SZTPD Administrator's Guide

Watsen Networks

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Abstract

This documentation is for the SZTPD product by Watsen Networks.

This documentation is still a work-in-progress. Some sections clearly indicate when material is pending, but there are also some missing sections, and other sections may not have enough detail.

SZTPD is currently in its "alpha" stage and details captured in this document may change.

Contents

1 Introduction

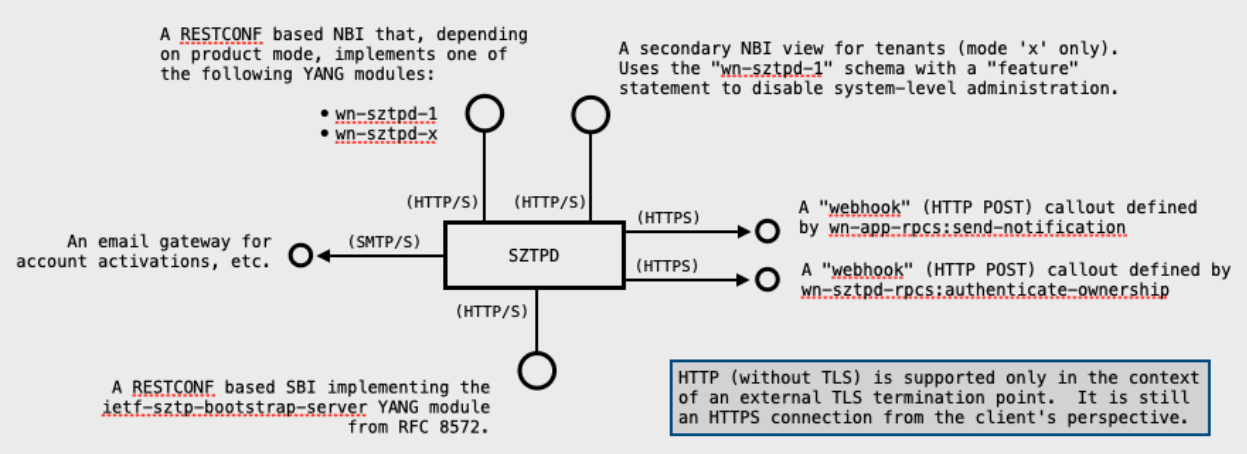
SZTPD is an implementation of a "bootstrap server", as defined in the Terminology section of RFC 8572, also known as an "SZTP server", as defined in the Terminology section of draft-kwatsen-netconf-sztp- csr".

SZTPD is provided as software, an asynchronous event-driven Python-based executable. SZTPD is an application (not a library) that includes a northbound API for configuration, a southbound API for device bootstrapping requests, and eastbound hooks for integration with other business systems.

This documentation is in preparation for a "1.0.0" release, using the common "major.minor.patch" semantic versioning convention.

2 API Introduction

The following picture illustrates the API interfaces implemented by SZTPD:



The various aspects of this picture are discussed in the following sections.

2.1 Northbound API

The Northbound Interface (NBI) API is the largest API presented by SZTPD. The NBI is the interface enabling the setting of configuration, the viewing of operational state, and the reception of notifications (both system events and bootstrapping progress reports).

The NBI is a RESTCONF RFC 8040 based API that implements one of the three YANG modules:

- wn-sztpd-1
- wn-sztpd-x

where '1' and 'x' refer to the SZTPD product mode. Each product mode has a distinct (though highly related) data model for the NBI.

The scope of the NBI is extended to also include the outbound interface SZTPD uses to deliver notifications to northbound controller/NMS applications (i.e., implementing a "receive-notification" HTTP POST request.

The data-model for the "receive-notification" request is formally defined in the YANG module "wn-sztp-callbacks" for specification purpose only. It does not imply that the northbound controller/NMS application must implement RESTCONF. Integrating applications only need to implement support for a single HTTP POST request ("bootstrap-complete").

See the Northbound Interface section for more information about the NBI.

2.2 Southbound API

The southbound interface (SBI) implements the bootstrap server API defined in Section 7 of RFC 8572. The SBI is a RESTCONF RFC 8040 based API that implements the "ietf-sztp-bootstrap-server" YANG module.

The SBI is fully described in Section 7 of RFC 8572.

Device-agent developers need to be aware that SZTPD currently only returns, in its get−bootstrapping−data RPC-reply, CMS structures that are neither signed nor encrypted, but these are planning to be supported in upcoming releases of SZTPD. It is strongly suggested that the CMS-processing code switches on the top-most content-type's OID:

- if id_ct_sztpConveyedInfoJSON, then
  - this IS supported in SZTPD 1.0
- if id-envelopedData, then first decrypt with private key
  - this is NOT supported in SZTPD 1.0 (but plan for it!)
- if id-signedData, then verify signature using owner certificate
  - this is NOT supported in SZTPD 1.0 (but plan for it!)

Device agent developers should also be aware that the SZTPD's RFC 8572 implementation currently only implements support for JSON-based API. An XML-based API could be introduced relatively easily, but it is a low-priority item pending market demand.

SZTPD's SBI is unaffected by SZTPD product modes.

2.3 East/West-bound API

The east/west API is for product installation and integration into backend business systems. Currently two integration points are defined to:

1. enable SZTPD to send notifications
2. enable SZTPD to verify device ownership

These integration points are unaffected by SZTPD product modes.

FIXME: describe the specific messages here?

3 Getting Started

This section presents a few examples illustrating some common interactions with SZTPD.

These examples use the ubiquitous curl command line utility program for illustration purposes only. It is expected that production code would use a programming language to achieve the same result.

These examples assume a freshly installed SZTPD, i.e., using the default values described in [Defaults]. To run a fresh instance of SZTPD, in one window, run the following command:

```
$ export SZTPD_MODE=0; sztpd sqlite:///:memory:
```


3.1 Fetching Host-meta

RFC 8040 defines a discovery protocol for determining a RESTCONF server's root resource location. SZTPD uses /restconf for the root resource location.

Request:

```
$ curl -i http://127.0.0.1:8080/.well-known/host-meta
```

Response:

```
HTTP/1.1 200 OK
Server: <redacted>
Content-Type: application/xrd+xml; charset=utf-8
Content-Length: 104
Date: Thu, 23 Jan 2020 19:49:23 GMT

<XRD xmlns="http://docs.oasis-open.org/ns/xri/xrd-1.0">
  <Link rel="restconf" href="/restconf"/>
</XRD>
```

3.2 Fetching the RESTCONF Root Resource

RFC 8040 defines an ability to query the RESTCONF server's root resource to determine, for instance, what yang-library version it is using.

Request:

```
$ curl -i http://127.0.0.1:8080/restconf
```

Response:

```
HTTP/1.1 200 OK
Server: <redacted>
Content-Type: application/yang-data+json; charset=utf-8
Content-Length: 120
Date: Thu, 23 Jan 2020 19:50:07 GMT

{
  "ietf-restconf:restconf" : {
    "data" : {},
    "operations" : {},
    "yang-library-version" : "2019-01-04"
  }
}
```

3.3 Get the YANG Library for this RESTCONF server.

The YANG Library is described in RFC 8525. RESTCONF clients may use it to understand what schema the connected server implements, which varies by the 'use-for' node in the Transport configuration.

Knowing the schema implemented is important to developer understanding SZTPD's various APIs. This is especially true for the 'native' and 'tenant' interface' types. These interface types present SZTPD's Northbound API.

Note that, for understanding the 'rfc8572' interface type presented by SZTPD's Southbound API, section 7 of RFC 8572 in highly recommended.

The following request shows that the 'wn-sztpd-1' YANG module is "implemented". Had we chosen mode 'x' when the sztpd process was started in the Getting Started section, then 'wn-sztpd-1' would be "imported" while 'wn-sztpd-x' would be "implemented".

Note that the 'tenant' interface type is effectively the 'wn-sztpd-1' with the 'system-level-administration-disabled' feature set.

Request:

```
$ curl -i http://127.0.0.1:8080/restconf/ds/ietf-datastores:operational/ietf-yang-library:yang-library
```

Response:

```
HTTP/1.1 200 OK
Server: <redacted>
Content-Type: application/yang-data+json; charset=utf-8
Content-Length: 8422
Date: Thu, 23 Jan 2020 19:52:23 GMT

{
    "ietf-yang-library:modules-state": {
        "module-set-id": "unset",
        "module": [
            {
                "name": "ietf-yang-types",
                "revision": "2013-07-15",
                "namespace": "urn:ietf:params:xml:ns:yang:ietf-yang-types",
                "conformance-type": "import"
            },
            {
                "name": "ietf-inet-types",
                "revision": "2013-07-15",
                "namespace": "urn:ietf:params:xml:ns:yang:ietf-inet-types",
                "conformance-type": "import"
            },
            {
                "name": "ietf-datastores",
                "revision": "2018-02-14",
                "namespace": "urn:ietf:params:xml:ns:yang:ietf-yang-datastores",
                "conformance-type": "import"
            },
            {
                "name": "ietf-yang-library",
                "revision": "2019-01-04",
                "namespace": "urn:ietf:params:xml:ns:yang:ietf-yang-library",
                "conformance-type": "import"
            },
            {
                "name": "iana-crypt-hash",
                "revision": "2014-08-06",
                "namespace": "urn:ietf:params:xml:ns:yang:iana-crypt-hash",
                "conformance-type": "import"
            },
            {
                "name": "ietf-x509-cert-to-name",
                "revision": "2014-12-10",
                "namespace": "urn:ietf:params:xml:ns:yang:ietf-x509-cert-to-name",
                "conformance-type": "implement"
            },
            {
                "name": "ietf-restconf",
                "revision": "2017-01-26",
                "namespace": "urn:ietf:params:xml:ns:yang:ietf-restconf",
                "conformance-type": "import"
            },
            {
                "name": "ietf-netconf-acm",
                "revision": "2018-02-14",
                "namespace": "urn:ietf:params:xml:ns:yang:ietf-netconf-acm",
                "conformance-type": "import"
            },
            {
                "name": "ietf-sztp-conveyed-info",
                "revision": "2019-04-30",
                "schema": "https://example.com/test.yang",
                "namespace": "urn:ietf:params:xml:ns:yang:ietf-sztp-conveyed-info",
                "conformance-type": "implement"
            },
            {
                "name": "ietf-crypto-types",
                "revision": "2020-01-23",
                "schema": "https://example.com/test.yang",
                "namespace": "urn:ietf:params:xml:ns:yang:ietf-crypto-types",
                "conformance-type": "implement"
            },
            {
                "name": "iana-hash-algs",
                "revision": "2020-01-23",
                "schema": "https://example.com/test.yang",
                "namespace": "urn:ietf:params:xml:ns:yang:iana-hash-algs",
                "conformance-type": "import"
            },
            {
                "name": "iana-symmetric-algs",
                "revision": "2020-01-23",
                "schema": "https://example.com/test.yang",
                "namespace": "urn:ietf:params:xml:ns:yang:iana-symmetric-algs",
                "conformance-type": "import"
            },
            {
                "name": "iana-asymmetric-algs",
                "revision": "2020-01-23",
                "schema": "https://example.com/test.yang",
                "namespace": "urn:ietf:params:xml:ns:yang:iana-asymmetric-algs",
                "conformance-type": "import"
            },
            {
                "name": "ietf-truststore",
                "revision": "2020-01-23",
                "feature": [
                    "x509-certificates"
```



```
            ],
            "schema": "https://example.com/test.yang",
            "namespace": "urn:ietf:params:xml:ns:yang:ietf-truststore",
            "conformance-type": "import"
        },
        {
            "name": "ietf-keystore",
            "revision": "2020-01-23",
            "schema": "https://example.com/test.yang",
            "namespace": "urn:ietf:params:xml:ns:yang:ietf-keystore",
            "conformance-type": "import"
        },
        {
            "name": "ietf-tcp-common",
            "revision": "2020-01-23",
            "schema": "https://example.com/test.yang",
            "namespace": "urn:ietf:params:xml:ns:yang:ietf-tcp-common",
            "conformance-type": "import"
        },
        {
            "name": "ietf-tcp-client",
            "revision": "2020-01-23",
            "schema": "https://example.com/test.yang",
            "namespace": "urn:ietf:params:xml:ns:yang:ietf-tcp-client",
            "conformance-type": "import"
        },
        {
            "name": "ietf-tcp-server",
            "revision": "2020-01-23",
            "schema": "https://example.com/test.yang",
            "namespace": "urn:ietf:params:xml:ns:yang:ietf-tcp-server",
            "conformance-type": "import"
        },
        {
            "name": "ietf-tls-common",
            "revision": "2020-01-23",
            "schema": "https://example.com/test.yang",
            "namespace": "urn:ietf:params:xml:ns:yang:ietf-tls-common",
            "conformance-type": "import"
        },
        {
            "name": "ietf-tls-client",
            "revision": "2020-01-23",
            "feature": [
                "x509-certificate-auth",
                "client-auth-config-supported"
            ],
            "schema": "https://example.com/test.yang",
            "namespace": "urn:ietf:params:xml:ns:yang:ietf-tls-client",
            "conformance-type": "import"
        },
        {
            "name": "ietf-tls-server",
            "revision": "2020-01-23",
            "feature": [
                "x509-certificate-auth",
                "client-auth-config-supported"
            ],
            "schema": "https://example.com/test.yang",
            "namespace": "urn:ietf:params:xml:ns:yang:ietf-tls-server",
            "conformance-type": "import"
        },
        {
            "name": "ietf-http-client",
            "revision": "2020-01-23",
            "schema": "https://example.com/test.yang",
            "namespace": "urn:ietf:params:xml:ns:yang:ietf-http-client",
            "conformance-type": "import"
        },
        {
            "name": "ietf-http-server",
            "revision": "2020-01-23",
            "schema": "https://example.com/test.yang",
            "namespace": "urn:ietf:params:xml:ns:yang:ietf-http-server",
            "conformance-type": "import"
        },
        {
            "name": "ietf-restconf-server",
            "revision": "2020-01-23",
            "feature": [
                "http-listen",
                "https-listen"
            ],
            "schema": "https://example.com/test.yang",
            "namespace": "urn:ietf:params:xml:ns:yang:ietf-restconf-server",
            "conformance-type": "import"
        },
        {
            "name": "wn-x509-c2n",
            "revision": "2020-01-23",
            "namespace": "https://watsen.net/wnc2n",
            "conformance-type": "implement"
        },
        {
            "name": "wn-app",
            "revision": "2020-01-23",
            "schema": "https://example.com/test.yang",
            "namespace": "https://watsen.net/wnapp",
            "conformance-type": "import"
        },
        {
            "name": "wn-sztpd-0",
            "revision": "2020-01-23",
            "feature": [
                "onboarding-supported"
            ],
            "schema": "https://example.com/defs.yang",
```



```
                "namespace": "https://watsen.net/sztpd-0",
                "conformance-type": "imported"
            },
            {
                "name": "wn-sztpd-1",
                "revision": "2020-01-23",
                "feature": [
                    "onboarding-supported"
                ],
                "schema": "https://example.com/defs.yang",
                "namespace": "https://watsen.net/sztpd-1",
                "conformance-type": "implement"
            }
        ]
    }
}
```

3.4 Get the Current (Default) Configuration

Request:

```
$ curl -i http://127.0.0.1:8080/restconf/ds/ietf-datastores:running
```

Response:

```
HTTP/1.1 200 OK
Server: <redacted>
Content-Type: application/yang-data+json; charset=utf-8
Content-Length: 486
Date: Thu, 23 Jan 2020 19:55:47 GMT

{
    "wn-sztpd-1:transport": {
        "listen": {
            "endpoint": [
                {
                    "name": "default startup endpoint",
                    "use-for": [
                        "native-interface"
                    ],
                    "http": {
                        "tcp-server-parameters": {
                            "local-address": "127.0.0.1"
                        }
                    }
                }
            ]
        }
    }
}
```

3.5 Configure an Administrator

As was mentioned previously, a freshly installed SZTPD has no administrator account configured, and yet it requires one, and thus the first write operation to a freshly installed SZTPD instance must configure at least one administrator account. The following illustrates this using a POST request.

Request:

```
$ cat admin_accounts.json
{
  "wn-sztpd-1:admin-accounts":{
    "admin-account": [
      {
        "email-address": "my-admin@example.com",
        "password": "$0$my-secret",
        "access": "unrestricted"
      }
    ]
  }
}

$ curl -i -X POST --data @admin_accounts.json -H "Content-Type:application/yang-data+json" http://127.0.0.1:8080/restconf/ds/ietf-datastores:running
```

Response:

```
HTTP/1.1 201 Created
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Thu, 23 Jan 2020 20:19:27 GMT
```


3.6 Create a Device Type

Request:

```
cat device-types.json
{
  "wn-sztpd-1:device-types": {
    "device-type": [
      {
        "name": "my-device-type"
      }
    ]
  }
}

$ curl -i -X POST --data @device-types.json -H "Content-Type:application/yang-data+json" http://127.0.0.1:8080/restconf/ds/ietf-datastores:running
```

Response:

```
HTTP/1.1 401 Unauthorized
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Thu, 23 Jan 2020 20:24:21 GMT
```

Again, but this time with authentication!

Request:

```
[Note: '\' line endings per BCP XXX, RFC XXXX]

$ curl -i -X POST --user my-admin@example.com:my-secret --data @device-types.json \
-H "Content-Type:application/yang-data+json" http://127.0.0.1:8080/restconf/ds/ietf-datastores:running
```

Response:

```
HTTP/1.1 201 Created
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Thu, 23 Jan 2020 20:29:19 GMT
```

3.7 Create a Device

Alert: be mindful that this example uses the mode-1 schema, and each YANG schema has different ways to configured devices (i.e., if there is a list of devices and if they're under the "/tenants/tenant" tree.

Request:

```
[Note: '\' line endings per BCP XXX, RFC XXXX]

$ cat devices.json
{
  "wn-sztpd-1:devices": {
    "device": [
      {
        "serial-number": "my-serial-number",
        "device-type": "my-device-type",
        "activation-code": "$0$my-secret"
      }
    ]
  }
}

$ curl -i -X POST --user my-admin@example.com:my-secret --data @devices.json \
-H "Content-Type:application/yang-data+json" http://127.0.0.1:8080/restconf/ds/ietf-datastores:running
```

Response:

```
HTTP/1.1 201 Created
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Thu, 23 Jan 2020 20:32:23 GMT
```


3.8 Again, with a Single PUT

When initializing a fresh system, it is often easiest to replace the entire contents of the SZTPD running configuration with a single request to the server.

The following single PUT achieves the same result as all of the above commands combined.

Note that the system-provided default '/transport' node is included in the PUT as well, as otherwise the system will complain that it's being deleted.

Request:

```
$ cat running.json
{
  "wn-sztpd-1:transport": {
    "listen": {
      "endpoint": [
        {
          "name": "default startup endpoint",
          "use-for": [
            "native-interface"
          ],
          "http": {
            "tcp-server-parameters": {
              "local-address": "127.0.0.1"
            }
          }
        }
      ]
    }
  },
  "wn-sztpd-1:admin-accounts":{
    "admin-account": [
      {
        "email-address": "my-admin@example.com",
        "password": "$0$my-secret",
        "access": "unrestricted"
      }
    ]
  },
  "wn-sztpd-1:device-types": {
    "device-type": [
      {
        "name": "my-device-type"
      }
    ]
  },
  "wn-sztpd-1:devices": {
    "device": [
      {
        "serial-number": "my-serial-number",
        "device-type": "my-device-type",
        "activation-code": "$0$my-secret"
      }
    ]
  }
}

$ curl -i -X PUT --data @running.json -H "Content-Type:application/yang-data+json" http://127.0.0.1:8080/restconf/ds
/ietf-datastores:running
```

Response:

```
HTTP/1.1 204 No Content
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Thu, 23 Jan 2020 20:41:54 GMT
```

3.9 Initializing TLS

A production deployment must use TLS to protect the RESTCONF resources.

This section shows how to configure SZTPD to have:

- two listening ports, one for an NBI and the other for an SBI.
- two keys and their associated certificates in the Keystore.
- one trust anchor certificate in the Truststore for DevID-auth.
- one "device-type" identifying a specific Truststore cert to use.
- one "device" using the afore mentioned device-type.

For running code, please see the Simulator code.

This section uses scripts to generate its contents. These scripts use a PKI that has been instantiated as "pki" in the current directory. This 'pki' directory is the same as that in the Simulator code. These scripts could be run out of that directory, after creating an empty directory called "output".

The code below uses a sed script to replace placeholder values in a template to produce the configuration sent by PUT. These values are defined as follows:

Variable	Description
NBI_PORT	The port that the 'native' interface listens on
SBI_PORT	The port that the 'rfc8572' interface listens on
NBI_PRI_KEY_B64	The base64 encoding of the server's NBI private key.
NBI_PUB_KEY_B64	The base64 encoding of the server's NBI public key.
NBI_EE_CERT_B64	The base64 encoding of the server's NBI end-entity cert.
SBI_PRI_KEY_B64	The base64 encoding of the server's SBI private key.
SBI_PUB_KEY_B64	The base64 encoding of the server's SBI public key.
SBI_EE_CERT_B64	The base64 encoding of the server's SBI end-entity cert.

These are the base64 of the DER (not the PEM), that is, the header and footer ===== lines are missing, and all the B64 characters are on one line.

The private and public key values are the native OpenSSL values for private and public keys.

The certificate values are the degenerate form of a CMS (PKCS #7) commonly used to communicate a chain of certificates.

Script:

```
#!/bin/sh

OPENSSL="openssl"
TEMPDIR=`mktemp -d`

# NBI Port
NBI_PORT="8080"
NBI_PRI_KEY_B64=`$OPENSSL enc -base64 -A -in pki/sztpd1/nbi/end-entity/private_key.der`
NBI_PUB_KEY_B64=`$OPENSSL enc -base64 -A -in pki/sztpd1/nbi/end-entity/public_key.der`
cat pki/sztpd1/nbi/end-entity/my_cert.pem pki/sztpd1/nbi/intermediate2/my_cert.pem > $TEMPDIR/cert_chain.pem
$OPENSSL crl2pkcs7 -nocrl -certfile $TEMPDIR/cert_chain.pem -outform DER -out $TEMPDIR/cert_chain.cms
NBI_EE_CERT_B64=`$OPENSSL enc -base64 -A -in $TEMPDIR/cert_chain.cms`

# SBI Port
SBI_PORT="9090"
SBI_PRI_KEY_B64=`$OPENSSL enc -base64 -A -in pki/sztpd1/sbi/end-entity/private_key.der`
SBI_PUB_KEY_B64=`$OPENSSL enc -base64 -A -in pki/sztpd1/sbi/end-entity/public_key.der`
cat pki/sztpd1/sbi/end-entity/my_cert.pem pki/sztpd1/sbi/intermediate2/my_cert.pem > $TEMPDIR/cert_chain.pem
$OPENSSL crl2pkcs7 -nocrl -certfile $TEMPDIR/cert_chain.pem -outform DER -out $TEMPDIR/cert_chain.cms
SBI_EE_CERT_B64=`$OPENSSL enc -base64 -A -in $TEMPDIR/cert_chain.cms`

# client cert (DevID) trust anchor
cat pki/client/root-ca/my_cert.pem pki/client/intermediate1/my_cert.pem pki/client/intermediate2/my_cert.pem \
  > $TEMPDIR/ta_cert_chain.pem
$OPENSSL crl2pkcs7 -nocrl -certfile $TEMPDIR/ta_cert_chain.pem -outform DER -out $TEMPDIR/ta_cert_chain.cms
CLIENT_CERT_TA_B64=`$OPENSSL enc -base64 -A -in $TEMPDIR/ta_cert_chain.cms`

# initialize body for the PUT request
cat << EOM > $TEMPDIR/running.json
{
    "wn-sztpd-1:transport": {
        "listen": {
            "endpoint": [
                {
                    "name": "native-interface",
                    "use-for": [
                        "native-interface"
                    ],
                    "https": {
                        "tcp-server-parameters": {
                            "local-address": "0.0.0.0",
                            "local-port": $NBI_PORT
                        },
                        "tls-server-parameters": {
                            "server-identity": {
                                "certificate" : {
                                    "reference": {
                                        "asymmetric-key": "nbi-server-end-entity-key",
                                        "certificate": "nbi-server-end-entity-cert"
                                    }
                                }
                            }
                        }
                    }
                },
                {
```



```
                "name": "rfc8572-interface",
                "use-for": [
                    "rfc8572-interface"
                ],
                "https": {
                    "tcp-server-parameters": {
                        "local-address": "0.0.0.0",
                        "local-port": $SBI_PORT
                    },
                    "tls-server-parameters": {
                        "server-identity": {
                            "certificate" : {
                                "reference": {
                                    "asymmetric-key": "sbi-server-end-entity-key",
                                    "certificate": "sbi-server-end-entity-cert"
                                }
                            }
                        },
                        "client-authentication": {
                          "ca-certs": {
                            "local-truststore-reference": "my-device-identity-ca-certs"
                          }
                        }
                    }
                }
            }
        ]
    }
},
"wn-sztpd-1:admin-accounts": {
    "admin-account": [
        {
            "email-address": "my-admin@example.com",
            "password": "\$0\$my-secret",
            "access": "unrestricted"
        }
    ]
},
"wn-sztpd-1:keystore": {
    "asymmetric-keys": {
        "asymmetric-key": [
            {
                "name": "nbi-server-end-entity-key",
                "public-key-format": "ietf-crypto-types:subject-public-key-info-format",
                "public-key": "$NBI_PUB_KEY_B64",
                "private-key-format": "ietf-crypto-types:ec-private-key-format",
                "private-key": "$NBI_PRI_KEY_B64",
                "certificates": {
                    "certificate": [
                        {
                            "name": "nbi-server-end-entity-cert",
                            "cert": "$NBI_EE_CERT_B64"
                        }
                    ]
                }
            },
            {
                "name": "sbi-server-end-entity-key",
                "public-key-format": "ietf-crypto-types:subject-public-key-info-format",
                "public-key": "$SBI_PUB_KEY_B64",
                "private-key-format": "ietf-crypto-types:ec-private-key-format",
                "private-key": "$SBI_PRI_KEY_B64",
                "certificates": {
                    "certificate": [
                        {
                            "name": "sbi-server-end-entity-cert",
                            "cert": "$SBI_EE_CERT_B64"
                        }
                    ]
                }
            }
        ]
    }
},
"wn-sztpd-1:truststore": {
    "certificate-bags": {
        "certificate-bag": [
            {
                "name": "my-device-identity-ca-certs",
                "description": "A set of TA certs that can be used to authenticate device client certs.",
                "certificate": [
                    {
                        "name": "my-device-identity-ca-cert-circa-2020",
                        "cert": "$CLIENT_CERT_TA_B64"
                    }
                ]
            }
        ]
    }
},
"wn-sztpd-1:device-types": {
    "device-type": [
        {
            "name": "my-device-type",
            "identity-certificates": {
                "verification": {
                    "local-truststore-reference": {
                        "certificate-bag": "my-device-identity-ca-certs",
                        "certificate": "my-device-identity-ca-cert-circa-2020"
                    }
                },
                "serial-number-extraction": "wn-x509-c2n:serial-number"
            }
        }
    ]
},
"wn-sztpd-1:devices": {
```



```
        "device": [
            {
                "serial-number": "my-serial-number",
                "device-type": "my-device-type",
                "activation-code": "\$0\$my-secret"
            }
        ]
    }
}
EOM


# PUT running
curl -i -X PUT --data @$TEMPDIR/running.json -H "Content-Type:application/yang-data+json" \
  http://127.0.0.1:8080/restconf/ds/ietf-datastores:running 1> output/put_running.out 2> /dev/null

rm -rf "$TEMPDIR"
```

Output:

```
HTTP/1.1 100 Continue

HTTP/1.1 204 No Content
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:48 GMT
```

3.10 Give Server time to restart

Since this change modifies the "/transport" tree, the SZTPD instance sends a SIGHUP to itself, thus causing it to reload the configuration and re-open listening ports per configuration.

SZTPD takes about 2 seconds to reload with a relatively empty configuration. Once sufficient time has elapsed (a few seconds), the configured ports will be available.

3.11 Ensuring the Ports are up

Below we first use the wrong URL scheme "http", and then correct it to "https", and then, finally, add the missing "–cacert" parameter. All these commands use "HEAD" against yang-library.

```
#!/bin/sh

printf "==== Output from NBI Port ====\n" 1> output/get_yang_library.out

printf "\n1) Incorrect 'http' (should be 'https'):\n\n" 1>> output/get_yang_library.out
curl -i --head --user my-admin@example.com:my-secret \
  http://127.0.0.1:8080/restconf/ds/ietf-datastores:operational/ietf-yang-library:yang-library \
  &> temp.out
sed -n '/curl/,$p' temp.out 1>> output/get_yang_library.out

printf "\n2) Correct 'https' (but missing '--cacert'):\n\n" 1>> output/get_yang_library.out
curl -i --head --user my-admin@example.com:my-secret \
  https://127.0.0.1:8080/restconf/ds/ietf-datastores:operational/ietf-yang-library:yang-library \
  &> temp.out
sed -n '/curl/,$p' temp.out 1>> output/get_yang_library.out

printf "\n3) Correct 'https' and '--cacert':\n\n" 1>> output/get_yang_library.out
curl -i --head --cacert nbi_trust_chain.pem --user my-admin@example.com:my-secret \
  https://127.0.0.1:8080/restconf/ds/ietf-datastores:operational/ietf-yang-library:yang-library \
  1>> output/get_yang_library.out 2> /dev/null


printf "\n\n==== Output from SBI Port ====\n" 1>> output/get_yang_library.out

printf "\n1) Incorrect 'http' (should be 'https')  [also note 'my-serial-number']:\n\n" 1>> output/get_yang_library.out
curl -i --head --user my-serial-number:my-secret \
  http://127.0.0.1:9090/restconf/ds/ietf-datastores:operational/ietf-yang-library:yang-library \
  &> temp.out
sed -n '/curl/,$p' temp.out 1>> output/get_yang_library.out

printf "\n2) Correct 'https' (but missing '--cacert'):\n\n" 1>> output/get_yang_library.out
curl -i --head --user my-serial-number:my-secret \
  https://127.0.0.1:9090/restconf/ds/ietf-datastores:operational/ietf-yang-library:yang-library \
  &> temp.out
sed -n '/curl/,$p' temp.out 1>> output/get_yang_library.out

printf "\n3) Correct 'https' and '--cacert' (but missing '--key' and '--cert'):\n\n" 1>> output/get_yang_library.out
curl -i --head --cacert sbi_trust_chain.pem --user my-serial-number:my-secret \
  https://127.0.0.1:9090/restconf/ds/ietf-datastores:operational/ietf-yang-library:yang-library \
  1>> output/get_yang_library.out 2> /dev/null

printf "\n4) Correct 'https', '--cacert', '--key', and '--cert':\n\n" 1>> output/get_yang_library.out
curl -i --head --cacert sbi_trust_chain.pem --key pki/client/end-entity/private_key.pem \
  --cert pki/client/end-entity/my_cert.pem --user my-serial-number:my-secret \
  https://127.0.0.1:9090/restconf/ds/ietf-datastores:operational/ietf-yang-library:yang-library \
  1>> output/get_yang_library.out 2> /dev/null
```



```
# cleanup
rm temp.out
```

Output:

```
=== Output from NBI Port ===

1) Incorrect 'http' (should be 'https'):

curl: (52) Empty reply from server

2) Correct 'https' (but missing '--cacert'):

curl: (60) SSL certificate problem: unable to get local issuer certificate
More details here: https://curl.haxx.se/docs/sslcerts.html

curl failed to verify the legitimacy of the server and therefore could not
establish a secure connection to it. To learn more about this situation and
how to fix it, please visit the web page mentioned above.

3) Correct 'https' and '--cacert':

HTTP/1.1 200 OK
Content-Type: application/yang-data+json; charset=utf-8
Server: <redacted>
Content-Length: 7807
Date: Sat, 20 Jun 2020 23:05:53 GMT



=== Output from SBI Port ===

1) Incorrect 'http' (should be 'https')  [also note 'my-serial-number']:

curl: (52) Empty reply from server

2) Correct 'https' (but missing '--cacert'):

curl: (60) SSL certificate problem: unable to get local issuer certificate
More details here: https://curl.haxx.se/docs/sslcerts.html

curl failed to verify the legitimacy of the server and therefore could not
establish a secure connection to it. To learn more about this situation and
how to fix it, please visit the web page mentioned above.

3) Correct 'https' and '--cacert' (but missing '--key' and '--cert'):

HTTP/1.1 401 Unauthorized
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:53 GMT


4) Correct 'https', '--cacert', '--key', and '--cert':

HTTP/1.1 200 OK
Content-Type: application/yang-data+json; charset=utf-8
Server: <redacted>
Content-Length: 1935
Date: Sat, 20 Jun 2020 23:05:53 GMT
```

3.12 Simulate Device Trying to Get Bootstrapping Data

This command fails because no "responses" have been configured for the device on the server. Note that error code 404 is used to indicate that the device may try again.

```
#!/bin/sh

# initialize the 'input' node for the RPC
cat << EOM > input.json
{
  "ietf-sztp-bootstrap-server:input" : {
    "hw-model" : "model-x",
    "os-name" : "vendor-os",
    "os-version" : "17.3R2.1",
    "nonce" : "extralongbase64encodedvalue="
  }
}
EOM

# POST 'input' for the "get-bootstrapping-data" RPC resource
curl -i -X POST --data @input.json -H "Content-Type:application/yang-data+json" --cacert sbi_trust_chain.pem \
  --key pki/client/end-entity/private_key.pem --cert pki/client/end-entity/my_cert.pem --user my-serial-number:my-secret \
  https://127.0.0.1:9090/restconf/operations/ietf-sztp-bootstrap-server:get-bootstrapping-data 1> output/post_rpc_input.out \
  2>/dev/null

# line-return needed for markdown
echo "" 1>> output/post_rpc_input.out

# cleanup
rm -f input.json
```


Output:

```
HTTP/1.1 404 Not Found
Content-Type: text/plain; charset=utf-8
Server: <redacted>
Content-Length: 24
Date: Sat, 20 Jun 2020 23:05:53 GMT

No responses configured.
```

3.13 Configuring a Redirect Response

Configure the '/bootstrapping-servers' node. This list contains all 'bootstrap-server' definitions, an ordered subset of which may be referenced by subsequent steps. Note that the port and trust-anchor nodes are replaced by variables.

```
#!/bin/sh

OPENSSL="openssl"

# generate values for placeholders
cat pki/sztpd2/sbi/root-ca/my_cert.pem pki/sztpd2/sbi/intermediate1/my_cert.pem > cert_chain.pem
$OPENSSL crl2pkcs7 -nocrl -certfile cert_chain.pem -outform DER -out cert_chain.cms
BOOTSVR_TA_CERT_B64=`$OPENSSL enc -base64 -A -in  cert_chain.cms`

# initialize body for the POST request
cat << EOM > bootstrap-servers.json
{
    "wn-sztpd-1:bootstrap-servers": {
        "bootstrap-server": [
            {
                "name": "my-bootstrap-server",
                "address": "127.0.0.1",
                "port": 9443,
                "trust-anchor": "$BOOTSVR_TA_CERT_B64"
            }
        ]
    }
}
EOM

# POST 'bootstrap-servers' to running
curl -i -X POST --data @bootstrap-servers.json -H "Content-Type:application/yang-data+json" --cacert \
  nbi_trust_chain.pem --user my-admin@example.com:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:running \
  1> output/post_bootstrap_servers.out 2>/dev/null

# cleanup
rm -f bootstrap-servers.json
rm -f cert_chain.pem
rm -f cert_chain.cms
```

Output:

```
HTTP/1.1 100 Continue

HTTP/1.1 201 Created
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:54 GMT
```


Configure the '/conveyed-information-responses' node. Configure a 'my-redirect-information' to return 'my-bootstrap-server'. An ordered list of bootstrap servers may be configured.

```
#!/bin/sh

OPENSSL="openssl"

# initialize body for the POST request
cat << EOM > conveyed-information-responses.json
{
    "wn-sztpd-1:conveyed-information-responses": {
        "redirect-information-response": [
            {
                "name": "my-redirect-information",
                "redirect-information": {
                    "bootstrap-server": [
                        "my-bootstrap-server"
                    ]
                }
            }
        ]
    }
}
EOM

# POST 'conveyed-information-responses' to running
curl -i -X POST --data @conveyed-information-responses.json -H "Content-Type:application/yang-data+json" --cacert \
  nbi_trust_chain.pem --user my-admin@example.com:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:running \
  1> output/post_conveyed_information_responses.out 2>/dev/null

# cleanup
rm -f conveyed-information-responses.json
```

Output:

```
HTTP/1.1 201 Created
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:54 GMT
```

Configure the 'response-manager' node inside the device object to return "my-redirect-information". A "catch-all" rule (i.e., one without any 'match-criteria' defined) that tells STZPD to return the just configured 'my-redirect-information'.

```
============================================================NOTE: '\' line wrapping per RFC 8792============================================================

#!/bin/sh

# initialize body for the POST request
cat << EOM > response-manager.json
{
    "wn-sztpd-1:response-manager": {
        "matched-response": [
            {
                "name": "catch-all-response",
                "response": {
                    "conveyed-information": {
                        "redirect-information": {
                            "reference": "my-redirect-information"
                        }
                    }
                }
            }
        ]
    }
}
EOM

# POST 'response-manager' to *device*
curl -i -X POST --data @response-manager.json -H "Content-Type:application/yang-data+json" --cacert nbi_trust_chain.pem --user my-admin@example.com\
:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:running/wn-sztpd-1:devices/device=my-serial-number 1> output/post_response_manager.ou\
t 2>/dev/null

# cleanup
rm -f response-manager.json
```

Output:

```
HTTP/1.1 201 Created
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:54 GMT
```


3.14 Simulate Device Getting Redirect Information

Accessing the get−bootstrapping−data RPC on the SBI again, now it works.

Request:

- Same as in the Simulate Device Trying to Get Bootstrapping Data section.

Output:

```
=============================== NOTE: '\' line wrapping per RFC 8792 ===============================

HTTP/1.1 200 OK
Content-Type: application/yang-data+json; charset=utf-8
Server: <redacted>
Content-Length: 2751
Date: Sat, 20 Jun 2020 23:05:54 GMT

{
    "ietf-sztp-bootstrap-server:output": {
        "conveyed-information": "MIIHyQYLKoZIhvcNAQkQASuggge4BIIHtHsKICAgICJpZXRmLXN6dHAtY29udmV5ZWQtaW5mbzpyZWRpcmVjdC1pbmZvcm1hdGlvbiI6IHsKICAgIC\
AgICAiYm9vdHN0cmFwLXNlcnZlciI6IFsKICAgICAgICAgICAgewogICAgICAgICAgICAgImFkZHJlc3MiOiAiMTI3LjAuMC4xIiwKICAgICAgICAgICAgICJwb3J0IjogOTQ0MywKI\
CAgICAgICAgICAgICAgICJ0cnVzdC1hbmNob3IiOiAiTUlJRkVBWUpLb1pJaHZjTkFRY0NvSUlGQVRDQ0JQMENBUUV4QURBTEJna3Foa2lHOXcwQkJ3R2dnZ1RqTUlJQ1dqQ0NBZitnQXdJQkFn\
SUJBVEFLQmdncWhrak9QQVFEQWpCMU1Rc3dDUVlEVlFRR0V3SlXREVkTUJzR0ExVUVDQXdVVFhrZ1UzUmhkR1VnYjNJZ1VISnZkbWx1WTJVeEdEQVdCZ05WQkFvTUQwMTVJRTI5WjJGdWFYcGh\
kR2x2YmpFUU1BNEdBMVVFQ3d3SFRYa2dWVzVwZERFYk1Ca0dBMVVFQXd3U2MySnBMM05sY25abGNpOXliMjkwTFdOaE1DQVhEVEl3TURZeE5ERXlORFUwT1ZvWUR6azVPVGt4TWpNeE1qTTFPVF\
U1V2pCMU1Rc3dDUVlEVlFRR0V3SlXREVkTUJzR0ExVUVDQXdVVFhrZ1UzUmhkR1VnYjNJZ1VISnZkbWx1WTJVeEdEQVdCZ05WQkFvTUQwMTVJRTI5WjJGdWFYcGhkR2x2YmpFUU1BNEdBMVVFQ\
3d3SFRYa2dWVzVwZERFYk1Ca0dBMVVFQXd3U2MySnBMM05sY25abGNpOXliMjkwTFdOaE1Ga3dFd1lIS29aSXpqMENBUVlJS29aSXpqMERBUWNEUWdBRWJxSXZXZk5JcXp6bEJBT1BpaTN5OXZP\
M0xOZ2VoK1laendWWW9VR3gxNTkzS3hkdWpyK1lTU1R5ZG9oOTdPL1NPa1d4MXJNVWZsY0tldlk1NU5RcURxTitNSHd3SFFZRFZSME9CQllFRkRCbHhqTGx6bTRsSzd4bFZ1WUF4QXMweWV0eE1\
Bd0dBMVVkRXdRRk1BTUJBZjh3RGdZRFZSMFBBUUgvQkFRREFnRUdNRDBHQTFVZEh3UTJNRFF3TXFBd29DNkdMR2gwZEhBNkx5OWpjbXd1WlhoaGJYQnNaUzVqYjIwL1kyRTjMkpwT25ObGNuWm\
xjanB5YjI5MExXTmhNQW9HQ0NxR1NNNDlCQU1DQTBrQU1FWUNJUURFVmpYczRGMWRuYzlrVU3SFdubWxBV3lrUTZXdmZkRG5FTzBRV0lwVFBRSWhBSStqNGVWbUw5bG9taVY4YzRJQS9VdEQyZ\
m5ZdW5OdHgyZmhDbFQ4Uk04Mk1JSUNnVENDQWlpZ0F3SUJBZ0lCQWpBS0JnZ3Foa2pPUFFRREFqQjFNUXN3Q1FZRFZRUUdFd0pZV0RFZE1Cc0dBMVVFQ0F3VVRYa2dVM1JoZEdVZ2IzSWdVSEp2\
ZG1sdVkyVXhHREFXQmdOVkJBb01EMDE1SUU5eVoyRnVhWHBoZEdsdmJqRVFNQTRHQTFVRUN3d0hUWGtnVlc1cGRERWJNQmtHQTFVRUF3d1NjMkpwTDNObGNuWmxjaTI5YjI5MExXTmhNQ0FYRFR\
Jd01EWXhOREV5TkRVMU1Gb1lEems1T1RreE1qTXhNak0xT1RVNVdqQjdNUXN3Q1FZRFZRUUdFd0pZV0RFZE1Cc0dBMVVFQ0F3VVRYa2dVM1JoZEdVZ2IzSWdVSEp2ZG1sdVkyVXhHREFXQmdOVk\
JBb01EMDE1SUU5eVoyRnVhWHBoZEdsdmJqRVFNQTRHQTFVRUN3d0hUWGtnVlc1cGRERWhNQjhHQTFVRUF3d1ljMkpwTDNObGNuWmxjaTIwYm5SbGNtMWxaR2xoZEdVeE1Ga3dFd1lIS29aSXpqM\
ENBUVlJS29aSXpqMERBUWNEUWdBRTFTd2JIUGtwVHgzaU81dVZuaVB2QitlOHZWYzJ2dGQ1VEhmS0daYkMzQ1E3UlJCcmF2M3JkYTd6MndzdHc2NEFVeVFsMGJsbHVFV016ZHBIcmJDTE1xT0Jv\
RENCblRBZEJnTlZIUTRFRmdRVVNGSlh6eEZvRkozeXlhZ0k5WWxremVCRlo2TXdId1lEVlIwakJCZ3dGb0FVTUdYR011WE9iaVVydkdWVzVnREVDeIRKNjNFd0RBWURWUjBUQkFVd0F3RUIvekF\
PQmdOVkhROEJBZjhFQkFNQ0FRWXdQUVlEVlIwZkJEWXdOREF5b0RDZ0xvVWXNhSFIwY0RvdkwyTnliQzVsZUdGdGNHeGxMbU52YlQ5alIUMXpZbWs2YzJWeWRtVnlPbkp2YjNRdFkyRXdDZ1lJS2\
9aSXpqMEVBd0lEUndBd1JBSWdKMzl3Z0VXOFBYN0VPaUlvTEQ1VFpBbDZPcGhxS0hodGxhRUVRWUFtVVdVQ0lDRkhYc04wZmVIS09xRUdBMlNsSjN1TE1vK2RyeVJaRGNPZVlhaUprK3Bob1FBe\
EFBPT0iCiAgICAgICAgICAgIH0KICAgICAgICBdCiAgICB9Cn0="
    }
}
```

3.15 Delete Redirect Information

Now delete all of the above config to get back to baseline, needed for upcoming Configuring an Onboarding Response section.

Note that the configuration is removed in the opposite order to avoid SZTPD throwing a validation error due to dangling references.

```
=============================== NOTE: '\' line wrapping per RFC 8792 ===============================

#!/bin/sh

# These are removed in opposite order to avoid dangling reference validation errors.
curl -i -X DELETE --cacert nbi_trust_chain.pem --user my-admin@example.com:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:running/wn-\
sztpd-1:devices/device=my-serial-number/response-manager 1> output/delete_redirect_info.out

curl -i -X DELETE --cacert nbi_trust_chain.pem --user my-admin@example.com:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:running/wn-\
sztpd-1:conveyed-information-responses 1>> output/delete_redirect_info.out

curl -i -X DELETE --cacert nbi_trust_chain.pem --user my-admin@example.com:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:running/wn-\
sztpd-1:bootstrap-servers 1>> output/delete_redirect_info.out
```

Output:

```
HTTP/1.1 204 No Content
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:54 GMT

HTTP/1.1 204 No Content
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:54 GMT

HTTP/1.1 204 No Content
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:54 GMT
```


3.16 Configuring an Onboarding Response

Configuring an onboarding response is done in much the same way, just with different nodes reflecting the difference between a "redirect" and an "onboarding" response.

First configure information about a hypothetical boot-image the device should be running:

```
#!/bin/sh

OPENSSL="openssl"

# initialize body for the POST request
dd if=/dev/urandom of=my-boot-image.img bs=64k count=1 >> /dev/null 2>&1
BOOT_IMG_HASH_VAL=`$OPENSSL dgst -sha256 -c my-boot-image.img | awk '{print $2}'`
cat << EOM > boot-images.json
{
    "wn-sztpd-1:boot-images": {
        "boot-image": [
            {
                "name": "my-boot-image.img",
                "download-uri": [ "https://example.com/my-boot-image.img" ],
                "image-verification": [
                    {
                        "hash-algorithm": "ietf-sztp-conveyed-info:sha-256",
                        "hash-value": "$BOOT_IMG_HASH_VAL"
                    }
                ]
            }
        ]
    }
}
EOM

# POST 'boot-images' to running
curl -i -X POST --data @boot-images.json -H "Content-Type:application/yang-data+json" --cacert \
  nbi_trust_chain.pem --user my-admin@example.com:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:running \
  1> output/post_boot_images.out 2>/dev/null

rm -rf my-boot-image.img boot-images.json
```

Output:

```
HTTP/1.1 201 Created
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:54 GMT
```

Configure information about the "pre" and "post" scripts the device should run:

```
#!/bin/sh

OPENSSL="openssl"

# encode a pre-configuration script
cat << EOM > my-pre-configuration-script
#/bin/bash
echo "inside the pre-configuration-script..."
EOM
PRE_SCRIPT_B64=`$OPENSSL enc -base64 -A -in my-pre-configuration-script`

# encode a post-configuration script
cat << EOM > my-post-configuration-script
#/bin/bash
echo "inside the post-configuration-script..."
EOM
POST_SCRIPT_B64=`$OPENSSL enc -base64 -A -in my-post-configuration-script`

# initialize body for the POST request
cat << EOM > scripts.json
{
    "wn-sztpd-1:scripts": {
        "pre-configuration-script": [
            {
                "name": "my-pre-configuration-script",
                "script": "$PRE_SCRIPT_B64"
            }
        ],
        "post-configuration-script": [
            {
                "name": "my-post-configuration-script",
                "script": "$POST_SCRIPT_B64"
            }
        ]
    }
}
EOM

# POST 'scripts' to running
curl -i -X POST --data @scripts.json -H "Content-Type:application/yang-data+json" --cacert \
  nbi_trust_chain.pem --user my-admin@example.com:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:running \
  1> output/post_scripts.out 2>/dev/null

# cleanup
rm -f scripts.json
rm -f my-pre-configuration-script
rm -f my-post-configuration-script
```


Output:

```
HTTP/1.1 201 Created
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:55 GMT
```

Set the device-specific configuration the device should run:

```
#!/bin/sh

OPENSSL="openssl"

# initialize body for the POST request
cat << EOM > my-configuration
<top xmlns="https://example.com/config">
  <any-xml-content-okay/>
</top>
EOM
CONFIG_B64=`$OPENSSL enc -base64 -A -in my-configuration`

cat << EOM > configurations.json
{
    "wn-sztpd-1:configurations": {
        "configuration": [
            {
                "name": "my-configuration",
                "configuration-handling": "merge",
                "config": "$CONFIG_B64"
            }
        ]
    }
}
EOM

# POST 'configurations.json' to running
curl -i -X POST --data @configurations.json -H "Content-Type:application/yang-data+json" --cacert \
  nbi_trust_chain.pem --user my-admin@example.com:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:running \
  1> output/post_configurations.out 2>/dev/null

# cleanup
rm -f my-configuration
rm -f configurations.json
```

Output:

```
HTTP/1.1 201 Created
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:55 GMT
```

Configure "conveyed-information" referencing all of the above:

```
#!/bin/sh

# initialize body for the POST request
cat << EOM > conveyed-information-responses.json
{
    "wn-sztpd-1:conveyed-information-responses": {
        "onboarding-information-response": [
            {
                "name": "my-onboarding-information",
                "onboarding-information": {
                    "boot-image": "my-boot-image.img",
                    "pre-configuration-script": "my-pre-configuration-script",
                    "configuration": "my-configuration",
                    "post-configuration-script": "my-post-configuration-script"
                }
            }
        ]
    }
}
EOM

# POST 'conveyed-information-responses' to running
curl -i -X POST --data @conveyed-information-responses.json \
  -H "Content-Type:application/yang-data+json" --cacert nbi_trust_chain.pem --user my-admin@example.com:my-secret \
  https://127.0.0.1:8080/restconf/ds/ietf-datastores:running 1> output/post_conveyed_information_responses2.out 2>/dev/null

rm -f conveyed-information-responses.json
```

Output:

```
HTTP/1.1 201 Created
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:55 GMT
```


Configure the 'response-manager' node inside the device object to return "my-onboarding-information". A "catch-all" rule (i.e., one without any 'match-criteria' defined) that tells STZPD to return the just configured 'my-redirect-information'.

```
================================================================NOTE: '\' line wrapping per RFC 8792================================================================

#!/bin/sh

# initialize body for the POST request
cat << EOM > response-manager.json
{
    "wn-sztpd-1:response-manager": {
        "matched-response": [
            {
                "name": "catch-all-response",
                "response": {
                    "conveyed-information": {
                        "onboarding-information": {
                            "reference": "my-onboarding-information"
                        }
                    }
                }
            }
        ]
    }
}
EOM

# POST 'response-manager' to *device*
curl -i -X POST --data @response-manager.json -H "Content-Type:application/yang-data+json" --cacert nbi_trust_chain.pem --user my-admin@example.com\
:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:running/wn-sztpd-1:devices/device=my-serial-number  1> output/post_response_manager2.\
out 2>/dev/null

# cleanup
rm -f response-manager.json
```

Output:

```
HTTP/1.1 201 Created
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:55 GMT
```

3.17 Simulate Device Getting Onboarding Information

Request:

- Same as in the Simulate Device Trying to Get Bootstrapping Data section.

Output:

```
================================================================NOTE: '\' line wrapping per RFC 8792================================================================

HTTP/1.1 200 OK
Content-Type: application/yang-data+json; charset=utf-8
Server: <redacted>
Content-Length: 1323
Date: Sat, 20 Jun 2020 23:05:55 GMT

{
    "ietf-sztp-bootstrap-server:output": {
        "conveyed-information": "MIIDmQYLKoZIhvcNAQkQASuggggOIBIIDhHsKICAgICJpZXRmLXN6dHAtY29udmV5ZWQtaW5mbzpvbmJvYXJkaW5nLWluZm9ybWF0aW9uIjogewogIC\
AgICAgICJfib290LWhtYWdlIjogewogICAgICAgICAiZG93bmxvYWQtdXJpIjogWwogICAgICAgICAgICAgImh0dHBzOi8vZXhhbXBsZS5jb20vbXlxtYm9vdC1pbWFnZS5pbWciCiAgI\
CAgICAgICAgIF0sCiAgICAgICAgICAgICJpbWFnZS12ZXJpZmljYXRpb24iOiBbCiAgICAgICAgICAgICB7CiAgICAgICAgICAgICAgImhhc2gtYWxnb3JpdGhtIjogImlkGYt\
c3p0cC1jb252ZXIlZC1pbmZvOnNoYS0yNTYiLAogICAgICAgICAgICAgICJoYXNoLXZhbHVlIjogImJjOmNkOjc1OmZkOjlhOjJmOjU2OjkzOjFiOmYwOmQ1OmNhOjZlOmQ5Ojk1OjB\
hOjFlOmIyOjlkOmE5OjczOjg5OmM3OmFlOjZmOmVkOjNjOmM1OjksOmM4OmJjOjZlIgogICAgICAgICAgICAgfQogICAgICAgICAgICBdCiAgICAgICAgfSwKICAgICAgICAicHJlLWNvbm\
ZpZ3VyYXRpb24tc2NyaXB0IjogIkd5OWlhVzR2WW1GemFBcGxZMmh2SUNKcGJuTnBaR1VnZEdobElIQnlaUzFqYjI1bWFXZDFjbUYwYVc5dUxYTmpjbWx3ZEM0dUxpSUsiLAogICAgICAgICAgICJjb\
25maWd1cmF0aW9uLWhhbmRsaW5nIjogIm1kcmdIiwKICAgICAgICAiY29uZmlndCIvbil6ICJQSFJ2Y0NCNGJXeHVjejBpYUhSMGNNTTZMMlY0WVcxd2JHVXVZMjl0TDJOdmJtWnBaeUlg\
Q2lBZ1BHRnVlUzE0Y1d3dFkyOXVkR1Z1ZEMxdmEyRjVMejRLUEM5MGIzQStDZz09IiwKICAgICAgICAicG9zdC1jb25maWd1cmF0aW9uLXNjcmlwdCI6ICJJeTlpYVc0dlltRnphQXBsWTJodkl\
DShBik5wWkdVZ2RHaGxISEJ2YzNRdFkyOXVabWxuZFhKaGRHbHZiaTF6WTNKcGNIUXVMaTRpQ2s9PSIKICAgH0KfQ==”
    }
}
```


3.18 Simulate Device Posting a Progress Report

In addition to RFC 8572 enabling a device to obtain bootstrapping data, it also enables a device to post progress reports that enable a controller / NMS application to:

1) learn of any issues preventing bootstrapping from succeeding.
2) learn of any dynamically-generated SSH host keys and/or TLS certificates, such as may be needed to authenticate the device via other protocols (e.g., NETCONF, RESTCONF, etc.)

```
#!/bin/sh

# initialize the 'input' node for the RPC
  cat << EOM > bootstrap-complete.json
{
  "ietf-sztp-bootstrap-server:input" : {
    "progress-type" : "bootstrap-complete",
    "message" : "Dynamically generated SSH host key included.",
    "ssh-host-keys" : {
      "ssh-host-key" : [
        {
          "algorithm" : "ssh-rsa",
          "key-data" : "base64encodedvalue=="
        }
      ]
    }
  }
}
EOM

# POST it to the "report-progress" RPC resource
curl -i -X POST --data @bootstrap-complete.json -H "Content-Type:application/yang-data+json" --cacert sbi_trust_chain.pem \
  --key pki/client/end-entity/private_key.pem --cert pki/client/end-entity/my_cert.pem --user my-serial-number:my-secret \
  https://127.0.0.1:9090/restconf/operations/ietf-sztp-bootstrap-server:report-progress 1> output/post_progress_report.out \
  2>/dev/null

# line-return needed for markdown
echo "" 1>> output/post_progress_report.out

# cleanup
rm -f bootstrap-complete.json
```

Output:

```
HTTP/1.1 204 No Content
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:55 GMT
```

3.19 Delete Onboarding Information

Now delete all of the onboarding config to get back to baseline (not that it matters).

Note that the configuration is removed in the opposite order to avoid SZTPD throwing a validation error due to dangling references.

```
============================================================NOTE: '\' line wrapping per RFC 8792 ============================================================

#!/bin/sh

# These are removed in opposite order to avoid dangling reference validation errors.

curl -i -X DELETE --cacert nbi_trust_chain.pem --user my-admin@example.com:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:running/wn-\
sztpd-1:devices/device=my-serial-number/response-manager 1> output/delete_onboarding_info.out 2>/dev/null

curl -i -X DELETE --cacert nbi_trust_chain.pem --user my-admin@example.com:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:running/wn-\
sztpd-1:conveyed-information-responses 1>> output/delete_onboarding_info.out 2>/dev/null

curl -i -X DELETE --cacert nbi_trust_chain.pem --user my-admin@example.com:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:running/wn-\
sztpd-1:boot-images 1>> output/delete_onboarding_info.out 2>/dev/null

curl -i -X DELETE --cacert nbi_trust_chain.pem --user my-admin@example.com:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:running/wn-\
sztpd-1:scripts 1>> output/delete_onboarding_info.out 2>/dev/null

curl -i -X DELETE --cacert nbi_trust_chain.pem --user my-admin@example.com:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:running/wn-\
sztpd-1:configurations 1>> output/delete_onboarding_info.out 2>/dev/null
```


Output:

```
HTTP/1.1 204 No Content
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:55 GMT

HTTP/1.1 204 No Content
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:55 GMT

HTTP/1.1 204 No Content
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:56 GMT

HTTP/1.1 204 No Content
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:56 GMT

HTTP/1.1 204 No Content
Server: <redacted>
Content-Length: 0
Content-Type: application/octet-stream
Date: Sat, 20 Jun 2020 23:05:56 GMT
```

3.20 View Audit Log

Notice how all the commands run above appear below.

```
#!/bin/sh

curl -i -X GET --cacert nbi_trust_chain.pem --user my-admin@example.com:my-secret \
  https://127.0.0.1:8080/restconf/ds/ietf-datastores:operational/wn-sztpd-1:audit-log \
  1> output/get_audit_log.out 2>/dev/null

# line-return needed for markdown
echo "" 1>> output/get_audit_log.out
```

Output:

```
HTTP/1.1 200 OK
Content-Type: application/yang-data+json; charset=utf-8
Server: <redacted>
Content-Length: 7773
Date: Sat, 20 Jun 2020 23:05:56 GMT

{
    "wn-sztpd-1:audit-log": {
        "log-entry": [
            {
                "timestamp": "2020-06-20T23:05:48Z",
                "source-ip": "127.0.0.1",
                "host": "127.0.0.1:8080",
                "method": "PUT",
                "path": "/restconf/ds/ietf-datastores:running",
                "outcome": "success",
                "comment": "No authorization required for fresh installs."
            },
            {
                "timestamp": "2020-06-20T23:05:53Z",
                "source-ip": "127.0.0.1",
                "host": "127.0.0.1:9090",
                "method": "HEAD",
                "path": "/restconf/ds/ietf-datastores:operational/ietf-yang-library:yang-library",
                "outcome": "failure",
                "comment": "Client cert required but none passed for serial number my-serial-number"
            },
            {
                "timestamp": "2020-06-20T23:05:53Z",
                "source-ip": "127.0.0.1",
                "host": "127.0.0.1:9090",
                "method": "HEAD",
                "path": "/restconf/ds/ietf-datastores:operational/ietf-yang-library:yang-library",
                "outcome": "success"
            },
            {
                "timestamp": "2020-06-20T23:05:53Z",
                "source-ip": "127.0.0.1",
                "host": "127.0.0.1:9090",
                "method": "POST",
                "path": "/restconf/operations/ietf-sztp-bootstrap-server:get-bootstrapping-data",
                "outcome": "success"
            },
            {
                "timestamp": "2020-06-20T23:05:54Z",
                "source-ip": "127.0.0.1",
                "host": "127.0.0.1:8080",
                "method": "POST",
                "path": "/restconf/ds/ietf-datastores:running",
```



```
            "outcome": "success"
        },
        {
            "timestamp": "2020-06-20T23:05:54Z",
            "source-ip": "127.0.0.1",
            "host": "127.0.0.1:8080",
            "method": "POST",
            "path": "/restconf/ds/ietf-datastores:running",
            "outcome": "success"
        },
        {
            "timestamp": "2020-06-20T23:05:54Z",
            "source-ip": "127.0.0.1",
            "host": "127.0.0.1:8080",
            "method": "POST",
            "path": "/restconf/ds/ietf-datastores:running/wn-sztpd-1:devices/device=my-serial-number",
            "outcome": "success"
        },
        {
            "timestamp": "2020-06-20T23:05:54Z",
            "source-ip": "127.0.0.1",
            "host": "127.0.0.1:9090",
            "method": "POST",
            "path": "/restconf/operations/ietf-sztp-bootstrap-server:get-bootstrapping-data",
            "outcome": "success"
        },
        {
            "timestamp": "2020-06-20T23:05:54Z",
            "source-ip": "127.0.0.1",
            "host": "127.0.0.1:8080",
            "method": "DELETE",
            "path": "/restconf/ds/ietf-datastores:running/wn-sztpd-1:devices/device=my-serial-number/response-manager",
            "outcome": "success"
        },
        {
            "timestamp": "2020-06-20T23:05:54Z",
            "source-ip": "127.0.0.1",
            "host": "127.0.0.1:8080",
            "method": "DELETE",
            "path": "/restconf/ds/ietf-datastores:running/wn-sztpd-1:conveyed-information-responses",
            "outcome": "success"
        },
        {
            "timestamp": "2020-06-20T23:05:54Z",
            "source-ip": "127.0.0.1",
            "host": "127.0.0.1:8080",
            "method": "DELETE",
            "path": "/restconf/ds/ietf-datastores:running/wn-sztpd-1:bootstrap-servers",
            "outcome": "success"
        },
        {
            "timestamp": "2020-06-20T23:05:54Z",
            "source-ip": "127.0.0.1",
            "host": "127.0.0.1:8080",
            "method": "POST",
            "path": "/restconf/ds/ietf-datastores:running",
            "outcome": "success"
        },
        {
            "timestamp": "2020-06-20T23:05:55Z",
            "source-ip": "127.0.0.1",
            "host": "127.0.0.1:8080",
            "method": "POST",
            "path": "/restconf/ds/ietf-datastores:running",
            "outcome": "success"
        },
        {
            "timestamp": "2020-06-20T23:05:55Z",
            "source-ip": "127.0.0.1",
            "host": "127.0.0.1:8080",
            "method": "POST",
            "path": "/restconf/ds/ietf-datastores:running",
            "outcome": "success"
        },
        {
            "timestamp": "2020-06-20T23:05:55Z",
            "source-ip": "127.0.0.1",
            "host": "127.0.0.1:8080",
            "method": "POST",
            "path": "/restconf/ds/ietf-datastores:running",
            "outcome": "success"
        },
        {
            "timestamp": "2020-06-20T23:05:55Z",
            "source-ip": "127.0.0.1",
            "host": "127.0.0.1:8080",
            "method": "POST",
            "path": "/restconf/ds/ietf-datastores:running/wn-sztpd-1:devices/device=my-serial-number",
            "outcome": "success"
        },
        {
            "timestamp": "2020-06-20T23:05:55Z",
            "source-ip": "127.0.0.1",
            "host": "127.0.0.1:9090",
            "method": "POST",
            "path": "/restconf/operations/ietf-sztp-bootstrap-server:get-bootstrapping-data",
            "outcome": "success"
        },
        {
            "timestamp": "2020-06-20T23:05:55Z",
            "source-ip": "127.0.0.1",
            "host": "127.0.0.1:9090",
            "method": "POST",
            "path": "/restconf/operations/ietf-sztp-bootstrap-server:report-progress",
            "outcome": "success"
        },
        {
```



```
                "timestamp": "2020-06-20T23:05:55Z",
                "source-ip": "127.0.0.1",
                "host": "127.0.0.1:8080",
                "method": "DELETE",
                "path": "/restconf/ds/ietf-datastores:running/wn-sztpd-1:devices/device=my-serial-number/response-manager",
                "outcome": "success"
            },
            {
                "timestamp": "2020-06-20T23:05:55Z",
                "source-ip": "127.0.0.1",
                "host": "127.0.0.1:8080",
                "method": "DELETE",
                "path": "/restconf/ds/ietf-datastores:running/wn-sztpd-1:conveyed-information-responses",
                "outcome": "success"
            },
            {
                "timestamp": "2020-06-20T23:05:55Z",
                "source-ip": "127.0.0.1",
                "host": "127.0.0.1:8080",
                "method": "DELETE",
                "path": "/restconf/ds/ietf-datastores:running/wn-sztpd-1:boot-images",
                "outcome": "success"
            },
            {
                "timestamp": "2020-06-20T23:05:56Z",
                "source-ip": "127.0.0.1",
                "host": "127.0.0.1:8080",
                "method": "DELETE",
                "path": "/restconf/ds/ietf-datastores:running/wn-sztpd-1:scripts",
                "outcome": "success"
            },
            {
                "timestamp": "2020-06-20T23:05:56Z",
                "source-ip": "127.0.0.1",
                "host": "127.0.0.1:8080",
                "method": "DELETE",
                "path": "/restconf/ds/ietf-datastores:running/wn-sztpd-1:configurations",
                "outcome": "success"
            }
        ]
    }
}
```

3.21 View Device's Bootstrapping Log

Notice how the three get-bootstrapping-data RPC requests from above all appear below.

```
================================================================NOTE: '\' line wrapping per RFC 8792================================================================

#!/bin/sh

curl -i -X GET --cacert nbi_trust_chain.pem --user my-admin@example.com:my-secret https://127.0.0.1:8080/restconf/ds/ietf-datastores:operational/wn\
-sztpd-1:devices/device=my-serial-number/bootstrapping-log 1> output/get_bootstrapping_log.out 2>/dev/null

# line-return needed for markdown
echo "" 1>> output/get_bootstrapping_log.out
```

Output:

```
HTTP/1.1 200 OK
Content-Type: application/yang-data+json; charset=utf-8
Server: <redacted>
Content-Length: 6615
Date: Sat, 20 Jun 2020 23:05:56 GMT

{
    "wn-sztpd-1:bootstrapping-log": {
        "log-entry": [
            {
                "timestamp": "2020-06-20T23:05:53Z",
                "source-ip": "127.0.0.1",
                "method": "HEAD",
                "path": "/restconf/ds/ietf-datastores:operational/ietf-yang-library:yang-library",
                "return-code": 200
            },
            {
                "timestamp": "2020-06-20T23:05:53Z",
                "source-ip": "127.0.0.1",
                "method": "POST",
                "path": "/restconf/operations/ietf-sztp-bootstrap-server:get-bootstrapping-data",
                "return-code": 404,
                "error-message": "No responses configured.",
                "event-details": {
                    "get-bootstrapping-data-event": {
                        "passed-input": {
                            "input": [
                                {
                                    "key": "hw-model",
                                    "value": "model-x"
                                },
                                {
                                    "key": "os-name",
                                    "value": "vendor-os"
                                },
                                {
                                    "key": "os-version",
                                    "value": "17.3R2.1"
```



```
                        },
                        {
                            "key": "nonce",
                            "value": "extralongbase64encodedvalue="
                        }
                    ]
                },
                "selected-response": "no-match-found"
            }
        }
    },
    {
        "timestamp": "2020-06-20T23:05:54Z",
        "source-ip": "127.0.0.1",
        "method": "POST",
        "path": "/restconf/operations/ietf-sztp-bootstrap-server:get-bootstrapping-data",
        "return-code": 200,
        "event-details": {
            "get-bootstrapping-data-event": {
                "passed-input": {
                    "input": [
                        {
                            "key": "hw-model",
                            "value": "model-x"
                        },
                        {
                            "key": "os-name",
                            "value": "vendor-os"
                        },
                        {
                            "key": "os-version",
                            "value": "17.3R2.1"
                        },
                        {
                            "key": "nonce",
                            "value": "extralongbase64encodedvalue="
                        }
                    ]
                },
                "selected-response": "catch-all-response",
                "response-details": {
                    "managed-response-supplied": {
                        "conveyed-information": {
                            "redirect-information": {
                                "referenced-definition": "my-redirect-information"
                            }
                        }
                    }
                }
            }
        }
    },
    {
        "timestamp": "2020-06-20T23:05:55Z",
        "source-ip": "127.0.0.1",
        "method": "POST",
        "path": "/restconf/operations/ietf-sztp-bootstrap-server:get-bootstrapping-data",
        "return-code": 200,
        "event-details": {
            "get-bootstrapping-data-event": {
                "passed-input": {
                    "input": [
                        {
                            "key": "hw-model",
                            "value": "model-x"
                        },
                        {
                            "key": "os-name",
                            "value": "vendor-os"
                        },
                        {
                            "key": "os-version",
                            "value": "17.3R2.1"
                        },
                        {
                            "key": "nonce",
                            "value": "extralongbase64encodedvalue="
                        }
                    ]
                },
                "selected-response": "catch-all-response",
                "response-details": {
                    "managed-response-supplied": {
                        "conveyed-information": {
                            "onboarding-information": {
                                "referenced-definition": "my-onboarding-information"
                            }
                        }
                    }
                }
            }
        }
    },
    {
        "timestamp": "2020-06-20T23:05:55Z",
        "source-ip": "127.0.0.1",
        "method": "POST",
        "path": "/restconf/operations/ietf-sztp-bootstrap-server:report-progress",
        "return-code": 204,
        "event-details": {
            "report-progress-event": {
                "passed-input": {
                    "progress-type": "bootstrap-complete",
                    "message": "Dynamically generated SSH host key included.",
                    "ssh-host-keys": {
                        "ssh-host-key": [
                            {
```



```
                                    "algorithm": "ssh-rsa",
                                    "key-data": "base64encodedvalue=="
                                }
                            ]
                        }
                    },
                    "dynamic-callout-result": {
                        "no-webhooks-configured": [
                            null
                        ]
                    }
                }
            }
        }
    ]
  }
}
```

4 Northbound Interface

This section provides a high-level overview of the API using YANG tree diagrams.

The tree diagrams enable the general structure of the data to be understood but, for full understanding, it is necessary to look at the YANG modules themselves.

The YANG modules used by SZTPD can be found in the "yang" directory in the sztpd installation directory (e.g., site-packages/sztpd/yang/*.yang). Each Python installation has its own location for where it installs Python modules. This may vary by the version of Python installed and if virtual environments are used. The following command can be used to find the directory the YANG files are located in:

```
python -c 'import pkg_resources; print(pkg_resources.resource_filename("sztpd", "yang/"))'
```

DISCLAIMER: the YANG models are unsually complex, due to the modules needing to present different product modes.

4.1 NBI Fundamentals

The following sections are presented in sorted order.

4.1.1 Administrator Accounts

The following tree diagram illustrates the NBI used for configuring "admin-accounts".

```
+--rw admin-accounts
   +--rw admin-account* [email-address]
      +--rw email-address                    string
      +--rw fullname?                        string
      +--rw password                         iana-crypt-hash:crypt-hash
      +--ro password-last-modified           ietf-yang-types:date-and-time
      +--rw access                           enumeration
      +---x resend-activation-email
```

Each account is keyed by an email address. Use of an email address enables mapping to subtenant mapping (for deployments running in product mode 'x', as email addresses are globally unique, and otherwise enables the email-based administrator account verification mechanism provided by SZTPD.

4.1.2 Audit Log

The following tree diagram illustrates the NBI used viewing audit logs ("ro" stands for "read-only").

```
+--ro audit-log
   +--ro log-entry*
      +--ro timestamp          ietf-yang-types:date-and-time
      +--ro source-ip          ietf-inet-types:ip-address
      +--ro source-proxies*    string
      +--ro host               string
```



```
      +--ro method             enumeration
      +--ro path               string
      +--ro outcome            enumeration
      +--ro comment?           string
```

4.1.3 Boot Images

The following tree diagram illustrates the NBI used for configuring boot-image records.

```
+--rw boot-images {wn-sztpd-0:onboarding-supported}?
   +--rw boot-image* [name]
      +--rw name                          string
      +--rw os-name?                      string
      +--rw os-version?                   string
      +--rw download-uri*                 ietf-inet-types:uri
      +--rw image-verification* [hash-algorithm]
      |  +--rw hash-algorithm     identityref
      |  +--rw hash-value         ietf-yang-types:hex-string
      +--ro reference-statistics
         +--ro reference-count    uint32
         +--ro last-referenced    union
```

The boot-image records are used in constructing RFC 8572 based "onboarding information" responses.

4.1.4 Bootstrap Servers

The following tree diagram illustrates the NBI used for configuring "bootstrap-server" records.

```
+--rw bootstrap-servers
   +--rw bootstrap-server* [name]
      +--rw name                          string
      +--rw address                       ietf-inet-types:host
      +--rw port?                         ietf-inet-types:port-number <443>
      +--rw trust-anchor?                 ietf-crypto-types:trust-anchor-cert-cms
      +--ro reference-statistics
         +--ro reference-count    uint32
         +--ro last-referenced    union
```

The bootstrap-server records are used in constructing RFC 8572 based "redirect information" responses.

4.1.5 Configurations

The following tree diagram illustrates the NBI used for configuring configuration records.

```
+--rw configurations {wn-sztpd-0:onboarding-supported}?
   +--rw configuration* [name]
      +--rw name                          string
      +--rw configuration-handling?       enumeration
      +--rw config?                       binary
      +--ro reference-statistics
         +--ro reference-count    uint32
         +--ro last-referenced    union
```

The configuration records are used in constructing RFC 8572 based "onboarding information" responses.

4.1.6 Conveyed Information Responses

The following tree diagram illustrates the NBI used for configuring conveyed-information-responses records.

```
+--rw conveyed-information-responses
   +--rw redirect-information-response* [name]
   |  +--rw name                          string
   |  +--rw redirect-information
   |  |  +--rw bootstrap-server*   -> ../../../../bootstrap-servers/bootstrap-server/name
   |  +--ro reference-statistics
   |     +--ro reference-count    uint32
   |     +--ro last-referenced    union
   +--rw onboarding-information-response* [name] {wn-sztpd-0:onboarding-supported}?
      +--rw name                          string
      +--rw onboarding-information
      |  +--rw boot-image                   -> ../../../../boot-images/boot-image/name
      |  +--rw pre-configuration-script?    -> ../../../../scripts/pre-configuration-script/name
      |  +--rw configuration?               -> ../../../../configurations/configuration/name
      |  +--rw post-configuration-script?   -> ../../../../scripts/post-configuration-script/name
      +--ro reference-statistics
```



```
          +--ro reference-count     uint32
          +--ro last-referenced     union
```

The conveyed-information-responses records are used in constructing RFC 8572 based "redirect" and "on-boarding" information responses.

4.1.7 Device-Types

The "/device-types" tree enables configuration of device types to be recognized by the system.

Not only is being able to associate a device with a type helpful on its own, but each "device-type" entry enables more than just that, as explained below.

The device-types list contains an optional reference to the specific trust-anchor certificate in the Keystore used by the transport. This enables application specific verification that the device's client certificate (i.e., its IDevID) exactly matches the expected certificate chain.

Similarly, the device-types list contains an optional "ownership-authorization" webhook enabling SZTPD to ensure that the specific tenant is the rightful owner of configured serial-numbers.

Important: In the "tenant" view, this entire data-tree is read-only. That is, all the "rw" would be shown as "ro" if this were the tenant view's tree diagram. The /device-types tree is read-only in the "tenant" view because device types can only be set at the system level via the 'native' view.

The following tree diagram illustrates the NBI used for configuring device records.

```
============================================================NOTE: '\' line wrapping per RFC 8792============================================================

  +--rw device-types
     +--rw device-type* [name]
        +--rw name                          string
        +--rw identity-certificates!
        |  +--rw verification
        |  |  +--rw local-truststore-reference {ietf-truststore:certificates}?
        |  |     +--rw certificate-bag    -> /truststore/certificate-bags/certificate-bag/name
        |  |     +--rw certificate        -> /truststore/certificate-bags/certificate-bag[name = current()/../certificate-bag]/certificate/name
        |  +--rw serial-number-extraction?   identityref <wn-x509-c2n:serial-number>
        +--rw ownership-authorization!
        |  +--rw https
        |     +--rw tcp-client-parameters
        |     |  +--rw remote-address     inet:host
        |     |  +--rw remote-port?       inet:port-number <443>
        |     +--rw tls-client-parameters
        |     |  +--rw client-identity!
        |     |  |  +--rw (auth-type)
        |     |  |     +--:(certificate) {ietf-tls-client:x509-certificate-auth}?
        |     |  |        +--rw certificate
        |     |  |           +--rw (local-or-keystore)
        |     |  +--rw server-authentication
        |     |     +--rw ca-certs! {ietf-tls-client:x509-certificate-auth}?
        |     |     |  +--rw (local-or-truststore)
        |     |     |     +--:(local-truststore) {ietf-truststore:certificates}?
        |     |     |        +--rw local-truststore-reference {ietf-truststore:certificates}?
        |     |     |           +--rw certificate-bag    -> /truststore/certificate-bags/certificate-bag/name
        |     |     |           +--rw certificate        -> /truststore/certificate-bags/certificate-bag[name = current()/../certificate-bag]/certi\
ficate/name
        |     |     +--rw ee-certs! {ietf-tls-client:x509-certificate-auth}?
        |     |        +--rw (local-or-truststore)
        |     |           +--:(local-truststore) {ietf-truststore:certificates}?
        |     |              +--rw local-truststore-reference {ietf-truststore:certificates}?
        |     |                 +--rw certificate-bag    -> /truststore/certificate-bags/certificate-bag/name
        |     |                 +--rw certificate        -> /truststore/certificate-bags/certificate-bag[name = current()/../certificate-bag]/certi\
ficate/name
        |     +--rw http-client-parameters
        |        +--rw client-identity!
        |           +--rw (auth-type)
        |              +--:(basic)
        |                 +--rw basic {ietf-http-client:basic-auth}?
        |                    +--rw user-id      string
        |                    +--rw password     string
        +--rw voucher-aquisition!
           +--rw https
              +--rw tcp-client-parameters
              |  +--rw remote-address     inet:host
              |  +--rw remote-port?       inet:port-number <443>
              +--rw tls-client-parameters
              |  +--rw client-identity!
              |  |  +--rw (auth-type)
              |  |     +--:(certificate) {ietf-tls-client:x509-certificate-auth}?
              |  |        +--rw certificate
              |  |           +--rw (local-or-keystore)
              |  +--rw server-authentication
              |     +--rw ca-certs! {ietf-tls-client:x509-certificate-auth}?
              |     |  +--rw (local-or-truststore)
              |     |     +--:(local-truststore) {ietf-truststore:certificates}?
              |     |        +--rw local-truststore-reference {ietf-truststore:certificates}?
              |     |           +--rw certificate-bag    -> /truststore/certificate-bags/certificate-bag/name
```



```
              |     |           +--rw certificate        -> /truststore/certificate-bags/certificate-bag[name = current()/../certificate-bag]/certi\
ficate/name
              |     +--rw ee-certs! {ietf-tls-client:x509-certificate-auth}?
              |        +--rw (local-or-truststore)
              |           +--:(local-truststore) {ietf-truststore:certificates}?
              |              +--rw local-truststore-reference {ietf-truststore:certificates}?
              |                 +--rw certificate-bag    -> /truststore/certificate-bags/certificate-bag/name
              |                 +--rw certificate        -> /truststore/certificate-bags/certificate-bag[name = current()/../certificate-bag]/certi\
ficate/name
              +--rw http-client-parameters
                 +--rw client-identity!
                    +--rw (auth-type)
                       +--:(basic)
                          +--rw basic {ietf-http-client:basic-auth}?
                             +--rw user-id      string
                             +--rw password     string
```

4.1.8 Devices

The following tree diagram illustrates the NBI used for configuring device records.

```
=============================================================NOTE: '\' line wrapping per RFC 8792=============================================================

  +--rw devices
     +--rw device* [serial-number]
        +--rw serial-number                        string
        +--rw activation-code?                     iana-crypt-hash:crypt-hash
        +--rw response-manager
        |  +--rw matched-response* [name]
        |     +--rw name                 string
        |     +--rw match-criteria!
        |     |  +--rw match* [key]
        |     |     +--rw key             string
        |     |     +--rw not?            empty
        |     |     +--rw (test-type)
        |     |        +--:(present)
        |     |        |  +--rw present?    empty
        |     |        +--:(value)
        |     |        |  +--rw value?     string
        |     |        +--:(regex)
        |     |           +--rw regex?     string
        |     +--rw response
        |        +--rw reporting-level?      enumeration <minimal> {wn-sztpd-0:onboarding-supported}?
        |        +--rw (response-handler)
        |           +--:(none)
        |           |  +--rw none?    empty
        |           +--:(use-dynamic-callout)
        |           |  +--rw dynamic-callout
        |           |     +--rw reference?    -> ../../../../../../../../dynamic-callouts/dynamic-callout/name
        |           +--:(managed-response)
        |              +--rw conveyed-information
        |                 +--rw (conveyed-information-handler)
        |                    +--:(use-dynamic-callout)
        |                    |  +--rw dynamic-callout
        |                    |     +--rw reference?    -> ../../../../../../../../dynamic-callouts/dynamic-callout/name
        |                    +--:(redirect-information)
        |                    |  +--rw redirect-information
        |                    |     +--rw (local-or-reference)
        |                    |        +--:(reference)
        |                    |           +--rw reference?    -> ../../../../../../../../conveyed-information-responses/redirect-information-response\
/name
        |                    +--:(onboarding-information) {wn-sztpd-0:onboarding-supported}?
        |                       +--rw onboarding-information
        |                          +--rw (local-or-reference)
        |                             +--:(reference)
        |                                +--rw reference?    -> ../../../../../../../../conveyed-information-responses/onboarding-information-respon\
se/name
        +--ro bootstrapping-log
        |  +--ro log-entry*
        |     +--ro timestamp          ietf-yang-types:date-and-time
        |     +--ro source-ip          ietf-inet-types:ip-address
        |     +--ro method             string
        |     +--ro path               string
        |     +--ro return-code        uint16
        |     +--ro error-message?     string
        |     +--ro event-details
        |        +--ro (event-type)
        |           +--:(get-bootstrapping-data-event)
        |           |  +--ro get-bootstrapping-data-event
        |           |     +--ro passed-input
        |           |     |  +--ro (input-type)
        |           |     |     +--:(no-input-passed)
        |           |     |     |  +--ro no-input-passed?    empty
        |           |     |     +--:(input)
        |           |     |        +--ro input*
        |           |     |           +--ro key       string
        |           |     |           +--ro value     union
        |           |     +--ro selected-response?          union
        |           |     +--ro response-details
        |           |        +--ro (response-type)
        |           |           +--:(managed)
        |           |              +--ro managed-response-supplied
        |           |                 +--ro conveyed-information
        |           |                    +--ro (conveyed-information-handler)
        |           |                       +--:(dynamic-callout)
        |           |                          |  +--ro dynamic-callout-result
        |           |                          |     +--ro (result-type)?
        |           |                          |        +--:(no-callout-configured)
        |           |                          |        |  +--ro no-callout-configured?    empty
        |           |                          |        +--:(callout-configured)
```



```
|          |                      |          +--ro name?             string
|          |                      |          +--ro (callout-type)?
|          |                      |             +--:(callback)
|          |                      |                | +--ro callback-results
|          |                      |                |    +--ro (exit-status)
|          |                      |                |       +--:(exited-successfully)
|          |                      |                |       |  +--ro exited-successfully?   empty
|          |                      |                |       +--:(exception-thrown)
|          |                      |                |          +--ro exception-thrown?   empty
|          |                      |                +--:(webhook) {wn-app:webhook-based-callouts}?
|          |                      |                   +--ro webhook-results
|          |                      |                      +--ro webhook*
|          |                      |                         +--ro name             string
|          |                      |                         +--ro uri              ietf-inet-types:uri
|          |                      |                         +--ro (result-type)?
|          |                      |                            +--:(connection-error)
|          |                      |                            |  +--ro connection-error?   string
|          |                      |                            +--:(http-status-code)
|          |                      |                               +--ro http-status-code    string
|          |                      +--:(redirect-information)
|          |                      |  +--ro redirect-information
|          |                      |     +--ro (local-or-reference)
|          |                      |        +--:(reference)
|          |                      |           +--ro referenced-definition?   string
|          |                      +--:(onboarding-information) {wn-sztpd-0:onboarding-supported}?
|          |                         +--ro onboarding-information
|          |                            +--ro (local-or-reference)
|          |                               +--:(reference)
|          |                                  +--ro referenced-definition?   string
|          +--:(report-progress-event) {wn-sztpd-0:onboarding-supported}?
|             +--ro report-progress-event
|                +--ro passed-input
|                |  +--ro progress-type         string
|                |  +--ro message?              string
|                |  +--ro ssh-host-keys?        anydata
|                |  +--ro trust-anchor-certs?   anydata
|                +--ro dynamic-callout-result
|                   +--ro (result-type)?
|                      +--:(no-callout-configured)
|                      |  +--ro no-callout-configured?   empty
|                      +--:(callout-configured)
|                         +--ro name?             string
|                         +--ro (callout-type)?
|                            +--:(callback)
|                            |  +--ro callback-results
|                            |     +--ro (exit-status)
|                            |        +--:(exited-successfully)
|                            |        |  +--ro exited-successfully?   empty
|                            |        +--:(exception-thrown)
|                            |           +--ro exception-thrown?   empty
|                            +--:(webhook) {wn-app:webhook-based-callouts}?
|                               +--ro webhook-results
|                                  +--ro webhook*
|                                     +--ro name             string
|                                     +--ro uri              ietf-inet-types:uri
|                                     +--ro (result-type)?
|                                        +--:(connection-error)
|                                        |  +--ro connection-error?   string
|                                        +--:(http-status-code)
|                                           +--ro http-status-code    string
|
+--ro lifecycle-statistics
|  +--ro nbi-access-stats
|  |  +--ro created                ietf-yang-types:date-and-time
|  |  +--ro num-times-modified     uint16
|  |  +--ro last-modified          ietf-yang-types:date-and-time
|  +--ro sbi-access-stats
|     +--ro num-times-accessed     uint16
|     +--ro first-accessed         ietf-yang-types:date-and-time
|     +--ro last-accessed          ietf-yang-types:date-and-time
+--rw device-type                     -> /device-types/device-type/name
```

Device records are keyed by serial number, enabling device to tenant mapping, as serial numbers are globally unique.

Each device record includes the device's lifecycle statistics (key north and south bound interactions) and bootstrapping log (a history of device-initiated interactions)

The device records are used in constructing RFC 8572 based "redirect" and "onboarding" information responses.

4.1.9 Dynamic Callouts

The following tree diagram illustrates the NBI used for configuring dynamic callouts, which may either be implemented via a call into a plugin or via a webhook[1].

```
=============================================================NOTE: '\' line wrapping per RFC 8792=============================================================

  +--rw dynamic-callouts
     +--rw dynamic-callout* [name]
        +--rw name                string
        +--rw rpc-supported       identityref
        +--rw (callout-type)
           +--:(use-callback)
           |  +--rw callback
           |     +--rw plugin       -> /preferences/system/plugins/plugin/name
           |     +--rw function     -> /preferences/system/plugins/plugin[name = current()/../plugin]/functions/function/name
           +--:(use-webhooks) {wn-app:webhook-based-callouts}?
              +--rw webhooks
                 +--rw webhook* [name]
                 |  +--rw name            string
                 |  +--rw encoding?       enumeration <json>
                 |  +--rw (transport)
                 |     +--:(https) {ietf-restconf-client:https-initiate}?
                 |     |  +--rw https
                 |     |     +--rw tcp-client-parameters
                 |     |     |  +--rw remote-address     ietf-inet-types:host
                 |     |     |  +--rw remote-port?       ietf-inet-types:port-number <443>
                 |     |     +--rw tls-client-parameters
                 |     |     |  +--rw client-identity!
                 |     |     |  |  +--rw (auth-type)
                 |     |     |  |     +--:(certificate) {ietf-tls-client:x509-certificate-auth}?
                 |     |     |  |        +--rw certificate
                 |     |     |  |           +--rw (local-or-keystore)
                 |     |     |  |              +--:(local-keystore)
                 |     |     |  |                 +--rw local-keystore-reference
                 |     |     |  |                    +--rw asymmetric-key     -> ../../../../../../../../../../keystore/asymmetric-keys/asymmetric-k\
ey/name
                 |     |     |  |                    +--rw certificate        -> ../../../../../../../../../../keystore/asymmetric-keys/asymmetric-k\
ey[name = current()/../asymmetric-key]/certificates/certificate/name
                 |     |     |  +--rw server-authentication
                 |     |     |     +--rw ca-certs! {ietf-tls-client:x509-certificate-auth}?
                 |     |     |     |  +--rw (local-or-truststore)
                 |     |     |     |     +--:(local-truststore) {ietf-truststore:certificates}?
                 |     |     |     |        +--rw local-truststore-reference?   -> ../../../../../../../../../truststore/certificate-bags/certifica\
te-bag/name
                 |     |     |     +--rw ee-certs! {ietf-tls-client:x509-certificate-auth}?
                 |     |     |        +--rw (local-or-truststore)
                 |     |     |           +--:(local-truststore) {ietf-truststore:certificates}?
                 |     |     |              +--rw local-truststore-reference?   -> ../../../../../../../../../truststore/certificate-bags/certifica\
te-bag/name
                 |     |     +--rw http-client-parameters
                 |     |     |  +--rw client-identity!
                 |     |     |     +--rw (auth-type)
                 |     |     |        +--:(basic)
                 |     |     |           +--rw basic {ietf-http-client:basic-auth}?
                 |     |     |              +--rw user-id      string
                 |     |     |              +--rw password     string
                 |     |     +--rw restconf-client-parameters
                 |     +--:(http)
                 |        +--rw http
                 |           +--rw tcp-client-parameters
                 |           |  +--rw remote-address     ietf-inet-types:host
                 |           |  +--rw remote-port?       ietf-inet-types:port-number <80>
                 |           +--rw http-client-parameters
                 |              +--rw client-identity!
                 |                 +--rw (auth-type)
                 |                    +--:(basic)
                 |                       +--rw basic {ietf-http-client:basic-auth}?
                 |                          +--rw user-id      string
                 |                          +--rw password     string
                 |
                 +--rw round-robin!
                    +--rw amount     uint16
                    +--rw units      enumeration
```

[1] A list of webhooks are configurable only for HA reasons.

4.1.10 Keystore

The following tree diagram illustrates the NBI used for configuring keys held in the keystore.

```
+--rw keystore
   +--rw asymmetric-keys
   |  +--rw asymmetric-key* [name]
   |     +--rw name                                  string
   |     +--rw public-key-format                     identityref
   |     +--rw public-key                            binary
   |     +--rw private-key-format?                   identityref
   |     +--rw (private-key-type)
   |     |  +--:(private-key)
   |     |  |  +--rw private-key?    binary
   |     |  +--:(hidden-private-key)
   |     |  |  +--rw hidden-private-key?    empty
   |     |  +--:(encrypted-private-key)
   |     |     +--rw encrypted-private-key
   |     |        +--rw (key-type)
   |     |        +--rw value?        binary
   |     +--rw certificates
   |     |  +--rw certificate* [name]
   |     |     +--rw name                          string
   |     |     +--rw cert                          ietf-crypto-types:end-entity-cert-cms
   |     |     +---n certificate-expiration
   |     |        +--ro expiration-date     ietf-yang-types:date-and-time
   |     |     +--ro reference-statistics
   |     |        +--ro reference-count     uint32
   |     |        +--ro last-referenced     union
   |     +---x generate-certificate-signing-request {ietf-crypto-types:certificate-signing-request-generation}?
   |     |  +--rw input
   |     |  |  +---w subject        binary
   |     |  |  +---w attributes?    binary
   |     |  +--rw output
   |     |     +--ro certificate-signing-request    ietf-crypto-types:csr
   |     +--ro reference-statistics
   |        +--ro reference-count     uint32
   |        +--ro last-referenced     union
   +--rw symmetric-keys
      +--rw symmetric-key* [name]
         +--rw name            string
         +--rw key-format?     identityref
         +--rw (key-type)
            +--:(key)
            |  +--rw key?    binary
            +--:(hidden-key)
            |  +--rw hidden-key?    empty
            +--:(encrypted-key)
               +--rw encrypted-key
                  +--rw (key-type)
                  +--rw value?        binary
```

The keys held in the keystore are used in the transport configuration, e.g., to hold SZTPD's private key used for each listening port] (see the Listening Ports and the APIs They Present in the Installation Guide).

4.1.11 Preferences

The following tree diagram illustrates the NBI used for configuring system and tenant-level preferences.

```
  +--rw preferences
     +--rw admin-accounts
     |  +--rw new-account-verification
     |  |  +--rw subject?    string <$ZTPD new account verification required.>
     |  |  +--rw cc?         string <$CREATOR_FULL_NAME <$CREATOR_EMAIL_ADDRESS$>>
     |  |  +--rw body?       string <$ACCOUNT_FULL_NAME,

You are receiving this email because I created a new account
for you on the SZTPD ($SZTP_SERVER_ADDRESS).  You
account's login is "$ACCOUNT_EMAIL_ADDRESS".

Please activate your account via the following URL:
$VERIFICATION_URI (This URL expires in 48 hours).

Note that I CC-ed myself on this email and you may contact
me to verify the veracity of this email.

Thanks,
$CREATOR_FULL_NAME
>
     |  +--rw passwords
     |     +--rw strength-testing!
     |        +--rw min-length?    uint16 <16>
     +--rw notification-delivery!
     |  +--rw dynamic-callout
     |     +--rw reference     -> ../../../../dynamic-callouts/dynamic-callout/name
     +--rw system
        +--rw hostname?               ietf-inet-types:host
        +--rw email-from-address?     string <$ZTPD Administrator <root@$SZTP_SERVER_ADDRESS$>>
        +--rw features
        |  +--rw onboarding-supported?    boolean <true> {wn-sztpd-0:onboarding-supported}?
        +--rw plugins
           +--rw plugin* [name]
              +--rw name           string
              +--rw functions
                 +--rw function* [name]
```



```
                +--rw name     string
```

4.1.12 Scripts

The following tree diagram illustrates the NBI used for configuring script records.

```
  +--rw scripts {wn-sztpd-0:onboarding-supported}?
     +--rw pre-configuration-script* [name]
     |  +--rw name                          string
     |  +--rw script?                       ietf-sztp-conveyed-info:script
     |  +--ro reference-statistics
     |     +--ro reference-count     uint32
     |     +--ro last-referenced     union
     +--rw post-configuration-script* [name]
        +--rw name                          string
        +--rw script?                       ietf-sztp-conveyed-info:script
        +--ro reference-statistics
           +--ro reference-count     uint32
           +--ro last-referenced     union
```

The script records are used in constructing RFC 8572 based "onboarding information" responses.

4.1.13 Tenants

For deployments using product mode 'x', the following tree diagram illustrates a snippet of the NBI used for configuring tenants.

```
  +--rw tenants
     +--rw tenant* [name]
```

Unlike all the other Northbound Interface sections, this section illustrates only the place in the hierarchy where the tenant containers are defined. Not shown are that each tenant container contains an instance of every other Northbound Interface section in it as well (with exception to the transport, which can only be configured by the host system.

4.1.14 Transport

The following tree diagram illustrates the NBI used for configuring transport records.

```
============================================================NOTE: '\' line wrapping per RFC 8792 ============================================================

  +--rw transport
     +--rw listen! {ietf-restconf-server:http-listen or ietf-restconf-server:https-listen}?
        +--rw endpoint* [name]
           +--rw name           string
           +--rw (transport)
           |  +--:(http) {ietf-restconf-server:http-listen}?
           |  |  +--rw http
           |  |     +--rw external-endpoint!
           |  |     |  +--rw address     ietf-inet-types:ip-address
           |  |     |  +--rw port?       ietf-inet-types:port-number <443>
           |  |     +--rw tcp-server-parameters
           |  |     |  +--rw local-address     ietf-inet-types:ip-address
           |  |     |  +--rw local-port?       ietf-inet-types:port-number <80>
           |  |     +--rw http-server-parameters
           |  |     |  +--rw server-name?              string
           |  |     +--rw restconf-server-parameters
           |  |        +--rw client-identity-mappings
           |  |           +--rw cert-to-name* [id]
           |  |              +--rw id            uint32
           |  |              +--rw fingerprint?  ietf-x509-cert-to-name:tls-fingerprint
           |  |              +--rw map-type      identityref
           |  |              +--rw name          string
           |  +--:(https) {ietf-restconf-server:https-listen}?
           |     +--rw https
           |        +--rw tcp-server-parameters
           |        |  +--rw local-address     ietf-inet-types:ip-address
           |        |  +--rw local-port?       ietf-inet-types:port-number <443>
           |        +--rw tls-server-parameters
           |        |  +--rw server-identity
           |        |  |  +--rw (auth-type)
           |        |  |     +--:(certificate) {ietf-tls-server:x509-certificate-auth}?
           |        |  |        +--rw certificate
           |        |  |           +--rw (local-or-keystore)
           |        |  |              +--:(local-keystore)
           |        |  |                 +--rw reference
           |        |  |                    +--rw asymmetric-key?   -> /keystore/asymmetric-keys/asymmetric-key/name
           |        |  |                    +--rw certificate?      -> /keystore/asymmetric-keys/asymmetric-key[name = current()/../asymmetric-key]\
/certificates/certificate/name
```



```
|       |  +--rw client-authentication! {ietf-tls-server:client-auth-config-supported}?
|       |     +--rw ca-certs! {ietf-tls-server:x509-certificate-auth}?
|       |     |  +--rw (local-or-truststore)
|       |     |     +--:(local-truststore) {ietf-truststore:certificates,ietf-tls-server:client-auth-config-supported}?
|       |     |        +--rw local-truststore-reference?   -> /truststore/certificate-bags/certificate-bag/name
|       |     +--rw ee-certs! {ietf-tls-server:x509-certificate-auth}?
|       |        +--rw (local-or-truststore)
|       |           +--:(local-truststore) {ietf-truststore:certificates,ietf-tls-server:client-auth-config-supported}?
|       |              +--rw local-truststore-reference?   -> /truststore/certificate-bags/certificate-bag/name
|       +--rw http-server-parameters
|       |  +--rw server-name?              string
|       +--rw restconf-server-parameters
|          +--rw client-identity-mappings
|             +--rw cert-to-name* [id]
|                +--rw id              uint32
|                +--rw fingerprint?    ietf-x509-cert-to-name:tls-fingerprint
|                +--rw map-type        identityref
|                +--rw name            string
+--rw use-for*      enumeration
```

Each device records includes the device's bootstrapping log, a history of interactions with the device.

The transport configuration defines the listening ports SZTPD opens.

4.1.15 Truststore

The following tree diagram illustrates the NBI used for configuring trust-anchors held in the truststore.

```
+--rw truststore
   +--rw certificate-bags! {ietf-truststore:certificates}?
      +--rw certificate-bag* [name]
         +--rw name                          string
         +--rw description?                  string
         +--rw certificate* [name]
         |  +--rw name                          string
         |  +--rw cert                          ietf-crypto-types:trust-anchor-cert-cms
         |  +--n certificate-expiration
         |     +--ro expiration-date     ietf-yang-types:date-and-time
         |  +--ro reference-statistics
         |     +--ro reference-count     uint32
         |     +--ro last-referenced     union
         +--ro reference-statistics
            +--ro reference-count     uint32
            +--ro last-referenced     union
```

The trust-anchors held in the truststore are use for many purposes (e.g., to authenticate clients, to authenticate remote systems, etc.).

4.2 Advanced Features

4.2.1 Triggers

4.2.1.1 Configuration-based

SZTPD reacts to some triggers automatically.

SZTPD reacts to some configurations chanfges. Simple examples include:

- automatically hash client passwords.
- automatically SIGHUP when transport is configured.
- incrementing/decrementing opstate counters.

Configuration-based triggers are discussed further in Tracking.

4.2.1.2 Clock-based

SZTPD may set clock triggers. For instance, to note when an object should be purged.

4.2.2 Tracking

Much of SZTPD's reactive functionality depends on triggers.

4.2.2.1 Reference Statistics

SZTPD will be able to track where referenced objects are used so as to detect when the objects are no longer referenced. Timestamps track when the object was created, last modified, first referenced, and last referenced.

4.2.2.2 Expiration Tracking

Known when an object was last referenced enables SZTPD to determine when the object will be subject to expiration, unless updated or referenced in the interim.

4.2.2.3 Device Lifecycle Statistics

Devices are special objects in that nothing references them and yet it is desired to purge them when appropriate and, furthermore, to track if/when a device performed bootstrapping events.

4.2.3 Webhooks

SZTPD uses "webhooks" to send data to or request data from another system. A webhook is effectively an HTTP "POST" request. When sending data, the body of the POST request includes the data being sent. When receiving data, the body of the POST response contains the data being received.

4.2.3.1 Notification Logging

SZTPD sends "notifications" for monitoring and application-level integration. Specifically, SZTPD sends notifications with expedited urgency when an object is getting close to expiration. Similarly, per RFC 8572, SZTPD uses notifications to relay "progress-reports" to integrating applications.

4.2.3.2 Device Ownership Authorization

SZTPD uses a webhook when needing to ascertain if a tenant is the rightful owner of a device, by way of the device's serial number.

4.3 Complete Tree Diagram

This section presents the complete tree diagrams for Mode-1 and Mode-x (native).

The tree diagrams provide an overview of the API's data model but, for complete understanding of the YANG model, it is necessary to look at the YANG modules directly (see [Tree Diagrams vs. YANG Modules] for details).

4.3.1 Mode-1's `native` view

The following tree diagram illustrates the entire NBI, from the perspective of the [Mode '1'] native interface.

```
=============================================================NOTE: '\' line wrapping per RFC 8792=============================================================

module: wn-sztpd-1
  +--rw preferences
  |  +--rw admin-accounts
  |  |  +--rw new-account-verification
  |  |  |  +--rw subject?    string <$SZTPD new account verification required.>
  |  |  |  +--rw cc?         string <$CREATOR-FULL-NAME <$CREATOR-EMAIL-ADDRESS$>>
  |  |  |  +--rw body?       string <$ACCOUNT-FULL-NAME,

You are receiving this email because I created a new account
for you on the SZTPD ($SZTP-SERVER-ADDRESS).  You
account's login is "$ACCOUNT-EMAIL-ADDRESS".

Please activate your account via the following URL:
$VERIFICATION-URI (This URL expires in 48-hours).

Note that I CC-ed myself on this email and you may contact
me to verify the veracity of this email.

Thanks,
$CREATOR-FULL-NAME
>
  |  |  +--rw passwords
  |  |     +--rw strength-testing!
  |  |        +--rw min-length?    uint16 <16>
  |  +--rw notification-delivery!
  |  |  +--rw dynamic-callout
  |  |     +--rw reference     -> ../../../../dynamic-callouts/dynamic-callout/name
  |  +--rw system
  |     +--rw hostname?               ietf-inet-types:host
  |     +--rw email-from-address?     string <$SZTPD Administrator <root@$SZTP-SERVER-ADDRESS$>>
  |     +--rw features
  |     |  +--rw onboarding-supported?    boolean <true> {wn-sztpd-0:onboarding-supported}?
  |     +--rw plugins
  |        +--rw plugin* [name]
  |           +--rw name          string
  |           +--rw functions
  |              +--rw function* [name]
  |                 +--rw name     string
  +--rw admin-accounts
  |  +--rw admin-account* [email-address]
  |     +--rw email-address                          string
  |     +--rw fullname?                              string
  |     +--rw password                               iana-crypt-hash:crypt-hash
  |     +--ro password-last-modified                 ietf-yang-types:date-and-time
  |     +--rw access                                 enumeration
  |     +---x resend-activation-email
  +--ro audit-log
  |  +--ro log-entry*
  |     +--ro timestamp          ietf-yang-types:date-and-time
  |     +--ro source-ip          ietf-inet-types:ip-address
  |     +--ro source-proxies*    string
  |     +--ro host               string
  |     +--ro method             enumeration
  |     +--ro path               string
  |     +--ro outcome            enumeration
  |     +--ro comment?           string
  +--rw truststore
  |  +--rw certificate-bags! {ietf-truststore:certificates}?
  |     +--rw certificate-bag* [name]
  |        +--rw name                              string
  |        +--rw description?                      string
  |        +--rw certificate* [name]
  |        |  +--rw name                              string
  |        |  +--rw cert                              ietf-crypto-types:trust-anchor-cert-cms
  |        |  +---n certificate-expiration
  |        |     +--ro expiration-date     ietf-yang-types:date-and-time
  |        |  +--ro reference-statistics
  |        |     +--ro reference-count     uint32
  |        |     +--ro last-referenced     union
  |        +--ro reference-statistics
  |           +--ro reference-count     uint32
  |           +--ro last-referenced     union
  +--rw keystore {not system-level-administration-disabled}?
  |  +--rw asymmetric-keys
  |  |  +--rw asymmetric-key* [name]
  |  |     +--rw name                                   string
  |  |     +--rw public-key-format                      identityref
  |  |     +--rw public-key                             binary
  |  |     +--rw private-key-format?                    identityref
  |  |     +--rw (private-key-type)
  |  |     |  +--:(private-key)
  |  |     |  |  +--rw private-key?    binary
```



```
   |  |     |  +--:(hidden-private-key)
   |  |     |  |  +--rw hidden-private-key?   empty
   |  |     |  +--:(encrypted-private-key)
   |  |     |     +--rw encrypted-private-key
   |  |     |        +--rw (key-type)
   |  |     |        +--rw value?        binary
   |  |     +--rw certificates
   |  |     |  +--rw certificate* [name]
   |  |     |     +--rw name                          string
   |  |     |     +--rw cert                          ietf-crypto-types:end-entity-cert-cms
   |  |     |     +---n certificate-expiration
   |  |     |        +--ro expiration-date    ietf-yang-types:date-and-time
   |  |     |     +--ro reference-statistics
   |  |     |        +--ro reference-count    uint32
   |  |     |        +--ro last-referenced    union
   |  |     +---x generate-certificate-signing-request {ietf-crypto-types:certificate-signing-request-generation}?
   |  |     |  +--rw input
   |  |     |  |  +---w subject        binary
   |  |     |  |  +---w attributes?    binary
   |  |     |  +--rw output
   |  |     |     +--ro certificate-signing-request    ietf-crypto-types:csr
   |  |     +--ro reference-statistics
   |  |        +--ro reference-count    uint32
   |  |        +--ro last-referenced    union
   |  +--rw symmetric-keys
   |     +--rw symmetric-key* [name]
   |        +--rw name             string
   |        +--rw key-format?      identityref
   |        +--rw (key-type)
   |           +--:(key)
   |           |  +--rw key?    binary
   |           +--:(hidden-key)
   |           |  +--rw hidden-key?    empty
   |           +--:(encrypted-key)
   |              +--rw encrypted-key
   |                 +--rw (key-type)
   |                 +--rw value?        binary
   +--rw dynamic-callouts
   |  +--rw dynamic-callout* [name]
   |     +--rw name              string
   |     +--rw rpc-supported     identityref
   |     +--rw (callout-type)
   |        +--:(use-callback)
   |        |  +--rw callback
   |        |     +--rw plugin       -> /preferences/system/plugins/plugin/name
   |        |     +--rw function     -> /preferences/system/plugins/plugin[name = current()/../plugin]/functions/function/name
   |        +--:(use-webhooks) {wn-app:webhook-based-callouts}?
   |           +--rw webhooks
   |              +--rw webhook* [name]
   |              |  +--rw name            string
   |              |  +--rw encoding?       enumeration <json>
   |              |  +--rw (transport)
   |              |     +--:(https) {ietf-restconf-client:https-initiate}?
   |              |     |  +--rw https
   |              |     |     +--rw tcp-client-parameters
   |              |     |     |  +--rw remote-address     ietf-inet-types:host
   |              |     |     |  +--rw remote-port?       ietf-inet-types:port-number <443>
   |              |     |     +--rw tls-client-parameters
   |              |     |     |  +--rw client-identity!
   |              |     |     |  |  +--rw (auth-type)
   |              |     |     |  |     +--:(certificate) {ietf-tls-client:x509-certificate-auth}?
   |              |     |     |  |        +--rw certificate
   |              |     |     |  |           +--rw (local-or-keystore)
   |              |     |     |  |              +--:(local-keystore)
   |              |     |     |  |                 +--rw local-keystore-reference
   |              |     |     |  |                    +--rw asymmetric-key     -> ../../../../../../../../../../keystore/asymmetric-keys/asymmetric-k\
ey/name
   |              |     |     |  |                    +--rw certificate        -> ../../../../../../../../../../keystore/asymmetric-keys/asymmetric-k\
ey[name = current()/../asymmetric-key]/certificates/certificate/name
   |              |     |     |  +--rw server-authentication
   |              |     |     |     +--rw ca-certs! {ietf-tls-client:x509-certificate-auth}?
   |              |     |     |     |  +--rw (local-or-truststore)
   |              |     |     |     |     +--:(local-truststore) {ietf-truststore:certificates}?
   |              |     |     |     |        +--rw local-truststore-reference?   -> ../../../../../../../../../truststore/certificate-bags/certifica\
te-bag/name
   |              |     |     |     +--rw ee-certs! {ietf-tls-client:x509-certificate-auth}?
   |              |     |     |        +--rw (local-or-truststore)
   |              |     |     |           +--:(local-truststore) {ietf-truststore:certificates}?
   |              |     |     |              +--rw local-truststore-reference?   -> ../../../../../../../../../truststore/certificate-bags/certifica\
te-bag/name
   |              |     |     +--rw http-client-parameters
   |              |     |     |  +--rw client-identity!
   |              |     |     |     +--rw (auth-type)
   |              |     |     |        +--:(basic)
   |              |     |     |           +--rw basic {ietf-http-client:basic-auth}?
   |              |     |     |              +--rw user-id      string
   |              |     |     |              +--rw password     string
   |              |     |     +--rw restconf-client-parameters
   |              |     +--:(http)
   |              |        +--rw http
   |              |           +--rw tcp-client-parameters
   |              |           |  +--rw remote-address     ietf-inet-types:host
   |              |           |  +--rw remote-port?       ietf-inet-types:port-number <80>
   |              |           +--rw http-client-parameters
   |              |              +--rw client-identity!
   |              |                 +--rw (auth-type)
   |              |                    +--:(basic)
   |              |                       +--rw basic {ietf-http-client:basic-auth}?
   |              |                          +--rw user-id      string
   |              |                          +--rw password     string
   |              |
   |              +--rw round-robin!
   |                 +--rw amount     uint16
   |                 +--rw units      enumeration
   +--rw transport {not system-level-administration-disabled}?
   |  +--rw listen! {ietf-restconf-server:http-listen or ietf-restconf-server:https-listen}?
   |     +--rw endpoint* [name]
   |        +--rw name           string
```



```
   |        +--rw (transport)
   |        |  +--:(http) {ietf-restconf-server:http-listen}?
   |        |  |  +--rw http
   |        |  |     +--rw external-endpoint!
   |        |  |     |  +--rw address     ietf-inet-types:ip-address
   |        |  |     |  +--rw port?       ietf-inet-types:port-number <443>
   |        |  |     +--rw tcp-server-parameters
   |        |  |     |  +--rw local-address     ietf-inet-types:ip-address
   |        |  |     |  +--rw local-port?       ietf-inet-types:port-number <80>
   |        |  |     +--rw http-server-parameters
   |        |  |     |  +--rw server-name?              string
   |        |  |     +--rw restconf-server-parameters
   |        |  |        +--rw client-identity-mappings
   |        |  |           +--rw cert-to-name* [id]
   |        |  |              +--rw id              uint32
   |        |  |              +--rw fingerprint?    ietf-x509-cert-to-name:tls-fingerprint
   |        |  |              +--rw map-type        identityref
   |        |  |              +--rw name            string
   |        |  +--:(https) {ietf-restconf-server:https-listen}?
   |        |     +--rw https
   |        |        +--rw tcp-server-parameters
   |        |        |  +--rw local-address     ietf-inet-types:ip-address
   |        |        |  +--rw local-port?       ietf-inet-types:port-number <443>
   |        |        +--rw tls-server-parameters
   |        |        |  +--rw server-identity
   |        |        |  |  +--rw (auth-type)
   |        |        |  |     +--:(certificate) {ietf-tls-server:x509-certificate-auth}?
   |        |        |  |        +--rw certificate
   |        |        |  |           +--rw (local-or-keystore)
   |        |        |  |              +--:(local-keystore)
   |        |        |  |                 +--rw reference
   |        |        |  |                    +--rw asymmetric-key?   -> /keystore/asymmetric-keys/asymmetric-key/name
   |        |        |  |                    +--rw certificate?      -> /keystore/asymmetric-keys/asymmetric-key[name = current()/../asymmetric-key]\
/certificates/certificate/name
   |        |        |  +--rw client-authentication! {ietf-tls-server:client-auth-config-supported}?
   |        |        |     +--rw ca-certs! {ietf-tls-server:x509-certificate-auth}?
   |        |        |     |  +--rw (local-or-truststore)
   |        |        |     |     +--:(local-truststore) {ietf-truststore:certificates,ietf-tls-server:client-auth-config-supported}?
   |        |        |     |        +--rw local-truststore-reference?   -> /truststore/certificate-bags/certificate-bag/name
   |        |        |     +--rw ee-certs! {ietf-tls-server:x509-certificate-auth}?
   |        |        |        +--rw (local-or-truststore)
   |        |        |           +--:(local-truststore) {ietf-truststore:certificates,ietf-tls-server:client-auth-config-supported}?
   |        |        |              +--rw local-truststore-reference?   -> /truststore/certificate-bags/certificate-bag/name
   |        |        +--rw http-server-parameters
   |        |        |  +--rw server-name?              string
   |        |        +--rw restconf-server-parameters
   |        |           +--rw client-identity-mappings
   |        |              +--rw cert-to-name* [id]
   |        |                 +--rw id              uint32
   |        |                 +--rw fingerprint?    ietf-x509-cert-to-name:tls-fingerprint
   |        |                 +--rw map-type        identityref
   |        |                 +--rw name            string
   |        +--rw use-for*       enumeration
   +--rw device-types
      |  +--rw device-type* [name]
      |     +--rw name                          string
      |     +--rw identity-certificates!
      |     |  +--rw verification
      |     |  |  +--rw local-truststore-reference {ietf-truststore:certificates}?
      |     |  |     +--rw certificate-bag    -> /truststore/certificate-bags/certificate-bag/name
      |     |  |     +--rw certificate        -> /truststore/certificate-bags/certificate-bag[name = current()/../certificate-bag]/certificate/name
      |     |  +--rw serial-number-extraction?   identityref <wn-x509-c2n:serial-number>
      |     +--rw ownership-authorization!
      |     |  +--rw https
      |     |     +--rw tcp-client-parameters
      |     |     |  +--rw remote-address     ietf-inet-types:host
      |     |     |  +--rw remote-port?       ietf-inet-types:port-number <443>
      |     |     +--rw tls-client-parameters
      |     |     |  +--rw client-identity!
      |     |     |  |  +--rw (auth-type)
      |     |     |  |     +--:(certificate) {ietf-tls-client:x509-certificate-auth}?
      |     |     |  |        +--rw certificate
      |     |     |  |           +--rw (local-or-keystore)
      |     |     |  +--rw server-authentication
      |     |     |     +--rw ca-certs! {ietf-tls-client:x509-certificate-auth}?
      |     |     |     |  +--rw (local-or-truststore)
      |     |     |     |     +--:(local-truststore) {ietf-truststore:certificates}?
      |     |     |     |        +--rw local-truststore-reference {ietf-truststore:certificates}?
      |     |     |     |           +--rw certificate-bag    -> /truststore/certificate-bags/certificate-bag/name
      |     |     |     |           +--rw certificate        -> /truststore/certificate-bags/certificate-bag[name = current()/../certificate-bag]/certi\
ficate/name
      |     |     |     +--rw ee-certs! {ietf-tls-client:x509-certificate-auth}?
      |     |     |        +--rw (local-or-truststore)
      |     |     |           +--:(local-truststore) {ietf-truststore:certificates}?
      |     |     |              +--rw local-truststore-reference {ietf-truststore:certificates}?
      |     |     |                 +--rw certificate-bag    -> /truststore/certificate-bags/certificate-bag/name
      |     |     |                 +--rw certificate        -> /truststore/certificate-bags/certificate-bag[name = current()/../certificate-bag]/certi\
ficate/name
      |     |     +--rw http-client-parameters
      |     |        +--rw client-identity!
      |     |           +--rw (auth-type)
      |     |              +--:(basic)
      |     |                 +--rw basic {ietf-http-client:basic-auth}?
      |     |                    +--rw user-id      string
      |     |                    +--rw password     string
      |     +--rw voucher-aquisition!
      |        +--rw https
      |           +--rw tcp-client-parameters
      |           |  +--rw remote-address     ietf-inet-types:host
      |           |  +--rw remote-port?       ietf-inet-types:port-number <443>
      |           +--rw tls-client-parameters
      |           |  +--rw client-identity!
      |           |  |  +--rw (auth-type)
      |           |  |     +--:(certificate) {ietf-tls-client:x509-certificate-auth}?
      |           |  |        +--rw certificate
      |           |  |           +--rw (local-or-keystore)
      |           |  +--rw server-authentication
```



```
   |           |     +--rw ca-certs! {ietf-tls-client:x509-certificate-auth}?
   |           |     |  +--rw (local-or-truststore)
   |           |     |     +--:(local-truststore) {ietf-truststore:certificates}?
   |           |     |        +--rw local-truststore-reference {ietf-truststore:certificates}?
   |           |     |           +--rw certificate-bag    -> /truststore/certificate-bags/certificate-bag/name
   |           |     |           +--rw certificate        -> /truststore/certificate-bags/certificate-bag[name = current()/../certificate-bag]/certi\
ficate/name
   |           |     +--rw ee-certs! {ietf-tls-client:x509-certificate-auth}?
   |           |        +--rw (local-or-truststore)
   |           |           +--:(local-truststore) {ietf-truststore:certificates}?
   |           |              +--rw local-truststore-reference {ietf-truststore:certificates}?
   |           |                 +--rw certificate-bag    -> /truststore/certificate-bags/certificate-bag/name
   |           |                 +--rw certificate        -> /truststore/certificate-bags/certificate-bag[name = current()/../certificate-bag]/certi\
ficate/name
   |           +--rw http-client-parameters
   |              +--rw client-identity!
   |                 +--rw (auth-type)
   |                    +--:(basic)
   |                       +--rw basic {ietf-http-client:basic-auth}?
   |                          +--rw user-id      string
   |                          +--rw password     string
   +--rw bootstrap-servers
   |  +--rw bootstrap-server* [name]
   |     +--rw name                            string
   |     +--rw address                         ietf-inet-types:host
   |     +--rw port?                           ietf-inet-types:port-number <443>
   |     +--rw trust-anchor?                   ietf-crypto-types:trust-anchor-cert-cms
   |     +--ro reference-statistics
   |        +--ro reference-count     uint32
   |        +--ro last-referenced     union
   +--rw boot-images {wn-sztpd-0:onboarding-supported}?
   |  +--rw boot-image* [name]
   |     +--rw name                            string
   |     +--rw os-name?                        string
   |     +--rw os-version?                     string
   |     +--rw download-uri*                   ietf-inet-types:uri
   |     +--rw image-verification* [hash-algorithm]
   |     |  +--rw hash-algorithm     identityref
   |     |  +--rw hash-value         ietf-yang-types:hex-string
   |     +--ro reference-statistics
   |        +--ro reference-count     uint32
   |        +--ro last-referenced     union
   +--rw scripts {wn-sztpd-0:onboarding-supported}?
   |  +--rw pre-configuration-script* [name]
   |  |  +--rw name                            string
   |  |  +--rw script?                         ietf-sztp-conveyed-info:script
   |  |  +--ro reference-statistics
   |  |     +--ro reference-count     uint32
   |  |     +--ro last-referenced     union
   |  +--rw post-configuration-script* [name]
   |     +--rw name                            string
   |     +--rw script?                         ietf-sztp-conveyed-info:script
   |     +--ro reference-statistics
   |        +--ro reference-count     uint32
   |        +--ro last-referenced     union
   +--rw configurations {wn-sztpd-0:onboarding-supported}?
   |  +--rw configuration* [name]
   |     +--rw name                            string
   |     +--rw configuration-handling?         enumeration
   |     +--rw config?                         binary
   |     +--ro reference-statistics
   |        +--ro reference-count     uint32
   |        +--ro last-referenced     union
   +--rw conveyed-information-responses
   |  +--rw redirect-information-response* [name]
   |  |  +--rw name                            string
   |  |  +--rw redirect-information
   |  |  |  +--rw bootstrap-server*   -> ../../../../bootstrap-servers/bootstrap-server/name
   |  |  +--ro reference-statistics
   |  |     +--ro reference-count     uint32
   |  |     +--ro last-referenced     union
   |  +--rw onboarding-information-response* [name] {wn-sztpd-0:onboarding-supported}?
   |     +--rw name                            string
   |     +--rw onboarding-information
   |     |  +--rw boot-image                    -> ../../../../boot-images/boot-image/name
   |     |  +--rw pre-configuration-script?     -> ../../../../scripts/pre-configuration-script/name
   |     |  +--rw configuration?                -> ../../../../configurations/configuration/name
   |     |  +--rw post-configuration-script?    -> ../../../../scripts/post-configuration-script/name
   |     +--ro reference-statistics
   |        +--ro reference-count     uint32
   |        +--ro last-referenced     union
   +--rw devices
      +--rw device* [serial-number]
         +--rw serial-number                     string
         +--rw activation-code?                  iana-crypt-hash:crypt-hash
         +--rw response-manager
         |  +--rw matched-response* [name]
         |     +--rw name               string
         |     +--rw match-criteria!
         |     |  +--rw match* [key]
         |     |     +--rw key            string
         |     |     +--rw not?           empty
         |     |     +--rw (test-type)
         |     |        +--:(present)
         |     |        |  +--rw present?    empty
         |     |        +--:(value)
         |     |        |  +--rw value?    string
         |     |        +--:(regex)
         |     |           +--rw regex?    string
         |     +--rw response
         |        +--rw reporting-level?      enumeration <minimal> {wn-sztpd-0:onboarding-supported}?
         |        +--rw (response-handler)
         |           +--:(none)
         |           |  +--rw none?    empty
         |           +--:(use-dynamic-callout)
         |              +--rw dynamic-callout
         |                 +--rw reference?   -> ../../../../../../../dynamic-callouts/dynamic-callout/name
```



```
|           +--:(managed-response)
|              +--rw conveyed-information
|                 +--rw (conveyed-information-handler)
|                    +--:(use-dynamic-callout)
|                    |  +--rw dynamic-callout
|                    |     +--rw reference?   -> ../../../../../../../../../dynamic-callouts/dynamic-callout/name
|                    +--:(redirect-information)
|                    |  +--rw redirect-information
|                    |     +--rw (local-or-reference)
|                    |        +--:(reference)
|                    |           +--rw reference?   -> ../../../../../../../../../conveyed-information-responses/redirect-information-response\
/name
|                    +--:(onboarding-information) {wn-sztpd-0:onboarding-supported}?
|                       +--rw onboarding-information
|                          +--rw (local-or-reference)
|                             +--:(reference)
|                                +--rw reference?   -> ../../../../../../../../../conveyed-information-responses/onboarding-information-respon\
se/name
+--ro bootstrapping-log
|  +--ro log-entry*
|     +--ro timestamp         ietf-yang-types:date-and-time
|     +--ro source-ip         ietf-inet-types:ip-address
|     +--ro method            string
|     +--ro path              string
|     +--ro return-code       uint16
|     +--ro error-message?    string
|     +--ro event-details
|        +--ro (event-type)
|           +--:(get-bootstrapping-data-event)
|           |  +--ro get-bootstrapping-data-event
|           |     +--ro passed-input
|           |     |  +--ro (input-type)
|           |     |     +--:(no-input-passed)
|           |     |     |  +--ro no-input-passed?   empty
|           |     |     +--:(input)
|           |     |        +--ro input*
|           |     |           +--ro key       string
|           |     |           +--ro value     union
|           |     +--ro selected-response?         union
|           |     +--ro response-details
|           |        +--ro (response-type)
|           |           +--:(managed)
|           |              +--ro managed-response-supplied
|           |                 +--ro conveyed-information
|           |                    +--ro (conveyed-information-handler)
|           |                       +--:(dynamic-callout)
|           |                       |  +--ro dynamic-callout-result
|           |                       |     +--ro (result-type)?
|           |                       |        +--:(no-callout-configured)
|           |                       |        |  +--ro no-callout-configured?   empty
|           |                       |        +--:(callout-configured)
|           |                       |           +--ro name?              string
|           |                       |           +--ro (callout-type)?
|           |                       |              +--:(callback)
|           |                       |              |  +--ro callback-results
|           |                       |              |     +--ro (exit-status)
|           |                       |              |        +--:(exited-successfully)
|           |                       |              |        |  +--ro exited-successfully?   empty
|           |                       |              |        +--:(exception-thrown)
|           |                       |              |           +--ro exception-thrown?   empty
|           |                       |              +--:(webhook) {wn-app:webhook-based-callouts}?
|           |                       |                 +--ro webhook-results
|           |                       |                    +--ro webhook*
|           |                       |                       +--ro name             string
|           |                       |                       +--ro uri              ietf-inet-types:uri
|           |                       |                       +--ro (result-type)?
|           |                       |                          +--:(connection-error)
|           |                       |                          |  +--ro connection-error?   string
|           |                       |                          +--:(http-status-code)
|           |                       |                             +--ro http-status-code    string
|           |                       +--:(redirect-information)
|           |                       |  +--ro redirect-information
|           |                       |     +--ro (local-or-reference)
|           |                       |        +--:(reference)
|           |                       |           +--ro referenced-definition?   string
|           |                       +--:(onboarding-information) {wn-sztpd-0:onboarding-supported}?
|           |                          +--ro onboarding-information
|           |                             +--ro (local-or-reference)
|           |                                +--:(reference)
|           |                                   +--ro referenced-definition?   string
|           +--:(report-progress-event) {wn-sztpd-0:onboarding-supported}?
|              +--ro report-progress-event
|                 +--ro passed-input
|                 |  +--ro progress-type         string
|                 |  +--ro message?              string
|                 |  +--ro ssh-host-keys?        anydata
|                 |  +--ro trust-anchor-certs?   anydata
|                 +--ro dynamic-callout-result
|                    +--ro (result-type)?
|                       +--:(no-callout-configured)
|                       |  +--ro no-callout-configured?   empty
|                       +--:(callout-configured)
|                          +--ro name?              string
|                          +--ro (callout-type)?
|                             +--:(callback)
|                             |  +--ro callback-results
|                             |     +--ro (exit-status)
|                             |        +--:(exited-successfully)
|                             |        |  +--ro exited-successfully?   empty
|                             |        +--:(exception-thrown)
|                             |           +--ro exception-thrown?   empty
|                             +--:(webhook) {wn-app:webhook-based-callouts}?
|                                +--ro webhook-results
|                                   +--ro webhook*
|                                      +--ro name             string
|                                      +--ro uri              ietf-inet-types:uri
|                                      +--ro (result-type)?
```



```
        |                                        +--:(connection-error)
        |                                        |  +--ro connection-error?   string
        |                                        +--:(http-status-code)
        |                                           +--ro http-status-code    string
        +--ro lifecycle-statistics
        |  +--ro nbi-access-stats
        |  |  +--ro created              ietf-yang-types:date-and-time
        |  |  +--ro num-times-modified   uint16
        |  |  +--ro last-modified        ietf-yang-types:date-and-time
        |  +--ro sbi-access-stats
        |     +--ro num-times-accessed   uint16
        |     +--ro first-accessed       ietf-yang-types:date-and-time
        |     +--ro last-accessed        ietf-yang-types:date-and-time
        +--rw device-type                    -> /device-types/device-type/name
```

4.3.2 Mode-X's `native` view

The following tree diagram illustrates the entire NBI, from the perspective of the Mode 'x' native interface (not the tenant interface.

```
=============================================================NOTE: '\' line wrapping per RFC 8792=============================================================

module: wn-sztpd-x
  +--rw device-types
  |  +--rw device-type* [name]
  |     +--rw name                          string
  |     +--rw identity-certificates!
  |     |  +--rw verification
  |     |  |  +--rw local-truststore-reference {ietf-truststore:certificates}?
  |     |  |     +--rw certificate-bag    -> /truststore/certificate-bags/certificate-bag/name
  |     |  |     +--rw certificate        -> /truststore/certificate-bags/certificate-bag[name = current()/../certificate-bag]/certificate/name
  |     |  +--rw serial-number-extraction?   identityref <wn-x509-c2n:serial-number>
  |     +--rw ownership-authorization!
  |     |  +--rw https
  |     |     +--rw tcp-client-parameters
  |     |     |  +--rw remote-address     ietf-inet-types:host
  |     |     |  +--rw remote-port?       ietf-inet-types:port-number <443>
  |     |     +--rw tls-client-parameters
  |     |     |  +--rw client-identity!
  |     |     |  |  +--rw (auth-type)
  |     |     |  |     +--:(certificate) {ietf-tls-client:x509-certificate-auth}?
  |     |     |  |        +--rw certificate
  |     |     |  |           +--rw (local-or-keystore)
  |     |     |  +--rw server-authentication
  |     |     |     +--rw ca-certs! {ietf-tls-client:x509-certificate-auth}?
  |     |     |     |  +--rw (local-or-truststore)
  |     |     |     |     +--:(local-truststore) {ietf-truststore:certificates}?
  |     |     |     |        +--rw local-truststore-reference {ietf-truststore:certificates}?
  |     |     |     |           +--rw certificate-bag    -> /truststore/certificate-bags/certificate-bag/name
  |     |     |     |           +--rw certificate        -> /truststore/certificate-bags/certificate-bag[name = current()/../certificate-bag]/certi\
ficate/name
  |     |     |     +--rw ee-certs! {ietf-tls-client:x509-certificate-auth}?
  |     |     |        +--rw (local-or-truststore)
  |     |     |           +--:(local-truststore) {ietf-truststore:certificates}?
  |     |     |              +--rw local-truststore-reference {ietf-truststore:certificates}?
  |     |     |                 +--rw certificate-bag    -> /truststore/certificate-bags/certificate-bag/name
  |     |     |                 +--rw certificate        -> /truststore/certificate-bags/certificate-bag[name = current()/../certificate-bag]/certi\
ficate/name
  |     |     +--rw http-client-parameters
  |     |        +--rw client-identity!
  |     |           +--rw (auth-type)
  |     |              +--:(basic)
  |     |                 +--rw basic {ietf-http-client:basic-auth}?
  |     |                    +--rw user-id     string
  |     |                    +--rw password    string
  |     +--rw voucher-aquisition!
  |        +--rw https
  |           +--rw tcp-client-parameters
  |           |  +--rw remote-address     ietf-inet-types:host
  |           |  +--rw remote-port?       ietf-inet-types:port-number <443>
  |           +--rw tls-client-parameters
  |           |  +--rw client-identity!
  |           |  |  +--rw (auth-type)
  |           |  |     +--:(certificate) {ietf-tls-client:x509-certificate-auth}?
  |           |  |        +--rw certificate
  |           |  |           +--rw (local-or-keystore)
  |           |  +--rw server-authentication
  |           |     +--rw ca-certs! {ietf-tls-client:x509-certificate-auth}?
  |           |     |  +--rw (local-or-truststore)
  |           |     |     +--:(local-truststore) {ietf-truststore:certificates}?
  |           |     |        +--rw local-truststore-reference {ietf-truststore:certificates}?
  |           |     |           +--rw certificate-bag    -> /truststore/certificate-bags/certificate-bag/name
  |           |     |           +--rw certificate        -> /truststore/certificate-bags/certificate-bag[name = current()/../certificate-bag]/certi\
ficate/name
  |           |     +--rw ee-certs! {ietf-tls-client:x509-certificate-auth}?
  |           |        +--rw (local-or-truststore)
  |           |           +--:(local-truststore) {ietf-truststore:certificates}?
  |           |              +--rw local-truststore-reference {ietf-truststore:certificates}?
  |           |                 +--rw certificate-bag    -> /truststore/certificate-bags/certificate-bag/name
  |           |                 +--rw certificate        -> /truststore/certificate-bags/certificate-bag[name = current()/../certificate-bag]/certi\
ficate/name
  |           +--rw http-client-parameters
  |              +--rw client-identity!
  |                 +--rw (auth-type)
  |                    +--:(basic)
  |                       +--rw basic {ietf-http-client:basic-auth}?
  |                          +--rw user-id     string
  |                          +--rw password    string
  +--rw preferences
```



```
   |  +--rw admin-accounts
   |  |  +--rw new-account-verification
   |  |  |  +--rw subject?    string <$ZTPD new account verification required.>
   |  |  |  +--rw cc?         string <$CREATOR-FULLNAME <CREATOR-EMAIL-ADDRESS$>>
   |  |  |  +--rw body?       string <$ACCOUNT-FULLNAME,

You are receiving this email because I created a new account
for you on the SZTPD ($SZTP-SERVER-ADDRESS).  You
account's login is "$ACCOUNT-EMAIL-ADDRESS".

Please activate your account via the following URL:
$VERIFICATION-URI (This URL expires in 48-hours).

Note that I CC-ed myself on this email and you may contact
me to verify the veracity of this email.

Thanks,
$CREATOR-FULLNAME
>
   |  |  +--rw passwords
   |  |     +--rw strength-testing!
   |  |        +--rw min-length?   uint16 <16>
   |  +--rw notification-delivery!
   |  |  +--rw dynamic-callout
   |  |     +--rw reference     -> ../../../../dynamic-callouts/dynamic-callout/name
   |  +--rw system
   |     +--rw hostname?               ietf-inet-types:host
   |     +--rw email-from-address?     string <$ZTPD Administrator <root@$SZTP-SERVER-ADDRESS$>>
   |     +--rw features
   |     |  +--rw onboarding-supported?    boolean <true> {wn-sztpd-0:onboarding-supported}?
   |     +--rw plugins
   |        +--rw plugin* [name]
   |           +--rw name          string
   |           +--rw functions
   |              +--rw function* [name]
   |                 +--rw name     string
   +--rw admin-accounts
   |  +--rw admin-account* [email-address]
   |     +--rw email-address                        string
   |     +--rw fullname?                            string
   |     +--rw password                             iana-crypt-hash:crypt-hash
   |     +--ro password-last-modified               ietf-yang-types:date-and-time
   |     +--rw access                               enumeration
   |     +---x resend-activation-email
   +--ro audit-log
   |  +--ro log-entry*
   |     +--ro timestamp          ietf-yang-types:date-and-time
   |     +--ro source-ip          ietf-inet-types:ip-address
   |     +--ro source-proxies*    string
   |     +--ro host               string
   |     +--ro method             enumeration
   |     +--ro path               string
   |     +--ro outcome            enumeration
   |     +--ro comment?           string
   +--rw truststore
   |  +--rw certificate-bags! {ietf-truststore:certificates}?
   |     +--rw certificate-bag* [name]
   |        +--rw name                            string
   |        +--rw description?                    string
   |        +--rw certificate* [name]
   |        |  +--rw name                            string
   |        |  +--rw cert                            ietf-crypto-types:trust-anchor-cert-cms
   |        |  +---n certificate-expiration
   |        |     +--ro expiration-date     ietf-yang-types:date-and-time
   |        |  +--ro reference-statistics
   |        |     +--ro reference-count     uint32
   |        |     +--ro last-referenced     union
   |        +--ro reference-statistics
   |           +--ro reference-count     uint32
   |           +--ro last-referenced     union
   +--rw keystore
   |  +--rw asymmetric-keys
   |  |  +--rw asymmetric-key* [name]
   |  |     +--rw name                                  string
   |  |     +--rw public-key-format                     identityref
   |  |     +--rw public-key                            binary
   |  |     +--rw private-key-format?                   identityref
   |  |     +--rw (private-key-type)
   |  |     |  +--:(private-key)
   |  |     |  |  +--rw private-key?    binary
   |  |     |  +--:(hidden-private-key)
   |  |     |  |  +--rw hidden-private-key?    empty
   |  |     |  +--:(encrypted-private-key)
   |  |     |     +--rw encrypted-private-key
   |  |     |        +--rw (key-type)
   |  |     |        +--rw value?        binary
   |  |     +--rw certificates
   |  |     |  +--rw certificate* [name]
   |  |     |     +--rw name                             string
   |  |     |     +--rw cert                             ietf-crypto-types:end-entity-cert-cms
   |  |     |     +---n certificate-expiration
   |  |     |        +--ro expiration-date     ietf-yang-types:date-and-time
   |  |     |     +--ro reference-statistics
   |  |     |        +--ro reference-count     uint32
   |  |     |        +--ro last-referenced     union
   |  |     +---x generate-certificate-signing-request {ietf-crypto-types:certificate-signing-request-generation}?
   |  |     |  +--rw input
   |  |     |  |  +---w subject        binary
   |  |     |  |  +---w attributes?    binary
   |  |     |  +--rw output
   |  |     |     +--ro certificate-signing-request     ietf-crypto-types:csr
   |  |     +--ro reference-statistics
   |  |        +--ro reference-count     uint32
   |  |        +--ro last-referenced     union
   |  +--rw symmetric-keys
   |     +--rw symmetric-key* [name]
   |        +--rw name           string
```



```
   |        +--rw key-format?    identityref
   |        +--rw (key-type)
   |           +--:(key)
   |           |  +--rw key?    binary
   |           +--:(hidden-key)
   |           |  +--rw hidden-key?    empty
   |           +--:(encrypted-key)
   |              +--rw encrypted-key
   |                 +--rw (key-type)
   |                 +--rw value?        binary
   +--rw dynamic-callouts
   |  +--rw dynamic-callout* [name]
   |     +--rw name              string
   |     +--rw rpc-supported     identityref
   |     +--rw (callout-type)
   |        +--:(use-callback)
   |        |  +--rw callback
   |        |     +--rw plugin       -> /preferences/system/plugins/plugin/name
   |        |     +--rw function     -> /preferences/system/plugins/plugin[name = current()/../plugin]/functions/function/name
   |        +--:(use-webhooks) {wn-app:webhook-based-callouts}?
   |           +--rw webhooks
   |              +--rw webhook* [name]
   |              |  +--rw name           string
   |              |  +--rw encoding?      enumeration <json>
   |              |  +--rw (transport)
   |              |     +--:(https) {ietf-restconf-client:https-initiate}?
   |              |     |  +--rw https
   |              |     |     +--rw tcp-client-parameters
   |              |     |     |  +--rw remote-address     ietf-inet-types:host
   |              |     |     |  +--rw remote-port?       ietf-inet-types:port-number <443>
   |              |     |     +--rw tls-client-parameters
   |              |     |     |  +--rw client-identity!
   |              |     |     |  |  +--rw (auth-type)
   |              |     |     |  |     +--:(certificate) {ietf-tls-client:x509-certificate-auth}?
   |              |     |     |  |        +--rw certificate
   |              |     |     |  |           +--rw (local-or-keystore)
   |              |     |     |  |              +--:(local-keystore)
   |              |     |     |  |                 +--rw local-keystore-reference
   |              |     |     |  |                    +--rw asymmetric-key     -> ../../../../../../../../../../keystore/asymmetric-keys/asymmetric-k\
ey/name
   |              |     |     |  |                    +--rw certificate        -> ../../../../../../../../../../keystore/asymmetric-keys/asymmetric-k\
ey[name = current()/../asymmetric-key]/certificates/certificate/name
   |              |     |     |  +--rw server-authentication
   |              |     |     |     +--rw ca-certs! {ietf-tls-client:x509-certificate-auth}?
   |              |     |     |     |  +--rw (local-or-truststore)
   |              |     |     |     |     +--:(local-truststore) {ietf-truststore:certificates}?
   |              |     |     |     |        +--rw local-truststore-reference?   -> ../../../../../../../../../truststore/certificate-bags/certifica\
te-bag/name
   |              |     |     |     +--rw ee-certs! {ietf-tls-client:x509-certificate-auth}?
   |              |     |     |        +--rw (local-or-truststore)
   |              |     |     |           +--:(local-truststore) {ietf-truststore:certificates}?
   |              |     |     |              +--rw local-truststore-reference?   -> ../../../../../../../../../truststore/certificate-bags/certifica\
te-bag/name
   |              |     |     +--rw http-client-parameters
   |              |     |     |  +--rw client-identity!
   |              |     |     |     +--rw (auth-type)
   |              |     |     |        +--:(basic)
   |              |     |     |           +--rw basic {ietf-http-client:basic-auth}?
   |              |     |     |              +--rw user-id      string
   |              |     |     |              +--rw password     string
   |              |     |     +--rw restconf-client-parameters
   |              |     +--:(http)
   |              |        +--rw http
   |              |           +--rw tcp-client-parameters
   |              |           |  +--rw remote-address     ietf-inet-types:host
   |              |           |  +--rw remote-port?       ietf-inet-types:port-number <80>
   |              |           +--rw http-client-parameters
   |              |              +--rw client-identity!
   |              |                 +--rw (auth-type)
   |              |                    +--:(basic)
   |              |                       +--rw basic {ietf-http-client:basic-auth}?
   |              |                          +--rw user-id      string
   |              |                          +--rw password     string
   |              |
   |              +--rw round-robin!
   |                 +--rw amount     uint16
   |                 +--rw units      enumeration
   +--rw transport
   |  +--rw listen! {ietf-restconf-server:http-listen or ietf-restconf-server:https-listen}?
   |     +--rw endpoint* [name]
   |        +--rw name           string
   |        +--rw (transport)
   |        |  +--:(http) {ietf-restconf-server:http-listen}?
   |        |  |  +--rw http
   |        |  |     +--rw external-endpoint!
   |        |  |     |  +--rw address     ietf-inet-types:ip-address
   |        |  |     |  +--rw port?       ietf-inet-types:port-number <443>
   |        |  |     +--rw tcp-server-parameters
   |        |  |     |  +--rw local-address     ietf-inet-types:ip-address
   |        |  |     |  +--rw local-port?       ietf-inet-types:port-number <80>
   |        |  |     +--rw http-server-parameters
   |        |  |     |  +--rw server-name?              string
   |        |  |     +--rw restconf-server-parameters
   |        |  |        +--rw client-identity-mappings
   |        |  |           +--rw cert-to-name* [id]
   |        |  |              +--rw id              uint32
   |        |  |              +--rw fingerprint?    ietf-x509-cert-to-name:tls-fingerprint
   |        |  |              +--rw map-type        identityref
   |        |  |              +--rw name            string
   |        |  +--:(https) {ietf-restconf-server:https-listen}?
   |        |     +--rw https
   |        |        +--rw tcp-server-parameters
   |        |        |  +--rw local-address     ietf-inet-types:ip-address
   |        |        |  +--rw local-port?       ietf-inet-types:port-number <443>
   |        |        +--rw tls-server-parameters
   |        |        |  +--rw server-identity
   |        |        |  |  +--rw (auth-type)
   |        |        |  |     +--:(certificate) {ietf-tls-server:x509-certificate-auth}?
```



```
   |        |        |  |        +--rw certificate
   |        |        |  |           +--rw (local-or-keystore)
   |        |        |  |              +--:(local-keystore)
   |        |        |  |                 +--rw reference
   |        |        |  |                    +--rw asymmetric-key?   -> /keystore/asymmetric-keys/asymmetric-key/name
   |        |        |  |                    +--rw certificate?      -> /keystore/asymmetric-keys/asymmetric-key[name = current()/../asymmetric-key]\
/certificates/certificate/name
   |        |        |  +--rw client-authentication! {ietf-tls-server:client-auth-config-supported}?
   |        |        |     +--rw ca-certs! {ietf-tls-server:x509-certificate-auth}?
   |        |        |     |  +--rw (local-or-truststore)
   |        |        |     |     +--:(local-truststore) {ietf-truststore:certificates,ietf-tls-server:client-auth-config-supported}?
   |        |        |     |        +--rw local-truststore-reference?   -> /truststore/certificate-bags/certificate-bag/name
   |        |        |     +--rw ee-certs! {ietf-tls-server:x509-certificate-auth}?
   |        |        |        +--rw (local-or-truststore)
   |        |        |           +--:(local-truststore) {ietf-truststore:certificates,ietf-tls-server:client-auth-config-supported}?
   |        |        |              +--rw local-truststore-reference?   -> /truststore/certificate-bags/certificate-bag/name
   |        |        +--rw http-server-parameters
   |        |        |  +--rw server-name?              string
   |        |        +--rw restconf-server-parameters
   |        |           +--rw client-identity-mappings
   |        |              +--rw cert-to-name* [id]
   |        |                 +--rw id              uint32
   |        |                 +--rw fingerprint?    ietf-x509-cert-to-name:tls-fingerprint
   |        |                 +--rw map-type        identityref
   |        |                 +--rw name            string
   |        +--rw use-for*       enumeration
   +--rw tenants
      +--rw tenant* [name]
         +--rw name                                string
         +--rw preferences
         |  +--rw admin-accounts
         |  |  +--rw new-account-verification
         |  |  |  +--rw subject?   string <SZTPD new account verification required.>
         |  |  |  +--rw cc?        string <$CREATOR-FULLNAME <$CREATOR-EMAIL-ADDRESS$>>
         |  |  |  +--rw body?      string <$ACCOUNT-FULLNAME,

You are receiving this email because I created a new account
for you on the SZTPD ($SZTP-SERVER-ADDRESS).  You
account's login is "$ACCOUNT-EMAIL-ADDRESS".

Please activate your account via the following URL:
$VERIFICATION-URI (This URL expires in 48-hours).

Note that I CC-ed myself on this email and you may contact
me to verify the veracity of this email.

Thanks,
$CREATOR-FULLNAME
>
         |  |  +--rw passwords
         |  |     +--rw strength-testing!
         |  |        +--rw min-length?    uint16 <16>
         |  +--rw notification-delivery!
         |     +--rw dynamic-callout
         |        +--rw reference    -> ../../../../dynamic-callouts/dynamic-callout/name
         +--rw admin-accounts
         |  +--rw admin-account* [email-address]
         |     +--rw email-address                        string
         |     +--rw fullname?                            string
         |     +--rw password                             iana-crypt-hash:crypt-hash
         |     +--ro password-last-modified               ietf-yang-types:date-and-time
         |     +--rw access                               enumeration
         |     +---x resend-activation-email
         +--ro audit-log
         |  +--ro log-entry*
         |     +--ro timestamp          ietf-yang-types:date-and-time
         |     +--ro source-ip          ietf-inet-types:ip-address
         |     +--ro source-proxies*    string
         |     +--ro host               string
         |     +--ro method             enumeration
         |     +--ro path               string
         |     +--ro outcome            enumeration
         |     +--ro comment?           string
         +--rw truststore
         |  +--rw certificate-bags! {ietf-truststore:certificates}?
         |     +--rw certificate-bag* [name]
         |        +--rw name                            string
         |        +--rw description?                    string
         |        +--rw certificate* [name]
         |        |  +--rw name                            string
         |        |  +--rw cert                            ietf-crypto-types:trust-anchor-cert-cms
         |        |  +---n certificate-expiration
         |        |     +--ro expiration-date    ietf-yang-types:date-and-time
         |        |  +--ro reference-statistics
         |        |     +--ro reference-count    uint32
         |        |     +--ro last-referenced    union
         |        +--ro reference-statistics
         |           +--ro reference-count    uint32
         |           +--ro last-referenced    union
         +--rw keystore
         |  +--rw asymmetric-keys
         |  |  +--rw asymmetric-key* [name]
         |  |     +--rw name                                  string
         |  |     +--rw public-key-format                     identityref
         |  |     +--rw public-key                            binary
         |  |     +--rw private-key-format?                   identityref
         |  |     +--rw (private-key-type)
         |  |     |  +--:(private-key)
         |  |     |  |  +--rw private-key?    binary
         |  |     |  +--:(hidden-private-key)
         |  |     |  |  +--rw hidden-private-key?    empty
         |  |     |  +--:(encrypted-private-key)
         |  |     |     +--rw encrypted-private-key
         |  |     |        +--rw (key-type)
         |  |     |        +--rw value?        binary
         |  |     +--rw certificates
         |  |     |  +--rw certificate* [name]
```



```
|  |  |     +--rw name                          string
|  |  |     +--rw cert                          ietf-crypto-types:end-entity-cert-cms
|  |  |     +--n certificate-expiration
|  |  |        +--ro expiration-date    ietf-yang-types:date-and-time
|  |  |     +--ro reference-statistics
|  |  |        +--ro reference-count    uint32
|  |  |        +--ro last-referenced    union
|  |  +---x generate-certificate-signing-request {ietf-crypto-types:certificate-signing-request-generation}?
|  |  |  +--rw input
|  |  |  |  +---w subject       binary
|  |  |  |  +---w attributes?   binary
|  |  |  +--rw output
|  |  |     +--ro certificate-signing-request    ietf-crypto-types:csr
|  |  +--ro reference-statistics
|  |     +--ro reference-count    uint32
|  |     +--ro last-referenced    union
|  +--rw symmetric-keys
|     +--rw symmetric-key* [name]
|        +--rw name           string
|        +--rw key-format?    identityref
|        +--rw (key-type)
|           +--:(key)
|           |  +--rw key?    binary
|           +--:(hidden-key)
|           |  +--rw hidden-key?    empty
|           +--:(encrypted-key)
|              +--rw encrypted-key
|                 +--rw (key-type)
|                 +--rw value?        binary
+--rw dynamic-callouts
|  +--rw dynamic-callout* [name]
|     +--rw name              string
|     +--rw rpc-supported     identityref
|     +--rw (callout-type)
|        +--:(use-callback)
|        |  +--rw callback
|        |     +--rw plugin       -> /preferences/system/plugins/plugin/name
|        |     +--rw function     -> /preferences/system/plugins/plugin[name = current()/../plugin]/functions/function/name
|        +--:(use-webhooks) {wn-app:webhook-based-callouts}?
|           +--rw webhooks
|              +--rw webhook* [name]
|                 |  +--rw name           string
|                 |  +--rw encoding?      enumeration <json>
|                 |  +--rw (transport)
|                 |     +--:(https) {ietf-restconf-client:https-initiate}?
|                 |     |  +--rw https
|                 |     |     +--rw tcp-client-parameters
|                 |     |     |  +--rw remote-address     ietf-inet-types:host
|                 |     |     |  +--rw remote-port?       ietf-inet-types:port-number <443>
|                 |     |     +--rw tls-client-parameters
|                 |     |     |  +--rw client-identity!
|                 |     |     |  |  +--rw (auth-type)
|                 |     |     |  |     +--:(certificate) {ietf-tls-client:x509-certificate-auth}?
|                 |     |     |  |        +--rw certificate
|                 |     |     |  |           +--rw (local-or-keystore)
|                 |     |     |  |              +--:(local-keystore)
|                 |     |     |  |                 +--rw local-keystore-reference
|                 |     |     |  |                    +--rw asymmetric-key     -> ../../../../../../../../../../keystore/asymmetric-keys/asymme\
tric-key/name
|                 |     |     |  |                    +--rw certificate        -> ../../../../../../../../../../keystore/asymmetric-keys/asymme\
tric-key[name = current()/../asymmetric-key]/certificates/certificate/name
|                 |     |     |  +--rw server-authentication
|                 |     |     |     +--rw ca-certs! {ietf-tls-client:x509-certificate-auth}?
|                 |     |     |     |  +--rw (local-or-truststore)
|                 |     |     |     |     +--:(local-truststore) {ietf-truststore:certificates}?
|                 |     |     |     |        +--rw local-truststore-reference?   -> ../../../../../../../../../truststore/certificate-bags/cer\
tificate-bag/name
|                 |     |     |     +--rw ee-certs! {ietf-tls-client:x509-certificate-auth}?
|                 |     |     |        +--rw (local-or-truststore)
|                 |     |     |           +--:(local-truststore) {ietf-truststore:certificates}?
|                 |     |     |              +--rw local-truststore-reference?   -> ../../../../../../../../../truststore/certificate-bags/cer\
tificate-bag/name
|                 |     |     +--rw http-client-parameters
|                 |     |     |  +--rw client-identity!
|                 |     |     |     +--rw (auth-type)
|                 |     |     |        +--:(basic)
|                 |     |     |           +--rw basic {ietf-http-client:basic-auth}?
|                 |     |     |              +--rw user-id      string
|                 |     |     |              +--rw password     string
|                 |     |     +--rw restconf-client-parameters
|                 |     +--:(http)
|                 |        +--rw http
|                 |           +--rw tcp-client-parameters
|                 |           |  +--rw remote-address     ietf-inet-types:host
|                 |           |  +--rw remote-port?       ietf-inet-types:port-number <80>
|                 |           +--rw http-client-parameters
|                 |              +--rw client-identity!
|                 |                 +--rw (auth-type)
|                 |                    +--:(basic)
|                 |                       +--rw basic {ietf-http-client:basic-auth}?
|                 |                          +--rw user-id      string
|                 |                          +--rw password     string
|                 |
|                 +--rw round-robin!
|                    +--rw amount     uint16
|                    +--rw units      enumeration
+--rw bootstrap-servers
|  +--rw bootstrap-server* [name]
|     +--rw name                          string
|     +--rw address                       ietf-inet-types:host
|     +--rw port?                         ietf-inet-types:port-number <443>
|     +--rw trust-anchor?                 ietf-crypto-types:trust-anchor-cert-cms
|     +--ro reference-statistics
|        +--ro reference-count    uint32
|        +--ro last-referenced    union
+--rw boot-images {wn-sztpd-0:onboarding-supported}?
|  +--rw boot-image* [name]
|     +--rw name                          string
```



```
|       |     +--rw os-name?                       string
|       |     +--rw os-version?                    string
|       |     +--rw download-uri*                  ietf-inet-types:uri
|       |     +--rw image-verification* [hash-algorithm]
|       |     |  +--rw hash-algorithm    identityref
|       |     |  +--rw hash-value        ietf-yang-types:hex-string
|       |     +--ro reference-statistics
|       |        +--ro reference-count    uint32
|       |        +--ro last-referenced    union
|       +--rw scripts {wn-sztpd-0:onboarding-supported}?
|       |  +--rw pre-configuration-script* [name]
|       |  |  +--rw name                           string
|       |  |  +--rw script?                        ietf-sztp-conveyed-info:script
|       |  |  +--ro reference-statistics
|       |  |     +--ro reference-count    uint32
|       |  |     +--ro last-referenced    union
|       |  +--rw post-configuration-script* [name]
|       |     +--rw name                           string
|       |     +--rw script?                        ietf-sztp-conveyed-info:script
|       |     +--ro reference-statistics
|       |        +--ro reference-count    uint32
|       |        +--ro last-referenced    union
|       +--rw configurations {wn-sztpd-0:onboarding-supported}?
|       |  +--rw configuration* [name]
|       |     +--rw name                           string
|       |     +--rw configuration-handling?        enumeration
|       |     +--rw config?                        binary
|       |     +--ro reference-statistics
|       |        +--ro reference-count    uint32
|       |        +--ro last-referenced    union
|       +--rw conveyed-information-responses
|       |  +--rw redirect-information-response* [name]
|       |  |  +--rw name                           string
|       |  |  +--rw redirect-information
|       |  |  |  +--rw bootstrap-server*   -> ../../../../bootstrap-servers/bootstrap-server/name
|       |  |  +--ro reference-statistics
|       |  |     +--ro reference-count    uint32
|       |  |     +--ro last-referenced    union
|       |  +--rw onboarding-information-response* [name] {wn-sztpd-0:onboarding-supported}?
|       |     +--rw name                           string
|       |     +--rw onboarding-information
|       |     |  +--rw boot-image                    -> ../../../../boot-images/boot-image/name
|       |     |  +--rw pre-configuration-script?     -> ../../../../scripts/pre-configuration-script/name
|       |     |  +--rw configuration?                -> ../../../../configurations/configuration/name
|       |     |  +--rw post-configuration-script?    -> ../../../../scripts/post-configuration-script/name
|       |     +--ro reference-statistics
|       |        +--ro reference-count    uint32
|       |        +--ro last-referenced    union
|       +--rw devices
|          +--rw device* [serial-number]
|             +--rw serial-number                     string
|             +--rw activation-code?                  iana-crypt-hash:crypt-hash
|             +--rw response-manager
|             |  +--rw matched-response* [name]
|             |     +--rw name              string
|             |     +--rw match-criteria!
|             |     |  +--rw match* [key]
|             |     |     +--rw key             string
|             |     |     +--rw not?            empty
|             |     |     +--rw (test-type)
|             |     |        +--:(present)
|             |     |        |  +--rw present?    empty
|             |     |        +--:(value)
|             |     |        |  +--rw value?    string
|             |     |        +--:(regex)
|             |     |           +--rw regex?    string
|             |     +--rw response
|             |        +--rw reporting-level?      enumeration <minimal> {wn-sztpd-0:onboarding-supported}?
|             |        +--rw (response-handler)
|             |           +--:(none)
|             |           |  +--rw none?    empty
|             |           +--:(use-dynamic-callout)
|             |           |  +--rw dynamic-callout
|             |           |     +--rw reference?    -> ../../../../../../../../dynamic-callouts/dynamic-callout/name
|             |           +--:(managed-response)
|             |              +--rw conveyed-information
|             |                 +--rw (conveyed-information-handler)
|             |                    +--:(use-dynamic-callout)
|             |                    |  +--rw dynamic-callout
|             |                    |     +--rw reference?    -> ../../../../../../../../dynamic-callouts/dynamic-callout/name
|             |                    +--:(redirect-information)
|             |                    |  +--rw redirect-information
|             |                    |     +--rw (local-or-reference)
|             |                    |        +--:(reference)
|             |                    |           +--rw reference?    -> ../../../../../../../../conveyed-information-responses/redirect-information-re\
sponse/name
|             |                    +--:(onboarding-information) {wn-sztpd-0:onboarding-supported}?
|             |                       +--rw onboarding-information
|             |                          +--rw (local-or-reference)
|             |                             +--:(reference)
|             |                                +--rw reference?    -> ../../../../../../../../conveyed-information-responses/onboarding-information-\
response/name
|             +--ro bootstrapping-log
|             |  +--ro log-entry*
|             |     +--ro timestamp         ietf-yang-types:date-and-time
|             |     +--ro source-ip         ietf-inet-types:ip-address
|             |     +--ro method            string
|             |     +--ro path              string
|             |     +--ro return-code       uint16
|             |     +--ro error-message?    string
|             |     +--ro event-details
|             |        +--ro (event-type)
|             |           +--:(get-bootstrapping-data-event)
|             |           |  +--ro get-bootstrapping-data-event
|             |           |     +--ro passed-input
|             |           |     |  +--ro (input-type)
|             |           |     |     +--:(no-input-passed)
```

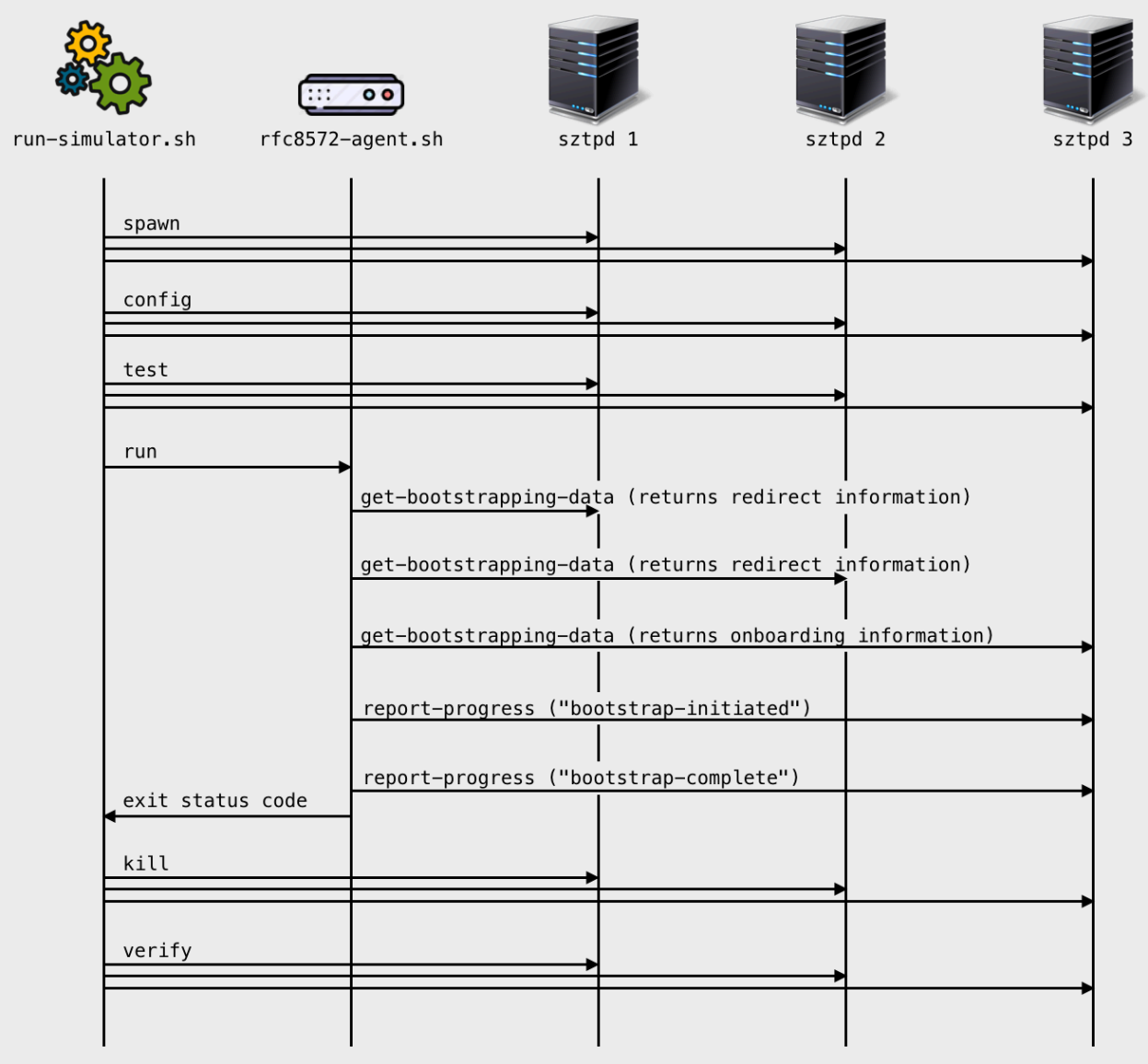


```
|           |     |     |  +--ro no-input-passed?   empty
|           |     |     +--:(input)
|           |     |        +--ro input*
|           |     |           +--ro key      string
|           |     |           +--ro value    union
|           |     +--ro selected-response?        union
|           |     +--ro response-details
|           |        +--ro (response-type)
|           |           +--:(managed)
|           |              +--ro managed-response-supplied
|           |                 +--ro conveyed-information
|           |                    +--ro (conveyed-information-handler)
|           |                       +--:(dynamic-callout)
|           |                       |  +--ro dynamic-callout-result
|           |                       |     +--ro (result-type)?
|           |                       |        +--:(no-callout-configured)
|           |                       |        |  +--ro no-callout-configured?   empty
|           |                       |        +--:(callout-configured)
|           |                       |           +--ro name?              string
|           |                       |           +--ro (callout-type)?
|           |                       |              +--:(callback)
|           |                       |                 |  +--ro callback-results
|           |                       |                 |     +--ro (exit-status)
|           |                       |                 |        +--:(exited-successfully)
|           |                       |                 |        |  +--ro exited-successfully?   empty
|           |                       |                 |        +--:(exception-thrown)
|           |                       |                 |           +--ro exception-thrown?   empty
|           |                       |                 +--:(webhook) {wn-app:webhook-based-callouts}?
|           |                       |                    +--ro webhook-results
|           |                       |                       +--ro webhook*
|           |                       |                          +--ro name              string
|           |                       |                          +--ro uri               ietf-inet-types:uri
|           |                       |                          +--ro (result-type)?
|           |                       |                             +--:(connection-error)
|           |                       |                             |  +--ro connection-error?   string
|           |                       |                             +--:(http-status-code)
|           |                       |                                +--ro http-status-code    string
|           |                       +--:(redirect-information)
|           |                       |  +--ro redirect-information
|           |                       |     +--ro (local-or-reference)
|           |                       |        +--:(reference)
|           |                       |           +--ro referenced-definition?   string
|           |                       +--:(onboarding-information) {wn-sztpd-0:onboarding-supported}?
|           |                          +--ro onboarding-information
|           |                             +--ro (local-or-reference)
|           |                                +--:(reference)
|           |                                   +--ro referenced-definition?   string
|           +--:(report-progress-event) {wn-sztpd-0:onboarding-supported}?
|              +--ro report-progress-event
|                 +--ro passed-input
|                 |  +--ro progress-type          string
|                 |  +--ro message?               string
|                 |  +--ro ssh-host-keys?         anydata
|                 |  +--ro trust-anchor-certs?    anydata
|                 +--ro dynamic-callout-result
|                    +--ro (result-type)?
|                       +--:(no-callout-configured)
|                       |  +--ro no-callout-configured?   empty
|                       +--:(callout-configured)
|                          +--ro name?              string
|                          +--ro (callout-type)?
|                             +--:(callback)
|                             |  +--ro callback-results
|                             |     +--ro (exit-status)
|                             |        +--:(exited-successfully)
|                             |        |  +--ro exited-successfully?   empty
|                             |        +--:(exception-thrown)
|                             |           +--ro exception-thrown?   empty
|                             +--:(webhook) {wn-app:webhook-based-callouts}?
|                                +--ro webhook-results
|                                   +--ro webhook*
|                                      +--ro name              string
|                                      +--ro uri               ietf-inet-types:uri
|                                      +--ro (result-type)?
|                                         +--:(connection-error)
|                                         |  +--ro connection-error?   string
|                                         +--:(http-status-code)
|                                            +--ro http-status-code    string
|
+--ro lifecycle-statistics
|  +--ro nbi-access-stats
|  |  +--ro created                ietf-yang-types:date-and-time
|  |  +--ro num-times-modified     uint16
|  |  +--ro last-modified          ietf-yang-types:date-and-time
|  +--ro sbi-access-stats
|     +--ro num-times-accessed     uint16
|     +--ro first-accessed         ietf-yang-types:date-and-time
|     +--ro last-accessed          ietf-yang-types:date-and-time
+--rw device-type                      -> /device-types/device-type/name
```


5 Simulator

A simulator has been developed, primarily to aid in the development of the RFC 8572 compliant bootstrapping agent, though inspection of its source code is helpful towards understand how to use SZTPD's Northbound Interface (e.g., its use of the curl command line utility).

5.1 Overview



The simulator (i.e., the script run−sztpd−test.sh) performs the following steps:

1. Start and initialize three SZTPD servers for the following roles:

Instance	Purpose
1	A trusted bootstrap server to redirect the device to instance #2.
2	An initially untrusted bootstrap server to redirect the device to instance #3.
3	An initially untrusted bootstrap server to give the device its onboarding data.

   Each SZTP server is an instance of the sztpd process.

2. Start an instance of a demo RFC 8572 agent (the rfc8572−simulator.sh script).

   Parameters are passed into the agent providing necessary values (e.g., the "serial-number" value).

3. Wait for the agent to complete and then shutdown the three SZTPD instances.

   No trace on the filesystem is retained as:

   1. the run−sztpd−test.sh and rfc8572−simulator.sh scripts cleans up after themselves.
   2. the sztpd processes are run using the [In-memory Database].

5.2 Dependencies

Successful execution of the requires a few packages to be installed.

- A UNIX-based system. (untested on Windows)
- Bash (the Bourne-Again SHell, any recent version)
- OpenSSL (both libraries and the command-line utility)
- Python (version 3.7 or greater)
- The following Python modules (all installed as dependencies to SZTPD)
- Curl (the curl utility, many times installed by OS)
- SZTPD

5.3 Downloading

When posted, the simulator can be downloaded here: https://watsen.net/support/.

5.4 Unarchiving

Unarchive the TGZ in a local directory, for example:

```
$ tar -xzvf ./sztpd-simulator-0.0.2.tgz

  // This command creates a directory called "sztpd-simulator".
```


Inside the "sztpd-simulator" directory are a number of files and directories:

Resource	Purpose
run-simulator.sh	The script that starts 3 SZTPD servers and an RFC 8572 agent.
rfc8572-agent.sh	A simple curl based agent that simulates an RFC 8572 agent.
templates/	A directory containing config used to init the SZTP instances.
pki/	A directory containing code to initialize the PKI for the demo.
xrd/	A directory containing files to validates the "host-meta" XRD.

5.5 Customizing Variables

There is little need to customize the simulator scripts before running.

The most likely customization is to alter the ports the various sztpd instances open. To adjust the ports used, please edit the top of the "run-sztpd-test.sh" and edit the various "PORT" values listed at the top of that file.

5.6 Initializing the PKI

The simulator creates a distinct PKI for each endpoint. As each SZTPD instance (in this demo) has two endpoints (an NBI and and SBI) and there are three SZTPD instances, a total of six certificate chains are created. Each certificate chain contains four certificates (a root certificate, two intermediate certificates, and an end-entity certificate), thus a total of Twenty-four certificates are created in total.

Whilst the certificates could be dynamically generated for each execution of the simulator, for multiple executions, having the PKI created already saves time.

Assuming the current directory is the "sztpd-simulator" directory, the following commands:

```
$ cd pki
$ make pki
$ cd ..
```

If ever needed, make clean can be used to return the directory hierarchy to its original form.

5.7 Running

Assuming the current directory is the "sztpd-simulator" directory, the following command will run the simulator:

```
$ ./run-sztpd-test.sh
```

Each time the simulator runs, it first tests if the PKI has been initialized. If the PKI has not been initialized, the simulator exits with the message:

```
PKI needs to be initialized first.
  - e.g., `cd pki; make pki; cd ..;`
```


Otherwise the simulator runs without any other prompts, producing output such as:

```
Creating instances...
  ^— Creating SZTPD instance 1...okay.  (SZTPD instance 1 running with PID 22089)
  ^— Creating SZTPD instance 2...okay.  (SZTPD instance 2 running with PID 220155)
  ^— Creating SZTPD instance 3...okay.  (SZTPD instance 3 running with PID 22091)

Giving servers a couple seconds to startup...

Configuring instances...
  ^— Configuring SZTPD instance 1...
  ^— Configuring SZTPD instance 2...
  ^— Configuring SZTPD instance 3...

Giving servers a couple seconds to open their ports...

Testing instances...
  ^— Testing SZTPD instance 1
  ^— Testing SZTPD instance 2
  ^— Testing SZTPD instance 3

Running simulator...
 ^— Getting bootstrapping data...
 ^— Processing bootstrapping data...
 ^— Processing redirect information...
 ^— Getting bootstrapping data from next server...
 ^— Processing bootstrapping data...
 ^— Processing redirect information...
 ^— Getting bootstrapping data from next server...
 ^— Processing bootstrapping data...
 ^— Processing onboarding information...
 ^— Bootstrap complete.

Killing `sztpd` instances...
  ^— Sending SIGTERM to instance 1 (PID 22089)
  ^— Sending SIGTERM to instance 2 (PID 22090)
  ^— Sending SIGTERM to instance 3 (PID 22091)

Giving servers a couple seconds to shutdown...

Verifying instances are killed...
  ^— Verifying SZTPD instance 1 killed...okay.
  ^— Verifying SZTPD instance 2 killed...okay.
  ^— Verifying SZTPD instance 3 killed...okay.

All done!
```

5.8 Cleaning Up

The simulator makes effort to clean up after itself. For instance, all files are created in a temporary directory. However, currently, if the simulator experiences an unexpected error, it may exit without first shutting down the sztpd instances.

If the sztpd instances are not removed, they can be removed manually. For instance:

```
$ ps | grep sztpd
23816 ttys024    0:02.01 python sztpd sqlite:///:memory:
23817 ttys024    0:02.01 python sztpd sqlite:///:memory:
23818 ttys024    0:02.01 python sztpd sqlite:///:memory:

$ kill 23816
$ kill 23817
$ kill 23818
```

