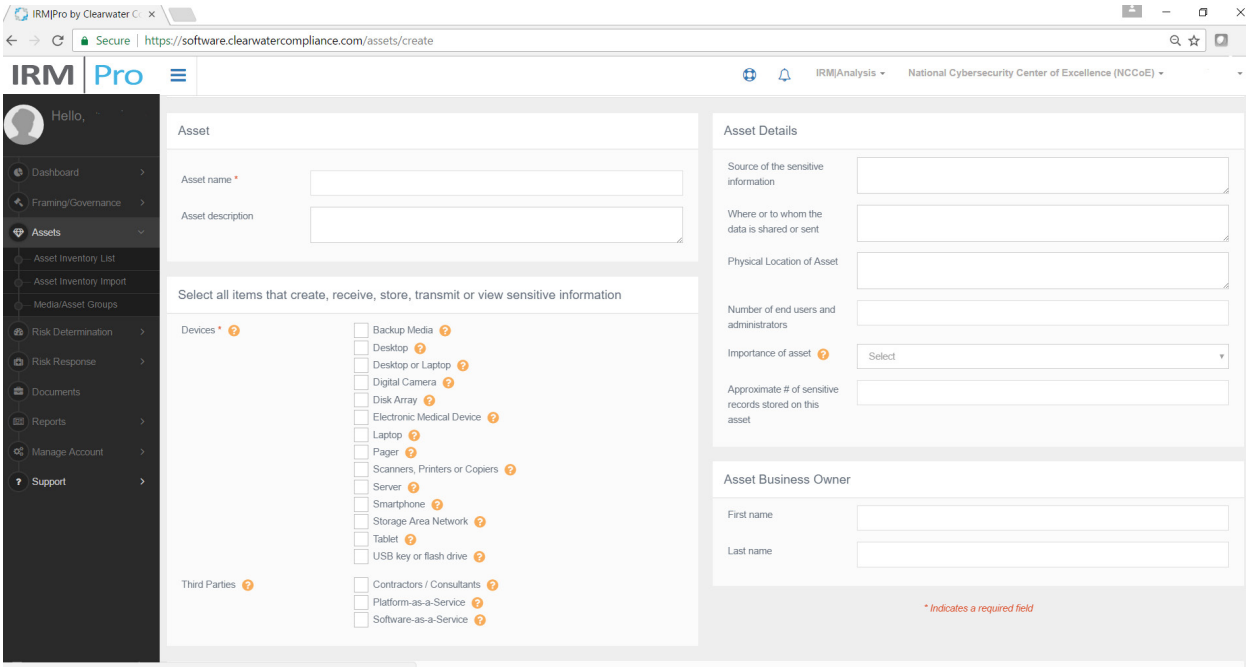


Figure 2-5: New Asset



To update an asset:

1. On the IRM|Analysis™ tool, expand *Assets* on the left menu bar.
2. Under Assets, click on *Asset Inventory List*.
3. On the *Asset Inventory List* page (see Figure 2-4), select the asset you want to edit, then click on the *Edit* button.
4. On the *Edit Media/Asset Groups* page (see Figure 2-7), enter the necessary information and click on the *Save* button.

To view and manage media/asset groups:

1. On the IRM|Analysis™ tool, expend *Assets* on the left menu bar.
2. Under Assets, click on Media/Asset Groups.
3. On the *Media/Asset Groups* (see Figure 2-6), scroll up and down to view the groups and select a group by clicking on the *Edit* button.
4. On the *Edit Media/Asset Groups page* (see Figure 2-7), enter the necessary information and click on the *Save* button.

Figure 2-6: Media/Asset Groups

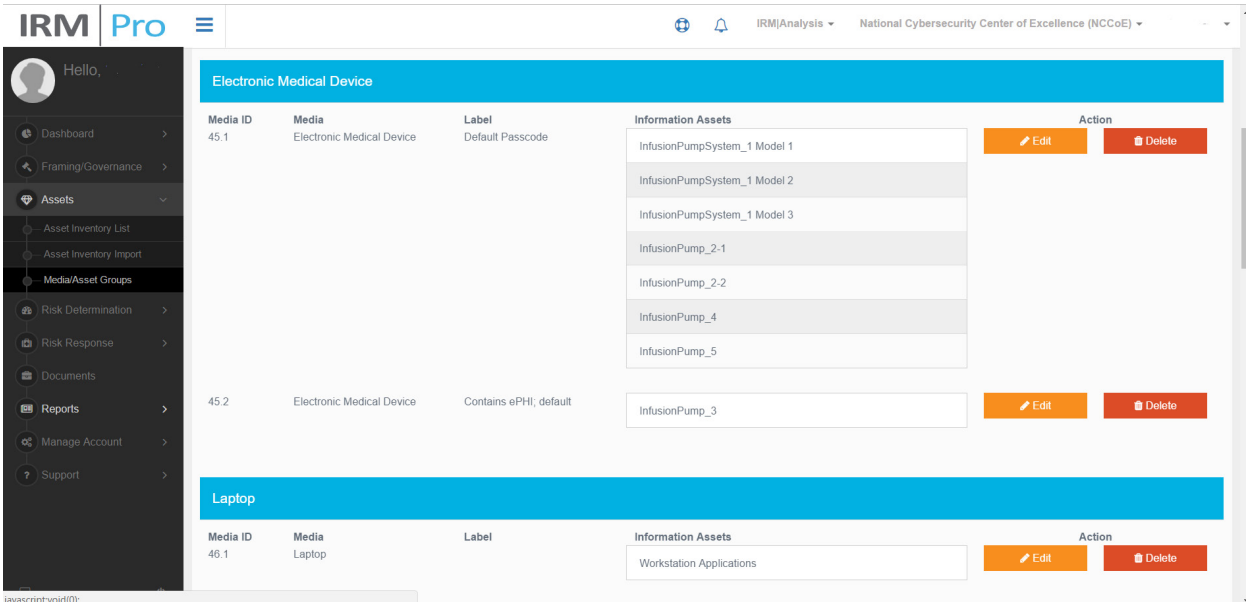
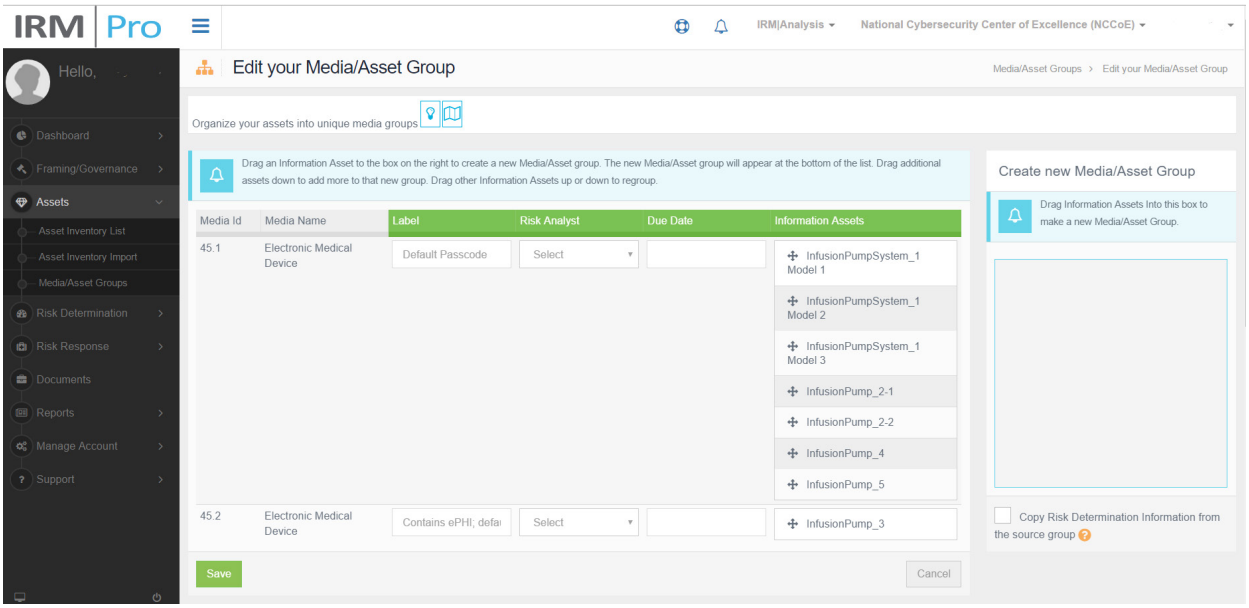


Figure 2-7: Edit Media/Asset Group



2.5.1.3 *Risk Determination*

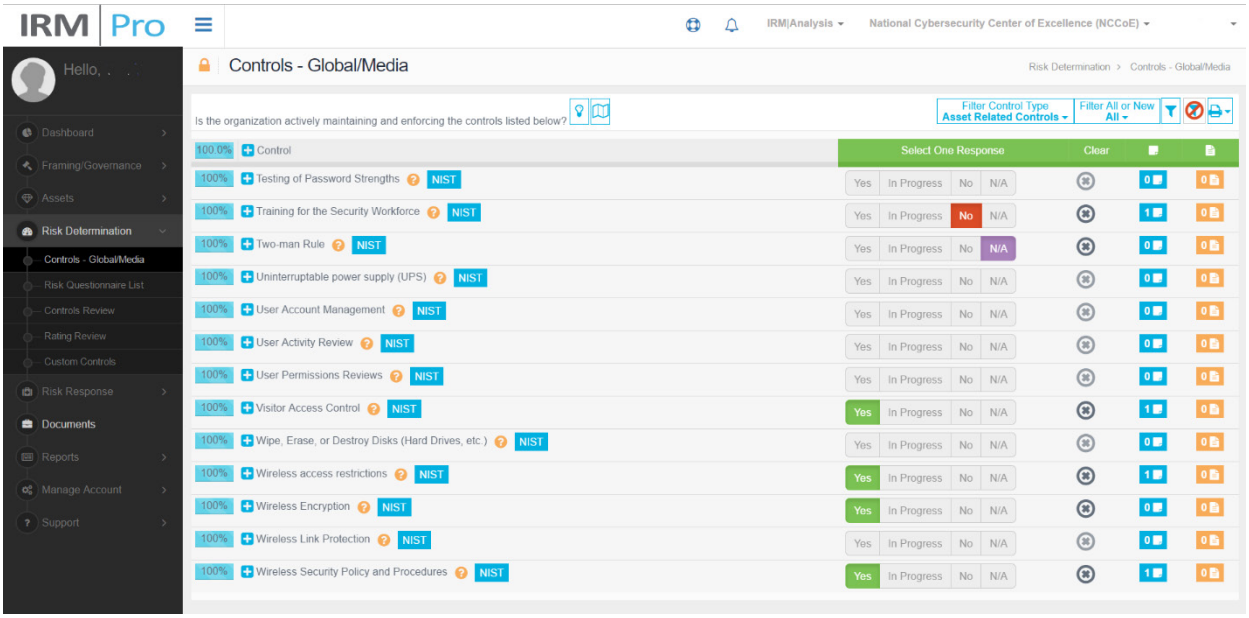
The IRM|Analysis™ tool uses different methods to determine risk. In this section, we show two ways to use the tool: Controls – Global/Media screen to document the status of a control; and the Risk Questionnaire List to select a given Media/Asset group.

To use the Risk Determination at Global/Media level:

1. On the IRM|Analysis™ tool, expand *Risk Determination* on the left menu bar.
2. Under Risk Determination, click on Controls – Global/Media.

3. On the *Controls – Global/Media* page (see Figure 2-8), scroll up and down to view the controls. For each control, select one of the responses (i.e., Yes, In Progress, No, and N/A) to indicate the response status.

Figure 2-8: Controls - Global/Media



To use the Risk Determination at the Asset/Media group level:

1. On the IRM|Analysis™ tool, expand *Risk Determination* on the left menu bar.
2. Under Risk Determination, click on Risk Questionnaire List.
3. On the *Risk Questionnaire List* page (see Figure 2-9), scroll up and down to view the media/asset groups.
4. For each relevant media/asset group, select the *Risk Analyst*, fill in the *Due Date* and click on the *Continue* button to get in the Risk Questionnaire Form (see Figure 2-10 – part 1 and Figure 2-11 – part 2).
5. For each control, select one of the responses (i.e., *Yes*, *In Progress*, *No*, and *N/A*) to indicate the response status (example shown in part 1), if it was already noted on the Controls Global/Media page.
6. Controls can be set globally or for individual Media/Asset Groups. The plus sign will expand the control to reveal the Media/Asset Groups so the control can be set individually. To illustrate, a global control can be set for Training for the Security Workforce but an individual control would be set for each of the Media/Asset groups associated with the User Activity Review since only a subset of assets may undergo a User Activity Review.
7. Then determine and select the Risk Likelihood and Risk Impact for the selected risk scenario (example shown in part 2) to populate the Risk Rating.
8. You may select the question mark for more information on the control and the NIST symbol for a quick reference to NIST SP800-53.

Figure 2-9: Risk Questionnaire List

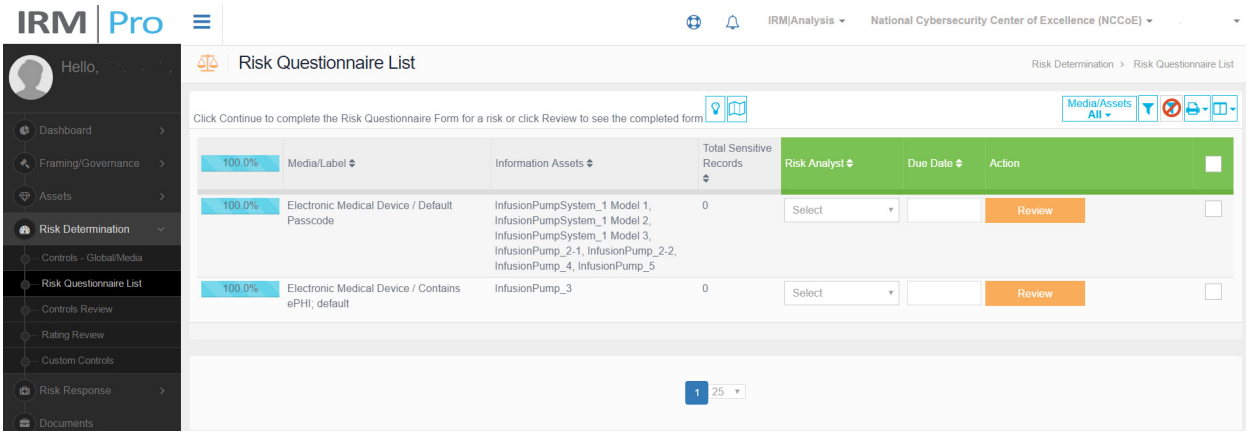
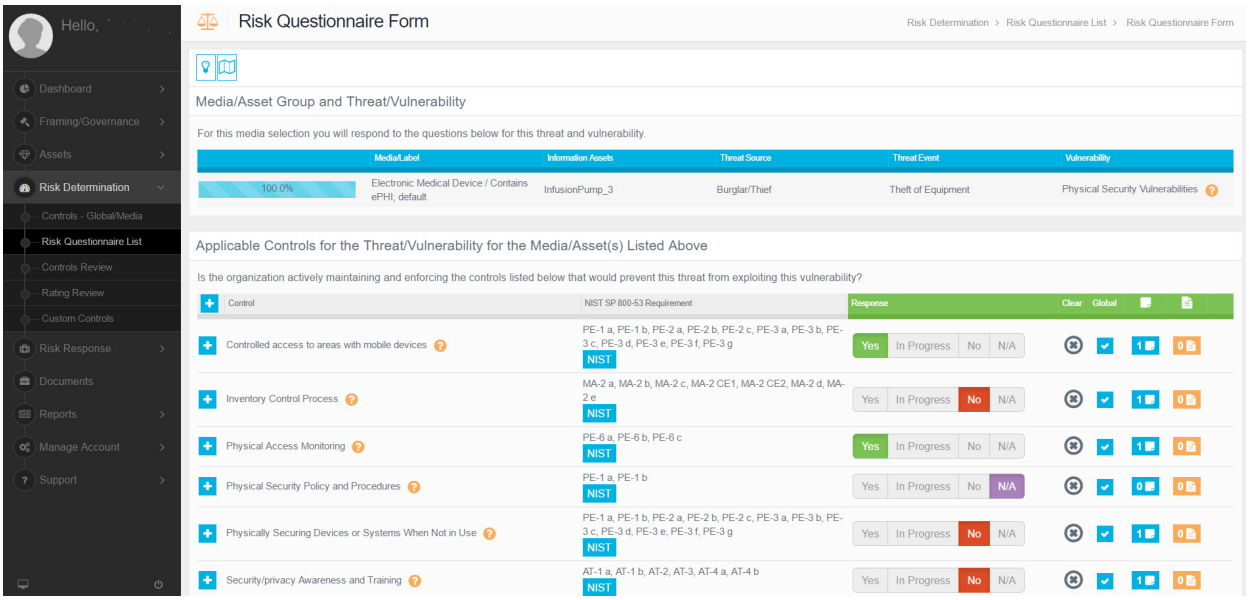
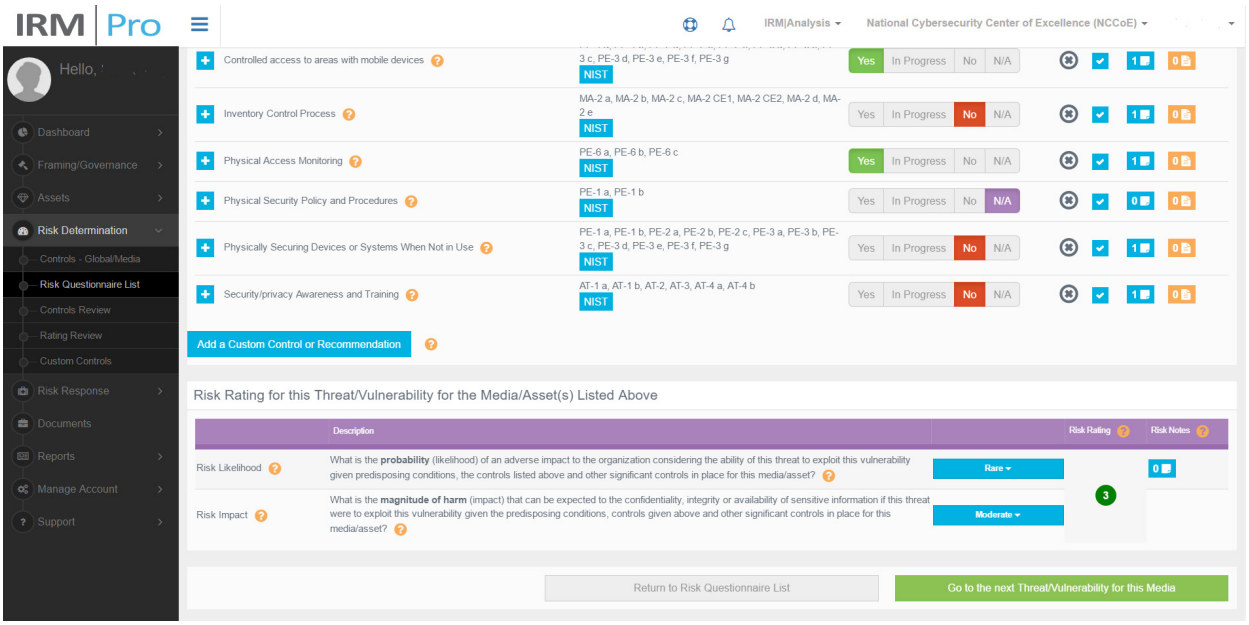


Figure 2-10: Risk Questionnaire Form (part 1)



990 **Figure 2-11: Risk Questionnaire Form (part 2)**



991

992 ### *2.5.1.4 Risk Response*

993 The IRM|Analysis™ tool enables users to try different methods of reviewing risk scenarios, acquiring a
994 risk rating, and seeing progress in a risk response workflow. The basics of using the tool follow.

995 Consider following these risk response steps:

996 1. In the IRM|Analysis™ tool, expand *Risk Response* in the left menu bar.

997 2. Under Risk Response, click on Risk Response List.

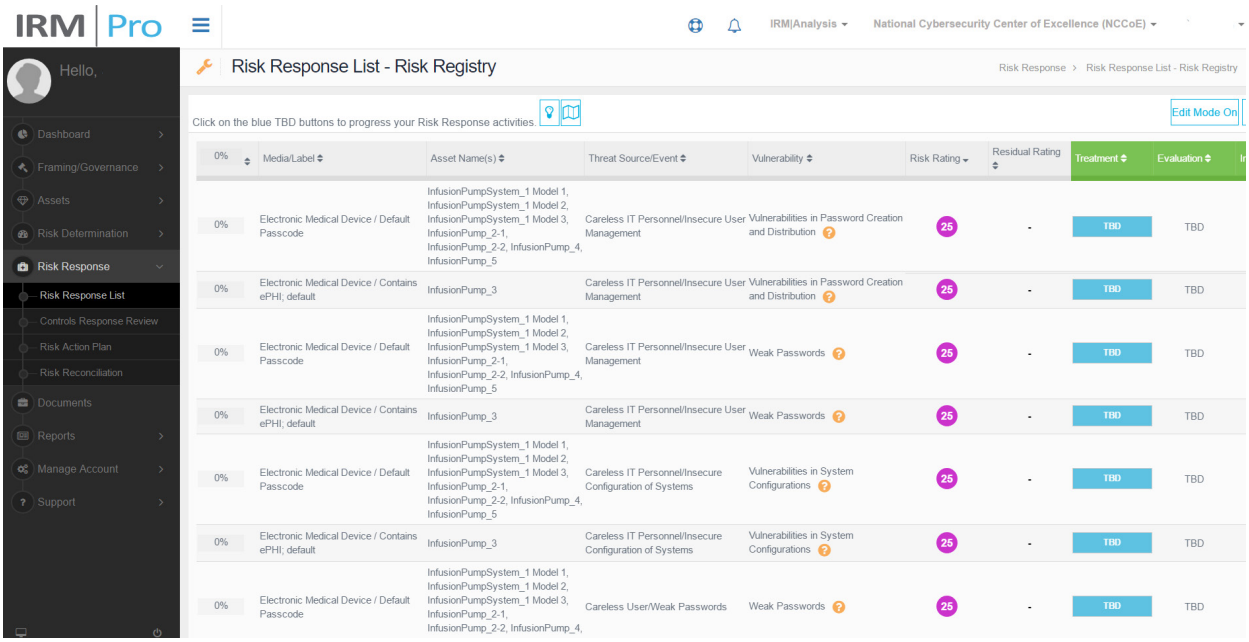
998 3. Only those risks which exceed the risk threshold established under *Framing/Governance* in the left
999 menu bar will move to the Risk Response portion of the software.

1000 4. On the *Risk Response List* page (see Figure 2-12), scroll up and down to view the Medial/Asset
1001 Groups along with the associated threat source, vulnerability, and risk rating.

1002 5. For each relevant risk response, click on the button under the Treatment column to enter the *Risk*
1003 *Treat and Evaluate Form* page of that risk (see Figure 2-13).

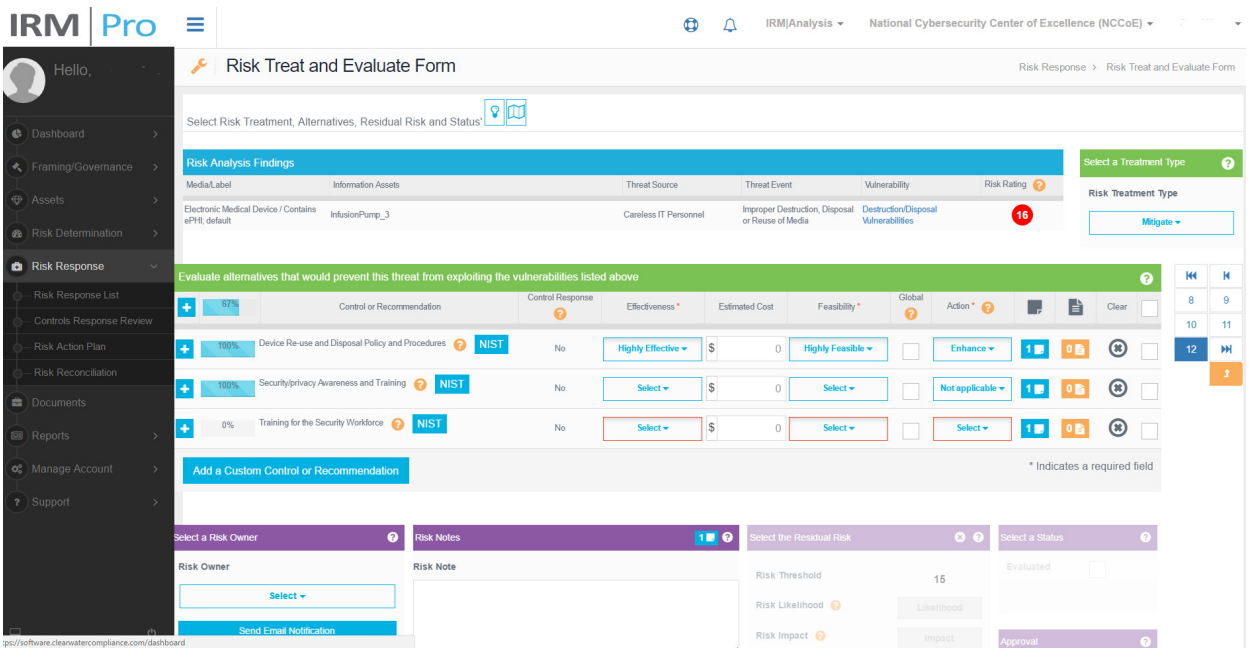
1004 6. On the *Risk Treat and Evaluate Form* page, perform the risk response analysis by selecting the risk
1005 treatment type; evaluate the control or recommendation; select risk owner; put risk notes, and so
1006 on.

1007 **Figure 2-12: Risk Response List - Risk Registry**



1008

1009 **Figure 2-13: Risk Treat and Evaluate Form**



1010

1011 *2.5.1.5 Dashboard and Report*

1012 The IRM|Analysis™ tool enables users to review their risk analyses with a dashboard or report format.
1013 To access the dashboard views, follow these steps:

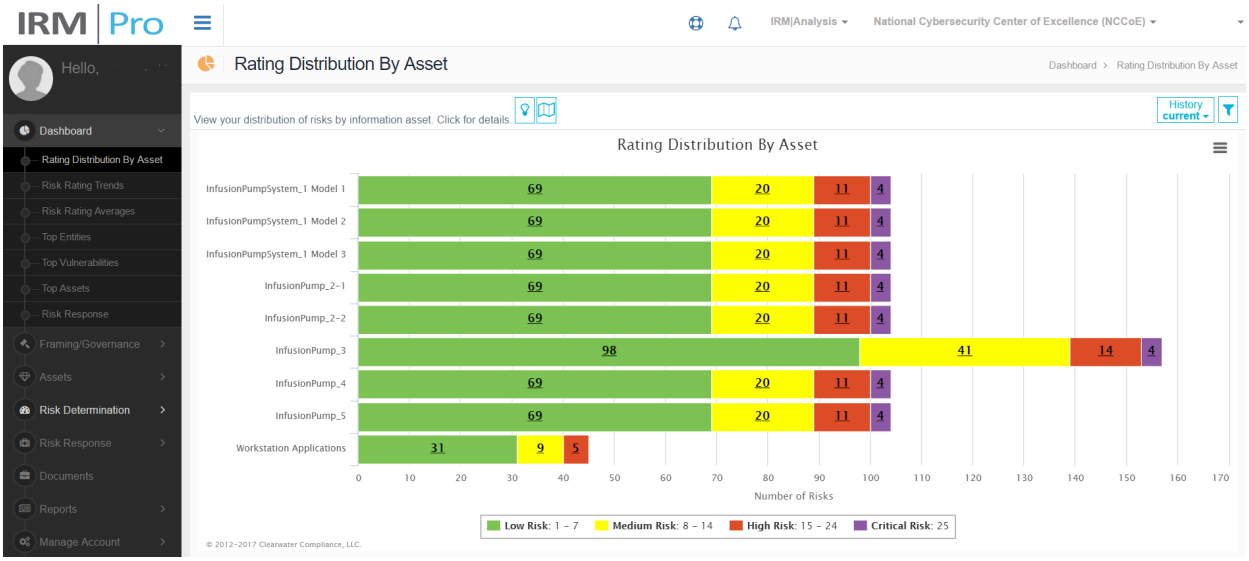
1014 1. On the IRM|Analysis™ tool, expand *Dashboard* on the left menu bar

1015 2. Under Dashboard, click on Rating Distribution by Asset

3. Example Dashboard: Rating Distribution by Asset page (see Figure 2-14 below)

You can also view other types of dashboards, such as *Risk Rating Trends* and *Risk Rating Averages*.

Figure 2-14: Dashboard Example

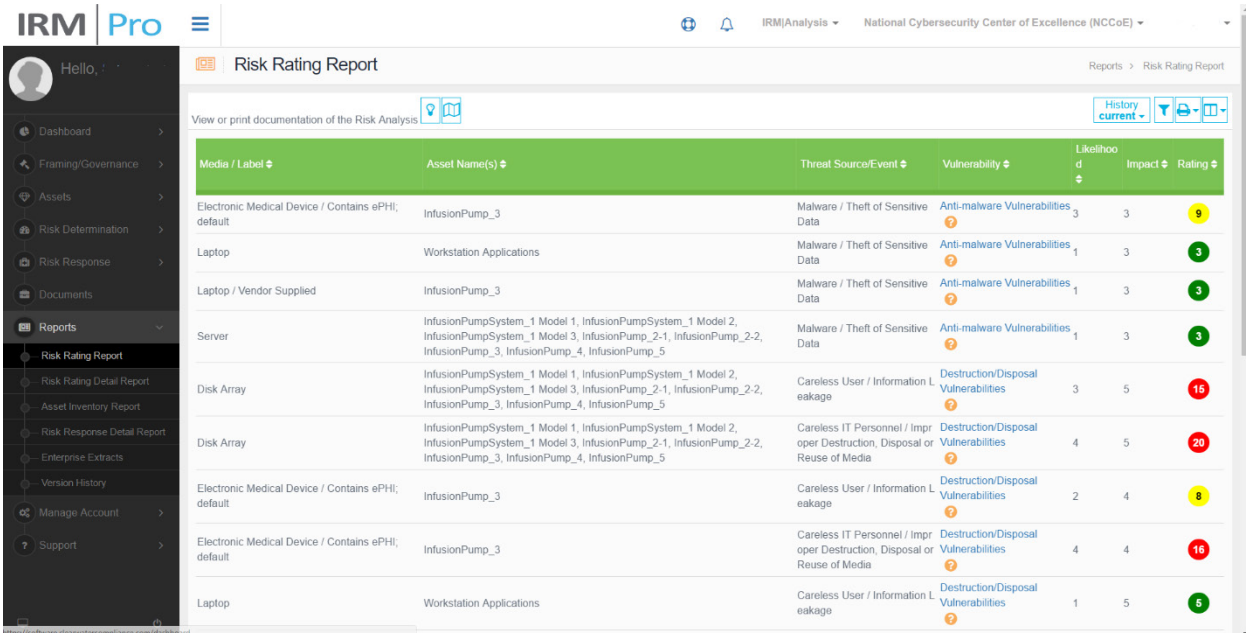


For report views, follow these steps:

1. On the IRM|Analysis™ tool, expand *Reports* on the left menu bar
2. Under Reports, click on Risk Rating Report
3. Example Report: *Risk Rating Report* page is showing (see Figure 2-15 below)

You can also view other types of dashboards, such as *Risk Rating Trends* and *Risk Rating Averages*.

1026 **Figure 2-15: Report Example**



1027

1028 2.5.2 MDISS MDRAP

1029 We used MDISS's cloud-based Medical Device Risk Assessment Platform (MDRAP), a questionnaire-
1030 based risk assessment tool to conduct the assessment on the medical devices. In our environment, we
1031 set up and configured wireless infusion pump systems from five manufactures and built the enterprise
1032 network to simulate a typical HDO environment.

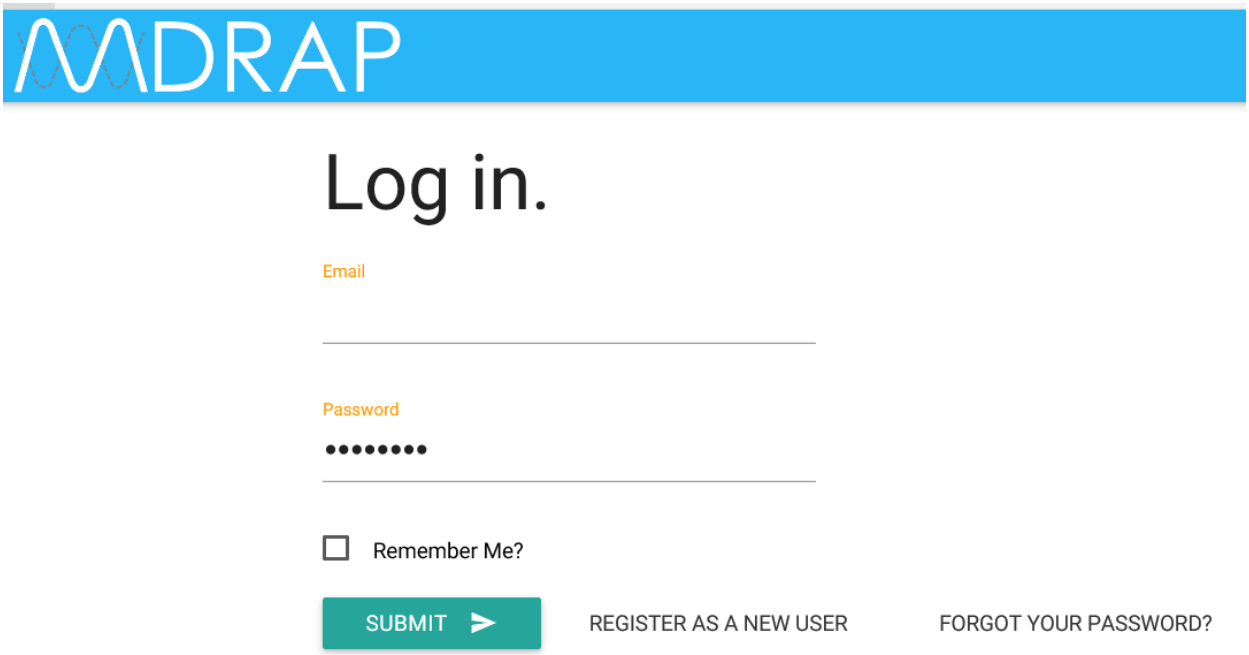
1033 Please note, this section does not show you how to conduct a risk assessment. Instead, we show these
1034 basic steps for using the MDRAP tool:

1035 - Login to MDRAP
1036 - Conduct Device Inventory
1037 - Risk Assessment
1038 - Dashboard and Reports.

1039 *2.5.2.1 Login to MDRAP*

1040 1. Within a browser, type https://mdrap.mdiss.org/ and click on *Log In*
1041 2. On the Login page (see Figure 2-16), enter the appropriate email and password
1042 3. Click on *Submit.*

1043 **Figure 2-16: MDRAP Login Page**



1044

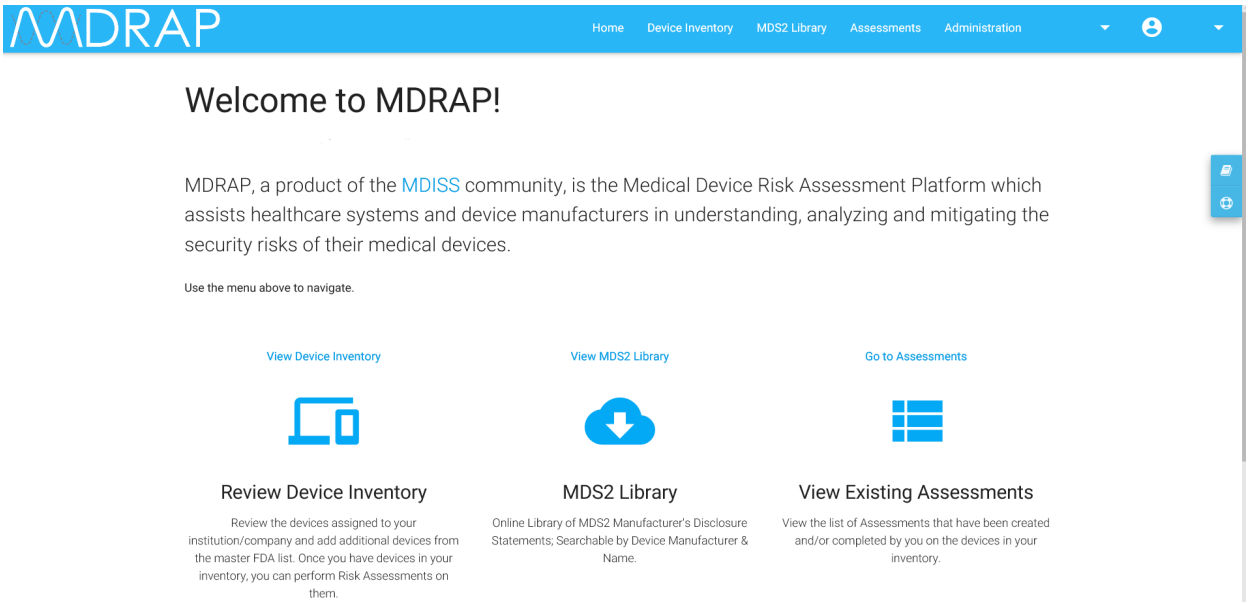
1045 ### *2.5.2.2 Conduct Device Inventory*

1046 We use the Device Inventory module of MDRAP to keep track all the infusion pumps and servers in our
1047 sample implementation. Add Device, per its name, enables us to add individual devices, while Bulk
1048 Import enables us to add a group of devices. Steps for using both methods follow.

1049 1. On the Welcome to MDRAP page (see Figure 2-17), click on Device Inventory on the menu bar or
1050 on the View Device Inventory link on the page.

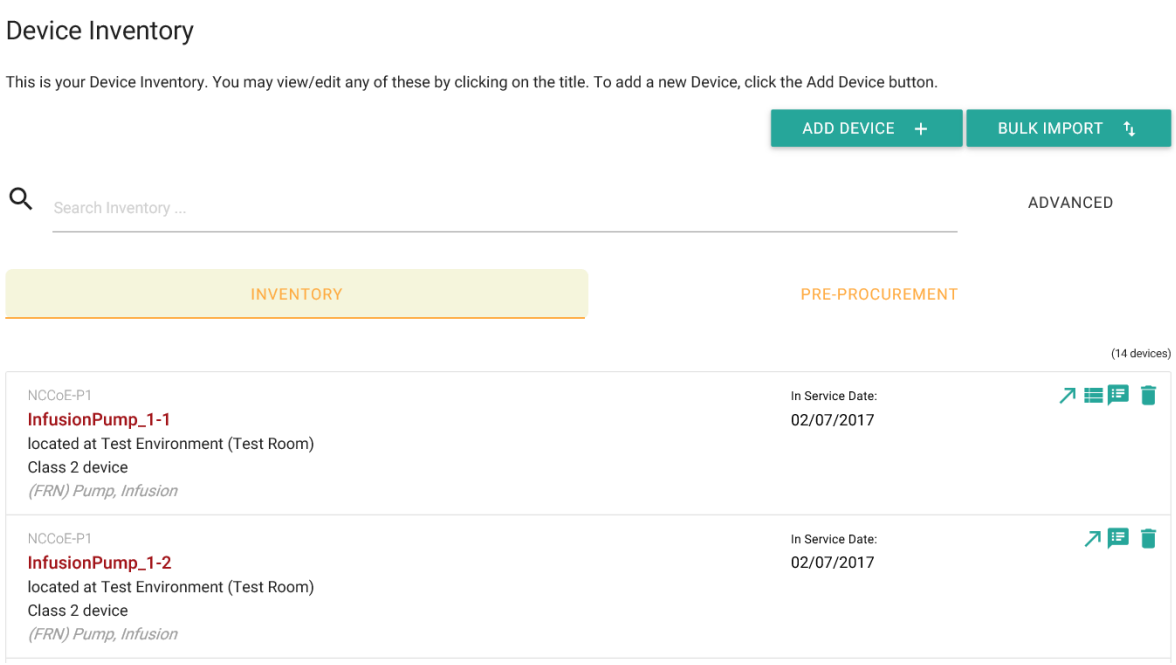
1051 2. On the Device Inventory page (Figure 2-18), add an individual device, or edit a device, or bulk import
1052 a group of devices.

1053 **Figure 2-17: MDRAP Welcome page**



1054

1055 **Figure 2-18: Device Inventory List**



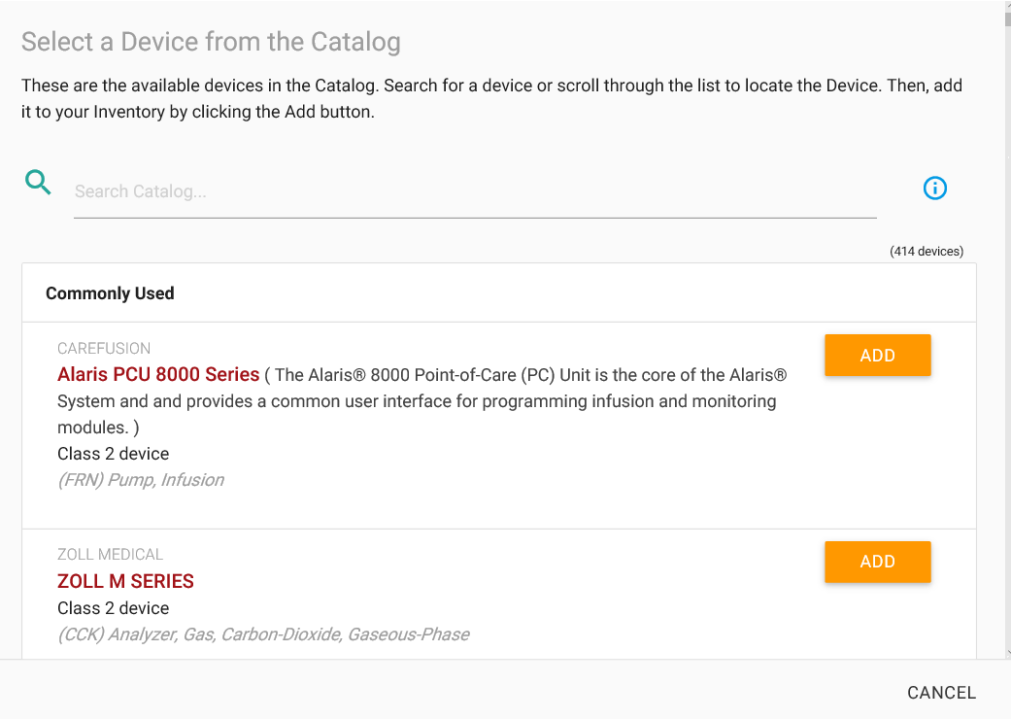
1056

1057 Add device:

1058 1. On the Device Inventory page (see Figure 2-18 above), click on ADD DEVICE.

1059 2. On Add Device page (see Figure 2-19 below), locate the device from the Category List, then click on
1060 ADD.

1061 **Figure 2-19: Add Device**



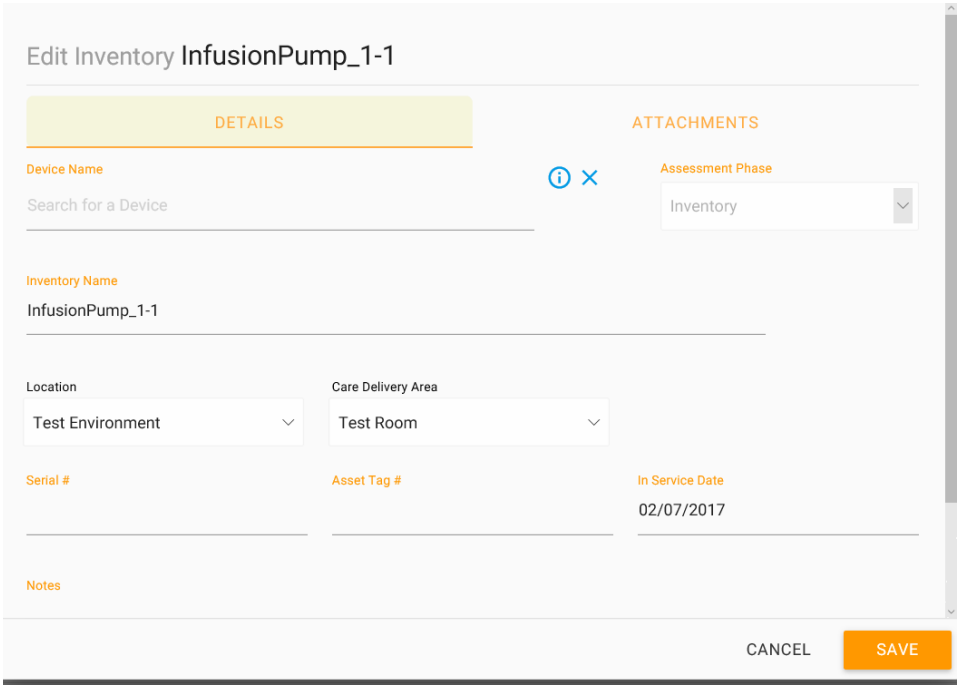
1062

1063 Edit a device:

1064 1. On the Device Inventory page (see Figure 2-18 above), locate the device from the list, click on the
1065 product name link or the Edit icon.

1066 2. On the Edit Inventory page (see Figure 2-20 below), update the data and click on Save.

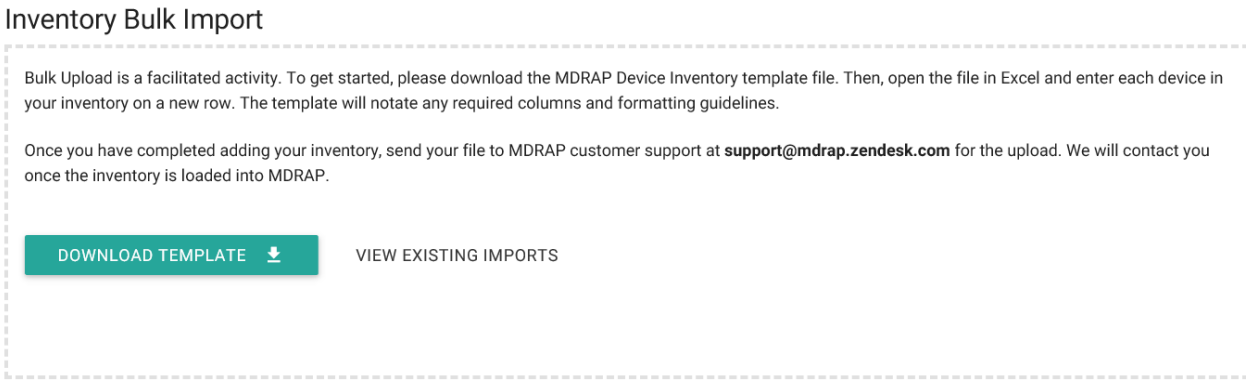
Figure 2-20: Edit Device



Bulk Import a group of devices:

1. On the Device Inventory page (see Figure 2-18: Device Inventory List above), click on BULK IMPORT button.
2. On Inventory Bulk Import page (see Figure 2-21 below), download the template, fill-in the data into the template.
3. Follow the instruction to upload and import the devices by using the template (see Figure 2-22).

Figure 2-21: Inventory Bulk Import



1078 **Figure 2-22: Device inventory Template Sample**

MDRAP Device Inventory Template

version 1.0.0
last updated 6/29/2016

** Required*
*** Enter a custom name as you refer to the device in your Organization; otherwise, leave it blank and it will default to the Device Name*

Device Name *	Manufacturer *	Location *	Department / Care Area *	Custom Name **	Serial #	Asset Tag	In Service On	Notes
InfusionPump_1-1	NCCoE-P1	NCCoE	Health Lab	CoE User				
PumpServer_1	NCCoE-P1	NCCoE	Health Lab	NCCoE User				
InfusionPump_1-2	NCCoE-P1	NCCoE	Health Lab	NCCoE User				
NetworkSetup_1	NCCoE-P1	NCCoE	Health Lab	NCCoE User				
InfusionPump_2-1	NCCoE-P2	NCCoE	Health Lab	NCCoE User				
InfusionPump_2-2	NCCoE-P2	NCCoE	Health Lab	NCCoE User				
PumpServer_2	NCCoE-P2	NCCoE	Health Lab	NCCoE User				
InfusionPump_3	NCCoE-P3	NCCoE	Health Lab	NCCoE User				
PumpServer_3	NCCoE-P3	NCCoE	Health Lab	NCCoE User				
NetworkSetup_3	NCCoE-P3	NCCoE	Health Lab	NCCoE User				
InfusionPump_4	NCCoE-P4	NCCoE	Health Lab	NCCoE User				
PumpServer_4	NCCoE-P4	NCCoE	Health Lab	NCCoE User				
InfusionPump_5	NCCoE-P5	NCCoE	Health Lab	NCCoE User				
PumpServer_5	NCCoE-P5	NCCoE	Health Lab	NCCoE User				

Inventory | Locations | Departments

1079

1080 ### *2.5.2.3 Risk Assessment*

1081 We created a risk assessment for each device by responding to the MDRAP's built-in questionnaire. The
1082 basic steps of creating a risk assessment for a given device follow:

1083 1. Create assessment

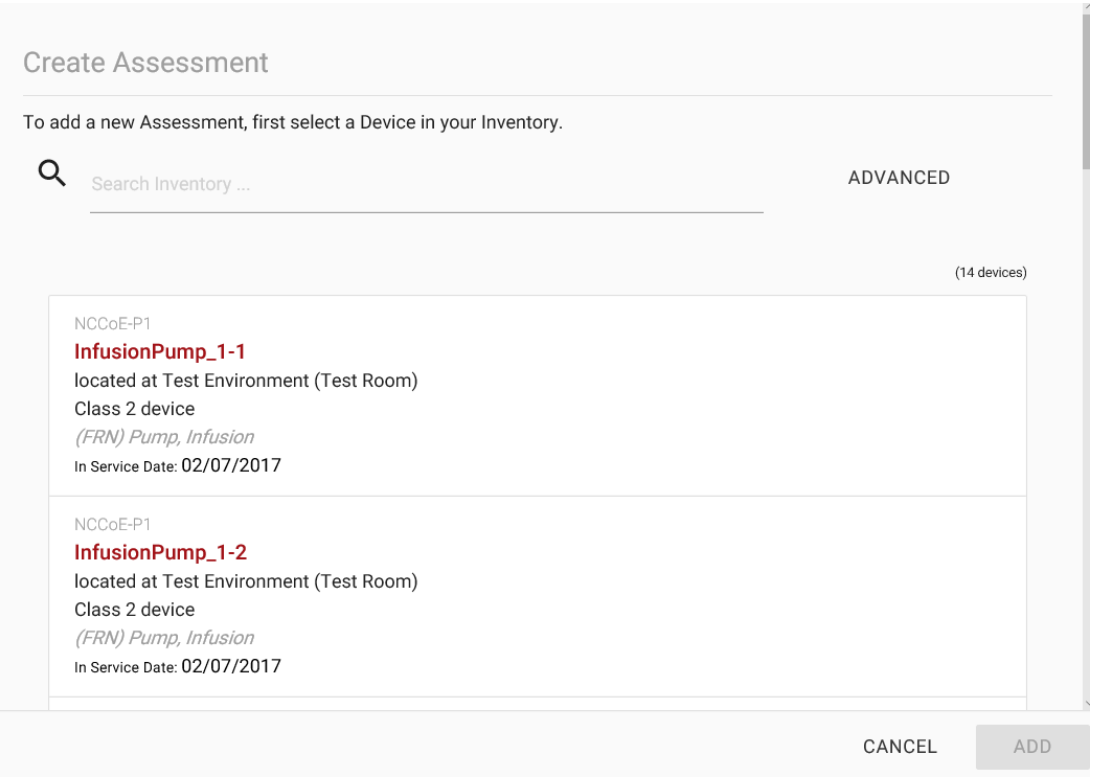
1084 d. On the *Welcome to MDRAP* page (see Figure 2-17 above), click on *Assessments* on the menu
1085 bar or *Go to Assessments* link on the page.

1086 e. On *Create Assessment* page 1(see Figure 2-23), select a device.

1087 f. On Create Assessment page 2 (see Figure 2-24), select Questionnaire type (i.e., MDISS
1088 Questionnaire).

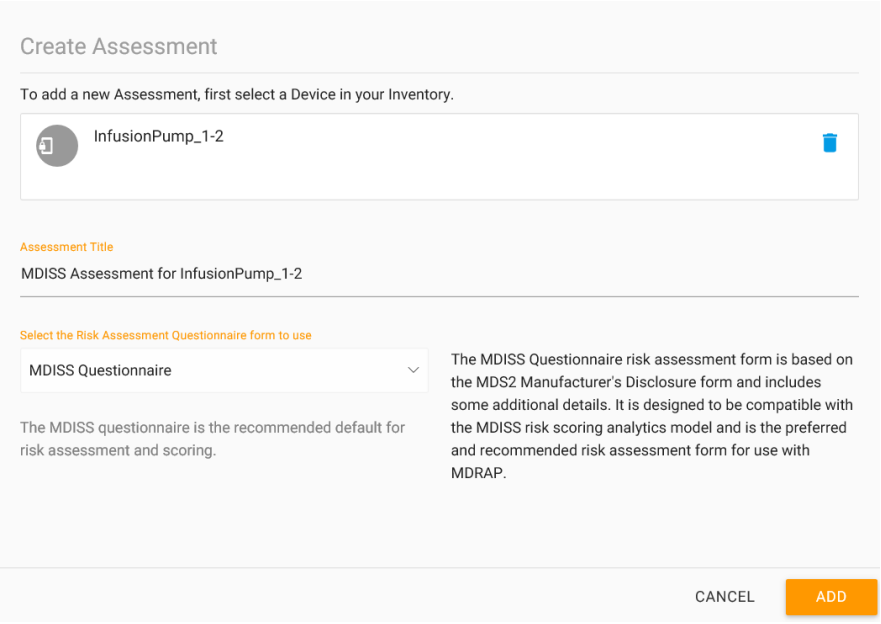
1089 g. Answer the questions and then click *Next* button (see example questionnaire pages in Figure
1090 2-25 and Figure 2-26).

1091 **Figure 2-23: Create Assessment (part 1)**



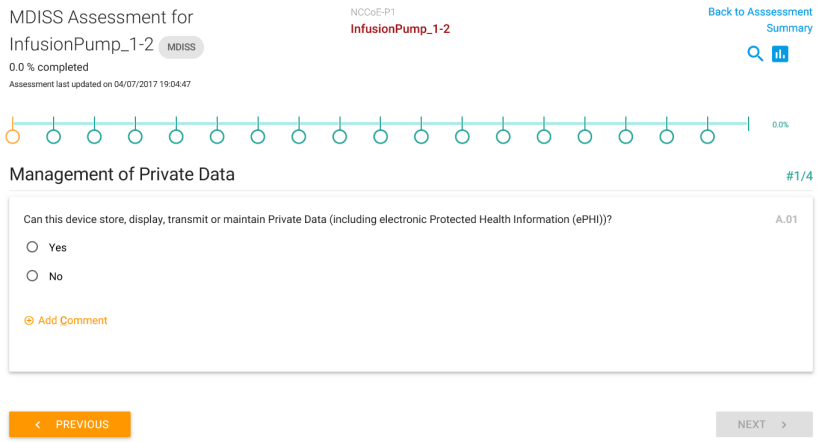
1092

1093 **Figure 2-24: Create Assessment (part 2)**



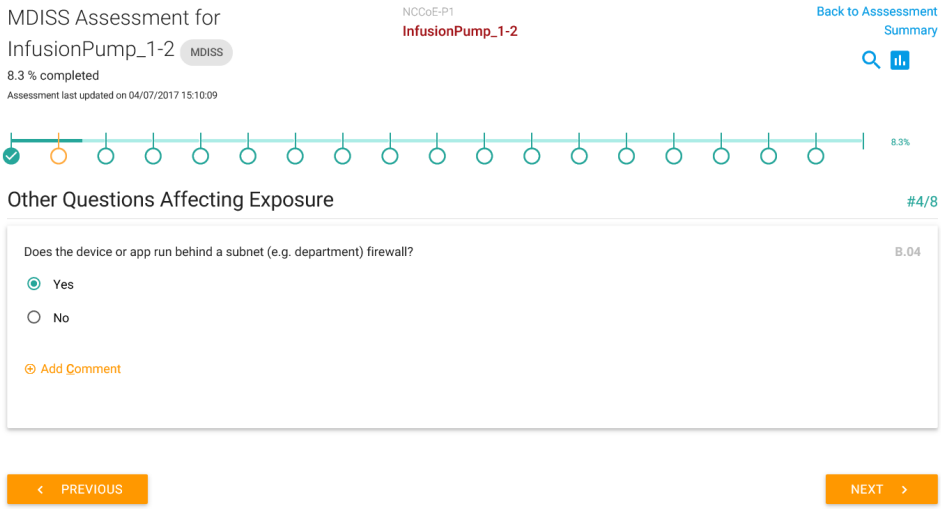
1094

1095 **Figure 2-25: Assessment Step (example 1)**



1096

1097 **Figure 2-26: Assessment Step (example 2)**

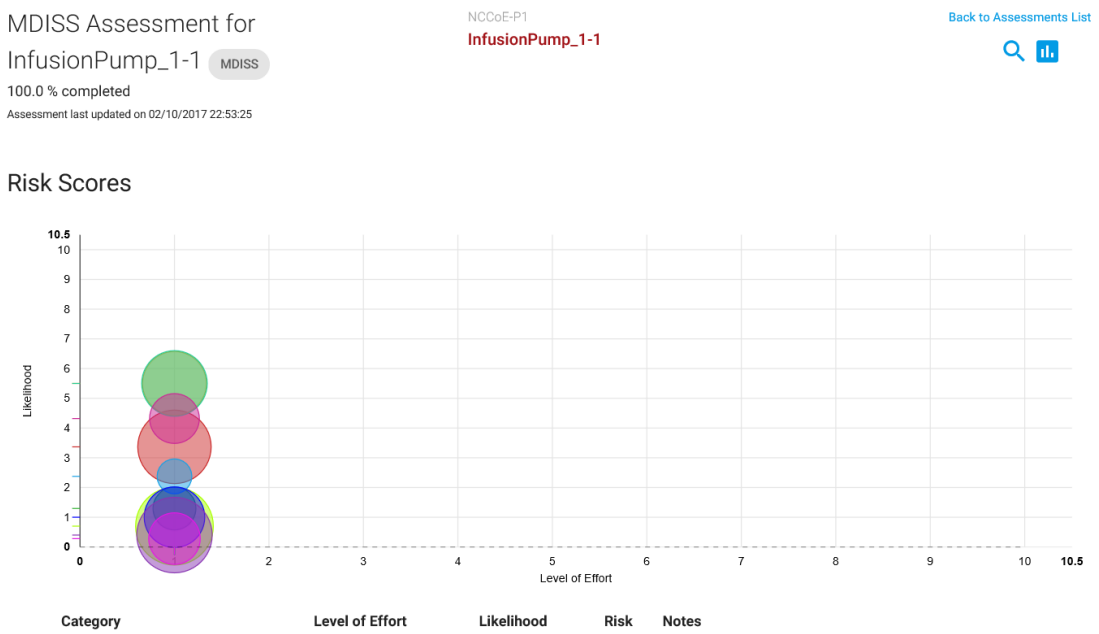


1098

1099 *2.5.2.4 Dashboard and Reports*

1100 MDRAP computes assessment results based on the responses to the questionnaires. For a given
1101 assessment (complete or partially complete), the assessment result is available for view as a dashboard
1102 (see Figure 2-27) or report (see Figure 2-28).

1103 **Figure 2-27: Assessment Result (dashboard example)**



1104

1105 **Figure 2-28: Assessment Result (report example)**

	Category	Level of Effort	Likelihood	Risk	Notes
	Audit Controls	1	3.367	5.25	* Patient identity not captured.
	Authorization	1	5.5	3.75	* Authorization can be bypassed using an API. * Operator can acquire root-level privilege. * Root-level privilege is the only authorization mode.
	Automatic Logoff	1	0.7	6	
	Cyber Security Product Upgrades	1	1.295	1.175	* Device OS is not supported by the OS manufacturer.
	Malware Detection / Protection	1	5.5	4	* No Virus Protection
	Other Scoreable MDS2 Security Categories	1	2.375	0.453	* No encrypption of data at rest. * No Fuzz-testing performed * Some device storage components not physically secured.
	Other Security Considerations - Remote Access	1	1	3.275	* Maintenance users require root privilege.
	Person Authentication	1	0.4	5.6	* Device does not store, display, transmit, or maintain ePHI. * Passwords cannot be set to expire. * Person authentication is not supported.
	System and Application Hardening	1	4.32	1.907	* Device transmits data in the clear on shared networks. * System does not alllow file-level access controls. * Unnecessary services active.
	Transmission Confidentiality &	1	0.28	2.118	

1106

Appendix A Baseline Configuration File

A.1 Baseline Configuration File

```
ASA Version 9.6(1)
!
interface Management0/0
 ip address 192.168.29.149 255.255.255.0
!
! optional, SSH, version is important as v1 is insecure and on by default, also set your own password!
username cisco password XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
aaa authentication ssh console LOCAL
! set to network and interface you want to manage from, can be WAN
ssh 192.168.29.0 255.255.255.0 management
ssh version 2
!
hostname internal-kmcfadde
!
! Configure network interfaces
interface GigabitEthernet0/0
 nameif WAN
 security-level 50
 ip address 192.168.100.149 255.255.255.0
 no shutdown
! optional, authenticated OSPF for excellence
 ospf authentication-key [L}N]@Uv
 ospf authentication message-digest
!
interface GigabitEthernet0/1
 nameif LAN
 security-level 100
 ip address 192.168.150.1 255.255.255.0
```

```
 no shutdown
!
! optional, DHCP Server
dhcpd address 192.168.150.220-192.168.150.250 LAN
dhcpd dns 8.8.8.8 8.8.4.4
dhcpd option 3 ip 192.168.150.1
dhcpd enable LAN
!
! optional, OSPFv2
router ospf 1
 network 192.168.100.0 255.255.255.0 area 0
 redistribute connected subnets
 redistribute static subnets
!
! Configure DNS resolution here, required for license activation
dns domain-lookup WAN
dns server-group DefaultDNS
 name-server 8.8.8.8
 name-server 8.8.4.4
!
license smart
 feature tier standard
 throughput level 1G
names
!
! optional, Configure time zone and NTP here
clock timezone EST -5
clock summer-time EDT recurring
ntp server 10.97.74.8
!
```

```
! Allow ping through LAN to WAN
policy-map global_policy
 class inspection_default
  inspect icmp
  inspect icmp error
!
! Show up in traceroute
policy-map global_policy
 class class-default
  set connection decrement-ttl
!
! Make ICMP/UDP traceroute work from LAN to WAN
object-group icmp-type PING-REPLIES
 icmp-object echo-reply
object-group icmp-type TRACEROUTE-REPLIES
 icmp-object time-exceeded
 icmp-object unreachable
 group-object PING-REPLIES
access-list 101 extended permit icmp any any object-group TRACEROUTE-REPLIES
access-list 101 extended permit icmp any any object-group PING-REPLIES
!
! Allow ICMP ping/traceroute from WAN to LAN
object-group icmp-type PING
 icmp-object echo
access-list 101 extended permit icmp any any object-group PING
!
! Allow UDP traceroute from WAN to LAN
object-group service TRACEROUTEUDP
 service-object udp destination gt 33434
access-list 101 extended permit object-group TRACEROUTEUDP any any
```

```
!
! example, allow a specific port on a host
! access-list 101 extended permit tcp any host 192.168.140.XXX eq www
!
! Add firewall rules we created to WAN interface
access-group 101 in interface WAN
!
! Example, set a static route
! route WAN 192.168.140.0 255.255.255.0 192.168.100.111
!
! SNMP
object network SNMPHOSTS
 subnet 192.168.29.0 255.255.255.0
snmp-server enable
snmp-server community public
snmp-server host-group management SNMPHOSTS
```

A.2 External Firewall and Guest Network ASA Configuration File

```
: Saved
:
: Serial Number: 9AK64JT2D2M
: Hardware:   ASAv, 2048 MB RAM, CPU Xeon E5 series 2200 MHz
:
ASA Version 9.6(1)
!
hostname border-kmcfadde
enable password 8Ry2YjIyt7RRXU24 encrypted
xlate per-session deny tcp any4 any4
xlate per-session deny tcp any4 any6
xlate per-session deny tcp any6 any4
xlate per-session deny tcp any6 any6
xlate per-session deny udp any4 any4 eq domain
xlate per-session deny udp any4 any6 eq domain
xlate per-session deny udp any6 any4 eq domain
xlate per-session deny udp any6 any6 eq domain
!
license smart
 feature tier standard
 throughput level 1G
names

!
interface GigabitEthernet0/0
 nameif WAN
 security-level 0
 ip address 10.32.3.10 255.255.255.0
!
```

```
interface GigabitEthernet0/1
 nameif LAN
 security-level 100
 ip address 192.168.100.101 255.255.255.0
 ospf authentication-key *****
 ospf authentication message-digest
!
interface GigabitEthernet0/2
 nameif GUEST
 security-level 100
 ip address 192.168.170.1 255.255.255.0
!
interface GigabitEthernet0/3
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/4
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/5
 shutdown
 no nameif
 no security-level
 no ip address
!
```

```
interface GigabitEthernet0/6
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/7
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/8
 shutdown
 no nameif
 no security-level
 no ip address
!
interface Management0/0
 management-only
 nameif management
 security-level 0
 ip address 192.168.29.147 255.255.255.0
!
ftp mode passive
clock timezone EST -5
clock summer-time EDT recurring
dns domain-lookup WAN
dns server-group DefaultDNS
 name-server 8.8.8.8
```

```
 name-server 8.8.4.4
object network LAN-SUBNETS
 subnet 192.168.0.0 255.255.0.0
object network SNMPHOSTS
 subnet 192.168.29.0 255.255.255.0
object-group icmp-type PING-REPLIES
 icmp-object echo-reply
object-group icmp-type TRACEROUTE-REPLIES
 icmp-object time-exceeded
 icmp-object unreachable
 group-object PING-REPLIES
object-group icmp-type PING
 icmp-object echo
object-group service TRACEROUTEUDP
 service-object udp destination gt 33434
access-list 101 extended permit icmp any any object-group TRACEROUTE-REPLIES
pager lines 23
mtu WAN 1500
mtu LAN 1500
mtu management 1500
mtu GUEST 1500
no failover
no monitor-interface service-module
icmp unreachable rate-limit 1 burst-size 1
no asdm history enable
arp timeout 14400
no arp permit-nonconnected
!
object network LAN-SUBNETS
 nat (LAN,WAN) dynamic interface
```

```
access-group 101 in interface WAN
!
route-map DEFAULT permit 10
 match interface WAN

!
router ospf 1
 network 192.168.100.0 255.255.255.0 area 0
 log-adj-changes
 redistribute connected subnets
 redistribute static subnets
 default-information originate
!
route WAN 0.0.0.0 0.0.0.0 10.32.3.1 1
timeout xlate 3:00:00
timeout pat-xlate 0:00:30
timeout conn 1:00:00 half-closed 0:10:00 udp 0:02:00 sctp 0:02:00 icmp 0:00:02
timeout sunrpc 0:10:00 h323 0:05:00 h225 1:00:00 mgcp 0:05:00 mgcp-pat 0:05:00
timeout sip 0:30:00 sip_media 0:02:00 sip-invite 0:03:00 sip-disconnect 0:02:00
timeout sip-provisional-media 0:02:00 uauth 0:05:00 absolute
timeout tcp-proxy-reassembly 0:01:00
timeout floating-conn 0:00:00
user-identity default-domain LOCAL
aaa authentication ssh console LOCAL
snmp-server host-group management SNMPHOSTS poll community *****
no snmp-server location
no snmp-server contact
snmp-server community *****
crypto ipsec security-association pmtu-aging infinite
crypto ca trustpoint _SmartCallHome_ServerCA
```

```
 no validation-usage
 crl configure
crypto ca trustpool policy
 auto-import
crypto ca certificate chain _SmartCallHome_ServerCA
 certificate ca 6ecc7aa5a7032009b8cebcf4e952d491
    308205ec 308204d4 a0030201 0202106e cc7aa5a7 032009b8 cebcf4e9 52d49130
    0d06092a 864886f7 0d010105 05003081 ca310b30 09060355 04061302 55533117
    30150603 55040a13 0e566572 69536967 6e2c2049 6e632e31 1f301d06 0355040b
    13165665 72695369 676e2054 72757374 204e6574 776f726b 313a3038 06035504
    0b133128 63292032 30303620 56657269 5369676e 2c20496e 632e202d 20466f72
    20617574 686f7269 7a656420 75736520 6f6e6c79 31453043 06035504 03133c56
    65726953 69676e20 436c6173 73203320 5075626c 69632050 72696d61 72792043
    65727469 66696361 74696f6e 20417574 686f7269 7479202d 20473530 1e170d31
    30303230 38303030 3030305a 170d3230 30323037 32333539 35395a30 81b5310b
    30090603 55040613 02555331 17301506 0355040a 130e5665 72695369 676e2c20
    496e632e 311f301d 06035504 0b131656 65726953 69676e20 54727573 74204e65
    74776f72 6b313b30 39060355 040b1332 5465726d 73206f66 20757365 20617420
    68747470 733a2f2f 7777772e 76657269 7369676e 2e636f6d 2f727061 20286329
    3130312f 302d0603 55040313 26566572 69536967 6e20436c 61737320 33205365
    63757265 20536572 76657220 4341202d 20473330 82012230 0d06092a 864886f7
    0d010101 05000382 010f0030 82010a02 82010100 b187841f c20c45f5 bcab2597
    a7ada23e 9cbaf6c1 39b88bca c2ac56c6 e5bb658e 444f4dce 6fed094a d4af4e10
    9c688b2e 957b899b 13cae234 34c1f35b f3497b62 83488174 d188786c 0253f9bc
    7f432657 5833833b 330a17b0 d04e9124 ad867d64 12dc744a 34a11d0a ea961d0b
    15fca34b 3bce6388 d0f82d0c 948610ca b69a3dca eb379c00 48358629 5078e845
    63cd1941 4ff595ec 7b98d4c4 71b350be 28b38fa0 b9539cf5 ca2c23a9 fd1406e8
    18b49ae8 3c6e81fd e4cd3536 b351d369 ec12ba56 6e6f9b57 c58b14e7 0ec79ced
    4a546ac9 4dc5bf11 b1ae1c67 81cb4455 33997f24 9b3f5345 7f861af3 3cfa6d7f
    81f5b84a d3f58537 1cb5a6d0 09e4187b 384efa0f 02030100 01a38201 df308201
```

db303406 082b0601 05050701 01042830 26302406 082b0601 05050730 01861868
7474703a 2f2f6f63 73702e76 65726973 69676e2e 636f6d30 12060355 1d130101
ff040830 060101ff 02010030 70060355 1d200469 30673065 060b6086 480186f8
45010717 03305630 2806082b 06010505 07020116 1c687474 70733a2f 2f777777
2e766572 69736967 6e2e636f 6d2f6370 73302a06 082b0601 05050702 02301e1a
1c687474 70733a2f 2f777777 2e766572 69736967 6e2e636f 6d2f7270 61303406
03551d1f 042d302b 3029a027 a0258623 68747470 3a2f2f63 726c2e76 65726973
69676e2e 636f6d2f 70636133 2d67352e 63726c30 0e060355 1d0f0101 ff040403
02010630 6d06082b 06010505 07010c04 61305fa1 5da05b30 59305730 55160969
6d616765 2f676966 3021301f 30070605 2b0e0302 1a04148f e5d31a86 ac8d8e6b
c3cf806a d448182c 7b192e30 25162368 7474703a 2f2f6c6f 676f2e76 65726973
69676e2e 636f6d2f 76736c6f 676f2e67 69663028 0603551d 11042130 1fa41d30
1b311930 17060355 04031310 56657269 5369676e 4d504b49 2d322d36 301d0603
551d0e04 1604140d 445c1653 44c1827e 1d20ab25 f40163d8 be79a530 1f060355
1d230418 30168014 7fd365a7 c2ddecbb f03009f3 4339fa02 af333133 300d0609
2a864886 f70d0101 05050003 82010100 0c8324ef ddc30cd9 589cfe36 b6eb8a80
4bd1a3f7 9df3cc53 ef829ea3 a1e697c1 589d756c e01d1b4c fad1c12d 05c0ea6e
b2227055 d9203340 3307c265 83fa8f43 379bea0e 9a6c70ee f69c803b d937f47a
6decd018 7d494aca 99c71928 a2bed877 24f78526 866d8705 404167d1 273aeddc
481d22cd 0b0b8bbc f4b17bfd b499a8e9 762ae11a 2d876e74 d388dd1e 22c6df16
b62b8214 0a945cf2 50ecafce ff62370d ad65d306 4153ed02 14c8b558 28a1ace0
5becb37f 954afb03 c8ad26db e6667812 4ad99f42 fbe198e6 42839b8f 8f6724e8
6119b5dd cdb50b26 058ec36e c4c875b8 46cfe218 065ea9ae a8819a47 16de0c28
6c2527b9 deb78458 c61f381e a4c4cb66

quit

telnet timeout 5

ssh stricthostkeycheck

ssh 192.168.29.0 255.255.255.0 management

ssh timeout 5

ssh version 2

```
ssh key-exchange group dh-group1-sha1
console timeout 0
dhcpd dns 8.8.8.8 8.8.4.4
dhcpd option 3 ip 192.168.170.1
!
dhcpd address 192.168.170.220-192.168.170.250 GUEST
dhcpd enable GUEST
!
dynamic-access-policy-record DfltAccessPolicy
username cisco password YBYvHe595lIMVg7Y encrypted
!
class-map inspection_default
 match default-inspection-traffic
!
!
policy-map type inspect dns migrated_dns_map_1
 parameters
  message-length maximum client auto
  message-length maximum 512
policy-map global_policy
 class inspection_default
  inspect dns migrated_dns_map_1
  inspect ftp
  inspect h323 h225
  inspect h323 ras
  inspect ip-options
  inspect netbios
  inspect rsh
  inspect rtsp
  inspect skinny
```

```
  inspect esmtp
  inspect sqlnet
  inspect sunrpc
  inspect tftp
  inspect sip
  inspect xdmcp
  inspect icmp
  inspect icmp error
 class class-default
  set connection decrement-ttl
!
service-policy global_policy global
prompt hostname context
no call-home reporting anonymous
call-home
 profile CiscoTAC-1
  no active
  destination address http https://tools.cisco.com/its/service/oddce/services/DDCEService
  destination address email callhome@cisco.com
  destination transport-method http
  subscribe-to-alert-group diagnostic
  subscribe-to-alert-group environment
  subscribe-to-alert-group inventory periodic monthly
  subscribe-to-alert-group configuration periodic monthly
  subscribe-to-alert-group telemetry periodic daily
 profile License
  destination address http https://tools.cisco.com/its/service/oddce/services/DDCEService
  destination transport-method http
Cryptochecksum:9ffa4947d875e0c501e036c54e80ee93
: end
```

A.3 Enterprise Services ASA Configuration File

```
: Saved
:
: Serial Number: 9AEHKLC171M
: Hardware:   ASAv, 2048 MB RAM, CPU Xeon E5 series 2200 MHz
:
ASA Version 9.6(1)
!
hostname enterprise-services-kmcfadde
enable password 8Ry2YjIyt7RRXU24 encrypted
xlate per-session deny tcp any4 any4
xlate per-session deny tcp any4 any6
xlate per-session deny tcp any6 any4
xlate per-session deny tcp any6 any6
xlate per-session deny udp any4 any4 eq domain
xlate per-session deny udp any4 any6 eq domain
xlate per-session deny udp any6 any4 eq domain
xlate per-session deny udp any6 any6 eq domain
!
license smart
 feature tier standard
 throughput level 1G
names
!
interface GigabitEthernet0/0
 nameif WAN
 security-level 50
 ip address 192.168.100.154 255.255.255.0
 ospf authentication-key *****
 ospf authentication message-digest
```

```
!
interface GigabitEthernet0/1
 nameif LAN
 security-level 100
 ip address 192.168.120.1 255.255.255.0
!
interface GigabitEthernet0/2
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/3
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/4
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/5
 shutdown
 no nameif
 no security-level
 no ip address
!
```

```
interface GigabitEthernet0/6
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/7
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/8
 shutdown
 no nameif
 no security-level
 no ip address
!
interface Management0/0
 management-only
 nameif management
 security-level 0
 ip address 192.168.29.154 255.255.255.0
!
ftp mode passive
clock timezone EST -5
clock summer-time EDT recurring
dns domain-lookup WAN
dns server-group DefaultDNS
 name-server 8.8.8.8
```

```
 name-server 8.8.4.4
object network SNMPHOSTS
 subnet 192.168.29.0 255.255.255.0
object-group service DNS
 service-object tcp-udp destination eq domain
object-group service SYMANTEC-DCS
 service-object tcp destination eq 4443
 service-object tcp destination eq https
 service-object tcp destination eq 8443
 service-object tcp destination eq 2222
access-list 101 extended permit icmp any any time-exceeded
access-list 101 extended permit icmp any any unreachable
access-list 101 extended permit icmp any any echo-reply
access-list 101 extended permit icmp any any echo
access-list 101 extended permit udp any any gt 33434
access-list 101 extended permit object-group DNS 192.168.140.0 255.255.255.0 host 192.168.120.162
access-list 101 extended permit object-group DNS 192.168.140.0 255.255.255.0 host 192.168.120.163
access-list 101 extended permit tcp any host 192.168.120.166 eq 8114
access-list 101 extended permit object-group SYMANTEC-DCS any host 192.168.120.167
pager lines 23
mtu management 1500
mtu WAN 1500
mtu LAN 1500
no failover
icmp unreachable rate-limit 1 burst-size 1
no asdm history enable
arp timeout 14400
no arp permit-nonconnected
access-group 101 in interface WAN
router ospf 1
```

```
 network 192.168.100.0 255.255.255.0 area 0
 log-adj-changes
 redistribute connected subnets
 redistribute static subnets
!
timeout xlate 3:00:00
timeout pat-xlate 0:00:30
timeout conn 1:00:00 half-closed 0:10:00 udp 0:02:00 sctp 0:02:00 icmp 0:00:02
timeout sunrpc 0:10:00 h323 0:05:00 h225 1:00:00 mgcp 0:05:00 mgcp-pat 0:05:00
timeout sip 0:30:00 sip_media 0:02:00 sip-invite 0:03:00 sip-disconnect 0:02:00
timeout sip-provisional-media 0:02:00 uauth 0:05:00 absolute
timeout tcp-proxy-reassembly 0:01:00
timeout floating-conn 0:00:00
user-identity default-domain LOCAL
aaa authentication ssh console LOCAL
snmp-server host-group management SNMPHOSTS poll community *****
no snmp-server location
no snmp-server contact
snmp-server community *****
crypto ipsec security-association pmtu-aging infinite
crypto ca trustpoint _SmartCallHome_ServerCA
 no validation-usage
 crl configure
crypto ca trustpool policy
 auto-import
crypto ca certificate chain _SmartCallHome_ServerCA
 certificate ca 6ecc7aa5a7032009b8cebcf4e952d491
    308205ec 308204d4 a0030201 0202106e cc7aa5a7 032009b8 cebcf4e9 52d49130
    0d06092a 864886f7 0d010105 05003081 ca310b30 09060355 04061302 55533117
    30150603 55040a13 0e566572 69536967 6e2c2049 6e632e31 1f301d06 0355040b
```

13165665 72695369 676e2054 72757374 204e6574 776f726b 313a3038 06035504
0b133128 63292032 30303620 56657269 5369676e 2c20496e 632e202d 20466f72
20617574 686f7269 7a656420 75736520 6f6e6c79 31453043 06035504 03133c56
65726953 69676e20 436c6173 73203320 5075626c 69632050 72696d61 72792043
65727469 66696361 74696f6e 20417574 686f7269 7479202d 20473530 1e170d31
30303230 38303030 3030305a 170d3230 30323037 32333539 35395a30 81b5310b
30090603 55040613 02555331 17301506 0355040a 130e5665 72695369 676e2c20
496e632e 311f301d 06035504 0b131656 65726953 69676e20 54727573 74204e65
74776f72 6b313b30 39060355 040b1332 5465726d 73206f66 20757365 20617420
68747470 733a2f2f 7777772e 76657269 7369676e 2e636f6d 2f727061 20286329
3130312f 302d0603 55040313 26566572 69536967 6e20436c 61737320 33205365
63757265 20536572 76657220 4341202d 20473330 82012230 0d06092a 864886f7
0d010101 05000382 010f0030 82010a02 82010100 b187841f c20c45f5 bcab2597
a7ada23e 9cbaf6c1 39b88bca c2ac56c6 e5bb658e 444f4dce 6fed094a d4af4e10
9c688b2e 957b899b 13cae234 34c1f35b f3497b62 83488174 d188786c 0253f9bc
7f432657 5833833b 330a17b0 d04e9124 ad867d64 12dc744a 34a11d0a ea961d0b
15fca34b 3bce6388 d0f82d0c 948610ca b69a3dca eb379c00 48358629 5078e845
63cd1941 4ff595ec 7b98d4c4 71b350be 28b38fa0 b9539cf5 ca2c23a9 fd1406e8
18b49ae8 3c6e81fd e4cd3536 b351d369 ec12ba56 6e6f9b57 c58b14e7 0ec79ced
4a546ac9 4dc5bf11 b1ae1c67 81cb4455 33997f24 9b3f5345 7f861af3 3cfa6d7f
81f5b84a d3f58537 1cb5a6d0 09e4187b 384efa0f 02030100 01a38201 df308201
db303406 082b0601 05050701 01042830 26302406 082b0601 05050730 01861868
7474703a 2f2f6f63 73702e76 65726973 69676e2e 636f6d30 12060355 1d130101
ff040830 060101ff 02010030 70060355 1d200469 30673065 060b6086 480186f8
45010717 03305630 2806082b 06010505 07020116 1c687474 70733a2f 2f777777
2e766572 69736967 6e2e636f 6d2f6370 73302a06 082b0601 05050702 02301e1a
1c687474 70733a2f 2f777777 2e766572 69736967 6e2e636f 6d2f7270 61303406
03551d1f 042d302b 3029a027 a0258623 68747470 3a2f2f63 726c2e76 65726973
69676e2e 636f6d2f 70636133 2d67352e 63726c30 0e060355 1d0f0101 ff040403
02010630 6d06082b 06010505 07010c04 61305fa1 5da05b30 59305730 55160969

```
    6d616765 2f676966 3021301f 30070605 2b0e0302 1a04148f e5d31a86 ac8d8e6b
    c3cf806a d448182c 7b192e30 25162368 7474703a 2f2f6c6f 676f2e76 65726973
    69676e2e 636f6d2f 76736c6f 676f2e67 69663028 0603551d 11042130 1fa41d30
    1b311930 17060355 04031310 56657269 5369676e 4d504b49 2d322d36 301d0603
    551d0e04 1604140d 445c1653 44c1827e 1d20ab25 f40163d8 be79a530 1f060355
    1d230418 30168014 7fd365a7 c2ddecbb f03009f3 4339fa02 af333133 300d0609
    2a864886 f70d0101 05050003 82010100 0c8324ef ddc30cd9 589cfe36 b6eb8a80
    4bd1a3f7 9df3cc53 ef829ea3 a1e697c1 589d756c e01d1b4c fad1c12d 05c0ea6e
    b2227055 d9203340 3307c265 83fa8f43 379bea0e 9a6c70ee f69c803b d937f47a
    6decd018 7d494aca 99c71928 a2bed877 24f78526 866d8705 404167d1 273aeddc
    481d22cd 0b0b8bbc f4b17bfd b499a8e9 762ae11a 2d876e74 d388dd1e 22c6df16
    b62b8214 0a945cf2 50ecafce ff62370d ad65d306 4153ed02 14c8b558 28a1ace0
    5becb37f 954afb03 c8ad26db e6667812 4ad99f42 fbe198e6 42839b8f 8f6724e8
    6119b5dd cdb50b26 058ec36e c4c875b8 46cfe218 065ea9ae a8819a47 16de0c28
    6c2527b9 deb78458 c61f381e a4c4cb66
  quit
telnet timeout 5
ssh stricthostkeycheck
ssh 192.168.29.0 255.255.255.0 management
ssh timeout 5
ssh version 2
ssh key-exchange group dh-group1-sha1
console timeout 0
dynamic-access-policy-record DfltAccessPolicy
username cisco password YBYvHe595lIMVg7Y encrypted
!
class-map inspection_default
 match default-inspection-traffic
!
!
```

```
policy-map type inspect dns migrated_dns_map_1
 parameters
  message-length maximum client auto
  message-length maximum 512
policy-map global_policy
 class inspection_default
  inspect dns migrated_dns_map_1
  inspect ftp
  inspect h323 h225
  inspect h323 ras
  inspect ip-options
  inspect netbios
  inspect rsh
  inspect rtsp
  inspect skinny
  inspect esmtp
  inspect sqlnet
  inspect sunrpc
  inspect tftp
  inspect sip
  inspect xdmcp
  inspect icmp
  inspect icmp error
 class class-default
  set connection decrement-ttl
!
service-policy global_policy global
prompt hostname context
no call-home reporting anonymous
call-home
```

```
 profile License
  destination address http https://tools.cisco.com/its/service/oddce/services/DDCEService
  destination transport-method http
 profile CiscoTAC-1
  no active
  destination address http https://tools.cisco.com/its/service/oddce/services/DDCEService
  destination address email callhome@cisco.com
  destination transport-method http
  subscribe-to-alert-group diagnostic
  subscribe-to-alert-group environment
  subscribe-to-alert-group inventory periodic monthly
  subscribe-to-alert-group configuration periodic monthly
  subscribe-to-alert-group telemetry periodic daily
Cryptochecksum:e57e00145eb4fd26d97b4b0109308140
: end
```

A.4 Biomedical Engineering

```
: Saved
:
: Serial Number: 9A3RHJVFPQS
: Hardware:   ASAv, 2048 MB RAM, CPU Xeon E5 series 2200 MHz
:
ASA Version 9.6(1)
!
hostname biomedical-kmcfadde
enable password 8Ry2YjIyt7RRXU24 encrypted
xlate per-session deny tcp any4 any4
xlate per-session deny tcp any4 any6
xlate per-session deny tcp any6 any4
xlate per-session deny tcp any6 any6
xlate per-session deny udp any4 any4 eq domain
xlate per-session deny udp any4 any6 eq domain
xlate per-session deny udp any6 any4 eq domain
xlate per-session deny udp any6 any6 eq domain
!
license smart
 feature tier standard
 throughput level 1G
names
!
interface GigabitEthernet0/0
 nameif WAN
 security-level 50
 ip address 192.168.100.152 255.255.255.0
 ospf authentication-key *****
 ospf authentication message-digest
```

```
!
interface GigabitEthernet0/1
 nameif LAN
 security-level 100
 ip address 192.168.140.1 255.255.255.0
!
interface GigabitEthernet0/2
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/3
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/4
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/5
 shutdown
 no nameif
 no security-level
 no ip address
!
```

```
interface GigabitEthernet0/6
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/7
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/8
 shutdown
 no nameif
 no security-level
 no ip address
!
interface Management0/0
 management-only
 nameif management
 security-level 0
 ip address 192.168.29.152 255.255.255.0
!
ftp mode passive
clock timezone EST -5
clock summer-time EDT recurring
dns domain-lookup WAN
dns server-group DefaultDNS
 name-server 8.8.8.8
```

```
 name-server 8.8.4.4
object network SNMPHOSTS
 subnet 192.168.29.0 255.255.255.0
object network PUMPS
 subnet 192.168.150.0 255.255.255.0
object-group icmp-type PING-REPLIES
 icmp-object echo-reply
object-group icmp-type TRACEROUTE-REPLIES
 icmp-object time-exceeded
 icmp-object unreachable
 group-object PING-REPLIES
object-group icmp-type PING
 icmp-object echo
object-group service TRACEROUTEUDP
 service-object udp destination gt 33434
object-group service BAXTERPORTS
 service-object tcp-udp destination eq 51244
object-group service SMITHSPORTS
 service-object tcp destination eq 1588
object-group service CAREFUSIONPORTS
 service-object tcp destination eq 3613
object-group service PCAPORTS
 service-object tcp destination eq https
 service-object tcp destination eq 11443
 service-object tcp destination eq 11444
object-group service PLUM360PORTS
 service-object tcp destination eq 8100
 service-object tcp destination eq 9292
object-group service HOSPIRAPUMPSIMPORTS
 service-object tcp destination eq https
```

```
 service-object tcp destination eq 8443
object-group service BBRAUNPORTS
 service-object tcp destination eq www
 service-object tcp destination eq https
 service-object tcp destination eq 8080
 service-object tcp destination eq 1500
 service-object tcp destination eq 4080
access-list 101 extended permit icmp any any object-group TRACEROUTE-REPLIES
access-list 101 extended permit object-group TRACEROUTEUDP any any
access-list 101 extended permit icmp any any object-group PING
access-list 101 extended permit icmp any any object-group PING-REPLIES
access-list 101 extended permit object-group SMITHSPORTS object PUMPS host 192.168.140.150
access-list 101 extended permit object-group CAREFUSIONPORTS object PUMPS host 192.168.140.158
access-list 101 extended permit object-group PCAPORTS object PUMPS host 192.168.140.160
access-list 101 extended permit object-group PLUM360PORTS object PUMPS host 192.168.140.160
access-list 101 extended permit object-group HOSPIRAPUMPSIMPORTS object PUMPS host
192.168.140.160
access-list 101 extended permit object-group BAXTERPORTS object PUMPS host 192.168.140.165
access-list 101 extended permit object-group BBRAUNPORTS object PUMPS host 192.168.140.169
pager lines 23
mtu WAN 1500
mtu LAN 1500
mtu management 1500
no failover
no monitor-interface service-module
icmp unreachable rate-limit 1 burst-size 1
no asdm history enable
arp timeout 14400
no arp permit-nonconnected
access-group 101 in interface WAN
```

```
router ospf 1
 network 192.168.100.0 255.255.255.0 area 0
 log-adj-changes
 redistribute connected subnets
 redistribute static subnets
!
timeout xlate 3:00:00
timeout pat-xlate 0:00:30
timeout conn 1:00:00 half-closed 0:10:00 udp 0:02:00 sctp 0:02:00 icmp 0:00:02
timeout sunrpc 0:10:00 h323 0:05:00 h225 1:00:00 mgcp 0:05:00 mgcp-pat 0:05:00
timeout sip 0:30:00 sip_media 0:02:00 sip-invite 0:03:00 sip-disconnect 0:02:00
timeout sip-provisional-media 0:02:00 uauth 0:05:00 absolute
timeout tcp-proxy-reassembly 0:01:00
timeout floating-conn 0:00:00
user-identity default-domain LOCAL
aaa authentication ssh console LOCAL
snmp-server host-group management SNMPHOSTS poll community *****
no snmp-server location
no snmp-server contact
snmp-server community *****
crypto ipsec security-association pmtu-aging infinite
crypto ca trustpoint _SmartCallHome_ServerCA
 no validation-usage
 crl configure
crypto ca trustpool policy
 auto-import
crypto ca certificate chain _SmartCallHome_ServerCA
 certificate ca 6ecc7aa5a7032009b8cebcf4e952d491
    308205ec 308204d4 a0030201 0202106e cc7aa5a7 032009b8 cebcf4e9 52d49130
    0d06092a 864886f7 0d010105 05003081 ca310b30 09060355 04061302 55533117
```

30150603 55040a13 0e566572 69536967 6e2c2049 6e632e31 1f301d06 0355040b
13165665 72695369 676e2054 72757374 204e6574 776f726b 313a3038 06035504
0b133128 63292032 30303620 56657269 5369676e 2c20496e 632e202d 20466f72
20617574 686f7269 7a656420 75736520 6f6e6c79 31453043 06035504 03133c56
65726953 69676e20 436c6173 73203320 5075626c 69632050 72696d61 72792043
65727469 66696361 74696f6e 20417574 686f7269 7479202d 20473530 1e170d31
30303230 38303030 3030305a 170d3230 30323037 32333539 35395a30 81b5310b
30090603 55040613 02555331 17301506 0355040a 130e5665 72695369 676e2c20
496e632e 311f301d 06035504 0b131656 65726953 69676e20 54727573 74204e65
74776f72 6b313b30 39060355 040b1332 5465726d 73206f66 20757365 20617420
68747470 733a2f2f 7777772e 76657269 7369676e 2e636f6d 2f727061 20286329
3130312f 302d0603 55040313 26566572 69536967 6e20436c 61737320 33205365
63757265 20536572 76657220 4341202d 20473330 82012230 0d06092a 864886f7
0d010101 05000382 010f0030 82010a02 82010100 b187841f c20c45f5 bcab2597
a7ada23e 9cbaf6c1 39b88bca c2ac56c6 e5bb658e 444f4dce 6fed094a d4af4e10
9c688b2e 957b899b 13cae234 34c1f35b f3497b62 83488174 d188786c 0253f9bc
7f432657 5833833b 330a17b0 d04e9124 ad867d64 12dc744a 34a11d0a ea961d0b
15fca34b 3bce6388 d0f82d0c 948610ca b69a3dca eb379c00 48358629 5078e845
63cd1941 4ff595ec 7b98d4c4 71b350be 28b38fa0 b9539cf5 ca2c23a9 fd1406e8
18b49ae8 3c6e81fd e4cd3536 b351d369 ec12ba56 6e6f9b57 c58b14e7 0ec79ced
4a546ac9 4dc5bf11 b1ae1c67 81cb4455 33997f24 9b3f5345 7f861af3 3cfa6d7f
81f5b84a d3f58537 1cb5a6d0 09e4187b 384efa0f 02030100 01a38201 df308201
db303406 082b0601 05050701 01042830 26302406 082b0601 05050730 01861868
7474703a 2f2f6f63 73702e76 65726973 69676e2e 636f6d30 12060355 1d130101
ff040830 060101ff 02010030 70060355 1d200469 30673065 060b6086 480186f8
45010717 03305630 2806082b 06010505 07020116 1c687474 70733a2f 2f777777
2e766572 69736967 6e2e636f 6d2f6370 73302a06 082b0601 05050702 02301e1a
1c687474 70733a2f 2f777777 2e766572 69736967 6e2e636f 6d2f7270 61303406
03551d1f 042d302b 3029a027 a0258623 68747470 3a2f2f63 726c2e76 65726973
69676e2e 636f6d2f 70636133 2d67352e 63726c30 0e060355 1d0f0101 ff040403

02010630 6d06082b 06010505 07010c04 61305fa1 5da05b30 59305730 55160969
6d616765 2f676966 3021301f 30070605 2b0e0302 1a04148f e5d31a86 ac8d8e6b
c3cf806a d448182c 7b192e30 25162368 7474703a 2f2f6c6f 676f2e76 65726973
69676e2e 636f6d2f 76736c6f 676f2e67 69663028 0603551d 11042130 1fa41d30
1b311930 17060355 04031310 56657269 5369676e 4d504b49 2d322d36 301d0603
551d0e04 1604140d 445c1653 44c1827e 1d20ab25 f40163d8 be79a530 1f060355
1d230418 30168014 7fd365a7 c2ddecbb f03009f3 4339fa02 af333133 300d0609
2a864886 f70d0101 05050003 82010100 0c8324ef ddc30cd9 589cfe36 b6eb8a80
4bd1a3f7 9df3cc53 ef829ea3 a1e697c1 589d756c e01d1b4c fad1c12d 05c0ea6e
b2227055 d9203340 3307c265 83fa8f43 379bea0e 9a6c70ee f69c803b d937f47a
6decd018 7d494aca 99c71928 a2bed877 24f78526 866d8705 404167d1 273aeddc
481d22cd 0b0b8bbc f4b17bfd b499a8e9 762ae11a 2d876e74 d388dd1e 22c6df16
b62b8214 0a945cf2 50ecafce ff62370d ad65d306 4153ed02 14c8b558 28a1ace0
5becb37f 954afb03 c8ad26db e6667812 4ad99f42 fbe198e6 42839b8f 8f6724e8
6119b5dd cdb50b26 058ec36e c4c875b8 46cfe218 065ea9ae a8819a47 16de0c28
6c2527b9 deb78458 c61f381e a4c4cb66

quit

telnet timeout 5

ssh stricthostkeycheck

ssh 192.168.29.0 255.255.255.0 management

ssh timeout 5

ssh version 2

ssh key-exchange group dh-group1-sha1

console timeout 0

dhcpd dns 192.168.120.163 192.168.120.162

dhcpd option 3 ip 192.168.140.1

!

dhcpd address 192.168.140.220-192.168.140.250 LAN

dhcpd enable LAN

!

```
dynamic-access-policy-record DfltAccessPolicy
username cisco password YBYvHe595lIMVg7Y encrypted
!
class-map inspection_default
 match default-inspection-traffic
!
!
policy-map type inspect dns migrated_dns_map_1
 parameters
  message-length maximum client auto
  message-length maximum 512
policy-map global_policy
 class inspection_default
  inspect dns migrated_dns_map_1
  inspect ftp
  inspect h323 h225
  inspect h323 ras
  inspect ip-options
  inspect netbios
  inspect rsh
  inspect rtsp
  inspect skinny
  inspect esmtp
  inspect sqlnet
  inspect sunrpc
  inspect tftp
  inspect sip
  inspect xdmcp
  inspect icmp
  inspect icmp error
```

```
 class class-default
  set connection decrement-ttl
!
service-policy global_policy global
prompt hostname context
no call-home reporting anonymous
call-home
 profile CiscoTAC-1
  no active
  destination address http https://tools.cisco.com/its/service/oddce/services/DDCEService
  destination address email callhome@cisco.com
  destination transport-method http
  subscribe-to-alert-group diagnostic
  subscribe-to-alert-group environment
  subscribe-to-alert-group inventory periodic monthly
  subscribe-to-alert-group configuration periodic monthly
  subscribe-to-alert-group telemetry periodic daily
 profile License
  destination address http https://tools.cisco.com/its/service/oddce/services/DDCEService
  destination transport-method http
Cryptochecksum:627e549de0a7dd97cd1379bbf37bc168
: end
```

A.5 Medical Devices Zone ASA Configuration File

```
: Saved

:
: Serial Number: 9AEWS2E5JRA
: Hardware:   ASAv, 2048 MB RAM, CPU Xeon E5 series 2200 MHz
:
ASA Version 9.6(1)
!
hostname medical-devices-kmcfadde
enable password 8Ry2YjIyt7RRXU24 encrypted
xlate per-session deny tcp any4 any4
xlate per-session deny tcp any4 any6
xlate per-session deny tcp any6 any4
xlate per-session deny tcp any6 any6
xlate per-session deny udp any4 any4 eq domain
xlate per-session deny udp any4 any6 eq domain
xlate per-session deny udp any6 any4 eq domain
xlate per-session deny udp any6 any6 eq domain
!
license smart
 feature tier standard
 throughput level 1G
names

!
interface GigabitEthernet0/0
 nameif WAN
 security-level 50
 ip address 192.168.100.149 255.255.255.0
 ospf authentication-key *****
 ospf authentication message-digest
!
interface GigabitEthernet0/1
 nameif LAN
 security-level 100
 ip address 192.168.150.1 255.255.255.0
!
interface GigabitEthernet0/2
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/3
 shutdown
 no nameif
```

```
 no security-level
 no ip address
!
interface GigabitEthernet0/4
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/5
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/6
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/7
 shutdown
 no nameif
 no security-level
 no ip address
!
interface GigabitEthernet0/8
 shutdown
 no nameif
 no security-level
 no ip address
!
interface Management0/0
 management-only
 nameif management
 security-level 0
 ip address 192.168.29.149 255.255.255.0
!
ftp mode passive
clock timezone EST -5
clock summer-time EDT recurring
dns domain-lookup WAN
dns server-group DefaultDNS
 name-server 8.8.8.8
 name-server 8.8.4.4
object network SNMPHOSTS
 subnet 192.168.29.0 255.255.255.0
```

```
object network PUMPSERVERS
 subnet 192.168.140.0 255.255.255.0
object network PUMPS
 subnet 192.168.150.0 255.255.255.0
object-group icmp-type PING-REPLIES
 icmp-object echo-reply
object-group service PCAPORTS
 service-object tcp destination eq https
 service-object tcp destination eq 11444
 service-object tcp destination eq 11443
 service-object tcp destination eq 8443
object-group icmp-type TRACEROUTE-REPLIES
 icmp-object time-exceeded
 icmp-object unreachable
 group-object PING-REPLIES
object-group icmp-type PING
 icmp-object echo
object-group service TRACEROUTEUDP
 service-object udp destination gt 33434
object-group service PLUM360PORTS
 service-object tcp destination eq 8100
 service-object tcp destination eq 9292
object-group service HOSPIRAPUMPSIMPORTS
 service-object tcp destination eq https
 service-object tcp destination eq 8443
object-group service BAXTERPUMPPORTS
 service-object tcp-udp destination eq 51243
object-group service BBRAUNPORTS
 service-object tcp destination eq www
 service-object tcp destination eq https
 service-object tcp destination eq 8080
 service-object tcp destination eq 1500
access-list LAN2WAN extended permit ip object PUMPS object PUMPSERVERS
access-list WAN2LAN extended permit object-group PCAPORTS host 192.168.140.160 o
bject PUMPS
access-list WAN2LAN extended permit icmp any any object-group PING
access-list WAN2LAN extended permit object-group TRACEROUTEUDP any any
access-list WAN2LAN extended permit icmp any any object-group TRACEROUTE-REPLIES
access-list WAN2LAN extended permit icmp any any object-group PING-REPLIES
access-list WAN2LAN extended permit object-group PLUM360PORTS host 192.168.140.1
60 object PUMPS
access-list WAN2LAN extended permit object-group HOSPIRAPUMPSIMPORTS host 192.16
8.140.160 object PUMPS
access-list WAN2LAN extended permit object-group BAXTERPUMPPORTS host 192.168.14
0.165 object PUMPS
access-list WAN2LAN extended permit object-group BBRAUNPORTS host 192.168.140.16
9 object PUMPS
pager lines 23
```

```
mtu WAN 1500
mtu LAN 1500
mtu management 1500
no failover
no monitor-interface service-module
icmp unreachable rate-limit 1 burst-size 1
no asdm history enable
arp timeout 14400
no arp permit-nonconnected
access-group WAN2LAN in interface WAN
access-group LAN2WAN in interface LAN
router ospf 1
 network 192.168.100.0 255.255.255.0 area 0
 log-adj-changes
 redistribute connected subnets
 redistribute static subnets
!
timeout xlate 3:00:00
timeout pat-xlate 0:00:30
timeout conn 1:00:00 half-closed 0:10:00 udp 0:02:00 sctp 0:02:00 icmp 0:00:02
timeout sunrpc 0:10:00 h323 0:05:00 h225 1:00:00 mgcp 0:05:00 mgcp-pat 0:05:00
timeout sip 0:30:00 sip_media 0:02:00 sip-invite 0:03:00 sip-disconnect 0:02:00
timeout sip-provisional-media 0:02:00 uauth 0:05:00 absolute
timeout tcp-proxy-reassembly 0:01:00
timeout floating-conn 0:00:00
user-identity default-domain LOCAL
aaa authentication ssh console LOCAL
snmp-server host-group management SNMPHOSTS poll community *****
no snmp-server location
no snmp-server contact
snmp-server community *****
crypto ipsec security-association pmtu-aging infinite
crypto ca trustpoint _SmartCallHome_ServerCA
 no validation-usage
 crl configure
crypto ca trustpool policy
 auto-import
crypto ca certificate chain _SmartCallHome_ServerCA
 certificate ca 6ecc7aa5a7032009b8cebcf4e952d491
    308205ec 308204d4 a0030201 0202106e cc7aa5a7 032009b8 cebcf4e9 52d49130
    0d06092a 864886f7 0d010105 05003081 ca310b30 09060355 04061302 55533117
    30150603 55040a13 0e566572 69536967 6e2c2049 6e632e31 1f301d06 0355040b
    13165665 72695369 676e2054 72757374 204e6574 776f726b 313a3038 06035504
    0b133128 63292032 30303620 56657269 5369676e 2c20496e 632e202d 20466f72
    20617574 686f7269 7a656420 75736520 6f6e6c79 31453043 06035504 03133c56
    65726953 69676e20 436c6173 73203320 5075626c 69632050 72696d61 72792043
    65727469 66696361 74696f6e 20417574 686f7269 7479202d 20473530 1e170d31
    30303230 38303030 3030305a 170d3230 30323037 32333539 35395a30 81b5310b
```

30090603 55040613 02555331 17301506 0355040a 130e5665 72695369 676e2c20
496e632e 311f301d 06035504 0b131656 65726953 69676e20 54727573 74204e65
74776f72 6b313b30 39060355 040b1332 5465726d 73206f66 20757365 20617420
68747470 733a2f2f 7777772e 76657269 7369676e 2e636f6d 2f727061 20286329
3130312f 302d0603 55040313 26566572 69536967 6e20436c 61737320 33205365
63757265 20536572 76657220 4341202d 20473330 82012230 0d06092a 864886f7
0d010101 05000382 010f0030 82010a02 82010100 b187841f c20c45f5 bcab2597
a7ada23e 9cbaf6c1 39b88bca c2ac56c6 e5bb658e 444f4dce 6fed094a d4af4e10
9c688b2e 957b899b 13cae234 34c1f35b f3497b62 83488174 d188786c 0253f9bc
7f432657 5833833b 330a17b0 d04e9124 ad867d64 12dc744a 34a11d0a ea961d0b
15fca34b 3bce6388 d0f82d0c 948610ca b69a3dca eb379c00 48358629 5078e845
63cd1941 4ff595ec 7b98d4c4 71b350be 28b38fa0 b9539cf5 ca2c23a9 fd1406e8
18b49ae8 3c6e81fd e4cd3536 b351d369 ec12ba56 6e6f9b57 c58b14e7 0ec79ced
4a546ac9 4dc5bf11 b1ae1c67 81cb4455 33997f24 9b3f5345 7f861af3 3cfa6d7f
81f5b84a d3f58537 1cb5a6d0 09e4187b 384efa0f 02030100 01a38201 df308201
db303406 082b0601 05050701 01042830 26302406 082b0601 05050730 01861868
7474703a 2f2f6f63 73702e76 65726973 69676e2e 636f6d30 12060355 1d130101
ff040830 060101ff 02010030 70060355 1d200469 30673065 060b6086 480186f8
45010717 03305630 2806082b 06010505 07020116 1c687474 70733a2f 2f777777
2e766572 69736967 6e2e636f 6d2f6370 73302a06 082b0601 05050702 02301e1a
1c687474 70733a2f 2f777777 2e766572 69736967 6e2e636f 6d2f7270 61303406
03551d1f 042d302b 3029a027 a0258623 68747470 3a2f2f63 726c2e76 65726973
69676e2e 636f6d2f 70636133 2d67352e 63726c30 0e060355 1d0f0101 ff040403
02010630 6d06082b 06010505 07010c04 61305fa1 5da05b30 59305730 55160969
6d616765 2f676966 3021301f 30070605 2b0e0302 1a04148f e5d31a86 ac8d8e6b
c3cf806a d448182c 7b192e30 25162368 7474703a 2f2f6c6f 676f2e76 65726973
69676e2e 636f6d2f 76736c6f 676f2e67 69663028 0603551d 11042130 1fa41d30
1b311930 17060355 04031310 56657269 5369676e 4d504b49 2d322d36 301d0603
551d0e04 1604140d 445c1653 44c1827e 1d20ab25 f40163d8 be79a530 1f060355
1d230418 30168014 7fd365a7 c2ddecbb f03009f3 4339fa02 af333133 300d0609
2a864886 f70d0101 05050003 82010100 0c8324ef ddc30cd9 589cfe36 b6eb8a80
4bd1a3f7 9df3cc53 ef829ea3 a1e697c1 589d756c e01d1b4c fad1c12d 05c0ea6e
b2227055 d9203340 3307c265 83fa8f43 379bea0e 9a6c70ee f69c803b d937f47a
6decd018 7d494aca 99c71928 a2bed877 24f78526 866d8705 404167d1 273aeddc
481d22cd 0b0b8bbc f4b17bfd b499a8e9 762ae11a 2d876e74 d388dd1e 22c6df16
b62b8214 0a945cf2 50ecafce ff62370d ad65d306 4153ed02 14c8b558 28a1ace0
5becb37f 954afb03 c8ad26db e6667812 4ad99f42 fbe198e6 42839b8f 8f6724e8
6119b5dd cdb50b26 058ec36e c4c875b8 46cfe218 065ea9ae a8819a47 16de0c28
6c2527b9 deb78458 c61f381e a4c4cb66
quit
telnet timeout 5
ssh stricthostkeycheck
ssh 192.168.29.0 255.255.255.0 management
ssh timeout 5
ssh version 2
ssh key-exchange group dh-group1-sha1
console timeout 0
dhcpd dns 192.168.150.1

```
dhcpd option 3 ip 192.168.150.1
!
dhcpd address 192.168.150.220-192.168.150.250 LAN
dhcpd enable LAN
!
dynamic-access-policy-record DfltAccessPolicy
username cisco password YBYvHe595lIMVg7Y encrypted
!
class-map inspection_default
 match default-inspection-traffic
!
!
policy-map type inspect dns migrated_dns_map_1
 parameters
  message-length maximum client auto
  message-length maximum 512
policy-map global_policy
 class inspection_default
  inspect dns migrated_dns_map_1
  inspect ftp
  inspect h323 h225
  inspect h323 ras
  inspect ip-options
  inspect netbios
  inspect rsh
  inspect rtsp
  inspect skinny
  inspect esmtp
  inspect sqlnet
  inspect sunrpc
  inspect tftp
  inspect sip
  inspect xdmcp
  inspect icmp
  inspect icmp error
 class class-default
  set connection decrement-ttl
!
service-policy global_policy global
prompt hostname context
no call-home reporting anonymous
call-home
 profile CiscoTAC-1
  no active
  destination address http https://tools.cisco.com/its/service/oddce/services/DD
CEService
  destination address email callhome@cisco.com
  destination transport-method http
```

```
  subscribe-to-alert-group diagnostic
  subscribe-to-alert-group environment
  subscribe-to-alert-group inventory periodic monthly
  subscribe-to-alert-group configuration periodic monthly
  subscribe-to-alert-group telemetry periodic daily
 profile License
  destination address http https://tools.cisco.com/its/service/oddce/services/DD
CEService
  destination transport-method http
Cryptochecksum:b2e10eb9d982ddbe5330e964af80d2d3

: end
```

A.6 Switch Configuration File

```
!
! Last configuration change at 22:21:08 UTC Wed Feb 22 2017 by cisco
! NVRAM config last updated at 23:22:47 UTC Wed Feb 22 2017 by cisco
!
version 15.0
no service pad
service timestamps debug datetime msec
service timestamps log datetime msec
service password-encryption
service compress-config
!
hostname Cisco3650-01
!
boot-start-marker
boot-end-marker
!
!
vrf definition Mgmt-vrf
 !
 address-family ipv4
 exit-address-family
 !
 address-family ipv6
 exit-address-family
!
logging console emergencies
enable secret 5 $1$FraY$.34n8ay7c.I7qwJttjHas0
enable password 7 023624481811003348
!
username admin privilege 15 password 7 04734A125E75606E0B4A
user-name cisco
 creation-time 1469560730
 privilege 15
 password 7 0523471B701862291B56
 type mgmt-user
no aaa new-model
switch 1 provision ws-c3650-48ps
!
ip domain-name nist.gov
ip device tracking
ip dhcp excluded-address 192.168.250.1 192.168.250.9
!
ip dhcp pool WLAN
 network 192.168.250.0 255.255.255.0
 default-router 192.168.250.1
 option 43 hex c0a8.fa02
```

```
!
!
vtp mode transparent
!
crypto pki trustpoint TP-self-signed-2035642131
 enrollment selfsigned
 subject-name cn=IOS-Self-Signed-Certificate-2035642131
 revocation-check none
 rsakeypair TP-self-signed-2035642131
!
!
crypto pki certificate chain TP-self-signed-2035642131
 certificate self-signed 01
  3082024D 308201B6 A0030201 02020101 300D0609 2A864886 F70D0101 04050030
  31312F30 2D060355 04031326 494F532D 53656C66 2D536967 6E65642D 43657274
  69666963 6174652D 32303335 36343231 3331301E 170D3136 30373236 32303436
  32355A17 0D323030 31303130 30303030 305A3031 312F302D 06035504 03132649
  4F532D53 656C662D 5369676E 65642D43 65727469 66696361 74652D32 30333536
  34323133 3130819F 300D0609 2A864886 F70D0101 01050003 818D0030 81890281
  8100F1C4 010AE138 9BD9BBCC 2E563180 698979B5 51F7B46B D122595E E7033DCA
  D80C9432 0728E47F 8CAC2629 40CEC617 5CDFFBD9 19744025 CB62CA75 8F6F0A9A
  34F790DD 07DA9D60 737196C1 FDD9E764 6D22EDA3 8D9E7DF5 6CD934E3 D89FA9D5
  C165F3EE E9E0EA9F 37742B00 2C4CFA0B C262E61B 95565B42 302B23E7 A1C85D9F
  5FDB0203 010001A3 75307330 0F060355 1D130101 FF040530 030101FF 30200603
  551D1104 19301782 15436973 636F3336 35302D30 312E6E69 73742E67 6F76301F
  0603551D 23041830 1680148F 3A1CDEB7 502DACB7 DF4E96E4 EA1470F1 CFD1F730
  1D060355 1D0E0416 04148F3A 1CDEB750 2DACB7DF 4E96E4EA 1470F1CF D1F7300D
  06092A86 4886F70D 01010405 00038181 004FE025 9B72B4D2 5391B847 F443B481
  4493F8BD 69D2FF3A 3C2E6D96 D7D83B92 91DBB84D DD47E242 9B2F45AC CA7C7CBC
  D7CB9660 2B07AE9B 0376D5A1 15CBA04B B326AADE AB213EB1 D625FBFF B2F54CCD
  40B1EB91 C6DD5E33 DEA8EEB3 20ECDE96 F42527D6 AD1F6A5D A261D394 FE358B8F
  317FAFD0 E853785D 777E1E1D 6F561A2A 07
      quit
!
!
!
!
!
diagnostic bootup level minimal
spanning-tree mode pvst
spanning-tree extend system-id
!
redundancy
 mode sso
!
!
vlan 20
!
```

```
vlan 1400
 name IP_DEV_BIOMEDICAL
!
vlan 1500
 name IP_DEV
!
vlan 1520
 name WIFI_MGMT
!
ip ssh version 2
!
class-map match-any non-client-nrt-class
  match non-client-nrt
!
policy-map port_child_policy
 class non-client-nrt-class
    bandwidth remaining ratio 10
!
!
!
!
!
!
interface GigabitEthernet0/0
 vrf forwarding Mgmt-vrf
 ip address 192.168.20.13 255.255.255.0
 negotiation auto
!
interface GigabitEthernet1/0/1
 switchport access vlan 1520
 switchport mode access
 spanning-tree portfast
!
interface GigabitEthernet1/0/2
 switchport access vlan 1520
 switchport mode access
 spanning-tree portfast
!
interface GigabitEthernet1/0/3
 switchport access vlan 1520
 switchport mode access
 spanning-tree portfast
!
interface GigabitEthernet1/0/4
 switchport access vlan 1520
 switchport mode access
 spanning-tree portfast
!
```

```
interface GigabitEthernet1/0/5
 spanning-tree portfast
!
interface GigabitEthernet1/0/6
 spanning-tree portfast
!
interface GigabitEthernet1/0/7
 spanning-tree portfast
!
interface GigabitEthernet1/0/8
 spanning-tree portfast
!
interface GigabitEthernet1/0/9
 spanning-tree portfast
!
interface GigabitEthernet1/0/10
 spanning-tree portfast
!
interface GigabitEthernet1/0/11
 spanning-tree portfast
!
interface GigabitEthernet1/0/12
 spanning-tree portfast
!
interface GigabitEthernet1/0/13
 spanning-tree portfast
!
interface GigabitEthernet1/0/14
 spanning-tree portfast
!
interface GigabitEthernet1/0/15
 spanning-tree portfast
!
interface GigabitEthernet1/0/16
 spanning-tree portfast
!
interface GigabitEthernet1/0/17
 spanning-tree portfast
!
interface GigabitEthernet1/0/18
 spanning-tree portfast
!
interface GigabitEthernet1/0/19
 spanning-tree portfast
!
interface GigabitEthernet1/0/20
 spanning-tree portfast
!
```

```
interface GigabitEthernet1/0/21
 spanning-tree portfast
!
interface GigabitEthernet1/0/22
 spanning-tree portfast
!
interface GigabitEthernet1/0/23
 spanning-tree portfast
!
interface GigabitEthernet1/0/24
 spanning-tree portfast
!
interface GigabitEthernet1/0/25
 spanning-tree portfast
!
interface GigabitEthernet1/0/26
 spanning-tree portfast
!
interface GigabitEthernet1/0/27
 spanning-tree portfast
!
interface GigabitEthernet1/0/28
 spanning-tree portfast
!
interface GigabitEthernet1/0/29
 spanning-tree portfast
!
interface GigabitEthernet1/0/30
 spanning-tree portfast
!
interface GigabitEthernet1/0/31
 spanning-tree portfast
!
interface GigabitEthernet1/0/32
 spanning-tree portfast
!
interface GigabitEthernet1/0/33
 spanning-tree portfast
!
interface GigabitEthernet1/0/34
 spanning-tree portfast
!
interface GigabitEthernet1/0/35
 spanning-tree portfast
!
interface GigabitEthernet1/0/36
 spanning-tree portfast
!
```

```
interface GigabitEthernet1/0/37
 spanning-tree portfast
!
interface GigabitEthernet1/0/38
 spanning-tree portfast
!
interface GigabitEthernet1/0/39
 spanning-tree portfast
!
interface GigabitEthernet1/0/40
 spanning-tree portfast
!
interface GigabitEthernet1/0/41
 switchport access vlan 1400
 spanning-tree portfast
!
interface GigabitEthernet1/0/42
 switchport access vlan 1400
 spanning-tree portfast
!
interface GigabitEthernet1/0/43
 switchport access vlan 1400
 spanning-tree portfast
!
interface GigabitEthernet1/0/44
 switchport access vlan 1400
 spanning-tree portfast
!
interface GigabitEthernet1/0/45
 description Set to 10/Half for Hospira
 switchport access vlan 1500
 speed 10
 duplex half
 spanning-tree portfast
!
interface GigabitEthernet1/0/46
 switchport access vlan 1500
 spanning-tree portfast
!
interface GigabitEthernet1/0/47
 description VLAN trunk
 switchport trunk allowed vlan 1400,1500,1520
 switchport mode trunk
 spanning-tree portfast
!
interface GigabitEthernet1/0/48
 description management connection on VL20
 switchport access vlan 20
```

```
 spanning-tree portfast
!
interface GigabitEthernet1/1/1
!
interface GigabitEthernet1/1/2
!
interface GigabitEthernet1/1/3
!
interface GigabitEthernet1/1/4
!
interface Vlan1
 no ip address
 shutdown
!
interface Vlan20
 ip address 192.168.20.13 255.255.255.0
!
interface Vlan1520
 description Wireless-MGMT
 ip address 192.168.250.1 255.255.255.0
!
no ip http server
no ip http secure-server
ip route 0.0.0.0 0.0.0.0 192.168.20.254
!
ip access-list extended SSH-Access
 permit tcp 192.168.20.0 0.0.0.255 any eq 22
 deny   ip any any log
!
access-list 10 permit 192.168.20.0 0.0.0.255
!
snmp-server community public RO 10
snmp-server location NCCoE
snmp-server contact nccoe_healthcare_dev@nist.gov
!
!
line con 0
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 access-class SSH-Access in
 exec-timeout 300 0
 password 7 022E454F5A5223014E1D
 login local
 transport input ssh
line vty 5 15
```

```
 access-class SSH-Access in
 exec-timeout 300 0
 password 7 022E454F5A5223014E1D
 login local
 transport input ssh
!
ntp server 10.97.74.8
wsma agent exec
 profile httplistener
 profile httpslistener
wsma agent config
 profile httplistener
 profile httpslistener
wsma agent filesys
 profile httplistener
 profile httpslistener
wsma agent notify
 profile httplistener
 profile httpslistener
!
wsma profile listener httplistener
 transport http
!
wsma profile listener httpslistener
 transport https
ap group default-group
end
```

A.7 Wireless Configuration

System Inventory

NAME: "Chassis" , DESCR: "Cisco Wireless Controller"

PID: AIR-CTVM-K9, VID: V01, SN: 96NTPERK0A6

Burned-in MAC Address..... 00:50:56:AC:6D:08

Maximum number of APs supported..... 200

System Information

Manufacturer's Name..... Cisco Systems Inc.

Product Name..... Cisco Controller

Product Version..... 8.2.111.0

RTOS Version..... 8.2.111.0

Bootloader Version..... 8.2.111.0

Emergency Image Version..... 8.2.111.0

Build Type..... DATA + WPS

System Name..... wlc

System Location.....

System Contact.....

System ObjectID..... 1.3.6.1.4.1.9.1.1631

IP Address..... 192.168.250.2

IPv6 Address..... ::

System Up Time..... 6 days 3 hrs 48 mins 20 secs

System Timezone Location.....

System Stats Realtime Interval..... 5

System Stats Normal Interval..... 180

Configured Country..... US - United States

State of 802.11b Network..... Enabled

State of 802.11a Network..... Enabled

Number of WLANs..... 2

Number of Active Clients..... 2

Burned-in MAC Address..... 00:50:56:AC:6D:08

Maximum number of APs supported..... 200

System Nas-Id.....

WLC MIC Certificate Types..... SHA1

Licensing Type..... RTU

vWLC config..... Small

Backup Controller Configuration

AP primary Backup Controller .....

AP secondary Backup Controller .....

System Time Information:

Time..... Thu Aug 18 20:05:16 2016

Timezone delta..... 0:0

Timezone location.....

NTP Servers

NTP Polling Interval..... 3600

Index	NTP Key Index	NTP Server	Status	NTP Msg Auth Status
1	0	192.168.250.1	Not Synched	AUTH DISABLED

Redundancy Information

Redundancy Mode ..... SSO DISABLED

Local State..... ACTIVE

Peer State..... N/A

Unit..... Primary

Unit ID..... 00:50:56:AC:6D:08

Redunadancy State..... N/A

Mobility MAC..... 00:50:56:AC:6D:08

Redundancy Management IP Address..... 0.0.0.0

Peer Redundancy Management IP Address..... 0.0.0.0

Redundancy Port IP Address..... 0.0.0.0

Peer Redundancy Port IP Address..... 169.254.0.0

AP Bundle Information

Primary AP Image	Size
ap1g1	12660
ap1g2	11748
ap1g3	13672
ap1g4	19256
ap3g1	9736
ap3g2	13480
ap3g3	18696
ap801	8064
ap802	9536

c1140 8636

c1520 7344

c1550 10628

c1570 11536

c602i 3864

version.info 4

Secondary AP Image Size

---------- ----

ap1g1 12660

ap1g2 11748

ap1g3 13672

ap1g4 19256

ap3g1 9736

ap3g2 13480

ap3g3 18696

ap801 8064

ap802 9536

c1140 8636

c1520 7344

c1550 10628

c1570 11536

c602i 3864

version.info 4

Switch Configuration

802.3x Flow Control Mode..... Disable

FIPS prerequisite features..... Disabled

WLANCC prerequisite features..... Disabled

UCAPL prerequisite features..... Disabled

secret obfuscation..... Enabled

Strong Password Check Features

case-check..... Enabled

consecutive-check..... Enabled

default-check..... Enabled

username-check..... Enabled

position-check..... Disabled

case-digit-check..... Disabled

Min. Password length..... 3

Min. Upper case chars..... 0

Min. Lower case chars..... 0

Min. Digits chars..... 0

Min. Special chars..... 0

Mgmt User

Password Lifetime [days]..... 0

Password Lockout..... Disabled

Lockout Attempts..... 3

Lockout Timeout [mins]..... 5

SNMPv3 User

Password Lifetime [days]..... 0

Password Lockout..... Disabled

Lockout Attempts..... 3

Lockout Timeout [mins]..... 5

Network Information

RF-Network Name..... WLAN

DNS Server IP.....

Web Mode..... Disable

Secure Web Mode..... Enable

Secure Web Mode Cipher-Option High..... Disable

Secure Web Mode Cipher-Option SSLv2..... Disable

Secure Web Mode RC4 Cipher Preference..... Disable

Secure Web Mode SSL Protocol..... Disable

OCSP..... Disabled

OCSP responder URL.....

Secure Shell (ssh)..... Enable

Secure Shell (ssh) Cipher-Option High..... Disable

Telnet..... Disable

Ethernet Multicast Forwarding..... Disable

Ethernet Broadcast Forwarding..... Disable

IPv4 AP Multicast/Broadcast Mode..... Unicast

IPv6 AP Multicast/Broadcast Mode..... Unicast

IGMP snooping..... Disabled

IGMP timeout..... 60 seconds

IGMP Query Interval..... 20 seconds

MLD snooping..... Disabled

MLD timeout..... 60 seconds

MLD query interval..... 20 seconds

User Idle Timeout..... 300 seconds

ARP Idle Timeout..... 300 seconds

Cisco AP Default Master..... Disable

AP Join Priority..... Disable

Mgmt Via Wireless Interface..... Disable

Mgmt Via Dynamic Interface..... Disable

Bridge MAC filter Config..... Enable

Bridge Security Mode..... EAP

Mesh Full Sector DFS..... Enable

Mesh Backhaul RRM..... Disable

AP Fallback ..... Enable

Web Auth CMCC Support ..... Disabled

Web Auth Redirect Ports 80

Web Auth Proxy Redirect ..... Disable

Web Auth Captive-Bypass ..... Disable

Web Auth Secure Web ..... Enable

Web Auth Secure Redirection ..... Disable

Fast SSID Change ..... Disabled

AP Discovery - NAT IP Only ..... Enabled

IP/MAC Addr Binding Check ..... Enabled

Link Local Bridging Status ..... Disabled

CCX-lite status ..... Disable

oeap-600 dual-rlan-ports ..... Disable

oeap-600 local-network ..... Enable

oeap-600 Split Tunneling (Printers)..... Disable

WebPortal Online Client 0

WebPortal NTF_LOGOUT Client 0

mDNS snooping..... Disabled

mDNS Query Interval..... 15 minutes

Web Color Theme..... Default

Capwap Prefer Mode..... IPv4

Network Profile..... Disabled

Client ip conflict detection (DHCP) ..... Disabled

Mesh BH RRM ..... Disable

Mesh Aggressive DCA..... Disable

Mesh Auto RF..... Disable

HTTP Profiling Port..... 80

Port Summary

Pr	Type	STP Stat	Admin Mode	Physical Mode	Physical Status	Link Status	Link Trap	POE
--	-------	----	-------	----------	----------	------	-------	---------

1 Normal Forw Enable Auto 1000 Full Up Enable N/A

AP Summary

Number of APs..... 2

Global AP User Name..... Not Configured

Global AP Dot1x User Name..... Not Configured

AP Name Slots AP Model Ethernet MAC Location Country IP Address Clients DSE Location

---------- ----- ---------- ---------- ---------- ---------- ---------- -------- ----------

AP78da.6ee0.08ec 2 AIR-CAP1602I-A-K9 78:da:6e:e0:08:ec default location US 192.168.250.10 0 [0 ,0 ,0]

AP24e9.b34b.f1ed 2 AIR-CAP1602I-A-K9 24:e9:b3:4b:f1:ed default location US 192.168.250.11 1 [0 ,0 ,0]

AP Tcp-Mss-Adjust Info

AP Name TCP State MSS Size

---------- -------- -------

AP78da.6ee0.08ec disabled -

AP24e9.b34b.f1ed disabled -

AP Location

Total Number of AP Groups..... 1

Site Name..... default-group

Site Description..... <none>

NAS-identifier..... none

Client Traffic QinQ Enable..... FALSE

DHCPv4 QinQ Enable..... FALSE

AP Operating Class..... Not-configured

Capwap Prefer Mode..... Not-configured

RF Profile

2.4 GHz band..... <none>

5 GHz band..... <none>

WLAN ID	Interface	Network Admission Control	Radio Policy
1	ip_dev	Disabled	None
2	ip_dev	Disabled	None

*AP3600 with 802.11ac Module will only advertise first 8 WLANs on 5GHz radios.

Lan Port configs

LAN	Status	POE	RLAN
1	Disabled	Disabled	None
2	Disabled		None
3	Disabled		None

External 3G/4G module configs

LAN	Status	POE	RLAN
1	Disabled		None

AP Name	Slots	AP Model	Ethernet MAC	Location	Port	Country	Priority

```
------------------ ----- ------------------ ----------------- ---------------- ---- ------- --------
AP78da.6ee0.08ec    2    AIR-CAP1602I-A-K9   78:da:6e:e0:08:ec  default location  1    US      1
AP24e9.b34b.f1ed    2    AIR-CAP1602I-A-K9   24:e9:b3:4b:f1:ed  default location  1    US      1
```

RF Profile

Number of RF Profiles..... 6

Out Of Box State..... Disabled

Out Of Box Persistence..... Disabled

RF Profile Name	Band	Description	11n-client-only	Applied
High-Client-Density-802.11a	5 GHz	<none>	disable	No
High-Client-Density-802.11bg	2.4 GHz	<none>	disable	No
Low-Client-Density-802.11a	5 GHz	<none>	disable	No
Low-Client-Density-802.11bg	2.4 GHz	<none>	disable	No
Typical-Client-Density-802.11a	5 GHz	<none>	disable	No
Typical-Client-Density-802.11bg	2.4 GHz	<none>	disable	No

RF Profile name..... High-Client-Density-802.11a

Description..... <none>

AP Group Name..... <none>

Radio policy..... 5 GHz

11n-client-only..... disabled

Transmit Power Threshold v1..... -65 dBm

Transmit Power Threshold v2..... -67 dBm

Min Transmit Power..... 7 dBm

Max Transmit Power..... 30 dBm

802.11a Operational Rates

802.11a 6M Rate..... Disabled

802.11a 9M Rate..... Disabled

802.11a 12M Rate..... Mandatory

802.11a 18M Rate..... Supported

802.11a 24M Rate..... Mandatory

802.11a 36M Rate..... Supported

802.11a 48M Rate..... Supported

802.11a 54M Rate..... Supported

Max Clients..... 200

WLAN ID	Max Clients
1	600
2	600

Trap Threshold

Clients..... 12 clients

Interference..... 10 %

Noise..... -70 dBm

Utilization..... 80 %

Multicast Data Rate..... 0

Rx Sop Threshold..... -78 dBm

Cca Threshold..... 0 dBm

Slot Admin State:..... Enabled

Band Select

Probe Response..... Disabled

Cycle Count..... 2 cycles

Cycle Threshold..... 200 milliseconds

Expire Suppression..... 20 seconds

Expire Dual Band..... 60 seconds

Client Rssi..... -80 dBm

Client Mid Rssi..... -80 dBm

Load Balancing

Denial..... 3 count

Window..... 5 clients

Coverage Data

Data..... -80 dBm

Voice..... -80 dBm

Minimum Client Level..... 3 clients

Exception Level..... 25 %

DCA Channel List..... 36,40,44,48,52,56,60,64,100,
104,108,112,116,120,124,128,
132,136,140,144,149,153,157,
161

DCA Bandwidth..... 20

DCA Foreign AP Contribution..... enabled

802.11n MCS Rates

MCS-00 Rate..... enabled

MCS-01 Rate..... enabled

MCS-02 Rate..... enabled

MCS-03 Rate..... enabled

MCS-04 Rate..... enabled

MCS-05 Rate..... enabled

MCS-06 Rate..... enabled

MCS-07 Rate..... enabled

MCS-08 Rate..... enabled

MCS-09 Rate..... enabled

MCS-10 Rate..... enabled

MCS-11 Rate..... enabled

MCS-12 Rate..... enabled

MCS-13 Rate..... enabled

MCS-14 Rate..... enabled

MCS-15 Rate..... enabled

MCS-16 Rate..... enabled

MCS-17 Rate..... enabled

MCS-18 Rate..... enabled

MCS-19 Rate..... enabled

MCS-20 Rate..... enabled

MCS-21 Rate..... enabled

MCS-22 Rate..... enabled

MCS-23 Rate..... enabled

MCS-24 Rate..... enabled

MCS-25 Rate..... enabled

MCS-26 Rate..... enabled

MCS-27 Rate..... enabled

MCS-28 Rate..... enabled

MCS-29 Rate..... enabled

MCS-30 Rate..... enabled

MCS-31 Rate..... enabled

Client Network Preference..... default

RF Profile name..... High-Client-Density-802.11bg

Description..... <none>

AP Group Name..... <none>

Radio policy..... 2.4 GHz

11n-client-only..... disabled

Transmit Power Threshold v1..... -70 dBm

Transmit Power Threshold v2..... -67 dBm

Min Transmit Power..... 7 dBm

Max Transmit Power..... 30 dBm

802.11b/g Operational Rates

802.11b/g 1M Rate..... Disabled

802.11b/g 2M Rate..... Disabled

802.11b/g 5.5M Rate..... Disabled

802.11b/g 11M Rate..... Disabled

802.11g 6M Rate..... Disabled

802.11g 9M Rate..... Supported

802.11g 12M Rate..... Mandatory

802.11g 18M Rate..... Supported

802.11g 24M Rate..... Supported

802.11g 36M Rate..... Supported

802.11g 48M Rate..... Supported

802.11g 54M Rate..... Supported

Max Clients..... 200

WLAN ID	Max Clients
1	600
2	600

Trap Threshold

Clients..... 12 clients

Interference..... 10 %

Noise..... -70 dBm

Utilization..... 80 %

Multicast Data Rate..... 0

Rx Sop Threshold..... -82 dBm

Cca Threshold..... 0 dBm

Slot Admin State:..... Enabled

Band Select

Probe Response..... Disabled

Cycle Count..... 2 cycles

Cycle Threshold..... 200 milliseconds

Expire Suppression..... 20 seconds

Expire Dual Band..... 60 seconds

Client Rssi..... -80 dBm

Client Mid Rssi..... -80 dBm

Load Balancing

Denial..... 3 count

Window..... 5 clients

Coverage Data

Data..... -80 dBm

Voice..... -80 dBm

Minimum Client Level..... 3 clients

Exception Level..... 25 %

DCA Channel List..... 1,6,11

DCA Bandwidth..... 20

DCA Foreign AP Contribution..... enabled

802.11n MCS Rates

MCS-00 Rate..... enabled

MCS-01 Rate..... enabled

MCS-02 Rate..... enabled

MCS-03 Rate..... enabled

MCS-04 Rate..... enabled

MCS-05 Rate..... enabled

MCS-06 Rate..... enabled

MCS-07 Rate..... enabled

MCS-08 Rate..... enabled

MCS-09 Rate..... enabled

MCS-10 Rate..... enabled

MCS-11 Rate..... enabled

MCS-12 Rate..... enabled

MCS-13 Rate..... enabled

MCS-14 Rate..... enabled

MCS-15 Rate..... enabled

MCS-16 Rate..... enabled

MCS-17 Rate..... enabled

MCS-18 Rate..... enabled

MCS-19 Rate..... enabled

MCS-20 Rate..... enabled

MCS-21 Rate..... enabled

MCS-22 Rate..... enabled

MCS-23 Rate..... enabled

MCS-24 Rate..... enabled

MCS-25 Rate..... enabled

MCS-26 Rate..... enabled

MCS-27 Rate..... enabled

MCS-28 Rate..... enabled

MCS-29 Rate..... enabled

MCS-30 Rate..... enabled

MCS-31 Rate..... enabled

Client Network Preference..... default

RF Profile name..... Low-Client-Density-802.11a

Description..... <none>

AP Group Name..... <none>

Radio policy..... 5 GHz

11n-client-only..... disabled

Transmit Power Threshold v1..... -60 dBm

Transmit Power Threshold v2..... -67 dBm

Min Transmit Power..... -10 dBm

Max Transmit Power..... 30 dBm

802.11a Operational Rates

802.11a 6M Rate..... Mandatory

802.11a 9M Rate..... Supported

802.11a 12M Rate..... Mandatory

802.11a 18M Rate..... Supported

802.11a 24M Rate..... Mandatory

802.11a 36M Rate..... Supported

802.11a 48M Rate..... Supported

802.11a 54M Rate..... Supported

Max Clients..... 200

WLAN ID	Max Clients
1	600
2	600

Trap Threshold

Clients..... 12 clients

Interference..... 10 %

Noise..... -70 dBm

Utilization..... 80 %

Multicast Data Rate..... 0

Rx Sop Threshold..... -80 dBm

Cca Threshold..... 0 dBm

Slot Admin State:..... Enabled

Band Select

Probe Response..... Disabled

Cycle Count..... 2 cycles

Cycle Threshold..... 200 milliseconds

Expire Suppression..... 20 seconds

Expire Dual Band..... 60 seconds

Client Rssi..... -80 dBm

Client Mid Rssi..... -80 dBm

Load Balancing

Denial..... 3 count

Window..... 5 clients

Coverage Data

Data..... -90 dBm

Voice..... -90 dBm

Minimum Client Level..... 2 clients

Exception Level..... 25 %

DCA Channel List..... 36,40,44,48,52,56,60,64,100,
104,108,112,116,120,124,128,
132,136,140,144,149,153,157,
161

DCA Bandwidth..... 20

DCA Foreign AP Contribution..... enabled

802.11n MCS Rates

MCS-00 Rate..... enabled

MCS-01 Rate..... enabled

MCS-02 Rate..... enabled

MCS-03 Rate..... enabled

MCS-04 Rate..... enabled

MCS-05 Rate..... enabled

MCS-06 Rate..... enabled

MCS-07 Rate..... enabled

MCS-08 Rate..... enabled

MCS-09 Rate..... enabled

MCS-10 Rate..... enabled

MCS-11 Rate..... enabled

MCS-12 Rate..... enabled

MCS-13 Rate..... enabled

MCS-14 Rate..... enabled

MCS-15 Rate..... enabled

MCS-16 Rate..... enabled

MCS-17 Rate..... enabled

MCS-18 Rate..... enabled

MCS-19 Rate..... enabled

MCS-20 Rate..... enabled

MCS-21 Rate..... enabled

MCS-22 Rate..... enabled

MCS-23 Rate..... enabled

MCS-24 Rate..... enabled

MCS-25 Rate..... enabled

MCS-26 Rate..... enabled

MCS-27 Rate..... enabled

MCS-28 Rate..... enabled

MCS-29 Rate..... enabled

MCS-30 Rate..... enabled

MCS-31 Rate..... enabled

Client Network Preference..... default

RF Profile name..... Low-Client-Density-802.11bg

Description..... <none>

AP Group Name..... <none>

Radio policy..... 2.4 GHz

11n-client-only..... disabled

Transmit Power Threshold v1..... -65 dBm

Transmit Power Threshold v2..... -67 dBm

Min Transmit Power..... -10 dBm

Max Transmit Power..... 30 dBm

802.11b/g Operational Rates

802.11b/g 1M Rate..... Mandatory

802.11b/g 2M Rate..... Mandatory

802.11b/g 5.5M Rate..... Mandatory

802.11b/g 11M Rate..... Mandatory

802.11g 6M Rate..... Supported

802.11g 9M Rate..... Supported

802.11g 12M Rate..... Supported

802.11g 18M Rate..... Supported

802.11g 24M Rate..... Supported

802.11g 36M Rate..... Supported

802.11g 48M Rate..... Supported

802.11g 54M Rate..... Supported

Max Clients..... 200

WLAN ID	Max Clients
1	600
2	600

Trap Threshold

Clients..... 12 clients

Interference..... 10 %

Noise..... -70 dBm

Utilization..... 80 %

Multicast Data Rate..... 0

Rx Sop Threshold..... -85 dBm

Cca Threshold..... 0 dBm

Slot Admin State:..... Enabled

Band Select

Probe Response..... Disabled

Cycle Count..... 2 cycles

Cycle Threshold..... 200 milliseconds

Expire Suppression..... 20 seconds

Expire Dual Band..... 60 seconds

Client Rssi..... -80 dBm

Client Mid Rssi..... -80 dBm

Load Balancing

Denial..... 3 count

Window..... 5 clients

Coverage Data

Data..... -90 dBm

Voice..... -90 dBm

Minimum Client Level..... 2 clients

Exception Level..... 25 %

DCA Channel List..... 1,6,11

DCA Bandwidth..... 20

DCA Foreign AP Contribution..... enabled

802.11n MCS Rates

MCS-00 Rate..... enabled

MCS-01 Rate..... enabled

MCS-02 Rate..... enabled

MCS-03 Rate..... enabled

MCS-04 Rate..... enabled

MCS-05 Rate..... enabled

MCS-06 Rate..... enabled

MCS-07 Rate..... enabled

MCS-08 Rate..... enabled

MCS-09 Rate..... enabled

MCS-10 Rate..... enabled

MCS-11 Rate..... enabled

MCS-12 Rate..... enabled

MCS-13 Rate..... enabled

MCS-14 Rate..... enabled

MCS-15 Rate..... enabled

MCS-16 Rate..... enabled

MCS-17 Rate..... enabled

MCS-18 Rate..... enabled

MCS-19 Rate..... enabled

MCS-20 Rate..... enabled

MCS-21 Rate..... enabled

MCS-22 Rate..... enabled

MCS-23 Rate..... enabled

MCS-24 Rate..... enabled

MCS-25 Rate..... enabled

MCS-26 Rate..... enabled

MCS-27 Rate..... enabled

MCS-28 Rate..... enabled

MCS-29 Rate..... enabled

MCS-30 Rate..... enabled

MCS-31 Rate..... enabled

Client Network Preference..... default

RF Profile name..... Typical-Client-Density-802.11a

Description..... <none>

AP Group Name..... <none>

Radio policy..... 5 GHz

11n-client-only..... disabled

Transmit Power Threshold v1..... -70 dBm

Transmit Power Threshold v2..... -67 dBm

Min Transmit Power..... -10 dBm

Max Transmit Power..... 30 dBm

802.11a Operational Rates

802.11a 6M Rate..... Mandatory

802.11a 9M Rate..... Supported

802.11a 12M Rate..... Mandatory

802.11a 18M Rate..... Supported

802.11a 24M Rate..... Mandatory

802.11a 36M Rate..... Supported

802.11a 48M Rate..... Supported

802.11a 54M Rate..... Supported

Max Clients..... 200

WLAN ID	Max Clients
1	600
2	600

Trap Threshold

Clients..... 12 clients

Interference..... 10 %

Noise..... -70 dBm

Utilization..... 80 %

Multicast Data Rate..... 0

Rx Sop Threshold..... AUTO

Cca Threshold..... 0 dBm

Slot Admin State:..... Enabled

Band Select

Probe Response..... Disabled

Cycle Count..... 2 cycles

Cycle Threshold..... 200 milliseconds

Expire Suppression..... 20 seconds

Expire Dual Band..... 60 seconds

Client Rssi..... -80 dBm

Client Mid Rssi..... -80 dBm

Load Balancing

Denial..... 3 count

Window..... 5 clients

Coverage Data

Data..... -80 dBm

Voice..... -80 dBm

Minimum Client Level..... 3 clients

Exception Level..... 25 %

DCA Channel List..... 36,40,44,48,52,56,60,64,100,
104,108,112,116,120,124,128,
132,136,140,144,149,153,157,
161

DCA Bandwidth..... 20

DCA Foreign AP Contribution..... enabled

802.11n MCS Rates

MCS-00 Rate..... enabled

MCS-01 Rate..... enabled

MCS-02 Rate..... enabled

MCS-03 Rate..... enabled

MCS-04 Rate..... enabled

MCS-05 Rate..... enabled

MCS-06 Rate..... enabled

MCS-07 Rate..... enabled

MCS-08 Rate..... enabled

MCS-09 Rate..... enabled

MCS-10 Rate..... enabled

MCS-11 Rate..... enabled

MCS-12 Rate..... enabled

MCS-13 Rate..... enabled

MCS-14 Rate..... enabled

MCS-15 Rate..... enabled

MCS-16 Rate..... enabled

MCS-17 Rate..... enabled

MCS-18 Rate..... enabled

MCS-19 Rate..... enabled

MCS-20 Rate..... enabled

MCS-21 Rate..... enabled

MCS-22 Rate..... enabled

MCS-23 Rate..... enabled

MCS-24 Rate..... enabled

MCS-25 Rate..... enabled

MCS-26 Rate..... enabled

MCS-27 Rate..... enabled

MCS-28 Rate..... enabled

MCS-29 Rate..... enabled

MCS-30 Rate..... enabled

MCS-31 Rate..... enabled

Client Network Preference..... default

RF Profile name..... Typical-Client-Density-802.11bg

Description..... <none>

AP Group Name..... <none>

Radio policy..... 2.4 GHz

11n-client-only..... disabled

Transmit Power Threshold v1..... -70 dBm

Transmit Power Threshold v2..... -67 dBm

Min Transmit Power..... -10 dBm

Max Transmit Power..... 30 dBm

802.11b/g Operational Rates

802.11b/g 1M Rate..... Disabled

802.11b/g 2M Rate..... Disabled

802.11b/g 5.5M Rate..... Disabled

802.11b/g 11M Rate..... Disabled

802.11g 6M Rate..... Disabled

802.11g 9M Rate..... Supported

802.11g 12M Rate..... Mandatory

802.11g 18M Rate..... Supported

802.11g 24M Rate..... Supported

802.11g 36M Rate..... Supported

802.11g 48M Rate..... Supported

802.11g 54M Rate..... Supported

Max Clients..... 200

WLAN ID	Max Clients
1	600
2	600

Trap Threshold

Clients..... 12 clients

Interference..... 10 %

Noise..... -70 dBm

Utilization..... 80 %

Multicast Data Rate..... 0

Rx Sop Threshold..... AUTO

Cca Threshold..... 0 dBm

Slot Admin State:..... Enabled

Band Select

Probe Response..... Disabled

Cycle Count..... 2 cycles

Cycle Threshold..... 200 milliseconds

Expire Suppression..... 20 seconds

Expire Dual Band..... 60 seconds

Client Rssi..... -80 dBm

Client Mid Rssi..... -80 dBm

Load Balancing

Denial..... 3 count

Window..... 5 clients

Coverage Data

Data..... -80 dBm

Voice..... -80 dBm

Minimum Client Level..... 3 clients

Exception Level..... 25 %

DCA Channel List..... 1,6,11

DCA Bandwidth..... 20

DCA Foreign AP Contribution..... enabled

802.11n MCS Rates

MCS-00 Rate..... enabled

MCS-01 Rate..... enabled

MCS-02 Rate..... enabled

MCS-03 Rate..... enabled

MCS-04 Rate..... enabled

MCS-05 Rate..... enabled

MCS-06 Rate..... enabled

MCS-07 Rate..... enabled

MCS-08 Rate..... enabled

MCS-09 Rate..... enabled

MCS-10 Rate..... enabled

MCS-11 Rate..... enabled

MCS-12 Rate..... enabled

MCS-13 Rate..... enabled

MCS-14 Rate..... enabled

MCS-15 Rate..... enabled

MCS-16 Rate..... enabled

MCS-17 Rate..... enabled

MCS-18 Rate..... enabled

MCS-19 Rate..... enabled

MCS-20 Rate..... enabled

MCS-21 Rate..... enabled

MCS-22 Rate..... enabled

MCS-23 Rate..... enabled

MCS-24 Rate..... enabled

MCS-25 Rate..... enabled

MCS-26 Rate..... enabled

MCS-27 Rate..... enabled

MCS-28 Rate..... enabled

MCS-29 Rate..... enabled

MCS-30 Rate..... enabled

MCS-31 Rate..... enabled

Client Network Preference..... default

AP Config

Cisco AP Identifier..... 3

Cisco AP Name..... AP78da.6ee0.08ec

Country code..... US - United States

Regulatory Domain allowed by Country..... 802.11bg:-A 802.11a:-AB

AP Country code..... US - United States

AP Regulatory Domain..... -A

Switch Port Number 1

MAC Address..... 78:da:6e:e0:08:ec

IP Address Configuration..... DHCP

IP Address..... 192.168.250.10

IP NetMask..... 255.255.255.0

Gateway IP Addr..... 192.168.250.1

NAT External IP Address..... None

CAPWAP Path MTU..... 1485

DHCP Release Override..... Disabled

Telnet State..... Globally Disabled

Ssh State..... Globally Disabled

Cisco AP Location..... default location

Cisco AP Floor Label..... 0

Cisco AP Group Name..... default-group

Primary Cisco Switch Name.....

Primary Cisco Switch IP Address..... Not Configured

Secondary Cisco Switch Name.....

Secondary Cisco Switch IP Address..... Not Configured

Tertiary Cisco Switch Name.....

Tertiary Cisco Switch IP Address..... Not Configured

Administrative State ..... ADMIN_ENABLED

Operation State ..... REGISTERED

Mirroring Mode ..... Disabled

AP Mode ..... FlexConnect

Public Safety ..... Disabled

ATF Mode: ..... Disable

AP SubMode ..... Not Configured

Rogue Detection ..... Enabled

AP Vlan Trunking ..... Disabled

Remote AP Debug ..... Disabled

Logging trap severity level ..... informational

Logging syslog facility ..... kern

S/W Version 8.2.111.0

Boot Version 15.2.2.0

Mini IOS Version 7.5.1.73

Stats Reporting Period 180

Stats Collection Mode ..... normal

LED State..... Enabled

PoE Pre-Standard Switch..... Disabled

PoE Power Injector MAC Addr..... Disabled

Power Type/Mode..... PoE/Full Power

Number Of Slots..... 2

AP Model..... AIR-CAP1602I-A-K9

AP Image..... C1600-K9W8-M

IOS Version..... 15.3(3)JC2$

Reset Button..... Enabled

AP Serial Number..... FGL1748W52Y

AP Certificate Type..... Manufacture Installed

AP Lag Status ..... Disable

Native Vlan Inheritance: ..... AP

FlexConnect Vlan mode :..... Disabled

FlexConnect Group..... Not a member of any group

Group VLAN ACL Mappings

Group VLAN Name to Id Mappings

Template in Modified State - apply it to see mappings

AP-Specific FlexConnect Policy ACLs :

L2Acl Configuration ..... Not Available

FlexConnect Local-Split ACLs :

WLAN ID	PROFILE NAME	ACL	TYPE

Flexconnect Central-Dhcp Values :

WLAN ID	PROFILE NAME	Central-Dhcp	DNS Override	Nat-Pat	Type
1	IP_Dev No Encryption	False	False	False	Wlan

Flex AVC visibility Configurations.....

WlanId	PROFILE NAME	Inherit-level Visibility	Flex Avc-profile
1	IP_Dev No Encryption	wlan-spec	disable none

FlexConnect Backup Auth Radius Servers :

Primary Radius Server..... Disabled

Secondary Radius Server..... Disabled

AP User Mode..... AUTOMATIC

AP User Name..... Cisco

AP Dot1x User Mode..... Not Configured

AP Dot1x User Name..... Not Configured

Cisco AP system logging host..... 255.255.255.255

AP Core Dump Config..... Disabled

AP Up Time..... 2 days, 22 h 22 m 20 s

AP LWAPP Up Time..... 2 days, 22 h 18 m 20 s

Join Date and Time..... Mon Aug 15 21:47:06 2016

Join Taken Time..... 0 days, 00 h 03 m 59 s

Attributes for Slot 0

Radio Type..... RADIO_TYPE_80211n-2.4

Administrative State ..... ADMIN_ENABLED

Operation State ..... UP

Mesh Radio Role ..... ACCESS

Radio Role ..... Client Serving (Remote)

CellId 0

Station Configuration

Configuration ..... AUTOMATIC

Number Of WLANs 1

Medium Occupancy Limit 100

CFP Period 4

CFP MaxDuration 60

BSSID 5c:a4:8a:be:ca:90

Operation Rate Set

1000 Kilo Bits..... MANDATORY

2000 Kilo Bits..... MANDATORY

5500 Kilo Bits..... MANDATORY

11000 Kilo Bits..... MANDATORY

6000 Kilo Bits..... SUPPORTED

9000 Kilo Bits..... SUPPORTED

12000 Kilo Bits..... SUPPORTED

18000 Kilo Bits..... SUPPORTED

24000 Kilo Bits..... SUPPORTED

36000 Kilo Bits..... SUPPORTED

48000 Kilo Bits..... SUPPORTED

54000 Kilo Bits..... SUPPORTED

MCS Set

MCS 0..... SUPPORTED

MCS 1..... SUPPORTED

MCS 2..... SUPPORTED

MCS 3..... SUPPORTED

MCS 4..... SUPPORTED

MCS 5..... SUPPORTED

MCS 6..... SUPPORTED

MCS 7..... SUPPORTED

MCS 8..... SUPPORTED

MCS 9..... SUPPORTED

MCS 10..... SUPPORTED

MCS 11..... SUPPORTED

MCS 12..... SUPPORTED

MCS 13..... SUPPORTED

MCS 14..... SUPPORTED

MCS 15..... SUPPORTED

MCS 16..... DISABLED

MCS 17..... DISABLED

MCS 18..... DISABLED

MCS 19..... DISABLED

MCS 20..... DISABLED

MCS 21..... DISABLED

MCS 22..... DISABLED

MCS 23..... DISABLED

MCS 24..... DISABLED

MCS 25..... DISABLED

MCS 26..... DISABLED

MCS 27..... DISABLED

MCS 28..... DISABLED

MCS 29..... DISABLED

MCS 30..... DISABLED

MCS 31..... DISABLED

Beacon Period 100

Fragmentation Threshold 2346

Multi Domain Capability Implemented ..... TRUE

Multi Domain Capability Enabled ..... TRUE

Country String ..... US

Multi Domain Capability

Configuration ..... AUTOMATIC

First Chan Num 1

Number Of Channels 11

MAC Operation Parameters

Configuration ..... AUTOMATIC

Fragmentation Threshold 2346

Packet Retry Limit 64

Tx Power

Num Of Supported Power Levels 6

Tx Power Level 1 ..... 22 dBm

Tx Power Level 2 ..... 19 dBm

Tx Power Level 3 ..... 16 dBm

Tx Power Level 4 ..... 13 dBm

Tx Power Level 5 ..... 10 dBm

Tx Power Level 6 ..... 7 dBm

Tx Power Configuration ..... AUTOMATIC

Current Tx Power Level 1

Tx Power Assigned By ..... DTPC

Phy OFDM parameters

Configuration ..... AUTOMATIC

Current Channel 11

Channel Assigned By ..... DCA

Extension Channel ..... NONE

Channel Width..... 20 Mhz

Allowed Channel List..... 1,2,3,4,5,6,7,8,9,10,11

TI Threshold ..... -50

DCA Channel List..... Global

Legacy Tx Beamforming Configuration ..... CUSTOMIZED

Legacy Tx Beamforming ..... ENABLED

Antenna Type..... INTERNAL_ANTENNA

Internal Antenna Gain (in .5 dBi units).... 8

Diversity..... DIVERSITY_ENABLED

802.11n Antennas

A..... ENABLED

B..... ENABLED

C..... ENABLED

Performance Profile Parameters

Configuration ..... AUTOMATIC

Interference threshold..... 10 %

Noise threshold..... -70 dBm

RF utilization threshold..... 80 %

Data-rate threshold..... 1000000 bps

Client threshold..... 12 clients

Coverage SNR threshold..... 12 dB

Coverage exception level..... 25 %

Client minimum exception level..... 3 clients

Rogue Containment Information

Containment Count..... 0

CleanAir Management Information

CleanAir Capable..... Yes

CleanAir Management Administration St.... Enabled

CleanAir Management Operation State..... Down

Rapid Update Mode..... Off

Spectrum Expert connection..... Enabled

CleanAir NSI Key..... C44B365F4CFF338BE94B85633D98944B

Spectrum Expert Connections counter.... 0

CleanAir Sensor State..... Configured

Radio Extended Configurations

Beacon period..... 100 milliseconds

Beacon range..... AUTO

Multicast buffer..... AUTO

Multicast data-rate..... AUTO

RX SOP threshold..... AUTO

CCA threshold..... AUTO

Attributes for Slot 1

Radio Type..... RADIO_TYPE_80211n-5

Radio Subband..... RADIO_SUBBAND_ALL

Administrative State ..... ADMIN_ENABLED

Operation State ..... UP

Mesh Radio Role ..... ACCESS

Radio Role ..... Client Serving (Remote)

CellId 0

Station Configuration

Configuration ..... AUTOMATIC

Number Of WLANs 1

Medium Occupancy Limit 100

CFP Period 4

CFP MaxDuration 60

BSSID 5c:a4:8a:be:ca:90

Operation Rate Set

6000 Kilo Bits..... MANDATORY

9000 Kilo Bits..... SUPPORTED

12000 Kilo Bits..... MANDATORY

18000 Kilo Bits..... SUPPORTED

24000 Kilo Bits..... MANDATORY

36000 Kilo Bits..... SUPPORTED

48000 Kilo Bits..... SUPPORTED

54000 Kilo Bits..... SUPPORTED

MCS Set

MCS 0..... SUPPORTED

MCS 1..... SUPPORTED

MCS 2..... SUPPORTED

MCS 3..... SUPPORTED

MCS 4..... SUPPORTED

MCS 5..... SUPPORTED

MCS 6..... SUPPORTED

MCS 7..... SUPPORTED

MCS 8..... SUPPORTED

MCS 9..... SUPPORTED

MCS 10..... SUPPORTED

MCS 11..... SUPPORTED

MCS 12..... SUPPORTED

MCS 13..... SUPPORTED

MCS 14..... SUPPORTED

MCS 15..... SUPPORTED

MCS 16..... DISABLED

MCS 17..... DISABLED

MCS 18..... DISABLED

MCS 19..... DISABLED

MCS 20..... DISABLED

MCS 21..... DISABLED

MCS 22..... DISABLED

MCS 23..... DISABLED

MCS 24..... DISABLED

MCS 25..... DISABLED

MCS 26..... DISABLED

MCS 27..... DISABLED

MCS 28..... DISABLED

MCS 29..... DISABLED

MCS 30..... DISABLED

MCS 31..... DISABLED

Beacon Period 100

Fragmentation Threshold 2346

Multi Domain Capability Implemented ..... TRUE

Multi Domain Capability Enabled ..... TRUE

Country String ..... US

Multi Domain Capability

Configuration ..... AUTOMATIC

First Chan Num 36

Number Of Channels 21

MAC Operation Parameters

Configuration ..... AUTOMATIC

Fragmentation Threshold 2346

Packet Retry Limit 64

Tx Power

Num Of Supported Power Levels 6

Tx Power Level 1 ..... 22 dBm

Tx Power Level 2 ..... 19 dBm

Tx Power Level 3 ..... 16 dBm

Tx Power Level 4 ..... 13 dBm

Tx Power Level 5 ..... 10 dBm

Tx Power Level 6 ..... 7 dBm

Tx Power Configuration ..... AUTOMATIC

Current Tx Power Level 1

Tx Power Assigned By ..... DTPC

Phy OFDM parameters

Configuration ..... AUTOMATIC

Current Channel 149

Channel Assigned By ..... DCA

Extension Channel ..... NONE

Channel Width..... 20 Mhz

Allowed Channel List..... 36,40,44,48,52,56,60,64,100,

..... 104,108,112,116,132,136,140,

..... 149,153,157,161,165

TI Threshold ..... -50

DCA Channel List..... Global

Legacy Tx Beamforming Configuration ..... CUSTOMIZED

Legacy Tx Beamforming ..... ENABLED

Antenna Type..... INTERNAL_ANTENNA

Internal Antenna Gain (in .5 dBi units).... 8

Diversity..... DIVERSITY_ENABLED

802.11n Antennas

A..... ENABLED

B..... ENABLED

C..... ENABLED

Performance Profile Parameters

Configuration ..... AUTOMATIC

Interference threshold..... 10 %

Noise threshold..... -70 dBm

RF utilization threshold..... 80 %

Data-rate threshold..... 1000000 bps

Client threshold..... 12 clients

Coverage SNR threshold..... 16 dB

Coverage exception level..... 25 %

Client minimum exception level..... 3 clients

Rogue Containment Information

Containment Count..... 0

CleanAir Management Information

CleanAir Capable..... Yes

CleanAir Management Administration St.... Enabled

CleanAir Management Operation State..... Down

Rapid Update Mode..... Off

Spectrum Expert connection..... Enabled

CleanAir NSI Key..... C44B365F4CFF338BE94B85633D98944B

Spectrum Expert Connections counter.... 0

CleanAir Sensor State..... Configured

Radio Extended Configurations

Beacon period..... 100 milliseconds

Beacon range..... AUTO

Multicast buffer..... AUTO

Multicast data-rate..... AUTO

RX SOP threshold..... AUTO

CCA threshold..... AUTO

Cisco AP Identifier..... 4

Cisco AP Name..... AP24e9.b34b.f1ed

Country code..... US - United States

Regulatory Domain allowed by Country..... 802.11bg:-A 802.11a:-AB

AP Country code..... US - United States

AP Regulatory Domain..... -A

Switch Port Number 1

MAC Address..... 24:e9:b3:4b:f1:ed

IP Address Configuration..... DHCP

IP Address..... 192.168.250.11

IP NetMask..... 255.255.255.0

Gateway IP Addr..... 192.168.250.1

NAT External IP Address..... None

CAPWAP Path MTU..... 1485

DHCP Release Override..... Disabled

Telnet State..... Globally Disabled

Ssh State..... Globally Disabled

Cisco AP Location..... default location

Cisco AP Floor Label..... 0

Cisco AP Group Name..... default-group

Primary Cisco Switch Name.....

Primary Cisco Switch IP Address..... Not Configured

Secondary Cisco Switch Name.....

Secondary Cisco Switch IP Address..... Not Configured

Tertiary Cisco Switch Name.....

Tertiary Cisco Switch IP Address..... Not Configured

Administrative State ..... ADMIN_ENABLED

Operation State ..... REGISTERED

Mirroring Mode ..... Disabled

AP Mode ..... FlexConnect

Public Safety ..... Disabled

ATF Mode: ..... Disable

AP SubMode ..... Not Configured

Rogue Detection ..... Enabled

AP Vlan Trunking ..... Disabled

Remote AP Debug ..... Disabled

Logging trap severity level ..... emergencies

Logging syslog facility ..... system

S/W Version 8.2.111.0

Boot Version 15.2.2.0

Mini IOS Version 7.5.1.73

Stats Reporting Period 180

Stats Collection Mode ..... normal

LED State..... Enabled

PoE Pre-Standard Switch..... Disabled

PoE Power Injector MAC Addr..... Disabled

Power Type/Mode..... PoE/Full Power

Number Of Slots..... 2

AP Model..... AIR-CAP1602I-A-K9

AP Image..... C1600-K9W8-M

IOS Version..... 15.3(3)JC2$

Reset Button..... Enabled

AP Serial Number..... FGL1748W52S

AP Certificate Type..... Manufacture Installed

AP Lag Status ..... Disable

Native Vlan Inheritance: ..... Group

FlexConnect Vlan mode :..... Disabled

FlexConnect Group..... Not a member of any group

Group VLAN ACL Mappings

Group VLAN Name to Id Mappings

Template in Modified State - apply it to see mappings

AP-Specific FlexConnect Policy ACLs :

L2Acl Configuration ..... Not Available

FlexConnect Local-Split ACLs :

WLAN ID	PROFILE NAME	ACL	TYPE

Flexconnect Central-Dhcp Values :

WLAN ID	PROFILE NAME	Central-Dhcp	DNS Override	Nat-Pat	Type
1	IP_Dev No Encryption	False	False	False	Wlan

Flex AVC visibility Configurations.....

WlanId	PROFILE NAME	Inherit-level Visibility	Flex Avc-profile
1	IP_Dev No Encryption	wlan-spec	disable none

FlexConnect Backup Auth Radius Servers :

Primary Radius Server..... Disabled

Secondary Radius Server..... Disabled

AP User Mode..... AUTOMATIC

AP User Name..... Cisco

AP Dot1x User Mode..... Not Configured

AP Dot1x User Name..... Not Configured

Cisco AP system logging host..... 255.255.255.255

AP Core Dump Config..... Disabled

AP Up Time..... 2 days, 22 h 22 m 16 s

AP LWAPP Up Time..... 2 days, 22 h 18 m 14 s

Join Date and Time..... Mon Aug 15 21:47:12 2016

Join Taken Time..... 0 days, 00 h 04 m 01 s

Attributes for Slot 0

Radio Type..... RADIO_TYPE_80211n-2.4

Administrative State ..... ADMIN_ENABLED

Operation State ..... UP

Mesh Radio Role ..... ACCESS

Radio Role ..... Client Serving (Remote)

CellId 0

Station Configuration

Configuration ..... AUTOMATIC

Number Of WLANs 1

Medium Occupancy Limit 100

CFP Period 4

CFP MaxDuration 60

BSSID 1c:1d:86:31:e5:50

Operation Rate Set

1000 Kilo Bits..... MANDATORY

2000 Kilo Bits..... MANDATORY

5500 Kilo Bits..... MANDATORY

11000 Kilo Bits..... MANDATORY

6000 Kilo Bits..... SUPPORTED

9000 Kilo Bits..... SUPPORTED

12000 Kilo Bits..... SUPPORTED

18000 Kilo Bits..... SUPPORTED

24000 Kilo Bits..... SUPPORTED

36000 Kilo Bits..... SUPPORTED

48000 Kilo Bits..... SUPPORTED

54000 Kilo Bits..... SUPPORTED

MCS Set

MCS 0..... SUPPORTED

MCS 1..... SUPPORTED

MCS 2..... SUPPORTED

MCS 3..... SUPPORTED

MCS 4..... SUPPORTED

MCS 5..... SUPPORTED

MCS 6..... SUPPORTED

MCS 7..... SUPPORTED

MCS 8..... SUPPORTED

MCS 9..... SUPPORTED

MCS 10..... SUPPORTED

MCS 11..... SUPPORTED

MCS 12..... SUPPORTED

MCS 13..... SUPPORTED

MCS 14..... SUPPORTED

MCS 15..... SUPPORTED

MCS 16..... DISABLED

MCS 17..... DISABLED

MCS 18..... DISABLED

MCS 19..... DISABLED

MCS 20..... DISABLED

MCS 21..... DISABLED

MCS 22..... DISABLED

MCS 23..... DISABLED

MCS 24..... DISABLED

MCS 25..... DISABLED

MCS 26..... DISABLED

MCS 27..... DISABLED

MCS 28..... DISABLED

MCS 29..... DISABLED

MCS 30..... DISABLED

MCS 31..... DISABLED

Beacon Period 100

Fragmentation Threshold 2346

Multi Domain Capability Implemented ..... TRUE

Multi Domain Capability Enabled ..... TRUE

Country String ..... US

Multi Domain Capability

Configuration ..... AUTOMATIC

First Chan Num 1

Number Of Channels 11

MAC Operation Parameters

Configuration ..... AUTOMATIC

Fragmentation Threshold 2346

Packet Retry Limit 64

Tx Power

Num Of Supported Power Levels 6

Tx Power Level 1 ..... 22 dBm

Tx Power Level 2 ..... 19 dBm

Tx Power Level 3 ..... 16 dBm

Tx Power Level 4 ..... 13 dBm

Tx Power Level 5 ..... 10 dBm

Tx Power Level 6 ..... 7 dBm

Tx Power Configuration ..... AUTOMATIC

Current Tx Power Level 1

Tx Power Assigned By ..... DTPC

Phy OFDM parameters

Configuration ..... AUTOMATIC

Current Channel 11

Channel Assigned By ..... DCA

Extension Channel ..... NONE

Channel Width..... 20 Mhz

Allowed Channel List..... 1,2,3,4,5,6,7,8,9,10,11

TI Threshold ..... -50

DCA Channel List..... Global

Legacy Tx Beamforming Configuration ..... CUSTOMIZED

Legacy Tx Beamforming ..... ENABLED

Antenna Type..... INTERNAL_ANTENNA

Internal Antenna Gain (in .5 dBi units).... 8

Diversity..... DIVERSITY_ENABLED

802.11n Antennas

A..... ENABLED

B..... ENABLED

C..... ENABLED

Performance Profile Parameters

Configuration ..... AUTOMATIC

Interference threshold..... 10 %

Noise threshold..... -70 dBm

RF utilization threshold..... 80 %

Data-rate threshold..... 1000000 bps

Client threshold..... 12 clients

Coverage SNR threshold..... 12 dB

Coverage exception level..... 25 %

Client minimum exception level..... 3 clients

Rogue Containment Information

Containment Count..... 0

CleanAir Management Information

CleanAir Capable..... Yes

CleanAir Management Administration St.... Disabled

CleanAir Management Operation State..... Down

Rapid Update Mode..... Off

Spectrum Expert connection..... Enabled

CleanAir NSI Key..... 8994C2313910BF9588C6693603B8F970

Spectrum Expert Connections counter.... 0

CleanAir Sensor State..... Configured

Radio Extended Configurations

Beacon period..... 100 milliseconds

Beacon range..... AUTO

Multicast buffer..... AUTO

Multicast data-rate..... AUTO

RX SOP threshold..... AUTO

CCA threshold..... AUTO

Attributes for Slot 1

Radio Type..... RADIO_TYPE_80211n-5

Radio Subband..... RADIO_SUBBAND_ALL

Administrative State ..... ADMIN_ENABLED

Operation State ..... UP

Mesh Radio Role ..... ACCESS

Radio Role ..... Client Serving (Remote)

CellId 0

Station Configuration

Configuration ..... AUTOMATIC

Number Of WLANs 1

Medium Occupancy Limit 100

CFP Period 4

CFP MaxDuration 60

BSSID 1c:1d:86:31:e5:50

Operation Rate Set

6000 Kilo Bits..... MANDATORY

9000 Kilo Bits..... SUPPORTED

12000 Kilo Bits..... MANDATORY

18000 Kilo Bits..... SUPPORTED

24000 Kilo Bits..... MANDATORY

36000 Kilo Bits..... SUPPORTED

48000 Kilo Bits..... SUPPORTED

54000 Kilo Bits..... SUPPORTED

MCS Set

MCS 0..... SUPPORTED

MCS 1..... SUPPORTED

MCS 2..... SUPPORTED

MCS 3..... SUPPORTED

MCS 4..... SUPPORTED

MCS 5..... SUPPORTED

MCS 6..... SUPPORTED

MCS 7..... SUPPORTED

MCS 8..... SUPPORTED

MCS 9..... SUPPORTED

MCS 10..... SUPPORTED

MCS 11..... SUPPORTED

MCS 12..... SUPPORTED

MCS 13..... SUPPORTED

MCS 14..... SUPPORTED

MCS 15..... SUPPORTED

MCS 16..... DISABLED

MCS 17..... DISABLED

MCS 18..... DISABLED

MCS 19..... DISABLED

MCS 20..... DISABLED

MCS 21..... DISABLED

MCS 22..... DISABLED

MCS 23..... DISABLED

MCS 24..... DISABLED

MCS 25..... DISABLED

MCS 26..... DISABLED

MCS 27..... DISABLED

MCS 28..... DISABLED

MCS 29..... DISABLED

MCS 30..... DISABLED

MCS 31..... DISABLED

Beacon Period 100

Fragmentation Threshold 2346

Multi Domain Capability Implemented ..... TRUE

Multi Domain Capability Enabled ..... TRUE

Country String ..... US

Multi Domain Capability

Configuration ..... AUTOMATIC

First Chan Num 36

Number Of Channels 21

MAC Operation Parameters

Configuration ..... AUTOMATIC

Fragmentation Threshold 2346

Packet Retry Limit 64

Tx Power

Num Of Supported Power Levels 6

Tx Power Level 1 ..... 22 dBm

Tx Power Level 2 ..... 19 dBm

Tx Power Level 3 ..... 16 dBm

Tx Power Level 4 ..... 13 dBm

Tx Power Level 5 ..... 10 dBm

Tx Power Level 6 ..... 7 dBm

Tx Power Configuration ..... AUTOMATIC

Current Tx Power Level 1

Tx Power Assigned By ..... DTPC

Phy OFDM parameters

Configuration ..... AUTOMATIC

Current Channel 48

Channel Assigned By ..... DCA

Extension Channel ..... NONE

Channel Width..... 20 Mhz

Allowed Channel List..... 36,40,44,48,52,56,60,64,100,

..... 104,108,112,116,132,136,140,

..... 149,153,157,161,165

TI Threshold ..... -50

DCA Channel List..... Global

Legacy Tx Beamforming Configuration ..... CUSTOMIZED

Legacy Tx Beamforming ..... ENABLED

Antenna Type..... INTERNAL_ANTENNA

Internal Antenna Gain (in .5 dBi units).... 8

Diversity..... DIVERSITY_ENABLED

802.11n Antennas

A..... ENABLED

B..... ENABLED

C..... ENABLED

Performance Profile Parameters

Configuration ..... AUTOMATIC

Interference threshold..... 10 %

Noise threshold..... -70 dBm

RF utilization threshold..... 80 %

Data-rate threshold..... 1000000 bps

Client threshold..... 12 clients

Coverage SNR threshold..... 16 dB

Coverage exception level..... 25 %

Client minimum exception level..... 3 clients

Rogue Containment Information

Containment Count..... 0

CleanAir Management Information

CleanAir Capable..... Yes

CleanAir Management Administration St.... Disabled

CleanAir Management Operation State..... Down

Rapid Update Mode..... Off

Spectrum Expert connection..... Enabled

CleanAir NSI Key..... 8994C2313910BF9588C6693603B8F970

Spectrum Expert Connections counter.... 0

CleanAir Sensor State..... Configured

Radio Extended Configurations

Beacon period..... 100 milliseconds

Beacon range..... AUTO

Multicast buffer..... AUTO

Multicast data-rate..... AUTO

RX SOP threshold..... AUTO

CCA threshold..... AUTO

AP Airewave Director Configuration

AP does not have the 802.11-abgn radio.

Number Of Slots..... 2

AP Name..... AP78da.6ee0.08ec

MAC Address..... 78:da:6e:e0:08:ec

Slot ID..... 0

Radio Type..... RADIO_TYPE_80211b/g

Sub-band Type..... All

Noise Information

Noise Profile..... PASSED

Interference Information

Interference Profile..... PASSED

Rogue Histogram (20)

.....

Load Information

Load Profile..... PASSED

Receive Utilization..... 0 %

Transmit Utilization..... 0 %

Channel Utilization..... 38 %

Attached Clients..... 0 clients

Coverage Information

Coverage Profile..... PASSED

Failed Clients..... 0 clients

Client Signal Strengths

RSSI -100 dbm..... 0 clients

RSSI -92 dbm..... 0 clients

RSSI -84 dbm..... 0 clients

RSSI -76 dbm..... 0 clients

RSSI -68 dbm..... 0 clients

RSSI -60 dbm..... 0 clients

RSSI -52 dbm..... 0 clients

Client Signal To Noise Ratios

SNR 0 dB..... 0 clients

SNR 5 dB..... 0 clients

SNR 10 dB..... 0 clients

SNR 15 dB..... 0 clients

SNR 20 dB..... 0 clients

SNR 25 dB..... 0 clients

SNR 30 dB..... 0 clients

SNR 35 dB..... 0 clients

SNR 40 dB..... 0 clients

SNR 45 dB..... 0 clients

Nearby APs

Radar Information

Channel Assignment Information

Current Channel Average Energy..... -127 dBm

Previous Channel Average Energy..... -127 dBm

Channel Change Count..... 415

Last Channel Change Time..... Thu Aug 18 20:01:53 2016

Recommended Best Channel..... 11

RF Parameter Recommendations

Power Level..... 1

RTS/CTS Threshold..... 2347

Fragmentation Threshold..... 2346

Antenna Pattern..... 0

Persistent Interference Devices

Class Type Channel DC (%%) RSSI (dBm) Last Update Time

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Number Of Slots..... 2

AP Name..... AP78da.6ee0.08ec

MAC Address..... 78:da:6e:e0:08:ec

Slot ID..... 1

Radio Type..... RADIO_TYPE_80211a

Sub-band Type..... All

Noise Information

Noise Profile..... PASSED

Interference Information

Interference Profile..... PASSED

Rogue Histogram (20/40/80/160)

.....

Load Information

Load Profile..... PASSED

Receive Utilization..... 0 %

Transmit Utilization..... 0 %

Channel Utilization..... 1 %

Attached Clients..... 0 clients

Coverage Information

Coverage Profile..... PASSED

Failed Clients..... 0 clients

Client Signal Strengths

RSSI -100 dbm..... 0 clients

RSSI -92 dbm..... 0 clients

RSSI -84 dbm..... 0 clients

RSSI -76 dbm..... 0 clients

RSSI -68 dbm..... 0 clients

RSSI -60 dbm..... 0 clients

RSSI -52 dbm..... 0 clients

Client Signal To Noise Ratios

SNR 0 dB..... 0 clients

SNR 5 dB..... 0 clients

SNR 10 dB..... 0 clients

SNR 15 dB..... 0 clients

SNR 20 dB..... 0 clients

SNR 25 dB..... 0 clients

SNR 30 dB..... 0 clients

SNR 35 dB..... 0 clients

SNR 40 dB..... 0 clients

SNR 45 dB..... 0 clients

Nearby APs

Radar Information

Channel Assignment Information

Current Channel Average Energy..... -127 dBm

Previous Channel Average Energy..... -127 dBm

Channel Change Count..... 417

Last Channel Change Time..... Thu Aug 18 20:05:14 2016

Recommended Best Channel..... 149

RF Parameter Recommendations

Power Level..... 1

RTS/CTS Threshold..... 2347

Fragmentation Threshold..... 2346

Antenna Pattern..... 0

Persistent Interference Devices

Class Type Channel DC (%%) RSSI (dBm) Last Update Time

All third party trademarks are the property of their respective owners.

AP does not have the 802.11-abgn radio.

Number Of Slots..... 2

AP Name..... AP24e9.b34b.f1ed

MAC Address..... 24:e9:b3:4b:f1:ed

Slot ID..... 0

Radio Type..... RADIO_TYPE_80211b/g

Sub-band Type..... All

Noise Information

Noise Profile..... PASSED

Interference Information

Interference Profile..... PASSED

Rogue Histogram (20)

.....

Load Information

Load Profile..... PASSED

Receive Utilization..... 0 %

Transmit Utilization..... 0 %

Channel Utilization..... 34 %

Attached Clients..... 1 clients

Coverage Information

Coverage Profile..... PASSED

Failed Clients..... 0 clients

Client Signal Strengths

RSSI -100 dbm..... 0 clients

RSSI -92 dbm..... 0 clients

RSSI -84 dbm..... 0 clients

RSSI -76 dbm..... 0 clients

RSSI -68 dbm..... 0 clients

RSSI -60 dbm..... 0 clients

RSSI -52 dbm..... 1 clients

Client Signal To Noise Ratios

SNR 0 dB..... 0 clients

SNR 5 dB..... 0 clients

SNR 10 dB..... 0 clients

SNR 15 dB..... 0 clients

SNR 20 dB..... 0 clients

SNR 25 dB..... 0 clients

SNR 30 dB..... 0 clients

SNR 35 dB..... 0 clients

SNR 40 dB..... 0 clients

SNR 45 dB..... 1 clients

Nearby APs

Radar Information

Channel Assignment Information

Current Channel Average Energy..... -127 dBm

Previous Channel Average Energy..... -127 dBm

Channel Change Count..... 415

Last Channel Change Time..... Thu Aug 18 20:01:53 2016

Recommended Best Channel..... 11

RF Parameter Recommendations

Power Level..... 1

RTS/CTS Threshold..... 2347

Fragmentation Threshold..... 2346

Antenna Pattern..... 0

Persistent Interference Devices

Class Type Channel DC (%%) RSSI (dBm) Last Update Time

---------- ------- ------ ---------- ----------

Number Of Slots..... 2

AP Name..... AP24e9.b34b.f1ed

MAC Address..... 24:e9:b3:4b:f1:ed

Slot ID..... 1

Radio Type..... RADIO_TYPE_80211a

Sub-band Type..... All

Noise Information

Noise Profile..... PASSED

Interference Information

Interference Profile..... PASSED

Rogue Histogram (20/40/80/160)

.....

Load Information

Load Profile..... PASSED

Receive Utilization..... 0 %

Transmit Utilization..... 0 %

Channel Utilization..... 0 %

Attached Clients..... 0 clients

Coverage Information

Coverage Profile..... PASSED

Failed Clients..... 0 clients

Client Signal Strengths

RSSI -100 dbm..... 0 clients

RSSI -92 dbm..... 0 clients

RSSI -84 dbm..... 0 clients

RSSI -76 dbm..... 0 clients

RSSI -68 dbm..... 0 clients

RSSI -60 dbm..... 0 clients

RSSI -52 dbm..... 0 clients

Client Signal To Noise Ratios

SNR 0 dB..... 0 clients

SNR 5 dB..... 0 clients

SNR 10 dB..... 0 clients

SNR 15 dB..... 0 clients

SNR 20 dB..... 0 clients

SNR 25 dB..... 0 clients

SNR 30 dB..... 0 clients

SNR 35 dB..... 0 clients

SNR 40 dB..... 0 clients

SNR 45 dB..... 0 clients

Nearby APs

Radar Information

Channel Assignment Information

Current Channel Average Energy..... -127 dBm

Previous Channel Average Energy..... -127 dBm

Channel Change Count..... 417

Last Channel Change Time..... Thu Aug 18 20:05:14 2016

Recommended Best Channel..... 48

RF Parameter Recommendations

Power Level..... 1

RTS/CTS Threshold..... 2347

Fragmentation Threshold..... 2346

Antenna Pattern..... 0

Persistent Interference Devices

Class Type Channel DC (%%) RSSI (dBm) Last Update Time

802.11a Configuration

802.11a Network..... Enabled

11acSupport..... Enabled

11nSupport..... Enabled

802.11a Low Band..... Enabled

802.11a Mid Band..... Enabled

802.11a High Band..... Enabled

802.11a Operational Rates

802.11a 6M Rate..... Mandatory

802.11a 9M Rate..... Supported

802.11a 12M Rate..... Mandatory

802.11a 18M Rate..... Supported

802.11a 24M Rate..... Mandatory

802.11a 36M Rate..... Supported

802.11a 48M Rate..... Supported

802.11a 54M Rate..... Supported

802.11n MCS Settings:

MCS 0..... Supported

MCS 1..... Supported

MCS 2..... Supported

MCS 3..... Supported

MCS 4..... Supported

MCS 5..... Supported

MCS 6..... Supported

MCS 7..... Supported

MCS 8..... Supported

MCS 9..... Supported

MCS 10..... Supported

MCS 11..... Supported

MCS 12..... Supported

MCS 13..... Supported

MCS 14..... Supported

MCS 15..... Supported

MCS 16..... Supported

MCS 17..... Supported

MCS 18..... Supported

MCS 19..... Supported

MCS 20..... Supported

MCS 21..... Supported

MCS 22..... Supported

MCS 23..... Supported

MCS 24..... Supported

MCS 25..... Supported

MCS 26..... Supported

MCS 27..... Supported

MCS 28..... Supported

MCS 29..... Supported

MCS 30..... Supported

MCS 31..... Supported

802.11ac MCS Settings:

Nss=1: MCS 0-9 ..... Supported

Nss=2: MCS 0-9 ..... Supported

Nss=3: MCS 0-9 ..... Supported

Nss=4: MCS 0-7 ..... Supported

802.11n Status:

A-MPDU Tx:

Priority 0..... Enabled

Priority 1..... Enabled

Priority 2..... Enabled

Priority 3..... Enabled

Priority 4..... Enabled

Priority 5..... Enabled

Priority 6..... Disabled

Priority 7..... Disabled

Aggregation scheduler..... Enabled

Frame Burst..... Automatic

Realtime Timeout..... 10

Non Realtime Timeout..... 200

A-MSDU Tx:

Priority 0..... Enabled

Priority 1..... Enabled

Priority 2..... Enabled

Priority 3..... Enabled

Priority 4..... Enabled

Priority 5..... Enabled

Priority 6..... Disabled

Priority 7..... Disabled

A-MSDU Max Subframes 3

A-MSDU MAX Length 8k

Rifs Rx ..... Enabled

Guard Interval ..... Any

Beacon Interval..... 100

CF Pollable mandatory..... Disabled

CF Poll Request mandatory..... Disabled

CFP Period..... 4

CFP Maximum Duration..... 60

Default Channel..... 36

Default Tx Power Level..... 0

DTPC Status..... Enabled

Fragmentation Threshold..... 2346

RSSI Low Check..... Disabled

RSSI Threshold..... -80

TI Threshold..... -50

Legacy Tx Beamforming setting..... Disabled

Traffic Stream Metrics Status..... Disabled

Expedited BW Request Status..... Disabled

World Mode..... Enabled

dfs-peakdetect..... Enabled

EDCA profile type..... default-wmm

Voice MAC optimization status..... Disabled

Call Admission Control (CAC) configuration

Voice AC:

```
  Voice AC - Admission control (ACM)..... Disabled
  Voice Stream-Size..... 84000
  Voice Max-Streams..... 2
  Voice max RF bandwidth..... 75
  Voice reserved roaming bandwidth..... 6
  Voice CAC Method ..... Load-Based
  Voice tspec inactivity timeout..... Disabled
 CAC SIP-Voice configuration
  SIP based CAC ..... Disabled
  SIP Codec Type ..... CODEC_TYPE_G711
  SIP call bandwidth ..... 64
  SIP call bandwith sample-size ..... 20
Video AC:
  Video AC - Admission control (ACM)..... Disabled
  Video max RF bandwidth..... Infinite
  Video reserved roaming bandwidth..... 0
  Video load-based CAC mode..... Disabled
  Video CAC Method ..... Static
 CAC SIP-Video Configuration
  SIP based CAC ..... Disabled
  Best-effort AC - Admission control (ACM)..... Disabled
  Background AC - Admission control (ACM)..... Disabled
Maximum Number of Clients per AP Radio..... 200

802.11a Advanced Configuration
Member RRM Information
AP Name                MAC Address      Slot Admin    Oper       Channel         TxPower
-------------------------------- ----------------- ---- -------- ----------- ------------------ -------------
AP78da.6ee0.08ec       5c:a4:8a:be:ca:90  1   ENABLED  UP        149*           *1/6 (22 dBm)
AP24e9.b34b.f1ed       1c:1d:86:31:e5:50  1   ENABLED  UP        48*            *1/6 (22 dBm)
```

802.11a Airewave Director Configuration

RF Event and Performance Logging

Channel Update Logging..... Off

Coverage Profile Logging..... Off

Foreign Profile Logging..... Off

Load Profile Logging..... Off

Noise Profile Logging..... Off

Performance Profile Logging..... Off

TxPower Update Logging..... Off

Default 802.11a AP performance profiles

802.11a Global Interference threshold..... 10 %

802.11a Global noise threshold..... -70 dBm

802.11a Global RF utilization threshold..... 80 %

802.11a Global throughput threshold..... 1000000 bps

802.11a Global clients threshold..... 12 clients

Default 802.11a AP monitoring

802.11a Monitor Mode..... enable

802.11a Monitor Mode for Mesh AP Backhaul..... disable

802.11a Monitor Channels..... Country channels

802.11a RRM Neighbor Discover Type..... Transparent

802.11a RRM Neighbor RSSI Normalization..... Enabled

802.11a AP Coverage Interval..... 90 seconds

802.11a AP Load Interval..... 60 seconds

802.11a AP Monitor Measurement Interval..... 180 seconds

802.11a AP Neighbor Timeout Factor..... 5

802.11a AP Report Measurement Interval..... 180 seconds

Leader Automatic Transmit Power Assignment

Transmit Power Assignment Mode..... AUTO

Transmit Power Update Interval..... 600 seconds

Transmit Power Threshold..... -70 dBm

```
  Transmit Power Neighbor Count..... 3 APs
  Min Transmit Power..... -10 dBm
  Max Transmit Power..... 30 dBm
  Update Contribution
    Noise..... Enable
    Interference..... Enable
    Load..... Disable
    Device Aware..... Disable
  Transmit Power Assignment Leader..... wlc (192.168.250.2) (::)
  Last Run..... 21 seconds ago
  Last Run Time..... 0 seconds
  TPC Mode..... Version 1
  TPCv2 Target RSSI..... -67 dBm
  TPCv2 VoWLAN Guide RSSI..... -67.0 dBm
  TPCv2 SOP..... -85.0 dBm
  TPCv2 Default Client Ant Gain..... 0.0 dBi
  TPCv2 Path Loss Decay Factor..... 3.6
  TPCv2 Search Intensity..... 10 Iterations



AP Name                  Channel   TxPower      Allowed Power Levels
-------------------------------- ---------- ------------ ------------------------
AP78da.6ee0.08ec         149*      *1/6 (22 dBm) [22/19/16/13/10/7/7/7]
AP24e9.b34b.f1ed         48*       *1/6 (22 dBm) [22/19/16/13/10/7/7/7]
Coverage Hole Detection
  802.11a Coverage Hole Detection Mode..... Enabled
  802.11a Coverage Voice Packet Count..... 100 packets
  802.11a Coverage Voice Packet Percentage..... 50%
  802.11a Coverage Voice RSSI Threshold..... -80 dBm
```

802.11a Coverage Data Packet Count..... 50 packets

802.11a Coverage Data Packet Percentage..... 50%

802.11a Coverage Data RSSI Threshold..... -80 dBm

802.11a Global coverage exception level..... 25 %

802.11a Global client minimum exception lev.... 3 clients

OptimizedRoaming

802.11a OptimizedRoaming Mode..... Disabled

802.11a OptimizedRoaming Reporting Interval.... 90 seconds

802.11a OptimizedRoaming Rate Threshold..... disabled

802.11a OptimizedRoaming Hysteresis..... 6 dB

OptimizedRoaming Stats

802.11a OptimizedRoaming Disassociations..... 0

802.11a OptimizedRoaming Rejections..... 0

Leader Automatic Channel Assignment

Channel Assignment Mode..... AUTO

Channel Update Interval..... 600 seconds

Anchor time (Hour of the day)..... 0

Update Contribution

Noise..... Enable

Interference..... Enable

Load..... Disable

Device Aware..... Disable

CleanAir Event-driven RRM option..... Disabled

Channel Assignment Leader..... wlc (192.168.250.2) (::)

Last Run..... 21 seconds ago

Last Run Time..... 0 seconds

DCA Sensitivity Level..... MEDIUM (15 dB)

DCA 802.11n/ac Channel Width..... 20 MHz

DCA Minimum Energy Limit..... -95 dBm

Channel Energy Levels

```
    Minimum..... -127 dBm
    Average..... -127 dBm
    Maximum..... -127 dBm
  Channel Dwell Times
    Minimum..... 0 days, 00 h 00 m 19 s
    Average..... 0 days, 00 h 00 m 19 s
    Maximum..... 0 days, 00 h 00 m 19 s
  802.11a 5 GHz Auto-RF Channel List
    Allowed Channel List..... 36,40,44,48,52,56,60,64,100,
                              104,108,112,116,120,124,128,
                              132,136,140,144,149,153,157,
                              161
    Unused Channel List..... 165
  802.11a 4.9 GHz Auto-RF Channel List
    Allowed Channel List.....
    Unused Channel List..... 1,2,3,4,5,6,7,8,9,10,11,12,
                              13,14,15,16,17,18,19,20,21,
                              22,23,24,25,26
  DCA Outdoor AP option..... Disabled
802.11a Radio RF Grouping
  RF Group Name..... WLAN
  RF Protocol Version(MIN)..... 101(30)
  RF Packet Header Version..... 2
  Group Role(Mode)..... LEADER(AUTO)
  Group State..... Idle
  Group Update Interval..... 600 seconds
  Group Leader..... wlc (192.168.250.2) (::)
  Group Member
          ..... wlc (192.168.250.2)
  Maximum/Current number of Group Member..... 20/1
```

Maximum/Current number of AP..... 500/2

Last Run..... 21 seconds ago

802.11a CleanAir Configuration

Clean Air Solution..... Disabled

Air Quality Settings:

Air Quality Reporting..... Enabled

Air Quality Reporting Period (min)..... 15

Air Quality Alarms..... Enabled

Air Quality Alarm Threshold..... 35

Unclassified Interference..... Disabled

Unclassified Severity Threshold..... 20

Interference Device Settings:

Interference Device Reporting..... Enabled

Interference Device Types:

TDD Transmitter..... Enabled

Jammer..... Enabled

Continuous Transmitter..... Enabled

DECT-like Phone..... Enabled

Video Camera..... Enabled

WiFi Inverted..... Enabled

WiFi Invalid Channel..... Enabled

SuperAG..... Enabled

Canopy..... Enabled

WiMax Mobile..... Enabled

WiMax Fixed..... Enabled

Interference Device Alarms..... Enabled

Interference Device Types Triggering Alarms:

TDD Transmitter..... Disabled

Jammer..... Enabled

Continuous Transmitter..... Disabled

DECT-like Phone..... Disabled

Video Camera..... Disabled

WiFi Inverted..... Enabled

WiFi Invalid Channel..... Enabled

SuperAG..... Disabled

Canopy..... Disabled

WiMax Mobile..... Disabled

WiMax Fixed..... Disabled

Additional Clean Air Settings:

CleanAir ED-RRM State..... Disabled

CleanAir ED-RRM Sensitivity..... Medium

CleanAir ED-RRM Custom Threshold..... 50

CleanAir Rogue Contribution..... Disabled

CleanAir Rogue Duty-Cycle Threshold..... 80

CleanAir Persistent Devices state..... Disabled

CleanAir Persistent Device Propagation..... Disabled

802.11a CleanAir AirQuality Summary

AQ = Air Quality

DFS = Dynamic Frequency Selection

AP Name Channel Avg AQ Min AQ Interferers DFS

---------- ------- ------ ------ ---------- ---

802.11b Configuration

802.11b Network..... Enabled

11gSupport..... Enabled

11nSupport..... Enabled

802.11b/g Operational Rates

802.11b/g 1M Rate..... Mandatory

802.11b/g 2M Rate..... Mandatory

802.11b/g 5.5M Rate..... Mandatory

802.11b/g 11M Rate..... Mandatory

802.11g 6M Rate..... Supported

802.11g 9M Rate..... Supported

802.11g 12M Rate..... Supported

802.11g 18M Rate..... Supported

802.11g 24M Rate..... Supported

802.11g 36M Rate..... Supported

802.11g 48M Rate..... Supported

802.11g 54M Rate..... Supported

802.11n MCS Settings:

MCS 0..... Supported

MCS 1..... Supported

MCS 2..... Supported

MCS 3..... Supported

MCS 4..... Supported

MCS 5..... Supported

MCS 6..... Supported

MCS 7..... Supported

MCS 8..... Supported

MCS 9..... Supported

MCS 10..... Supported

MCS 11..... Supported

MCS 12..... Supported

MCS 13..... Supported

MCS 14..... Supported

MCS 15..... Supported

MCS 16..... Supported

MCS 17..... Supported

MCS 18..... Supported

MCS 19..... Supported

MCS 20..... Supported

MCS 21..... Supported

MCS 22..... Supported

MCS 23..... Supported

MCS 24..... Supported

MCS 25..... Supported

MCS 26..... Supported

MCS 27..... Supported

MCS 28..... Supported

MCS 29..... Supported

MCS 30..... Supported

MCS 31..... Supported

802.11n Status:

A-MPDU Tx:

Priority 0..... Enabled

Priority 1..... Enabled

Priority 2..... Enabled

Priority 3..... Enabled

Priority 4..... Enabled

Priority 5..... Enabled

Priority 6..... Disabled

Priority 7..... Disabled

Aggregation scheduler..... Enabled

Realtime Timeout..... 10

Non Realtime Timeout..... 200

A-MSDU Tx:

Priority 0..... Enabled

Priority 1..... Enabled

Priority 2..... Enabled

Priority 3..... Enabled

Priority 4..... Enabled

Priority 5..... Enabled

Priority 6..... Disabled

Priority 7..... Disabled

A-MSDU Max Subframes 3

A-MSDU MAX Length 8k

Rifs Rx ..... Enabled

Guard Interval ..... Any

Beacon Interval..... 100

CF Pollable mode..... Disabled

CF Poll Request mandatory..... Disabled

CFP Period..... 4

CFP Maximum Duration..... 60

Default Channel..... 1

Default Tx Power Level..... 0

DTPC Status..... Enabled

RSSI Low Check..... Disabled

RSSI Threshold..... -80

Call Admission Limit 105

G711 CU Quantum 15

ED Threshold..... -50

Fragmentation Threshold..... 2346

PBCC mandatory..... Disabled

RTS Threshold..... 2347

Short Preamble mandatory..... Enabled

Short Retry Limit..... 7

Legacy Tx Beamforming setting..... Disabled

Traffic Stream Metrics Status..... Disabled

Expedited BW Request Status..... Disabled

World Mode..... Enabled

Faster Carrier Tracking Loop..... Disabled

EDCA profile type..... default-wmm

Voice MAC optimization status..... Disabled

Call Admission Control (CAC) configuration

Voice AC - Admission control (ACM)..... Disabled

Voice Stream-Size..... 84000

Voice Max-Streams..... 2

Voice max RF bandwidth..... 75

Voice reserved roaming bandwidth..... 6

Voice CAC Method..... Load-Based

Voice tspec inactivity timeout..... Disabled

CAC SIP-Voice configuration

SIP based CAC ..... Disabled

SIP Codec Type ..... CODEC_TYPE_G711

SIP call bandwidth: 64

SIP call bandwidth sample-size 20

Video AC - Admission control (ACM)..... Disabled

Video max RF bandwidth..... Infinite

Video reserved roaming bandwidth..... 0

Video load-based CAC mode..... Disabled

Video CAC Method ..... Static

CAC SIP-Video configuration

SIP based CAC ..... Disabled

Best-effort AC - Admission control (ACM)..... Disabled

Background AC - Admission control (ACM)..... Disabled

Maximum Number of Clients per AP..... 200

802.11b Advanced Configuration

Member RRM Information

AP Name	MAC Address	Admin	Oper	Channel	TxPower
AP78da.6ee0.08ec	5c:a4:8a:be:ca:90	ENABLED	UP	11*	*1/6 (22 dBm)
AP24e9.b34b.f1ed	1c:1d:86:31:e5:50	ENABLED	UP	11*	*1/6 (22 dBm)

802.11b Airewave Director Configuration

RF Event and Performance Logging

Channel Update Logging..... Off

Coverage Profile Logging..... Off

Foreign Profile Logging..... Off

Load Profile Logging..... Off

Noise Profile Logging..... Off

Performance Profile Logging..... Off

Transmit Power Update Logging..... Off

Default 802.11b AP performance profiles

802.11b Global Interference threshold..... 10 %

802.11b Global noise threshold..... -70 dBm

802.11b Global RF utilization threshold..... 80 %

802.11b Global throughput threshold..... 1000000 bps

802.11b Global clients threshold..... 12 clients

Default 802.11b AP monitoring

802.11b Monitor Mode..... enable

802.11b Monitor Channels..... Country channels

802.11b RRM Neighbor Discovery Type..... Transparent

802.11b RRM Neighbor RSSI Normalization..... Enabled

802.11b AP Coverage Interval..... 90 seconds

802.11b AP Load Interval..... 60 seconds

802.11b AP Monitor Measurement Interval..... 180 seconds

802.11b AP Neighbor Timeout Factor..... 5

802.11b AP Report Measurement Interval..... 180 seconds

Leader Automatic Transmit Power Assignment

Transmit Power Assignment Mode..... AUTO

Transmit Power Update Interval..... 600 seconds

Transmit Power Threshold..... -70 dBm

Transmit Power Neighbor Count..... 3 APs

Min Transmit Power..... -10 dBm

Max Transmit Power..... 30 dBm

Update Contribution

Noise..... Enable

Interference..... Enable

Load..... Disable

Device Aware..... Disable

Transmit Power Assignment Leader..... wlc (192.168.250.2) (::)

Last Run..... 225 seconds ago

Last Run Time..... 0 seconds

TPC Mode..... Version 1

TPCv2 Target RSSI..... -67 dBm

TPCv2 VoWLAN Guide RSSI..... -67.0 dBm

TPCv2 SOP..... -85.0 dBm

TPCv2 Default Client Ant Gain..... 0.0 dBi

TPCv2 Path Loss Decay Factor..... 3.6

TPCv2 Search Intensity..... 10 Iterations

```
AP Name                  Channel    TxPower      Allowed Power Levels
-------------------------------- ---------- ------------ ------------------------
AP78da.6ee0.08ec         *11        *1/6 (22 dBm) [22/19/16/13/10/7/7/7]
AP24e9.b34b.f1ed         *11        *1/6 (22 dBm) [22/19/16/13/10/7/7/7]
Coverage Hole Detection
  802.11b Coverage Hole Detection Mode..... Enabled
  802.11b Coverage Voice Packet Count..... 100 packets
  802.11b Coverage Voice Packet Percentage..... 50%
  802.11b Coverage Voice RSSI Threshold..... -80 dBm
  802.11b Coverage Data Packet Count..... 50 packets
  802.11b Coverage Data Packet Percentage..... 50%
  802.11b Coverage Data RSSI Threshold..... -80 dBm
  802.11b Global coverage exception level..... 25 %
  802.11b Global client minimum exception lev.... 3 clients
OptimizedRoaming
  802.11b OptimizedRoaming Mode..... Disabled
  802.11b OptimizedRoaming Reporting Interval.... 90 seconds
  802.11b OptimizedRoaming Rate Threshold..... disabled
  802.11b OptimizedRoaming Hysteresis..... 6 dB
OptimizedRoaming Stats
  802.11b OptimizedRoaming Disassociations..... 0
  802.11b OptimizedRoaming Rejections..... 0
Leader Automatic Channel Assignment
  Channel Assignment Mode..... AUTO
  Channel Update Interval..... 600 seconds
  Anchor time (Hour of the day)..... 0
  Update Contribution
    Noise..... Enable
    Interference..... Enable
```

```
    Load..................................... Disable
    Device Aware.............................. Disable
  CleanAir Event-driven RRM option.............. Disabled
  Channel Assignment Leader..................... wlc (192.168.250.2) (::)
  Last Run...................................... 225 seconds ago
  Last Run Time................................. 0 seconds

  DCA Sensitivity Level: ....................... MEDIUM (10 dB)
  DCA Minimum Energy Limit...................... -95 dBm
  Channel Energy Levels
    Minimum..................................... -127 dBm
    Average..................................... -127 dBm
    Maximum..................................... -127 dBm
  Channel Dwell Times
    Minimum..................................... 0 days, 00 h 03 m 43 s
    Average..................................... 0 days, 00 h 03 m 43 s
    Maximum..................................... 0 days, 00 h 03 m 43 s
  802.11b Auto-RF Allowed Channel List.......... 1,6,11
  Auto-RF Unused Channel List................... 2,3,4,5,7,8,9,10
802.11b Radio RF Grouping
  RF Group Name................................. WLAN
  RF Protocol Version(MIN)...................... 101(30)
  RF Packet Header Version...................... 2
  Group Role(Mode).............................. LEADER(AUTO)
  Group State................................... Idle
  Group Update Interval......................... 600 seconds
  Group Leader.................................. wlc (192.168.250.2) (::)
  Group Member
              ................................. wlc (192.168.250.2)
  Maximum/Current number of Group Member........ 20/1
```

Maximum/Current number of AP..... 500/2

Last Run..... 225 seconds ago

802.11b CleanAir Configuration

Clean Air Solution..... Disabled

Air Quality Settings:

Air Quality Reporting..... Enabled

Air Quality Reporting Period (min)..... 15

Air Quality Alarms..... Enabled

Air Quality Alarm Threshold..... 35

Unclassified Interference..... Disabled

Unclassified Severity Threshold..... 20

Interference Device Settings:

Interference Device Reporting..... Enabled

Interference Device Types:

Bluetooth Link..... Enabled

Microwave Oven..... Enabled

802.11 FH..... Enabled

Bluetooth Discovery..... Enabled

TDD Transmitter..... Enabled

Jammer..... Enabled

Continuous Transmitter..... Enabled

DECT-like Phone..... Enabled

Video Camera..... Enabled

802.15.4..... Enabled

WiFi Inverted..... Enabled

WiFi Invalid Channel..... Enabled

SuperAG..... Enabled

Canopy..... Enabled

Microsoft Device..... Enabled

WiMax Mobile..... Enabled

WiMax Fixed..... Enabled

BLE Beacon..... Enabled

Interference Device Alarms..... Enabled

Interference Device Types Triggering Alarms:

Bluetooth Link..... Disabled

Microwave Oven..... Disabled

802.11 FH..... Disabled

Bluetooth Discovery..... Disabled

TDD Transmitter..... Disabled

Jammer..... Enabled

Continuous Transmitter..... Disabled

DECT-like Phone..... Disabled

Video Camera..... Disabled

802.15.4..... Disabled

WiFi Inverted..... Enabled

WiFi Invalid Channel..... Enabled

SuperAG..... Disabled

Canopy..... Disabled

Microsoft Device..... Disabled

WiMax Mobile..... Disabled

WiMax Fixed..... Disabled

BLE Beacon..... Disabled

Additional Clean Air Settings:

CleanAir ED-RRM State..... Disabled

CleanAir ED-RRM Sensitivity..... Medium

CleanAir ED-RRM Custom Threshold..... 50

CleanAir Rogue Contribution..... Disabled

CleanAir Rogue Duty-Cycle Threshold..... 80

CleanAir Persistent Devices state..... Disabled

CleanAir Persistent Device Propagation..... Disabled

802.11a CleanAir AirQuality Summary

AQ = Air Quality

DFS = Dynamic Frequency Selection

AP Name	Channel	Avg AQ	Min AQ	Interferers	DFS

RF Density Optimization Configurations

FRA State..... Disabled

FRA Sensitivity..... low (100)

FAR Interval..... 1 Hour(s)

Last Run..... 2703 seconds ago

Last Run Time..... 0 seconds

AP Name	MAC Address	Slot	Current Band	COF %	Suggested Mode

COF : Coverage Overlap Factor

RF Client Steering Configurations

Client Steering Configuration Information

Macro to micro transition threshold..... -55 dBm

micro to Macro transition threshold..... -65 dBm

micro-Macro transition minimum client count.... 3

micro-Macro transition client balancing win.... 3

Probe suppression mode..... disabled

Probe suppression validity window..... 100 s

Probe suppression aggregate window..... 200 ms

Probe suppression transition aggressiveness.... 3

Probe suppression hysteresis..... -6 dBm

Mobility Configuration

Mobility Protocol Port..... 16666

Default Mobility Domain..... WLAN

Multicast Mode ..... Disabled

Mobility Domain ID for 802.11r..... 0xf6a2

Mobility Keepalive Interval..... 10

Mobility Keepalive Count..... 3

Mobility Group Members Configured..... 1

Mobility Control Message DSCP Value..... 0

Controllers configured in the Mobility Group

MAC Address	IP Address	Group Name	Multicast IP	Status
00:50:56:ac:6d:08	192.168.250.2	WLAN	0.0.0.0	Up

Mobility Hash Configuration

Default Mobility Domain..... WLAN

IP Address Hash Key

192.168.250.2 7a9b864fa2922672949cf9a66fd012a0ce8cc7b0

Self Signed Certificate details

SSC Hash validation..... Enabled.

SSC Device Certificate details:

Subject Name :

C=US, ST=California, L=San Jose, O=Cisco Virtual Wireless LAN Controller,

CN=DEVICE-vWLC-AIR-CTVM-K9-005056AC6338, emailAddress=support@vwlc.com

Validity :

Start : Jul 26 20:52:54 2016 GMT

End : Jun 4 20:52:54 2026 GMT

Hash key : 7a9b864fa2922672949cf9a66fd012a0ce8cc7b0

Mobility Foreign Map Configuration

WLAN ID	Foreign Mac Address	Interface

Advanced Configuration

Probe request filtering..... Enabled

Probes fwd to controller per client per radio.... 2

Probe request rate-limiting interval..... 500 msec

Aggregate Probe request interval..... 500 msec

Increased backoff parameters for probe respon.... Disabled

EAP-Identity-Request Timeout (seconds)..... 30

EAP-Identity-Request Max Retries..... 2

EAP Key-Index for Dynamic WEP..... 0

EAP Max-Login Ignore Identity Response..... enable

EAP-Request Timeout (seconds)..... 30

EAP-Request Max Retries..... 2

EAPOL-Key Timeout (milliseconds)..... 1000

EAPOL-Key Max Retries..... 2

EAP-Broadcast Key Interval..... 3600

dot11-padding..... Disabled

padding-size..... 0

Advanced Hotspot Commands

ANQP 4-way state..... Disabled

GARP Broadcast state: ..... Enabled

GAS request rate limit ..... Disabled

ANQP comeback delay in TUs(TU=1024usec)..... 1 TUs (=1mSec)

Location Configuration

RFID Tag data Collection..... Enabled

RFID timeout..... 1200 seconds

RFID mobility.....

Interface Configuration

Interface Name..... ip_dev

MAC Address..... 00:50:56:ac:6d:08

IP Address..... 192.168.150.2

IP Netmask..... 255.255.255.0

IP Gateway..... 192.168.150.1

External NAT IP State..... Disabled

External NAT IP Address..... 0.0.0.0

VLAN..... 1500

Quarantine-vlan..... 0

NAS-Identifier..... none

Physical Port..... 1

DHCP Proxy Mode..... Global

Primary DHCP Server..... Unconfigured

Secondary DHCP Server..... Unconfigured

DHCP Option 82..... Disabled

DHCP Option 82 bridge mode insertion..... Disabled

IPv4 ACL..... Unconfigured

mDNS Profile Name..... Unconfigured

AP Manager..... No

Guest Interface..... N/A

3G VLAN..... Disabled

L2 Multicast..... Enabled

Interface Name..... management

MAC Address..... 00:50:56:ac:6d:08

IP Address..... 192.168.250.2

IP Netmask..... 255.255.255.0

IP Gateway..... 192.168.250.1

External NAT IP State..... Disabled

External NAT IP Address..... 0.0.0.0

Link Local IPv6 Address..... fe80::250:56ff:feac:6d08/64

STATE ..... REACHABLE

Primary IPv6 Address..... ::/128

STATE ..... NONE

Primary IPv6 Gateway..... ::

Primary IPv6 Gateway Mac Address..... 00:00:00:00:00:00

STATE ..... INCOMPLETE

VLAN..... 1520

Quarantine-vlan..... 0

Physical Port..... 1

DHCP Proxy Mode..... Global

Primary DHCP Server..... 192.168.250.1

Secondary DHCP Server..... Unconfigured

DHCP Option 82..... Disabled

DHCP Option 82 bridge mode insertion..... Disabled

IPv4 ACL..... Unconfigured

IPv6 ACL..... Unconfigured

mDNS Profile Name..... Unconfigured

AP Manager..... Yes

Guest Interface..... N/A

L2 Multicast..... Enabled

Interface Name..... service-port

MAC Address..... 00:50:56:ac:63:38

IP Address..... 192.168.29.146

IP Netmask..... 255.255.255.0

Link Local IPv6 Address..... fe80::250:56ff:feac:6338/64

STATE ..... NONE

IPv6 Address..... ::/128

STATE ..... NONE

SLAAC..... Disabled

DHCP Protocol..... Disabled

AP Manager..... No

Guest Interface..... N/A

Speed 1Gbps

Duplex ..... Full

Auto Negotiation ..... Enabled

Link Status..... Up

Port specific Information:

inet addr:192.168.29.146 Bcast:192.168.29.255 Mask:255.255.255.0

inet6 addr: fe80::250:56ff:feac:6338/64 Scope:Link

UP BROADCAST RUNNING MULTICAST MTU:1430 Metric:1

RX packets:258830 errors:0 dropped:298 overruns:0 frame:0

TX packets:95115 errors:0 dropped:0 overruns:0 carrier:0

collisions:0 txqueuelen:1000

RX bytes:25069479 (23.9 MiB) TX bytes:55852901 (53.2 MiB)

Interface Name..... virtual

MAC Address..... 00:50:56:ac:6d:08

IP Address..... 1.1.1.1

Virtual DNS Host Name..... Disabled

AP Manager..... No

Guest Interface..... N/A

Interface Group Configuration

WLAN Configuration

WLAN Identifier..... 1

Profile Name..... IP_Dev No Encryption

Network Name (SSID)..... IP_Dev

Status..... Disabled

MAC Filtering..... Disabled

Broadcast SSID..... Enabled

AAA Policy Override..... Disabled

Network Admission Control

Client Profiling Status

Radius Profiling ..... Disabled

DHCP ..... Disabled

HTTP ..... Disabled

Local Profiling ..... Disabled

DHCP ..... Disabled

HTTP ..... Disabled

Radius-NAC State..... Disabled

SNMP-NAC State..... Disabled

Quarantine VLAN..... 0

Maximum number of Associated Clients..... 0

Maximum number of Clients per AP Radio..... 200

ATF Policy..... 0

Number of Active Clients..... 0

Exclusionlist Timeout..... 60 seconds

Session Timeout..... 86400 seconds

User Idle Timeout..... Disabled

Sleep Client..... disable

Sleep Client Timeout..... 720 minutes

User Idle Threshold..... 0 Bytes

NAS-identifier..... none

CHD per WLAN..... Enabled

Webauth DHCP exclusion..... Disabled

Interface..... ip_dev

Multicast Interface..... Not Configured

WLAN IPv4 ACL..... unconfigured

WLAN IPv6 ACL..... unconfigured

WLAN Layer2 ACL..... unconfigured

mDNS Status..... Disabled

mDNS Profile Name..... unconfigured

DHCP Server..... Default

DHCP Address Assignment Required..... Disabled

Static IP client tunneling..... Disabled

Tunnel Profile..... Unconfigured

Quality of Service..... Silver

Per-SSID Rate Limits..... Upstream Downstream

Average Data Rate..... 0 0

Average Realtime Data Rate..... 0 0

Burst Data Rate..... 0 0

Burst Realtime Data Rate..... 0 0

Per-Client Rate Limits..... Upstream Downstream

Average Data Rate..... 0 0

Average Realtime Data Rate..... 0 0

Burst Data Rate..... 0 0

Burst Realtime Data Rate..... 0 0

Scan Defer Priority..... 4,5,6

Scan Defer Time..... 100 milliseconds

WMM..... Allowed

WMM UAPSD Compliant Client Support..... Disabled

Media Stream Multicast-direct..... Disabled

CCX - AironetIe Support..... Enabled

CCX - Gratuitous ProbeResponse (GPR)..... Disabled

CCX - Diagnostics Channel Capability..... Disabled

Dot11-Phone Mode (7920)..... Disabled

Wired Protocol..... 802.1P (Tag=0)

Passive Client Feature..... Disabled

Peer-to-Peer Blocking Action..... Disabled

Radio Policy..... All

DTIM period for 802.11a radio..... 1

DTIM period for 802.11b radio..... 1

Radius Servers

Authentication..... Global Servers

Accounting..... Global Servers

Interim Update..... Enabled

Interim Update Interval..... 0

Framed IPv6 Acct AVP ..... Prefix

Dynamic Interface..... Disabled

Dynamic Interface Priority..... wlan

Local EAP Authentication..... Disabled

Radius NAI-Realm..... Disabled

Mu-Mimo..... Enabled

Security

802.11 Authentication:..... Open System

FT Support..... Disabled

Static WEP Keys..... Disabled

802.1X..... Disabled

Wi-Fi Protected Access (WPA/WPA2)..... Disabled

Wi-Fi Direct policy configured..... Disabled

EAP-Passthrough..... Disabled

CKIP ..... Disabled

Web Based Authentication..... Disabled

Web Authentication Timeout..... 300

Web-Passthrough..... Disabled

Mac-auth-server..... 0.0.0.0

Web-portal-server..... 0.0.0.0

Conditional Web Redirect..... Disabled

Splash-Page Web Redirect..... Disabled

Auto Anchor..... Disabled

FlexConnect Local Switching..... Enabled

FlexConnect Central Association..... Disabled

flexconnect Central Dhcp Flag..... Disabled

flexconnect nat-pat Flag..... Disabled

flexconnect Dns Override Flag..... Disabled

flexconnect PPPoE pass-through..... Disabled

flexconnect local-switching IP-source-guar.... Disabled

FlexConnect Vlan based Central Switching ..... Disabled

FlexConnect Local Authentication..... Disabled

FlexConnect Learn IP Address..... Enabled

Client MFP..... Optional but inactive (WPA2 not configured)

PMF..... Disabled

PMF Association Comeback Time..... 1

PMF SA Query RetryTimeout..... 200

Tkip MIC Countermeasure Hold-down Timer..... 60

Eap-params..... Not Applicable

Flex Avc Profile Name..... None

Flow Monitor Name..... None

Split Tunnel Configuration

Split Tunnel..... Disabled

Call Snooping..... Disabled

Roamed Call Re-Anchor Policy..... Disabled

SIP CAC Fail Send-486-Busy Policy..... Enabled

SIP CAC Fail Send Dis-Association Policy..... Disabled

KTS based CAC Policy..... Disabled

Assisted Roaming Prediction Optimization..... Disabled

802.11k Neighbor List..... Disabled

802.11k Neighbor List Dual Band..... Disabled

802.11v Directed Multicast Service..... Disabled

802.11v BSS Max Idle Service..... Enabled

802.11v BSS Transition Service..... Disabled

802.11v BSS Transition Disassoc Imminent..... Disabled

802.11v BSS Transition Disassoc Timer..... 200

802.11v BSS Transition OpRoam Disassoc Timer..... 40

DMS DB is empty

Band Select..... Disabled

Load Balancing..... Disabled

Multicast Buffer..... Disabled

Universal Ap Admin..... Disabled

Mobility Anchor List

WLAN ID	IP Address	Status	Priority
-------	---------------	------	--------

802.11u..... Disabled

MSAP Services..... Disabled

Local Policy

Priority Policy Name

-------- ---

WLAN Configuration

WLAN Identifier..... 2

Profile Name..... IP_Dev All WPA/WPA2 PSK

Network Name (SSID)..... IP_Dev

Status..... Enabled

MAC Filtering..... Disabled

Broadcast SSID..... Enabled

AAA Policy Override..... Disabled

Network Admission Control

Client Profiling Status

Radius Profiling ..... Disabled

DHCP ..... Disabled

HTTP ..... Disabled

Local Profiling ..... Disabled

DHCP ..... Disabled

HTTP ..... Disabled

Radius-NAC State..... Disabled

SNMP-NAC State..... Disabled

Quarantine VLAN..... 0

Maximum number of Associated Clients..... 0

Maximum number of Clients per AP Radio..... 200

ATF Policy..... 0

Number of Active Clients..... 2

Exclusionlist Timeout..... 60 seconds

Session Timeout..... 1800 seconds

User Idle Timeout..... Disabled

Sleep Client..... disable

Sleep Client Timeout..... 720 minutes

User Idle Threshold..... 0 Bytes

NAS-identifier..... none

CHD per WLAN..... Enabled

Webauth DHCP exclusion..... Disabled

Interface..... ip_dev

Multicast Interface..... Not Configured

WLAN IPv4 ACL..... unconfigured

WLAN IPv6 ACL..... unconfigured

WLAN Layer2 ACL..... unconfigured

mDNS Status..... Disabled

mDNS Profile Name..... unconfigured

DHCP Server..... Default

DHCP Address Assignment Required..... Disabled

Static IP client tunneling..... Disabled

Tunnel Profile..... Unconfigured

Quality of Service..... Silver

Per-SSID Rate Limits..... Upstream Downstream

Average Data Rate..... 0 0

Average Realtime Data Rate..... 0 0

Burst Data Rate..... 0 0

Burst Realtime Data Rate..... 0 0

Per-Client Rate Limits..... Upstream Downstream

Average Data Rate..... 0 0

Average Realtime Data Rate..... 0 0

Burst Data Rate..... 0 0

Burst Realtime Data Rate..... 0 0

Scan Defer Priority..... 4,5,6

Scan Defer Time..... 100 milliseconds

WMM..... Allowed

WMM UAPSD Compliant Client Support..... Disabled

Media Stream Multicast-direct..... Disabled

CCX - AironetIe Support..... Enabled

CCX - Gratuitous ProbeResponse (GPR)..... Disabled

CCX - Diagnostics Channel Capability..... Disabled

Dot11-Phone Mode (7920)..... Disabled

Wired Protocol..... 802.1P (Tag=0)

Passive Client Feature..... Disabled

Peer-to-Peer Blocking Action..... Disabled

Radio Policy..... All

DTIM period for 802.11a radio..... 1

DTIM period for 802.11b radio..... 1

Radius Servers

Authentication..... Global Servers

Accounting..... Global Servers

Interim Update..... Enabled

Interim Update Interval..... 0

Framed IPv6 Acct AVP ..... Prefix

Dynamic Interface..... Disabled

Dynamic Interface Priority..... wlan

Local EAP Authentication..... Disabled

Radius NAI-Realm..... Disabled

Mu-Mimo..... Enabled

Security

802.11 Authentication:..... Open System

FT Support..... Disabled

Static WEP Keys..... Disabled

802.1X..... Disabled

Wi-Fi Protected Access (WPA/WPA2)..... Enabled

WPA (SSN IE)..... Enabled

TKIP Cipher..... Enabled

AES Cipher..... Enabled

WPA2 (RSN IE)..... Enabled

TKIP Cipher..... Disabled

AES Cipher..... Enabled

OSEN IE..... Disabled

Auth Key Management

802.1x..... Disabled

PSK..... Enabled

CCKM..... Disabled

FT-1X(802.11r)..... Disabled

FT-PSK(802.11r)..... Disabled

PMF-1X(802.11w)..... Disabled

PMF-PSK(802.11w)..... Disabled

OSEN-1X..... Disabled

FT Reassociation Timeout..... 20

FT Over-The-DS mode..... Disabled

GTK Randomization..... Disabled

SKC Cache Support..... Disabled

CCKM TSF Tolerance..... 1000

Wi-Fi Direct policy configured..... Disabled

EAP-Passthrough..... Disabled

CKIP ..... Disabled

Web Based Authentication..... Disabled

Web Authentication Timeout..... 300

Web-Passthrough..... Disabled

Mac-auth-server..... 0.0.0.0

Web-portal-server..... 0.0.0.0

Conditional Web Redirect..... Disabled

Splash-Page Web Redirect..... Disabled

Auto Anchor..... Disabled

FlexConnect Local Switching..... Disabled

FlexConnect Central Association..... Disabled

flexconnect Central Dhcp Flag..... Disabled

flexconnect nat-pat Flag..... Disabled

flexconnect Dns Override Flag..... Disabled

flexconnect PPPoE pass-through..... Disabled

flexconnect local-switching IP-source-guar.... Disabled

FlexConnect Vlan based Central Switching ..... Disabled

FlexConnect Local Authentication..... Disabled

FlexConnect Learn IP Address..... Enabled

Client MFP..... Optional

PMF..... Disabled

PMF Association Comeback Time..... 1

PMF SA Query RetryTimeout..... 200

Tkip MIC Countermeasure Hold-down Timer..... 60

Eap-params..... Disabled

Flex Avc Profile Name..... None

Flow Monitor Name..... None

Split Tunnel Configuration

Split Tunnel..... Disabled

Call Snooping..... Disabled

Roamed Call Re-Anchor Policy..... Disabled

SIP CAC Fail Send-486-Busy Policy..... Enabled

SIP CAC Fail Send Dis-Association Policy..... Disabled

KTS based CAC Policy..... Disabled

Assisted Roaming Prediction Optimization..... Disabled

802.11k Neighbor List..... Disabled

802.11k Neighbor List Dual Band..... Disabled

802.11v Directed Multicast Service..... Disabled

802.11v BSS Max Idle Service..... Enabled

802.11v BSS Transition Service..... Disabled

802.11v BSS Transition Disassoc Imminent..... Disabled

802.11v BSS Transition Disassoc Timer..... 200

802.11v BSS Transition OpRoam Disassoc Timer..... 40

DMS DB is empty

Band Select..... Disabled

Load Balancing..... Disabled

Multicast Buffer..... Disabled

Universal Ap Admin..... Disabled

Mobility Anchor List

WLAN ID	IP Address	Status	Priority
-------	---------------	------	--------

802.11u..... Disabled

MSAP Services..... Disabled

Local Policy

Priority Policy Name

-------- ---

Policy Configuration

L2ACL Configuration

ACL Configuration

CPU ACL Configuration

CPU Acl Name..... NOT CONFIGURED

Wireless Traffic..... Disabled

Wired Traffic..... Disabled

RADIUS Configuration

Vendor Id Backward Compatibility..... Disabled

Call Station Id Case..... lower

Accounting Call Station Id Type..... Mac Address

Auth Call Station Id Type..... AP's Radio MAC Address:SSID

Extended Source Ports Support..... Enabled

Aggressive Failover..... Enabled

Keywrap..... Disabled

Fallback Test:

Test Mode..... Passive

Probe User Name..... cisco-probe

Interval (in seconds)..... 300

MAC Delimiter for Authentication Messages..... hyphen

MAC Delimiter for Accounting Messages..... hyphen

RADIUS Authentication Framed-MTU..... 1300 Bytes

Authentication Servers

Idx Type Server Address Port State Tout MgmtTout RFC3576 IPSec - AuthMode/Phase1/Group/Lifetime/Auth/Encr/Region

--- ---- ---------- ------ -------- ---- -------- ------- ----------

Accounting Servers

Idx Type Server Address Port State Tout MgmtTout RFC3576 IPSec - AuthMode/Phase1/Group/Lifetime/Auth/Encr/Region

--- ---- ---------- ------ -------- ---- -------- ------- ----------

TACACS Configuration

Fallback Test:

Interval (in seconds)..... 0

Authentication Servers

Idx Server Address Port State Tout MgmtTout

--- ---------- ------ ------- ----- --------

Authorization Servers

Idx Server Address Port State Tout MgmtTout

--- ---------- ------ ------- ----- --------

Accounting Servers

Idx Server Address Port State Tout MgmtTout

--- ---------- ------ ------- ----- --------

LDAP Configuration

Local EAP Configuration

User credentials database search order:

Primary ..... Local DB

Timer:

Active timeout 300

Configured EAP profiles:

EAP Method configuration:

EAP-FAST:

Server key ..... <hidden>

TTL for the PAC 10

Anonymous provision allowed ..... Yes

Authority ID 436973636f00000000000000000000000

Authority Information ..... Cisco A-ID

Dns Configuration

Radius port.....

Radius secret.....

Dns url.....

Dns timeout.....

Dns Serverip.....

Dns state..... Disable

Dns Auth Retransmit Timeout..... 2

Dns Acct Retransmit Timeout..... 2

Dns Auth Mgmt-Retransmit Timeout..... 2

Dns Network Auth..... Enable

Dns Mgmt Auth..... Enable

Dns Network Acct..... Enable

Dns RFC 3576 Auth..... Disable

Tacacs port.....

Tacacs secret..... 2

Dns url.....

Dns timeout.....

Dns Serverip.....

Dns state..... Disable

Fallback Radio Shut configuration:

Fallback Radio Shut: Disabled

Arp-caching: Disabled

Subnet Broadcast Drop: Disabled

FlexConnect Group Summary

FlexConnect Group Summary: Count: 0

Group Name # Aps

FlexConnect Group Detail

FlexConnect Vlan name Summary

Vlan-Name Id Status

--- ---

FlexConnect Vlan Name Detail

Route Info

Number of Routes..... 0

Destination Network Netmask Gateway

---------- ---------- ----------

Peer Route Info

Number of Routes..... 32555

Destination Network Netmask Gateway

---------- ---------- ----------

Qos Queue Length Info

Platinum queue length..... 100

Gold queue length..... 75

Silver queue length..... 50

Bronze queue length..... 25

Qos Profile Info

Description..... For Voice Applications

Maximum Priority..... voice

Unicast Default Priority..... voice

Multicast Default Priority..... voice

Per-SSID Rate Limits..... Upstream Downstream

Average Data Rate..... 0 0

Average Realtime Data Rate..... 0 0

Burst Data Rate..... 0 0

Burst Realtime Data Rate..... 0 0

Per-Client Rate Limits..... Upstream Downstream

Average Data Rate..... 0 0

Average Realtime Data Rate..... 0 0

Burst Data Rate..... 0 0

Burst Realtime Data Rate..... 0 0

protocol..... dot1p

dot1p..... 5

Description..... For Video Applications

Maximum Priority..... video

Unicast Default Priority..... video

Multicast Default Priority..... video

Per-SSID Rate Limits..... Upstream Downstream

Average Data Rate..... 0 0

Average Realtime Data Rate..... 0 0

Burst Data Rate..... 0 0

Burst Realtime Data Rate..... 0 0

Per-Client Rate Limits..... Upstream Downstream

Average Data Rate..... 0 0

Average Realtime Data Rate..... 0 0

Burst Data Rate..... 0 0

Burst Realtime Data Rate..... 0 0

protocol..... dot1p

dot1p..... 4

Description..... For Best Effort

Maximum Priority..... besteffort

Unicast Default Priority..... besteffort

Multicast Default Priority..... besteffort

Per-SSID Rate Limits..... Upstream Downstream

Average Data Rate..... 0 0

Average Realtime Data Rate..... 0 0

Burst Data Rate..... 0 0

Burst Realtime Data Rate..... 0 0

Per-Client Rate Limits..... Upstream Downstream

Average Data Rate..... 0 0

Average Realtime Data Rate..... 0 0

Burst Data Rate..... 0 0

Burst Realtime Data Rate..... 0 0

protocol..... dot1p

dot1p..... 0

Description..... For Background

Maximum Priority..... background

Unicast Default Priority..... background

Multicast Default Priority..... background

Per-SSID Rate Limits..... Upstream Downstream

Average Data Rate..... 0 0

Average Realtime Data Rate..... 0 0

Burst Data Rate..... 0 0

Burst Realtime Data Rate..... 0 0

Per-Client Rate Limits..... Upstream Downstream

Average Data Rate..... 0 0

Average Realtime Data Rate..... 0 0

Burst Data Rate..... 0 0

Burst Realtime Data Rate..... 0 0

protocol..... dot1p

dot1p..... 1

Mac Filter Info

Authorization List

Authorize MIC APs against Auth-list or AAA ..... disabled

Authorize LSC APs against Auth-List ..... disabled

APs Allowed to Join

AP with Manufacturing Installed Certificate.... yes

AP with Self-Signed Certificate..... no

AP with Locally Significant Certificate..... no

Load Balancing Info

Aggressive Load Balancing..... per WLAN enabling

Aggressive Load Balancing Window..... 5 clients

Aggressive Load Balancing Denial Count..... 3

Aggressive Load Balancing Uplink Threshold..... 50

Statistics (client-count based)

Total Denied Count..... 0 clients

Total Denial Sent..... 0 messages

Exceeded Denial Max Limit Count..... 0 times

None 5G Candidate Count..... 0 times

None 2.4G Candidate Count..... 0 times

Statistics (uplink-usage based)

Total Denied Count..... 0 clients

Total Denial Sent..... 0 messages

Exceeded Denial Max Limit Count..... 0 times

None 5G Candidate Count..... 0 times

None 2.4G Candidate Count..... 0 times

DHCP Info

DHCP Opt-82 RID Format: <AP radio MAC address>

DHCP Opt-82 Format: binary

DHCP Proxy Behaviour: disabled

Exclusion List ConfigurationUnable to retrieve exclusion-list entry

CDP Configuration

cdp version v2

Country Channels Configuration

```
Configured Country..... US  - United States
     KEY: * = Channel is legal in this country and may be configured manually.
          A = Channel is the Auto-RF default in this country.
          . = Channel is not legal in this country.
          C = Channel has been configured for use by Auto-RF.
          x = Channel is available to be configured for use by Auto-RF.
        (-,-) = (indoor, outdoor) regulatory domain allowed by this country.
-----------------:+-+-+-+-+-+-+-+-+-+-+-+-+-+-
   802.11bg     :
   Channels     :               1 1 1 1 1
                : 1 2 3 4 5 6 7 8 9 0 1 2 3 4
-----------------:+-+-+-+-+-+-+-+-+-+-+-+-+-+-
 US (-A   ,-AB  ): A * * * * A * * * * A . . .
-----------------:+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
   802.11a      :                   1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
   Channels     : 3 3 3 4 4 4 4 4 5 5 6 6 0 0 0 1 1 2 2 2 3 3 4 4 4 5 5 6 6 6 7
                : 4 6 8 0 2 4 6 8 2 6 0 4 0 4 8 2 6 0 4 8 2 6 0 4 9 3 7 1 5 9 3
-----------------:+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
 US (-AB  ,-AB  ): . A . A . A . A A A A A A A A A A A A A A A A A A A A A * . .
-----------------:+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
 4.9GHz 802.11a  :
   Channels     :               1 1 1 1 1 1 1 1 1 2 2 2 2 2 2
                : 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6
-----------------:+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
 US (-AB  ,-AB  ): * * * * * * * * * * * * * * * * * * * * A * * * * * A
-----------------:+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
```

WPS Configuration Summary

Auto-Immune

Auto-Immune..... Disabled

Auto-Immune by aWIPS Prevention..... Disabled

Client Exclusion Policy

Excessive 802.11-association failures..... Enabled

Excessive 802.11-authentication failures..... Enabled

Excessive 802.1x-authentication..... Enabled

IP-theft..... Enabled

Excessive Web authentication failure..... Enabled

Maximum 802.1x-AAA failure attempts..... 3

Signature Policy

Signature Processing..... Enabled

Management Frame Protection

Global Infrastructure MFP state..... DISABLED (*all infrastructure settings are overridden)

AP Impersonation detection..... Disabled

Controller Time Source Valid..... False

		WLAN	Client
WLAN ID	WLAN Name	Status	Protection
1	IP_Dev No Encryption	Disabled	Optional but inactive (WPA2 not configured)

2 IP_Dev All WPA/WPA2 PSK Enabled Optional

Custom Web Configuration

Radius Authentication Method..... PAP

Cisco Logo..... Enabled

CustomLogo..... None

Custom Title..... None

Custom Message..... None

Custom Redirect URL..... None

Web Authentication Type..... Internal Default

Logout-popup..... Enabled

External Web Authentication URL..... None

Configuration Per Profile:

Core dump Configuration

Core Dump upload is disabled

Rogue AP Configuration

Rogue Detection Security Level..... custom

Rogue Pending Time..... 180 secs

Rogue on wire Auto-Contain..... Disabled

Rogue using our SSID Auto-Contain..... Disabled

Valid client on rogue AP Auto-Contain..... Disabled

Rogue AP timeout..... 1200

Rogue Detection Report Interval..... 10

Rogue Detection Min Rssi..... -90

Rogue Detection Transient Interval..... 0

Rogue Detection Client Num Thershold..... 0

Validate rogue AP against AAA..... Disabled

Rogue AP AAA validation interval..... 0 secs

Total Rogues(AP+Ad-hoc) supported..... 800

Total Rogues classified..... 41

MAC Address	Classification	# APs	# Clients	Last Heard
04:bd:88:b5:2f:40	Friendly	2	0	Thu Aug 18 20:06:04 2016
04:bd:88:b5:2f:45	Friendly	2	0	Thu Aug 18 20:06:04 2016
04:bd:88:b5:2f:50	Friendly	0	0	Not Heard
04:bd:88:b5:2f:55	Friendly	0	0	Not Heard
04:bd:88:b5:4e:e0	Friendly	0	0	Not Heard
04:bd:88:b5:4e:f0	Friendly	0	0	Not Heard
04:bd:88:b5:5a:20	Unclassified	2	0	Thu Aug 18 20:06:04 2016
04:bd:88:b5:5a:21	Unclassified	2	0	Thu Aug 18 20:06:04 2016
04:bd:88:b6:0d:60	Friendly	0	0	Not Heard
04:bd:88:b6:0d:70	Friendly	0	0	Not Heard
04:bd:88:b6:0d:75	Friendly	0	0	Not Heard

04:bd:88:b6:0e:e0 Friendly 0 0 Not Heard

04:bd:88:b6:0e:f0 Friendly 0 0 Not Heard

04:bd:88:b6:0e:f5 Friendly 0 0 Not Heard

04:bd:88:b6:10:00 Friendly 0 0 Not Heard

04:bd:88:b6:10:10 Friendly 0 0 Not Heard

04:bd:88:b6:10:15 Friendly 0 0 Not Heard

04:bd:88:b6:10:60 Friendly 2 0 Thu Aug 18 20:06:04 2016

04:bd:88:b6:10:65 Unclassified 2 0 Thu Aug 18 20:06:04 2016

04:bd:88:b6:10:70 Friendly 0 0 Not Heard

04:bd:88:b6:10:75 Friendly 0 0 Not Heard

04:bd:88:b6:10:b5 Friendly 0 0 Not Heard

62:6d:c7:27:a6:98 Unclassified 2 0 Thu Aug 18 20:06:04 2016

6c:72:20:3e:af:26 Friendly 0 0 Not Heard

6c:72:20:3e:af:28 Friendly 0 0 Not Heard

6c:72:20:3e:af:2a Friendly 0 0 Not Heard

88:dc:96:30:d9:1b Friendly 0 0 Not Heard

8a:dc:96:30:d9:1b Friendly 0 0 Not Heard

9a:dc:96:30:d9:1b Friendly 0 0 Not Heard

e0:d1:73:02:b7:ab Friendly 0 0 Not Heard

e0:d1:73:02:b7:af Friendly 0 0 Not Heard

e0:d1:73:02:bc:2b Friendly 0 0 Not Heard

e0:d1:73:02:bc:2f Friendly 0 0 Not Heard

e0:d1:73:02:f6:6b Friendly 0 0 Not Heard

e0:d1:73:02:f6:6f Friendly 0 0 Not Heard

e0:d1:73:02:f9:4b Friendly 0 0 Not Heard

e0:d1:73:02:f9:4f Friendly 0 0 Not Heard

e0:d1:73:02:fa:4b Friendly 0 0 Not Heard

e0:d1:73:02:fa:4f Friendly 0 0 Not Heard

e0:d1:73:02:ff:1b Friendly 0 0 Not Heard

e0:d1:73:02:ff:1f Friendly 0 0 Not Heard

Rogue AP RLDP Configuration

Rogue Location Discovery Protocol..... Disabled

RLDP Schedule Config..... Disabled

RLDP Scheduling Operation..... Disabled

RLDP Retry..... 1

RLDP Start Time RLDP End Time Day

--- --- ---

Rogue Auto Contain Configuration

Containment Level..... 1

monitor_ap_only..... false

Adhoc Rogue Configuration

Detect and report Ad-Hoc Networks..... Enabled

Auto-Contain Ad-Hoc Networks..... Disabled

Total Rogues(Ad-Hoc+AP) supported 800

Total Ad-Hoc entries 0

Client MAC Address Adhoc BSSID State # APs Last Heard

--- --- --- --- ---

Rogue Client Configuration

Validate rogue clients against AAA..... Disabled

Validate rogue clients against MSE..... Disabled

Total Rogue Clients supported..... 3000

Total Rogue Clients present..... 0

MAC Address State # APs Last Heard

---------- ---------- ----- ----------

Ignore List Configuration

MAC Address

Rogue Rule Configuration

Priority Rule Name Rule state Class Type Notify State Match Hit Count

-------- ---------- ---------- ---------- -------- -------- ------ ---------

Media-Stream Configuration

Multicast-direct State..... disable

Allowed WLANs.....

Stream Name Start IP End IP Operation Status

---------- ---------- ---------- ----------

URL.....

E-mail.....

Phone.....

Note.....

State..... disable

2.4G Band Media-Stream Configuration

Multicast-direct..... Enabled

Best Effort..... Disabled

Video Re-Direct..... Enabled

Max Allowed Streams Per Radio..... Auto

Max Allowed Streams Per Client..... Auto

Max Video Bandwidth..... 0

Max Voice Bandwidth..... 75

Max Media Bandwidth..... 85

Min PHY Rate..... 6000

Max Retry Percentage..... 80

5G Band Media-Stream Configuration

Multicast-direct..... Enabled

Best Effort..... Disabled

Video Re-Direct..... Enabled

Max Allowed Streams Per Radio..... Auto

Max Allowed Streams Per Client..... Auto

Max Video Bandwidth..... 0

Max Voice Bandwidth..... 75

Max Media Bandwidth..... 85

Min PHY Rate..... 6000

Max Retry Percentage..... 80

Number of Clients..... 0

Client Mac	Stream Name	Stream Type	Radio	WLAN	QoS	Status
----------	----------	----------	----	----	------	-------

WLC Voice Call Statistics

WLC Voice Call Statistics for 802.11b Radio

WMM TSPEC CAC Call Stats

Total num of Calls in progress..... 0

Num of Roam Calls in progress..... 0

Total Num of Calls Admitted..... 0

Total Num of Roam Calls Admitted..... 0

Total Num of exp bw requests received..... 0

Total Num of exp bw requests Admitted..... 0

Total Num of Calls Rejected..... 0

Total Num of Roam Calls Rejected..... 0

Num of Calls Rejected due to insufficent bw.... 0

Num of Calls Rejected due to invalid params.... 0

Num of Calls Rejected due to PHY rate..... 0

Num of Calls Rejected due to QoS policy..... 0

SIP CAC Call Stats

Total Num of Calls in progress..... 0

Num of Roam Calls in progress..... 0

Total Num of Calls Admitted..... 0

Total Num of Roam Calls Admitted..... 0

Total Num of Preferred Calls Received..... 0

Total Num of Preferred Calls Admitted..... 0

Total Num of Ongoing Preferred Calls..... 0

Total Num of Calls Rejected(Insuff BW)..... 0

Total Num of Roam Calls Rejected(Insuff BW).... 0

KTS based CAC Call Stats

Total Num of Calls in progress..... 0

Num of Roam Calls in progress..... 0

Total Num of Calls Admitted..... 0

Total Num of Roam Calls Admitted..... 0

Total Num of Calls Rejected(Insuff BW)..... 0

Total Num of Roam Calls Rejected(Insuff BW).... 0

WLC Voice Call Statistics for 802.11a Radio

WMM TSPEC CAC Call Stats

Total num of Calls in progress..... 0

Num of Roam Calls in progress..... 0

Total Num of Calls Admitted..... 0

Total Num of Roam Calls Admitted..... 0

Total Num of exp bw requests received..... 0

Total Num of exp bw requests Admitted..... 0

Total Num of Calls Rejected..... 0

Total Num of Roam Calls Rejected..... 0

Num of Calls Rejected due to insufficent bw.... 0

Num of Calls Rejected due to invalid params.... 0

Num of Calls Rejected due to PHY rate..... 0

Num of Calls Rejected due to QoS policy..... 0

SIP CAC Call Stats

Total Num of Calls in progress..... 0

Num of Roam Calls in progress..... 0

Total Num of Calls Admitted..... 0

Total Num of Roam Calls Admitted..... 0

Total Num of Preferred Calls Received..... 0

Total Num of Preferred Calls Admitted..... 0

Total Num of Ongoing Preferred Calls..... 0

Total Num of Calls Rejected(Insuff BW)..... 0

Total Num of Roam Calls Rejected(Insuff BW).... 0

KTS based CAC Call Stats

Total Num of Calls in progress..... 0

Num of Roam Calls in progress..... 0

Total Num of Calls Admitted..... 0

Total Num of Roam Calls Admitted..... 0

Total Num of Calls Rejected(Insuff BW)..... 0

Total Num of Roam Calls Rejected(Insuff BW).... 0

WLC IPv6 Summary

Global Config..... Enabled

Reachable-lifetime value..... 300

Stale-lifetime value..... 86400

Down-lifetime value..... 30

RA Throttling..... Disabled

RA Throttling allow at-least..... 1

RA Throttling allow at-most..... 1

RA Throttling max-through..... 10

RA Throttling throttle-period..... 600

RA Throttling interval-option..... passthrough

NS Mulitcast CacheMiss Forwarding..... Disabled

NA Mulitcast Forwarding..... Enabled

IPv6 Capwap UDP Lite..... Enabled

Operating System IPv6 state..... Enabled

mDNS Service Summary

Number of Services..... 10

Mobility learning status ..... Enabled

Service-Name	LSS	Origin	No SP	Service-string
AirTunes	No	All	0	_raop._tcp.local.
Airplay	No	All	0	_airplay._tcp.local.
Googlecast	No	All	0	_googlecast._tcp.local.
HP_Photosmart_Printer_1	No	All	0	_universal._sub._ipp._tcp.local.
HP_Photosmart_Printer_2	No	All	0	_cups._sub._ipp._tcp.local.
HomeSharing	No	All	0	_home-sharing._tcp.local.
Printer-IPP	No	All	0	_ipp._tcp.local.
Printer-IPPS	No	All	0	_ipps._tcp.local.
Printer-LPD	No	All	0	_printer._tcp.local.
Printer-SOCKET	No	All	0	_pdl-datastream._tcp.local.

* -> If access policy is enabled LSS will be ignored.

mDNS service-group Summary

Access Policy Status..... Disabled

Total number of mDNS Policies..... 1

Number of Admin configured Policies..... 1

Sl No	Service Group Name	Description	Origin
1	default-mdns-policy	Default Access Policy created by WLC	WLC

mDNS profile detailed

Profile Name..... default-mdns-profile

Profile Id..... 1

No of Services..... 10

Services..... AirTunes

Airplay

Googlecast

HP_Photosmart_Printer_1

HP_Photosmart_Printer_2

HomeSharing

Printer-IPP

Printer-IPPS

Printer-LPD

Printer-SOCKET

No. Interfaces Attached..... 0

No. Interface Groups Attached..... 0

No. Wlans..... 0

No. Local Policies Attached..... 0

mDNS AP Summary

Number of mDNS APs..... 0

PMIPv6 Global Configuration

PMIPv6 Profile Summary

No Profile Created.

PMIPv6 MAG Statistics

PMIPv6 domain has to be configured first

EoGRE Global Configuration

Heartbeat Interval.....60

Max Heartbeat Skip Count.....3

Interface.....management

EoGRE Gateway Configuration

EoGRE Domain Configuration

Domain Name Gateways Active Gateway

---------- ---------- ----------

EoGRE Profile Configuration

WLAN Express Setup Information.

WLAN Express Setup - ..... False

Flex Avc Profile summary.

Profile-Name	Number of Rules	status
==========	==========	========

Flex Avc Profile Detailed Configuration.

Certificate Summary.

Web Administration Certificate..... 3rd Party

Web Authentication Certificate..... Locally Generated

Certificate compatibility mode:..... off

Lifetime Check Ignore for MIC ..... Disable

Lifetime Check Ignore for SSC ..... Disable

Smart-licensing status Summary.

Call-home Summary.

Hotspot Icon Summary.

Unable to find Icon directory in flash.

Coredump Summary

Core Dump upload is disabled

Memory Summary

---------- System Memory Summary ----------

System Name:wlc Primary SW Ver:8.2.111.0

Current Time:Thu Aug 18 20:06:33 2016 System UP Time:6 days 3 hrs 49 mins 39 secs

NAME: "Chassis" , DESCR: "Cisco Wireless Controller"

PID: AIR-CTVM-K9, VID: V01, SN: 96NTPERK0A6

Total System Memory..... (2057560 KB) 2009 MB

Total System Free Memory..... (909360 KB) 888 MB (44 %)

Total Memory in Buffers..... (1104 KB)

Total Memory in Cache..... (266564 KB) 260 MB

Total Active Memory..... (511540 KB) 499 MB

Total InActive Memory..... (238112 KB) 232 MB

Total Memory in Anon Pages..... (481984 KB) 470 MB

Total Memory in Slab..... (11004 KB) 10 MB

Total Memory in Page Tables..... (2748 KB) 2 MB

WLC Peak Memory..... (1402280 KB) 1369 MB

WLC Virtual Memory Size..... (1383912 KB) 1351 MB

WLC Resident Memory..... (506340 KB) 494 MB

WLC Data Segment Memory..... (1318240 KB) 1287 MB

Total Heap Including Mapped Pages..... (399115 KB) 389 MB

Total Memory in Pmalloc Pools..... (350174 KB) 341 MB

Total Used Memory in Pmalloc Pools..... (324913 KB) 317 MB

Total Free Memory in Pmalloc Pools..... (16706 KB) 16 MB

---------- Pmalloc Pools Information ----------

Index Pool-Size Chunks-In-Pool Chunks-In-Use Memory(Size/Used/Free)KB

0 16 50000 5351 5468 /4771 /697

1 64 40000 16626 6250 /4789 /1460

2 128 52800 52677 11550 /11534 /15

3 256 9400 9377 3231 /3225 /5

4 384 6000 287 2812 /670 /2142

5 512 16000 15 9500 /1507 /7992

6 1024 13100 12985 14328 /14213 /115

7 2048 1000 712 2093 /1517 /576

8 4096 1000 74 4093 /389 /3704

9 Raw-Pool 0 524 290800 /290800 /0

---------- MBUF Information ----------

Maximum number of Mbufs..... 24576

Number of Mbufs Free..... 24560

Number of Mbufs In Use..... 16

Mesh Configuration

Mesh Range..... 12000

Mesh Statistics update period..... 3 minutes

Backhaul with client access status..... disabled

Backhaul with extended client access status..... disabled

Background Scanning State..... disabled

Subset Channel Sync State..... disabled

Backhaul Amsdu State..... enabled

Backhaul RRM..... disabled

Mesh Auto RF..... disabled

Mesh Security

Security Mode..... EAP

External-Auth..... disabled

Use MAC Filter in External AAA server..... disabled

Force External Authentication..... disabled

LSC Only MAP Authentication..... disabled

Mesh Alarm Criteria

Max Hop Count..... 4

Recommended Max Children for MAP..... 10

Recommended Max Children for RAP..... 20

Low Link SNR..... 12

High Link SNR..... 60

Max Association Number..... 10

Association Interval..... 60 minutes

Parent Change Numbers..... 3

Parent Change Interval..... 60 minutes

Mesh Multicast Mode..... In-Out

Mesh CAC Mode..... enabled

Mesh Full Sector DFS..... enabled

Mesh Ethernet Bridging VLAN Transparent Mode..... enabled

Mesh DCA channels for serial backhaul APs..... disabled

Outdoor Ext. UNII B Domain channels(for BH)..... disabled

Mesh Advanced LSC..... disabled

Advanced LSC AP Provisioning ..... disabled

Open Window..... disabled

Provision Controller..... disabled

Mesh Slot Bias..... enabled

Mesh Convergence Method..... standard

Mesh Channel Change Notification..... disabled

Mesh Ethernet Bridging STP BPDU Allowed..... disabled

Mesh RAP downlink backhaul..... 802.11Radio-A (Slot 1)

Appendix B Sample Pump Configuration Parameters

B.1 Example of Pump Configuration File

SN=2011304

Pump serial number - must match SN of receiving pump

SIGMA Spectrum Settings

[NETWORK CONFIGURATION]

DHCP=0 DHCP disabled - IP, GATEWAY, NETMASK, and DNS must be valid

DHCP=1 DHCP enabled - IP, GATEWAY, NETMASK, and DNS must be blank

DHCP=1

IP=

GATEWAY=

NETMASK=

DNS=

Leave either SIGMAGW or MULTICAST blank

SIGMAGW set to DNS name or IP address of SIGMA gateway server

SIGMAGW=192.168.140.165

MULTICAST group default is 239.237.12.87

MULTICAST=

DEVICEID set to device alias

Limited to 20 alpha-numeric characters (0-1,A-Z,a-z), blank is acceptable

DEVICEID=000345

[WIFI CONFIGURATION]

BSS=0 Infrastructure mode (Access point)

BSS=1 Join or Create Ad-Hoc (peer-to-peer)

BSS=2 Join only Ad-Hoc (peer-to-peer)

BSS=3 Join any

BSS=0

SSID= set to wireless network name

SSID=IP_Dev_Cert

802.11 Mode - 'b', 'g', and/or 'a'

802.11b=1

802.11g=1

802.11a=1

CHANNEL=0 search channels

CHANNEL=0

SECURITY=0 Any available security method

SECURITY=1 Open system (no-encryption)

SECURITY=2 WEP shared key

SECURITY=3 WPA pre-shared key

SECURITY=4 WPA with 802.1x authentication

SECURITY=5 WEP with 802.1x authentication

SECURITY=6 LEAP

SECURITY=7 EAP-FAST

SECURITY=4

WEPKEYINDEX=0-3

WEPKEYINDEX=0

WEPKEY may be blank or 10 (64-bit) or 26 (128-bit) hex (0-1 and a-f)

characters long

WEPKEY=

WPAENCRYPTION=0 Any

WPAENCRYPTION=1 WEP

WPAENCRYPTION=2 TKIP

WPAENCRYPTION=3 CCMP (AES)

WPAENCRYPTION=4 Open (no encryption)

WPAENCRYPTION=3

WPAPSK must be blank if WPA PSK is not used

WPAPSK may 64 hex (0-1 and a-f) characters long to specify a PSK

WPAPSK may be 8-63 ascii characters long to specify a passphrase

WPAPSK=

802.1X/EAP Authentication method

Set one, or more, authentication methods to 1 to enable them, all others should be 0

LEAP=0

PEAP/MSCHAPv2=0

EAP-TLS=1

EAP-FAST=0

IDENTITY= 802.1X Identity (username)

IDENTITY=BaxterCert

PASSWORD= 802.1X Password

PASSWORD=

Certificate information follows, required for authentication modes that use a certificate.

All certificates and private keys must be PEM format (base64 encoded).

Client certificate, both cert and private key are required.

Certificate and key information is not output for security reasons.

Certificate information is radio specific, so the MAC address of the Wireless Battery Module

of the attached, or soon to be attached module must match.

If the certs or keys required a password, it should be specified in the 802.1x PASSWORD field above.

The MAC address specified below must match the module connected to the pump.

MAC=00:40:9d:66:db:45

CLIENTCERT=

-----BEGIN RSA PRIVATE KEY-----

MIIEowIBAAKCAQEAuhKvGS9womnF7tmM1IOWuzbvMct7u+TDYtoQSNEitAYe5Bjr

XR+tQOT/2b08nJUjVNl91/+3t2i9qUDDU58DTKKir9dmR5ridHlaIyhts8fB7h2a

rZ74YK+4/A1C2mNpmwqwDQlwWhJzJgSe5XeZF0ALTdS3LEggwpuPb6Eo2Wbnqwr0

/tbsRvaeEjwcIGOwmuy1v8TkrbSKeFt9I4B54Pcl3KsxbnnUjH7JIV9h/0nyrOKi

z2P+3maogCnOwxRQp79j/IgCS3JbUBMG14gKnxorJgLuBovqpsWIYO6k/qohIpyg

Vevc0UUj8XiyEun1ldT1SCXYke/I9jauLBB6OQIDAQABAoIBAHjnmw7qXG2r/Qju

IywTNOYBE/tvFL9KLgsVVm96NOp0762W45hm9NSt9/ErnS7BWWvQxoyLhHyQemx3
wHOdZy9snflUJQlyAqNcFs2xf1bJ/aETa2ZVXV61z6U3mLD+16f+kdZmw7JDOr8B
UZ4Y0EjjPHUeOsdzNpY9Lj6CoWBg+V3+TEo3WCqHsqHN8yoVKP30Xnfb1JMgRLf/
infhI6Qg6QKBM++vWQjlUYuM4hbQtQ6HmwWv2epu8YHFdmm3jTSrv+W8lBbY2N5D
N9tZsdUJ54NHiVZTjVmAXCxSpBp3+yTOMRpnzgW0v8MLMhFanjIC5QypG712HIQx
gk7LZGECgYEA4vB26UpZNxsOlgzcEQP8fQ82Dk5xNjb9e7qDSD85LUppR6F4xwNs
QPyFVYRemb+pQyIwn1X2SNAdRvsDwSsFVTV9ENi1PzlHbOfaBWE9/VNMaz8vCjfr
teC3So6bIWllHNeoOl8d1wrTOtGZFENH/H4DoOBC7U0aoYjvtnYBplMCgYEA0eaJ
mITPESmZRZI8kaCb/TrWLTZmH2SOCPgC/qVmJ2FiQ8iT3KJXJ5d8ophY84Kay4le
axVUUgIdKNyvNrf038Rx0DirN+qznSKPJuMdY+tnCxaXBjTj/tSwkeiNamZOXHeH
boVlReX6ONDvT+u9MkvMxDmhwBb9G4izw26a88MCgYAhqyFJLTGdPlNkqZXApIHC
IA6aAsNDEtd6kspFXrPh50dFTEx54iUeYxh4/oF2d/vprNnf2cYHOXEOhdEhyHsr
EBt082G4dowFOUScRbgHrGMLCj21W2SKAEPROOUFCPjqVYhs2I25yK5b7Jq0aeL1
L9Dj/kGPqT/JNWKzBEDsZwKBgQDFNt5BN0d20Kb5/xR5n3Xwz788a8g35rqtIplt
uOnqRk2Vcne67a0FvgeUnZ+17BiU9FSKOFgpVWMgaXkW6HBjbqehBB2bRCHOmhH2
b53Fq//9IxRy+G7fl+busJluRwGJT6Un6p3kttgLWgQAC3aQMzgJhjy7xt25aQ+9
p8ZfEQKBgB6jQAT31FxvPFHyjU4NdFeogJd2c2nFbkC7aqOEPKNG9Nbzn/VVWh7x
Rx7Axua3D2OYrCH7V1NcR9X1dInpyj/hYXc5/VdtLZ2yhEc2GiG/jfgNWk2W2BZd
2NLf54bgV67lkC2yKMK/5wBru+V73WmqvWfQ4KsMesLLBBzMRvJa

-----END RSA PRIVATE KEY-----
-----BEGIN CERTIFICATE-----
MIIFWzCCBEOgAwIBAgIQAr0FxoUrLR0mLxVp3m/RJzANBgkqhkiG9w0BAQsFADBx
MQswCQYDVQQGEwJVUzEVMBMGA1UEChMMRGlnaUNlcnQgSW5jMRkwFwYDVQQLExB3
d3cuZGlnaWNlcnQuY29tMTAwLgYDVQQDEydEaWdpQ2VydCBUZXN0IEludGVybWVk
aWF0ZSBSb290IENBIFNIQTIwHhcNMTcwMzE1MDAwMDAwWhcNMTgwMzE1MTIwMDAw
WjCBiDELMAkGA1UEBhMCVVMxCzAJBgNVBAgTAk1EMRIwEAYDVQQHEwlSb2Nrdmls
bGUxNzA1BgNVBAoTLk5hdGlvbmFsIEluc3RpdHV0ZSBvZiBTdGFuZGFyZHMgYW5k
IFRlY2hub2xvZ3kxDjAMBgNVBAsTBU5DQ29FMQ8wDQYDVQQDEwZCYXh0ZXIwggEi
MA0GCSqGSIb3DQEBAQUAA4IBDwAwggEKAoIBAQC6Eq8ZL3CiacXu2YzUg5a7Nu8x

y3u75MNi2hBI0SK0Bh7kGOtdH61A5P/ZvTyclSNU2X3X/7e3aL2pQMNTnwNMoqKv
12ZHmuJ0eVojKG2zx8HuHZqtnvhgr7j8DULaY2mbCrANCXBaEnMmBJ7ld5kXQAtN
1LcsSCDCm49voSjZZuerCvT+1uxG9p4SPBwgY7Ca7LW/xOSttIp4W30jgHng9yXc
qzFuedSMfskhX2H/SfKs4qLPY/7eZqiAKc7DFFCnv2P8iAJLcltQEwbXiAqfGism
Au4Gi+qmxYhg7qT+qiEinKBV69zRRSPxeLIS6fWV1PVlJdiR78j2Nq4sEHo5AgMB
AAGjggHVMIIB0TAfBgNVHSMEGDAWgBSJVf2JvOIQPPttTh8w+fmCi1xh4jAdBgNV
HQ4EFgQU3PsIuQqjWZ2eFYrcKNhdYi7Rf1owEQYDVR0RBAowCIIGQmF4dGVyMA4G
A1UdDwEB/wQEAwIFoDAdBgNVHSUEFjAUBggrBgEFBQcDAQYIKwYBBQUHAwIwgZUG
A1UdHwSBjTCBijBDoEGgP4Y9aHR0cDovL2NybDN0ZXN0LmRpZ2ljZXJ0LmNvbS9E
aWdpQ2VydFRlc3RJbnRlcm1lZGlhdGVTSEEyLmNybDBDoEGgP4Y9aHR0cDovL2Ny
bDN0ZXN0LmRpZ2ljZXJ0LmNvbS9EaWdpQ2VydFRlc3RJbnRlcm1lZGlhdGVTSEEy
LmNybDAhBgNVHSAEGjAYMAwGCmCGSAGG/WxjAQEwCAYGZ4EMAQICMIGDBggrBgEF
BQcBAQR3MHUwKAYIKwYBBQUHMAGGHGh0dHA6Ly9vY3NwdGVzdC5kaWdpY2VydC5j
b20wSQYIKwYBBQUHMAKGPWh0dHA6Ly9jYWNlcnRzLmRpZ2ljZXJ0LmNvbS9EaWdp
Q2VydFRlc3RJbnRlcm1lZGlhdGUtU0hBMi5jcnQwDAYDVR0TAQH/BAIwADANBgkq
hkiG9w0BAQsFAAOCAQEAe7Rc6PbIfEjSQpCZ3UpZ7zqWruov44nmSKvR/X4MJITM
z9k3S+TzGOGYnq7bHBF1mjLt0l5K/BDWSG6LY5clSYJuGCbC/dSNFk9G+lzBKs5S
5xJxk8HeAt4OHOWmtEhZ7S4np7zUBcRu1koHbw4vW/lYJBvxRF1Sdd0ypyBP4X81
D2mX+LmFo2rlLSExurr5rd1s6Pna2FRBEjoyM78ID9AmKENqeioDi+hxGLlQROOt
y7aZU8yWcec7nad9iUGO/pMDdhbWexpvp4CBihxYkUMQcf8RaqTkJM8fLAdvPq9P
oQuBuMi+qPtI3WkTgfwr49usBzgbrdNPc/5MRQEz8Q==

-----END CERTIFICATE-----

Client certificate expiration date, GMT in the format: MM/DD/YYYY HH:MM:SS.

CLIENTCERTEXPIRE=

Trusted certificates, maximum of 5.

TRUSTEDCERTS=

-----BEGIN CERTIFICATE-----

MIIGSTCCBTGgAwIBAgIEM6qqqjANBgkqhkiG9w0BAQsFADBkMQswCQYDVQQGEwJV

UzEVMBMGA1UEChMMRGlnaUNlcnQgSW5jMRkwFwYDVQQLExB3d3cuZGlnaWNlcnQu
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