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Trusted Internet of Things (IoT) Device Network-Layer Onboarding and Lifecycle Management

Enhancing Internet Protocol-Based IoT Device and Network Security

Volume D:
Functional Demonstrations

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PRELIMINARY DRAFT

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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: iot-onboarding@nist.gov.

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NATIONAL CYBERSECURITY CENTER OF EXCELLENCE

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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.

KEYWORDS

application-layer onboarding; bootstrapping; Internet of Things (IoT); Manufacturer Usage Description (MUD); network-layer onboarding; onboarding; Wi-Fi Easy Connect.

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The Technology Partners/Collaborators who participated in this build submitted their capabilities in response to a notice in the Federal Register. Respondents with relevant capabilities or product components 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:

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Contents

List of Tables

1 Introduction

In this project, the National Cybersecurity Center of Excellence (NCCoE) applies standards, recommended practices, and commercially available technology to demonstrate various mechanisms for trusted network-layer onboarding of IoT devices and lifecycle management of those devices. We show how to provision network credentials to IoT devices in a trusted manner and maintain a secure posture throughout the device lifecycle.

This volume of the NIST Cybersecurity Practice Guide describes functional demonstration scenarios that are designed to showcase the security capabilities and characteristics supported by trusted IoT device network-layer onboarding and lifecycle management solutions. Section 2, Functional Demonstration Playbook, defines the scenarios and lists the capabilities that can be showcased in each one. Section 3, Functional Demonstration Results, reports which capabilities have been demonstrated by each of the project's implemented solutions.

1.1 How to Use This Guide

This NIST Cybersecurity Practice Guide demonstrates a standards-based reference design for implementing trusted IoT device network-layer onboarding and lifecycle management and describes various example implementations of this reference design. Each of these implementations, which are known as *builds,* are standards-based and are designed to help provide assurance that networks are not put at risk as new IoT devices are added to them and also to help safeguard IoT devices from being taken over by unauthorized networks. The reference design described in this practice guide is modular and can be deployed in whole or in part, enabling organizations to incorporate trusted IoT device network-layer onboarding and lifecycle management into their legacy environments according to goals that they have prioritized based on risk, cost, and resources.

NIST is adopting an agile process to publish this content. Each volume is being made available as soon as possible rather than delaying release until all volumes are completed. Work continues on implementing the example solutions and developing other parts of the content. As a preliminary draft, we will publish at least one additional draft for public comment before it is finalized.

When complete, this guide will contain five volumes:

- NIST SP 1800-36A: *Executive Summary* – why we wrote this guide, the challenge we address, why it could be important to your organization, and our approach to solving this challenge
- NIST SP 1800-36B*: Approach, Architecture, and Security Characteristics* – what we built and why
- NIST SP 1800-36C: *How-To Guides* – instructions for building the example implementations, including all the security-relevant details that would allow you to replicate all or parts of this project

- NIST SP 1800-36D: *Functional Demonstrations* – use cases that have been defined to showcase trusted IoT device network-layer onboarding and lifecycle management security capabilities, and the results of demonstrating these use cases with each of the example implementations **(you are here)**
- NIST SP 1800-36E*: Risk and Compliance Management* – risk analysis and mapping of trusted IoT device network-layer onboarding and lifecycle management security characteristics to cybersecurity standards and recommended practices

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 1800-36A*, which describes the following topics:

- challenges that enterprises face in migrating to the use of trusted IoT device network-layer onboarding
- example solutions 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 1800-36B*, which describes what we did and why.

Also, Section 4 of *NIST SP 1800-36E* will be of particular interest. Section 4, *Mappings*, maps logical components of the general trusted IoT device network-layer onboarding and lifecycle management reference design to security characteristics listed in various cybersecurity standards and recommended practices documents, including *Framework for Improving Critical Infrastructure Cybersecurity* (NIST Cybersecurity Framework) and *Security and Privacy Controls for Information Systems and Organizations* (NIST SP 800-53).

You might share the *Executive Summary, NIST SP 1800-36A*, with your leadership team members to help them understand the importance of using standards-based trusted IoT device network-layer onboarding and lifecycle management implementations.

IT professionals who want to implement similar solutions will find the whole practice guide useful. You can use the how-to portion of the guide, *NIST SP 1800-36C*, to replicate all or parts of the builds created in our lab. The how-to portion of the guide provides specific product installation, configuration, and integration instructions for implementing the example solution. We do not re-create 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. Also, you can use *Functional Demonstrations, NIST SP 1800-36D*, which provides the use cases that have been defined to showcase trusted IoT device network-layer onboarding and lifecycle management security capabilities and the results of demonstrating these use cases with each of the example implementations.

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 these particular products. Your organization can adopt this solution or one that adheres to these guidelines in whole, or you can use this guide as a starting point for tailoring and implementing parts of a trusted IoT device network-layer onboarding and lifecycle management. Your organization's security experts should identify the products that will best integrate with your existing tools and IT system infrastructure. We hope that you will seek products that are congruent with applicable standards and recommended practices.

A NIST Cybersecurity Practice Guide does not describe "the" solution, but example solutions. This is a preliminary draft guide. As the project progresses, the preliminary draft will be updated, and additional volumes will also be released for comment. We seek feedback on the publication's contents and welcome your input. Comments, suggestions, and success stories will improve subsequent versions of this guide. Please contribute your thoughts to iot-onboarding@nist.gov.

2 Functional Demonstration Playbook

Five scenarios have been defined that demonstrate capabilities related to various aspects of trusted IoT device network-layer onboarding, application-layer onboarding, and device lifecycle management. These scenarios are as follows:

- Scenario 1: Trusted Network-Layer Onboarding
- Scenario 2: Trusted Application-Layer Onboarding
- Scenario 3: Re-Onboarding a Device
- Scenario 4: Ongoing Device Validation
- Scenario 5: Establishment and Maintenance of Credential and Device Security Posture Throughout the Lifecycle

We executed the trusted network-layer onboarding and lifecycle management scenarios using both onboarding builds that have been implemented as part of this project. The capabilities that were demonstrated depend both on the features of the network-layer onboarding protocol (i.e., Wi-Fi Easy Connect) that the build supports and on any additional mechanisms the build may have integrated (e.g., application-layer onboarding).

Sections 2.1 through 2.5 define each of the five onboarding scenarios.

2.1 Scenario 1: Trusted Network-Layer Onboarding

This scenario involves trusted network-layer onboarding of an authorized IoT device to a local network that is operated by the owner of the IoT device. Onboarding is performed after the device has booted up and is placed in onboarding mode. Because the organization that is operating the local network is the owner of the IoT device, the device is authorized to onboard to the network and the network is authorized to onboard the device. In this scenario, after the identities of the device and the network are authenticated, a *network onboarding component*—a logical component authorized to onboard devices on behalf of the network—provisions unique network credentials to the device over a secure channel. These network credentials are not just specific to the device; they are also specific to the local network. The device then uses these credentials to connect to the network. Table 2-1 lists the capabilities that may be demonstrated in this scenario.

Table 2-1 Scenario 1 Trusted Network-Layer Onboarding Capabilities That May Be Demonstrated

Demo ID	Capability	Description
S1.C1	Device Authentication	The onboarding mechanism authenticates the device's identity.
S1.C2	Device Authorization	The onboarding mechanism verifies that the device is authorized to onboard to the network.
S1.C3	Network Authentication	The device can verify the network's identity.
S1.C4	Network Authorization	The device can verify that the network is authorized to take control of it.
S1.C5	Secure Local Credentialing	The onboarding mechanism securely provisions local network credentials to the device.
S1.C6	Secure Storage	The credentials are provisioned to secure hardware-backed storage on the device.
S1.C7	Network Selection	The onboarding mechanism provides the IoT device with the identifier of the network to which the device should onboard.
S1.C8	Interoperability	The network-layer onboarding mechanism can onboard two types of IoT devices (e.g., different device vendors and models).

2.2 Scenario 2: Trusted Application-Layer Onboarding

This scenario involves trusted application-layer onboarding that is performed automatically on an IoT device after the device connects to a network. As a result, this scenario can be thought of as a series of steps that would be performed as an extension of Scenario 1. As part of these steps, the device automatically mutually authenticates with a trusted application-layer onboarding service and establishes an encrypted connection to that application-layer onboarding service so the service can provision the device with application-layer credentials. The application-layer credentials could, for example, enable the device to securely connect to a trusted lifecycle management service to check for available updates or patches. For the application-layer onboarding mechanism to be trusted, it must establish an encrypted connection to the device without exposing any information that must be protected to ensure the confidentiality of that connection. Two types of application-layer onboarding are defined in NIST SP

1800-36B: *streamlined* and *independent*. Table 2-2 lists the capabilities that may be demonstrated in this scenario, including both types of application-layer onboarding.

Table 2-2 Scenario 2 Trusted Application-Layer Onboarding Capabilities That May Be Demonstrated

Demo ID	Capability	Description
S2.C1	Automatic Initiation of Streamlined Application-Layer Onboarding	The device can automatically (i.e., with no manual intervention required) initiate trusted application-layer onboarding after performing network-layer onboarding and connecting to the network. In this case, the application-layer onboarding bootstrapping information has been securely conveyed to the device during the network-layer onboarding process.
S2.C2	Automatic Initiation of Independent Application-Layer Onboarding	The device can automatically (i.e., with no manual intervention required) initiate trusted application-layer onboarding after performing network-layer onboarding and connecting to the network. In this case, the application-layer onboarding bootstrapping information has been pre-provisioned to the device by the device manufacturer or integrator (e.g., as part of an application that has been installed on the device during the manufacturing process).
S2.C3	Trusted Application-Layer Onboarding	The device and a trusted application service can establish an encrypted connection without exposing any information that must be protected to ensure the confidentiality of the connection. They can then use that secure association to exchange application-layer information.

2.3 Scenario 3: Re-Onboarding a Device

This scenario involves re-onboarding an IoT device to a network after deleting its network credentials so that the device can be re-credentialed and re-connected. If the device also supports application-layer onboarding, application-layer onboarding should also be able to be performed again after the device reconnects to the network. Table 2-3 lists the capabilities that may be demonstrated in this scenario.

Table 2-3 Scenario 3 Re-Onboarding Capabilities That May Be Demonstrated

Demo ID	Capability	Description
S3.C1	Credential Deletion	The device’s network credential can be deleted.
S3.C2	De-Credentialed Device Cannot Connect	After the device’s network credential has been deleted, the device is not able to connect to or communicate on the network securely.

Demo ID	Capability	Description
S3.C3	Re-Onboarding (network layer)	After the device's network credential has been deleted, the network-layer onboarding mechanism can securely re-provision a network credential to the device, which the device can then use to connect to the network securely.
S3.C4	Re-Onboarding (application layer)	After the device's network and application-layer credentials have been deleted and the device has been re-onboarded at the network layer and re-connected to the network, the device can again perform trusted application-layer onboarding.

2.4 Scenario 4: Ongoing Device Validation

This scenario involves ongoing validation of a device, not only as part of a trusted boot or attestation process prior to permitting the device to undergo network-layer onboarding, but also after the device has connected to the network. It may involve one or more security mechanisms that are designed to evaluate, validate, or respond to device trustworthiness using methods such as examining device behavior, ensuring device authenticity and integrity, and assigning the device to a specific network segment based on its conformance to policy criteria. Table 2-4 lists the capabilities that may be demonstrated in this scenario.

Table 2-4 Scenario 4 Ongoing Device Validation Capabilities That May Be Demonstrated

Demo ID	Capability	Description
S4.C1	Device Attestation (initial)	The network-layer onboarding mechanism requires successful device attestation prior to permitting the device to be onboarded.
S4.C2	Device Attestation (application layer)	The application-layer onboarding mechanism requires successful device attestation prior to permitting the device to be onboarded.
S4.C3	Device Attestation (ongoing)	Successful device attestation is required prior to permitting the device to perform some operation (e.g., accessing a high-value resource).
S4.C4	Local Network Segmentation (initial)	Upon connection, the IoT device is assigned to some local network segment in accordance with policy, which may include an assessment of its security posture.
S4.C5	Behavioral Analysis	Device behavior is observed to determine whether the device meets the policy criteria required to be permitted to perform a given operation (e.g., to access a high-value resource or be placed on a given network segment).

Demo ID	Capability	Description
S4.C6	Local Network Segmentation (ongoing)	The IoT device can be reassigned to a different network segment based on ongoing assessments of its conformance to policy criteria.

2.5 Scenario 5: Establishment and Maintenance of Credential and Device Security Posture Throughout the Lifecycle

This scenario involves steps used to help establish and maintain the security posture of both the device's network credentials and the device itself. It includes the capability to download and validate the device's most recent firmware updates, to securely integrate with a device intent enforcement mechanism (e.g., Manufacturer Usage Description (MUD) (RFC 8520)), to keep the device updated and patched, and to establish and maintain the device's network credentials by provisioning X.509 certificates to the device and updating expired network credentials. Table 2-5 lists the capabilities that may be demonstrated in this scenario.

Table 2-5 Scenario 5 Credential and Device Posture Establishment and Maintenance Capabilities That May Be Demonstrated

Demo ID	Capability	Description
S5.C1	Trusted Firmware Updates	The device can download the most recent firmware update and verify its signature before it is installed.
S5.C2	Credential Certificate Provisioning	The onboarding mechanism can interact with a certificate authority to sign a device's X.509 certificate and provision it onto the device.
S5.C3	Credential Update	The device's network credential can be updated after it expires.
S5.C4	Server Attestation	Successful server attestation is required prior to permitting the server to perform some operation on the device (e.g., prior to downloading and installing updates onto the device).
S5.C5	Secure Integration with MUD	The network-layer onboarding mechanism can convey necessary device intent information (e.g., the IoT device's MUD URL) to the network in encrypted form, thereby securely binding this information to the device and ensuring its confidentiality and integrity.
S5.C6	Lifecycle Management Establishment	The device has a lifecycle management service and can automatically establish a secure association with it after performing network-layer onboarding and connecting to the network.

3 Functional Demonstration Results

This section records the capabilities that were demonstrated for each of the builds.

3.1 Build 1 Demonstration Results

Table 3-1 lists the capabilities that were demonstrated by Build 1.

Table 3-1 Build 1 Capabilities Demonstrated

Demo ID	Capability	Description	Demonstrated?	Explanation/Notes
Scenario 1: Trusted Network-Layer Onboarding				
S1.C1	Device Authentication	The onboarding mechanism authenticates the device's identity.	Yes	DPP performs device authentication.
S1.C2	Device Authorization	The onboarding mechanism verifies that the device is authorized to onboard to the network.	Yes	When the device's URI is found on the HPE cloud service, this verifies that the device is authorized to onboard to the network.
S1.C3	Network Authentication	The device can verify the network's identity.	No	This could be supported by providing the IoT device with the DPP URI of the network, but the UXI sensor used in this build lacks the user interface needed to do so.
S1.C4	Network Authorization	The device can verify that the network is authorized to take control of it.	Yes	The network that possesses the device's public key is implicitly authorized to onboard the device by virtue of its knowledge of the device's public key. While this is not cryptographic, it does provide a certain level of assurance that the "wrong" network doesn't take control of the device.

Demo ID	Capability	Description	Demonstrated?	Explanation/Notes
S1.C5	Secure Local Credentialing	The onboarding mechanism securely provisions local network credentials to the device.	Yes	DPP provisions the device's network credentials over an encrypted channel.
S1.C6	Secure Storage	The credentials are provisioned to secure hardware-backed storage on the device.	Yes	The bootstrapping credentials are stored in a TPM 2.0 hardware enclave.
S1.C7	Network Selection	The onboarding mechanism provides the IoT device with the identifier of the network to which the device should onboard.	Yes	The network responds to device chirps.
S1.C8	Interoperability	The network-layer onboarding mechanism can onboard two types of IoT devices (e.g., different device vendors and models).	Yes	IoT devices from Build 2 were successfully onboarded in Build 1.
Scenario 2: Trusted Application-Layer Onboarding				
S2.C1	Automatic Initiation of Streamlined Application-Layer Onboarding	The device can automatically (i.e., with no manual intervention required) initiate trusted application-layer onboarding after performing network-layer onboarding and connecting to the network. In this case, the application-layer onboarding bootstrapping information has been securely conveyed to the device during the	No	Not supported in this build.

Demo ID	Capability	Description	Demonstrated?	Explanation/Notes
		network-layer onboarding process.		
S2.C2	Automatic Initiation of Independent Application-Layer Onboarding	The device can automatically (i.e., with no manual intervention required) initiate trusted application-layer onboarding after performing network-layer onboarding and connecting to the network. In this case, the application-layer onboarding bootstrapping information has been pre-provisioned to the device by the device manufacturer or integrator (e.g., as part of an application that has been installed on the device during the manufacturing process).	Yes	Once onboarded, the UXI sensor automatically initiates application-layer onboarding to the UXI application.
S2.C3	Trusted Application-Layer Onboarding	The device and a trusted application service can establish an encrypted connection without exposing any information that must be protected to ensure the confidentiality of the connection. They can then use that secure association to exchange application-layer information.	Yes	Once onboarded, the UXI sensor establishes a secure connection with the UXI cloud, which provisions the sensor with its credentials for the UXI application. Later, the sensor uploads data to the UXI application securely.
Scenario 3: Re-Onboarding a Device				

Demo ID	Capability	Description	Demonstrated?	Explanation/Notes
S3.C1	Credential Deletion	The device's network credential can be deleted.	Yes	Factory reset and manual credential removal were leveraged.
S3.C2	De-Credentialed Device Cannot Connect	After the device's network credential has been deleted, the device is not able to connect to or communicate on the network securely.	Yes	Observed.
S3.C3	Re-Onboarding (network layer)	After the device's network credential has been deleted, the network-layer onboarding mechanism can security re-provision a network credential to the device, which the device can then use to connect to the network securely.	Yes	Observed.
S3.C4	Re-Onboarding (application layer)	After the device's network and application-layer credentials have been deleted and the device has been re-onboarded at the network layer and re-connected to the network, the device can again perform trusted application-layer onboarding.	Yes	Observed.
Scenario 4: Ongoing Device Validation				
S4.C1	Device Attestation (initial)	The network-layer onboarding mechanism requires successful device attestation prior	No	Not supported in this build.

Demo ID	Capability	Description	Demonstrated?	Explanation/Notes
		to permitting the device to be onboarded.		
S4.C2	Device Attestation (application layer)	The application-layer onboarding mechanism requires successful device attestation prior to permitting the device to be onboarded.	No	Not supported in this build.
S4.C3	Device Attestation (ongoing)	Successful device attestation is required prior to permitting the device to perform some operation (e.g., accessing a high-value resource).	No	Not supported in this build.
S4.C4	Local Network Segmentation (initial)	Upon connection, the IoT device is assigned to some local network segment in accordance with policy, which may include an assessment of its security posture.	No	Not demonstrated in this phase.
S4.C5	Behavioral Analysis	Device behavior is observed to determine whether the device meets the policy criteria required to be permitted to perform a given operation (e.g., to access a high-value resource or be placed on a given network segment).	No	Not supported in this build.
S4.C6	Local Network Segmentation (ongoing)	The IoT device can be reassigned to a different network segment based on ongoing assessments	No	Not supported in this build.

Demo ID	Capability	Description	Demonstrated?	Explanation/Notes
		of its conformance to policy criteria.		
Scenario 5: Establishment and Maintenance of Credential and Device Security Posture Throughout the Lifecycle				
S5.C1	Trusted Firmware Updates	The device can download the most recent firmware update and verify its signature before it is installed.	No	Not supported in this build.
S5.C2	Credential Certificate Provisioning	The onboarding mechanism can interact with a certificate authority to sign a device's X.509 certificate and provision it onto the device.	Yes	This capability has been successfully demonstrated. Ongoing work will look to demonstrate the capability with the WISeKey CA.
S5.C3	Credential Update	The device's network credential can be updated after it expires.	No	Not demonstrated in this phase.
S5.C4	Server Attestation	Successful server attestation is required prior to permitting the server to perform some operation on the device (e.g., prior to downloading and installing updates onto the device).	No	Not supported in this build.
S5.C5	Secure Integration with MUD	The network-layer onboarding mechanism can convey necessary device intent information (e.g., the IoT device's MUD URL) to the network in encrypted form, thereby securely binding this information to the	No	Supported by DPP, but not demonstrated because Build 1 is not integrated with MUD or any other device intent enforcement mechanism.

Demo ID	Capability	Description	Demonstrated?	Explanation/Notes
		device and ensuring its confidentiality and integrity.		
S5.C6	Lifecycle Management Establishment	The device has a lifecycle management service and can automatically establish a secure association with it after performing network-layer onboarding and connecting to the network.	No	Not supported in this build.

264 ## 3.2 Build 2 Demonstration Results

265 Table 3-2 lists the capabilities that were demonstrated by Build 2.

266 Table 3-2 Build 2 Capabilities Demonstrated

Demo ID	Capability	Description	Demonstrated?	Explanation/Notes
		Scenario 1: Trusted Network-Layer Onboarding		
S1.C1	Device Authentication	The onboarding mechanism authenticates the device's identity.	Yes	DPP performs device authentication.
S1.C2	Device Authorization	The onboarding mechanism verifies that the device is authorized to onboard to the network.	Yes	Only devices that have been added/approved by the administrator are onboarded. When the device's URI is found, the controller authorizes the device to join the network.
S1.C3	Network Authentication	The device can verify the network's identity.	No	This could be supported by providing the IoT device with the DPP URI of the network, but this is

Demo ID	Capability	Description	Demonstrated?	Explanation/Notes
				not currently implemented.
S1.C4	Network Authorization	The device can verify that the network is authorized to take control of it.	Yes	The network that possesses the device's public key is implicitly authorized to onboard the device by virtue of its knowledge of the device's public key. While this is not cryptographic, it does provide a certain level of assurance that the "wrong" network doesn't take control of the device.
S1.C5	Secure Local Credentialing	The onboarding mechanism securely provisions local network credentials to the device.	Yes	DPP provisions the device's network credentials over an encrypted channel.
S1.C6	Secure Storage	The credentials are provisioned to secure hardware-backed storage on the device.	No	The IoT device does not have secure hardware-backed storage.
S1.C7	Network Selection	The onboarding mechanism provides the IoT device with the identifier of the network to which the device should onboard.	Yes	Network responds to device chirps.
S1.C8	Interoperability	The network-layer onboarding mechanism can onboard two types of IoT devices (e.g., different device vendors and models).	Yes	Build 2 was able to onboard the IoT devices from Build 1.
Scenario 2: Trusted Application-Layer Onboarding				
S2.C1	Automatic Initiation of Streamlined	The device can automatically (i.e., with no manual intervention	Yes	This has been demonstrated with the

Demo ID	Capability	Description	Demonstrated?	Explanation/Notes
	Application-Layer Onboarding	required) initiate trusted application-layer onboarding after performing network-layer onboarding and connecting to the network. In this case, the application-layer onboarding bootstrapping information has been securely conveyed to the device during the network-layer onboarding process.		OCF Iotivity custom extension.
S2.C2	Automatic Initiation of Independent Application-Layer Onboarding	The device can automatically (i.e., with no manual intervention required) initiate trusted application-layer onboarding after performing network-layer onboarding and connecting to the network. In this case, the application-layer onboarding bootstrapping information has been pre-provisioned to the device by the device manufacturer or integrator (e.g., as part of an application that has been installed on the device during the manufacturing process).	No	Not supported in this build.
S2.C3	Trusted Application-Layer Onboarding	The device and a trusted application service can establish an encrypted connection without	Yes	Once the device is onboarded to the network using DPP, the credentials for the application layer

Demo ID	Capability	Description	Demonstrated?	Explanation/Notes
		exposing any information that must be protected to ensure the confidentiality of the connection. They can then use that secure association to exchange application-layer information.		onboarding are sent over the secure channel and provisioned by the onboarding tool (OBT).
Scenario 3: Re-Onboarding a Device				
S3.C1	Credential Deletion	The device's network credential can be deleted.	Yes	Supports factory reset.
S3.C2	De-Credentialed Device Cannot Connect	After the device's network credential has been deleted, the device is not able to connect to or communicate on the network securely.	Yes	Observed.
S3.C3	Re-Onboarding (network layer)	After the device's network credential has been deleted, the network-layer onboarding mechanism can security re-provision a network credential to the device, which the device can then use to connect to the network securely.	Yes	Observed.
S3.C4	Re-Onboarding (application layer)	After the device's network and application-layer credentials have been deleted and the device has been re-onboarded at the network layer and re-connected to the network, the device can again perform trusted application-layer onboarding.	Yes	Observed.

Demo ID	Capability	Description	Demonstrated?	Explanation/Notes
Scenario 4: Ongoing Device Validation				
S4.C1	Device Attestation (initial)	The network-layer onboarding mechanism requires successful device attestation prior to permitting the device to be onboarded.	No	Not supported in this build.
S4.C2	Device Attestation (application layer)	The application-layer onboarding mechanism requires successful device attestation prior to permitting the device to be onboarded.	No	Not supported in this build.
S4.C3	Device Attestation (ongoing)	Successful device attestation is required prior to permitting the device to perform some operation (e.g., accessing a high-value resource).	No	Not supported in this build.
S4.C4	Local Network Segmentation (initial)	Upon connection, the IoT device is assigned to some local network segment in accordance with policy, which may include an assessment of its security posture.	Yes	When the device is connected to the network, the gateway places it in a restricted network segment based on policy.
S4.C5	Behavioral Analysis	Device behavior is observed to determine whether the device meets the policy criteria required to be permitted to perform a given operation (e.g., to access a high-value resource or be placed on a given network segment).	No	Not supported in this build.

Demo ID	Capability	Description	Demonstrated?	Explanation/Notes
S4.C6	Local Network Segmentation (ongoing)	The IoT device can be reassigned to a different network segment based on ongoing assessments of its conformance to policy criteria.	Yes	Device can be moved to new network segments programmatically. The policy to do this is not defined in this build.
Scenario 5: Establishment and Maintenance of Credential and Device Security Posture Throughout the Lifecycle				
S5.C1	Trusted Firmware Updates	The device can download the most recent firmware update and verify its signature before it is installed.	No	Not supported in this build.
S5.C2	Credential Certificate Provisioning	The onboarding mechanism can interact with a certificate authority to sign a device's X.509 certificate and provision it onto the device.	No	Not supported in this build.
S5.C3	Credential Update	The device's network credential can be updated after it expires.	No	Not demonstrated in this phase.
S5.C4	Server Attestation	Successful server attestation is required prior to permitting the server to perform some operation on the device (e.g., prior to downloading and installing updates onto the device).	No	Not supported in this build.
S5.C5	Secure Integration with MUD	The network-layer onboarding mechanism can convey necessary device intent information (e.g., the IoT device's MUD URL) to the network in encrypted form, thereby securely binding	No	Supported by DPP, but not demonstrated because Build 2 is not integrated with MUD or any other device intent enforcement mechanism.

Demo ID	Capability	Description	Demonstrated?	Explanation/Notes
		this information to the device and ensuring its confidentiality and integrity.		
S5.C6	Lifecycle Management Establishment	The device has a lifecycle management service and can automatically establish a secure association with it after performing network-layer onboarding and connecting to the network.	No	Not supported in this build.