Use gRPC Protocol to Define Network Operations with Data Models

XR devices ship with the YANG files that define the data models they support. Using a management protocol such as NETCONF or gRPC, you can programmatically query a device for the list of models it supports and retrieve the model files.

gRPC is an open-source RPC framework. It is based on Protocol Buffers (Protobuf), which is an open source binary serialization protocol. gRPC provides a flexible, efficient, automated mechanism for serializing structured data, like XML, but is smaller and simpler to use. You define the structure using protocol buffer message types in `.proto` files. Each protocol buffer message is a small logical record of information, containing a series of name-value pairs.

gRPC encodes requests and responses in binary. gRPC is extensible to other content types along with Protobuf. The Protobuf binary data object in gRPC is transported over HTTP/2.

gRPC supports distributed applications and services between a client and server. gRPC provides the infrastructure to build a device management service to exchange configuration and operational data between a client and a server. The structure of the data is defined by YANG models.

Note All 64-bit IOS XR platforms support gRPC and TCP protocols. All 32-bit IOS XR platforms support only TCP protocol.

Cisco gRPC IDL uses the protocol buffers interface definition language (IDL) to define service methods, and define parameters and return types as protocol buffer message types. The gRPC requests are encoded and sent to the router using JSON. Clients can invoke the RPC calls defined in the IDL to program the router.

The following example shows the syntax of the proto file for a gRPC configuration:

```
syntax = "proto3";

package IOSXRExtensibleManagabilityService;

service gRPCConfigOper {

    rpc GetConfig(ConfigGetArgs) returns(stream ConfigGetReply) {};

    rpc MergeConfig(ConfigArgs) returns(ConfigReply) {};

    rpc DeleteConfig(ConfigArgs) returns(ConfigReply) {};
```

```
    rpc ReplaceConfig(ConfigArgs) returns(ConfigReply) {};

    rpc CliConfig(CliConfigArgs) returns(CliConfigReply) {};

    rpc GetOper(GetOperArgs) returns(stream GetOperReply) {};

    rpc CommitReplace(CommitReplaceArgs) returns(CommitReplaceReply) {};
}
message ConfigGetArgs {
     int64 ReqId = 1;
     string yangpathjson = 2;
}

message ConfigGetReply {
    int64 ResReqId = 1;
    string yangjson = 2;
    string errors = 3;
}

message GetOperArgs {
     int64 ReqId = 1;
     string yangpathjson = 2;
}

message GetOperReply {
    int64 ResReqId = 1;
    string yangjson = 2;
    string errors = 3;
}

message ConfigArgs {
    int64 ReqId = 1;
    string yangjson = 2;

}

message ConfigReply {
    int64 ResReqId = 1;
    string errors = 2;
}

message CliConfigArgs {
    int64 ReqId = 1;
    string cli = 2;
}

message CliConfigReply {
    int64 ResReqId = 1;
    string errors = 2;
}

message CommitReplaceArgs {
     int64 ReqId = 1;
     string cli = 2;
     string yangjson = 3;
}

message CommitReplaceReply {
     int64 ResReqId = 1;
     string errors = 2;
}
```

Example for gRPCExec configuration:

```
service gRPCExec {
    rpc ShowCmdTextOutput(ShowCmdArgs) returns(stream ShowCmdTextReply) {};
    rpc ShowCmdJSONOutput(ShowCmdArgs) returns(stream ShowCmdJSONReply) {};

}

message ShowCmdArgs {
     int64 ReqId = 1;
     string cli = 2;
}

message ShowCmdTextReply {
    int64 ResReqId =1;
    string output = 2;
    string errors = 3;
}
```

Example for OpenConfiggRPC configuration:

```
service OpenConfiggRPC {
     rpc SubscribeTelemetry(SubscribeRequest) returns (stream SubscribeResponse) {};
     rpc UnSubscribeTelemetry(CancelSubscribeReq) returns (SubscribeResponse) {};
     rpc GetModels(GetModelsInput) returns (GetModelsOutput) {};
}

message GetModelsInput {
     uint64  requestId   = 1;
     string  name        = 2;
    string  namespace   = 3;
    string  version     = 4;
    enum MODLE_REQUEST_TYPE {
         SUMMARY = 0;
         DETAIL  = 1;
     }
     MODLE_REQUEST_TYPE requestType = 5;
}

message GetModelsOutput {
     uint64  requestId   = 1;
     message ModelInfo {
         string  name        = 1;
         string  namespace   = 2;
        string  version     = 3;
         GET_MODEL_TYPE  modelType = 4;
         string modelData = 5;
     }
     repeated ModelInfo models = 2;
     OC_RPC_RESPONSE_TYPE responseCode = 3;
     string msg = 4;
}
```

This article describes, with a use case to configure interfaces on a router, how data models helps in a faster programmatic and standards-based configuration of a network, as comapared to CLI.

- gRPC Operations, on page 4
- gRPC over UNIX Domain Sockets, on page 13
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- Configure Interfaces Using Data Models in a gRPC Session, on page 66

gRPC Operations

The following are the defined manageability service gRPC operations for Cisco IOS XR:

gRPC Operation	Description
GetConfig	Retrieves the configuration from the router.
GetModels	Gets the supported Yang models on the router
MergeConfig	Merges the input config with the existing device configuration.
DeleteConfig	Deletes one or more subtrees or leaves of configuration.
ReplaceConfig	Replaces part of the existing configuration with the input configuration.
CommitReplace	Replaces all existing configuration with the new configuration provided.
GetOper	Retrieves operational data.
CliConfig	Invokes the input CLI configuration.
ShowCmdTextOutput	Returns the output of a show command in the text form
ShowCmdJSONOutput	Returns the output of a show command in JSON form.

gRPC Operation to Get Configuration

This example shows how a gRPC GetConfig request works for LLDP feature.

The client initiates a message to get the current configuration of LLDP running on the router. The router responds with the current LLDP configuration.

<table>
<tr><th>gRPC Request (Client to Router)</th><th>gRPC Response (Router to Client)</th></tr>
<tr><td><pre>
rpc GetConfig
  {
   "Cisco-IOS-XR-cdp-cfg:cdp": [
    "cdp": "running-configuration"
    ]
  }

rpc GetConfig
  {
   "Cisco-IOS-XR-ethernet-lldp-cfg:lldp": [
    "lldp": "running-configuration"
    ]
  }
</pre></td><td><pre>
{
 "Cisco-IOS-XR-cdp-cfg:cdp": {
  "timer": 50,
  "enable": true,
  "log-adjacency": [
   null
  ],
  "hold-time": 180,
  "advertise-v1-only": [
   null
  ]
 }
}

{
"Cisco-IOS-XR-ethernet-lldp-cfg:lldp": {
  "timer": 60,
  "enable": true,
  "reinit": 3,
  "holdtime": 150
}
}
</pre></td></tr>
</table>

gRPC Authentication Modes

gRPC supports the following authentication modes to secure communication between clients and servers. These authentication modes help ensure that only authorized entities can access the gRPC services, like gNOI, gRIBI, and P4RT. Upon receiving a gRPC request, the device will authenticate the user and perform various authorization checks to validate the user.

The following table lists the authentication type and configuration requirements:

Table 1: gRPC Authentication Modes and Configuration Requirements

Type	Authentication Method	Authorization Method	Configuration Requirement	Requirement From Client
Metadata with TLS	username, password	username	**grpc**	username, password, and CA
Metadata without TLS	username, password	username	**grpc no-tls**	username, password
Metadata with Mutual TLS	username, password	username	**grpc tls-mutual**	username, password, client certificate, client key, and CA
Certificate based Authentication	client certificate's common name field	username from client certificate's common name field	**grpc tls-mutual** and **grpc certificate authentication**	client certificate, client key, and CA

Certificate based Authentication

In Extensible Manageability Services (EMS) gRPC, the certificates play a vital role in ensuring secure and authenticated communication. The EMS gRPC utilizes the following certificates for authentication:

```
/misc/config/grpc/ems.pem
/misc/config/grpc/ems.key
/misc/config/grpc/ca.cert
```

Note For clients to use the certificates, ensure to copy the certificates from **/misc/config/grpc/**

Generation of Certificates

These certificates are typically generated using a Certificate Authority (CA) by the device. The EMS certificates, including the server certificate (**ems.pem**), public key (**ems.key**), and CA certificate (**ca.cert**), are generated with specific parameters like the common name **ems.cisco.com** to uniquely identify the EMS server and placed in the **/misc/config/grpc/** location.

The default certificates that are generated by the server are Server-only TLS certificates and by using these certificates you can authenticate the identity of the server.

Usage of Certificates

These certificates are used for enabling secure communication through Transport Layer Security (TLS) between gRPC clients and the EMS server. The client should use **ems.pem** and **ca.cert** to initiate the TLS authentication.

To update the certificates, ensure to copy the new certificates that has been generated earlier to the location and restart the server.

Custom Certificates

If you want to use your own certificates for EMS gRPC communication, then you can follow a workflow to generate a custom certificates with the required parameters and then configure the EMS server to use these custom certificates. This process involves replacing the default EMS certificates with the custom ones and ensuring that the gRPC clients also trust the custom CA certificate. For more information on how to customize the **common-name**, see *Certificate Common-Name For Dial-in Using gRPC Protocol*.

Authenticate gRPC Services

Note Typically, gRPC clients include the username and password in the gRPC metadata fields.

Procedure

Use any one of the following configuration type to authenticate any gRPC service.

- **Metadata with TLS**

```
Router#config
Router(config)#grpc
Router(config-grpc)#commit
```

- **Metadata without TLS**

```
Router#config
Router(config)#grpc
Router(config-grpc)#no-tls
Router(config-grpc)#commit
```

- **Metadata with Mutual TLS**

```
Router#config
Router(config)#grpc
Router(config-grpc)#tls-mutual
Router(config-grpc)#commit
```

- **Certificate based Authentication**

```
Router(config)#grpc
Router(config-grpc)#tls-mutual
Router(config-grpc)#certificate-authentication
Router(config-grpc)#commit
```

SPIFFE ID-Based Authentication and Authorization Services for gRPC Services

Table 2: Feature History Table

Feature Name	Release Information	Description
SPIFFE ID-Based Authentication and Authorization Services for gRPC Services	Release 24.2.11	You can now securely manage service identities for workloads that communicate over gRPC. This capability is critical for environments such as distributed systems, where workloads move across different platforms. This security measure is feasible because workloads can use the Secure Production Identity Framework for Everyone (SPIFFE) ID and SPIFFE Verifiable Identity Document (SVID) to encrypt and authenticate gRPC traffic. This feature introduces the following changes: CLI: • **aaa map-to username** Yang Data Models: • New XPaths for `Cisco-IOS-XR-um-aaa-task-user-cfg.yang` • New XPaths for `Cisco-IOS-XR-aaa-locald-cfg.yang` (see GitHub, YANG Data Models Navigator)

The SPIFFE standard specifies a framework that can bootstrap and issue identities to services across diverse environments and organizational boundaries. SPIFFE assigns a unique identity to each workload with a SPIFFE ID and securely encapsulates it within a SPIFFE Verifiable Identity Document (SVID). The SVID, which is short-lived, corresponds exclusively to its SPIFFE ID and can be encoded either as an X.509 certificate or as a JSON Web Token (JWT). This dual-format capability facilitates robust identity verification.

This feature provides a mechanism for mapping a SPIFFE ID to an XR user for authorization purposes. This feature enables Extensible Manageability Services (EMS) to use the SVID, which are certificates that essentially contain SPIFFE IDs, to perform the following operations:

- Authentication via mTLS
- AuthZ authorization using the SVID

The XR authorization occurs with the XR user which is mapped to the SPIFFE ID. Mapping the SPIFFE ID to a username is required for gRPC services to perform IOS XR authentication and authorization before executing any operations on the device. If the authz evaluation is successful then only the connection request is processed; otherwise, access is denied.

Workflow for SPIFFE ID-Based Authentication and Authorization for gRPC Services

The high-level workflow of SPIFFE ID-based authentication and authorization for gRPC services involves the following steps:

1. The EMS starts searching for the *spiffe-user-map.json* file at the location `/misc/config/grpc/gnsi/credentialz/spiffe-user-map.json`.
2. If the file exists, it is parsed, and the mapping is stored globally in the `aaa/auth package`.
3. If the file does not exist or parsing is unsuccessful, the mapping will be empty.
4. The EMS registers with the configuration manager to receive updates for the `aaa` configuration.
5. When processing requests in the Authentication interceptor, the spiffe-user mapping API checks for the SPIFFE ID mapping in the map created in step 2.
6. If the mapping exists, the API responds with the corresponding username.
7. If the mapping does not exist but the `aaa` configuration exists, the API responds with the configured username.
8. If neither the mapping nor the `aaa` configuration is present, the API responds with an empty string.
9. Upon a client connecting to the server, the server interceptor extracts the SPIFFE ID from the client's certificate and uses the mapping stored in the `aaa/auth package` to find the corresponding username.
10. The username identifies it and then includes the metadata into the context.
11. gRPC services that require XR Authorization will later verify the access rights for the username identified in the previous step when handling the request.
12. If the mapping is unsuccessful, the request is passed to the relevant service, such as gNMI, which then decides whether to grant or deny access based on its authorization requirements.

Authenticate and Authorize gRPC Service Requests Using the SPIFFE Standard

Before you begin

Before authenticating and authorizing gRPC service requests using the SPIFFE standard, ensure the following prerequisites are met:

- Enable mutual TLS authentication with the `tls-mutual` command.
- Enable certificate authentication with the `certificate-authentication` command to facilitate SPIFFE ID recognition. For more information, see Authenticate gRPC Services, on page 6.
- Configure the gNSI Authz policy by setting the principal to the SPIFFE-ID for service-level authorization (gNSI AuthZ).

After establishing the connection, the gRPC server extracts the SPIFFE ID from the client's certificate.

To authenticate and authorize gRPC service requests using the SPIFFE standard, follow these steps:

Procedure

Step 1 Configure the username in the system.

Example:

```
Router#show running-config aaa
Thu Oct 12 11:43:15.771 UTC
username cisco
 group root-lr
 group cisco-support
 password 7 104D000A061843595F
!
```

Step 2 Map the SPIFFE ID to a username using the **aaa map-to username** command. This command assigns a default username to any SPIFFE ID.

```
Router(config)#aaa map-to username cisco spiffe-id any
Router(config)#commit
```

Note
Each SPIFFE ID supports only one username.

Step 3 Evaluate the client's SPIFFE ID against the service-level authorization policy (gNSI AuthZ). For more information about gNSI authz policies, see gRPC Network Security Interface , on page 46.

Certificate Common-Name For Dial-in Using gRPC Protocol

Table 3: Feature History Table

Feature Name	Release Information	Description
Certificate Common-Name For Dial-in Using gRPC Protocol	Release 24.1.1	You can now specify a **common-name** for the certificate generated by the router while using gRPC dial-in. Earlier, the **common-name** in the certificate was fixed as *ems.cisco.com* and was not configurable. Using a specified **common-name** avoids potential certification failures where you may specify a hostname different from the fixed common name to connect to the router. The feature introduces these changes: **CLI:** • **grpc certificate common-name** **YANG Data Model:** • New XPath for `Cisco-IOS-XR-um-grpc-cfg.yang` • New XPath for `Cisco-IOS-XR-man-ems-cfg` (see GitHub, YANG Data Models Navigator)

When using gRPC dial-in on Cisco IOS-XR router, the **common-name** associated with the certificate generated by the router is fixed as *ems.cisco.com* and this caused failure during certificate verification.

From Cisco IOS XR Release 24.1.1, you can now have the flexibility of specifying the common-name in the certificate using the **grpc certifcate common-name** command. This allows gRPC clients to verify if the domain name in the certificate matches the domain name of the gRPC server being accessed.

Configure Certificate Common Name For Dial-in

Configure a common name to be used in EMSD certificates for gRPC dial-in.

Procedure

Step 1 Configure a common name.

Example:

```
Router#config
Router(config)#grpc
Router(config-grpc)#certificate common-name cisco.com
Router(config-grpc)#commit
```

Use the show command to verify the common name:

```
Router#show grpc
Certificate common name                 : cisco.com
```

Note

For the above configuration to be successful, ensure to regenerate the certificate. so that the new EMSD certificates include the configured common name.

To **regenerate** the self-signed certificate, perform the following steps.

Step 2 Remove the certificates: `/misc/config/grpc/ems.pem`, `/misc/config/grpc/ems.key`, and `/misc/config/grpc/ca.cert` from `/misc/config/grpc` file.

Example:

```
Router#run ls -ltr /misc/config/grpc/

total 16
drwx------. 2 root root 4096 Feb 14 09:17 dialout
-rw-rw-rw-. 1 root root 1505 Feb 14 10:58 ems.pem
-rw-------. 1 root root 1675 Feb 14 10:58 ems.key
-rw-r--r--. 1 root root 1505 Feb 14 10:58 ca.cert
```

```
Router#run rm -rf /misc/config/grpc/ems.pem /misc/config/grpc/ems.key
```

```
Router#run ls -ltr /misc/config/grpc/

total 8
drwx------. 2 root root 4096 Feb 14 09:17 dialout
-rw-r--r--. 1 root root 1505 Feb 14 10:58 ca.cert
```

Step 3 Restart gRPC server by toggling the TLS configuration.

Configure gRPC with non TLS and then re-configure with TLS.

Example:

```
Router#config
Router(config)#grpc
Router(config-grpc)#no-tls
Router(config-grpc)#commit
```

```
Router#run ls -ltr /misc/config/grpc/

total 8
drwx------. 2 root root 4096 Feb 14 09:17 dialout
-rw-r--r--. 1 root root 1505 Feb 14 10:58 ca.cert
```

```
Router#config
Router(config)#grpc
Router(config-grpc)#no no-tls
Router(config-grpc)#commit
```

```
Router#run ls -ltr /misc/config/grpc/

total 16
drwx------. 2 root root 4096 Feb 14 09:17 dialout
-rw-rw-rw-. 1 root root 1505 Feb 14 14:23 ems.pem
```

```
-rw-------. 1 root root 1675 Feb 14 14:23 ems.key
-rw-r--r--. 1 root root 1505 Feb 14 14:23 ca.cert
```

Copy the newly generated `/misc/config/grpc/ems.pem` certificate in this path (from the device) to the gRPC client.

gRPC over UNIX Domain Sockets

Table 4: Feature History Table

Feature Name	Release Information	Description
gRPC Connections over UNIX domain sockets for Enhanced Security and Control	Release 7.5.1	This feature allows local containers and scripts on the router to establish gRPC connections over UNIX domain sockets. These sockets provide better inter-process communication eliminating the need to manage passwords for local communications. Configuring communication over UNIX domain sockets also gives you better control of permissions and security because UNIX file permissions come into force. This feature introduces the **grpc local-connection** command.

You can use local containers to establish gRPC connections via a TCP protocol where authentication using username and password is mandatory. This functionality is extended to establish gRPC connections over UNIX domain sockets, eliminating the need to manage password rotations for local communications.

When gRPC is configured on the router, the gRPC server starts and then registers services such as gRPC Network Management Interface and gRPC Network Operations Interface . After all the gRPC server registrations are complete, the listening socket is opened to listen to incoming gRPC connection requests. Currently, a TCP listen socket is created with the IP address, VRF, or gRPC listening port. With this feature, the gRPC server listens over UNIX domain sockets that must be accessible from within the container via a local connection by default. With the UNIX socket enabled, the server listens on both TCP and UNIX sockets. However, if disable the UNIX socket, the server listens only on the TCP socket. The socket file is located at /var/lib/docker/ems/grpc.sock directory.

The following process shows the configuration changes required to enable or disable gRPC over UNIX domain sockets.

Procedure

Step 1 Configure the gRPC server.

Example:

```
Router(config)#grpc
Router(config-grpc)#local-connection
Router(config-grpc)#commit
```

To disable the UNIX socket use the following command.

```
Router(config-grpc)#no local-connection
```

The gRPC server restarts after you enable or disable the UNIX socket. If you disable the socket, any active gRPC sessions are dropped and the gRPC data store is reset.

The scale of gRPC requests remains the same and is split between the TCP and Unix socket connections. The maximum session limit is 256, if you utilize the 256 sessions on Unix sockets, further connections on either TCP or UNIX sockets is rejected.

Step 2 Verify that the local-connection is successfully enabled.

Example:

```
Router#show grpc status
Thu Nov 25 16:51:30.382 UTC
*************************show gRPC status**********************
---------------------------------------------------------------
transport                        :     grpc
access-family                    :     tcp4
TLS                              :     enabled
trustpoint                       :
listening-port                   :     57400
local-connection                 :     enabled
max-request-per-user             :     10
max-request-total                :     128
max-streams                      :     32
max-streams-per-user             :     32
vrf-socket-ns-path               :     global-vrf
min-client-keepalive-interval    :     300
_______________________________________________________________
```

A gRPC client must dial into the socket to send connection requests.

The following is an example of a Go client connecting to UNIX socket:

```
const sockAddr =
"/var/lib/docker/ems/grpc.sock"
...
func UnixConnect(addr string, t time.Duration) (net.Conn, error) {
    unix_addr, err := net.ResolveUnixAddr("unix", sockAddr)
    conn, err := net.DialUnix("unix", nil, unix_addr)
    return conn, err
}


func main() {
...
    opts = append(opts, grpc.WithTimeout(time.Second*time.Duration(*operTimeout)))
    opts = append(opts, grpc.WithDefaultCallOptions(grpc.MaxCallRecvMsgSize(math.MaxInt32)))
    ...
    opts = append(opts, grpc.WithDialer(UnixConnect))
    conn, err := grpc.Dial(sockAddr, opts...)
    ...
}
```

gRPC Network Management Interface

gRPC Network Management Interface (gNMI) is a gRPC-based network management protocol used to modify, install or delete configuration from network devices. It is also used to view operational data, control and generate telemetry streams from a target device to a data collection system. It uses a single protocol to manage configurations and stream telemetry data from network devices.

The subscription in a gNMI does not require prior sensor path configuration on the target device. Sensor paths are requested by the collector (such as pipeline), and the subscription mode can be specified for each path. gNMI uses gRPC as the transport protocol and the configuration is same as that of gRPC.

gNMI Operations

gNMI Operation	Supported Release	Description	Additional Details
Capabilities	Release 7.0.1	Retrieves the metadata of the network device.	—
Get	Release 7.0.1	Retrieve state data, configuration, and operational information from a network device	—
Set	Release 7.0.1	You can modify the state of a network device such as router's configuration, replace router's entire configuration sections, or delete specific parts of the configuration using the **Set** operation.	—
Subscribe	Release 24.2.1	Subscribes to a stream of updates for specific paths within the device's data model.	Stream Telemetry Data for LLDP Statistics

gNMI Wildcard in Schema Path

Table 5: Feature History Table

Feature Name	Release Information	Description
Use gNMI Get Request With Wildcard Key to Retrieve Data	Release 7.5.2	You use a gRPC Network Management Interface (gNMI) `Get` request with wildcard key to retrieve the configuration and operational data of all the elements in the data model schema paths. In earlier releases, you had to specify the correct key to retrieve data. The router returned a JSON error message if the key wasn't specified in a list node. For more information about using wildcard search in gNMI requests, see the Github repository.

gNMI protocol supports wildcards to indicate all elements at a given subtree in the schema. These wildcards are used for telemetry subscriptions or gNMI `Get` requests. The encoding of the path in gNMI uses a structured format. This format consists of a set of elements such as the path name and keys. The keys are represented as string values, regardless of their type within the schema that describes the data. gNMI supports the following options to retrieve data using wildcard search:

- **Single-level wildcard:** The name of a path element is specified as an asterisk (*). The following sample shows a wildcard as the key name. This operation returns the description for all interfaces on a device.

```
path {
  elem {
    name: "interfaces"
  }
  elem {
    name: "interface"
    key {
     key: "name"
      value: "*"
    }
  }
  elem {
    name: "config"
  }
  elem {
    name: "description"
  }
}
```

- **Multi-level wildcard:** The name of the path element is specified as an ellipsis (…). The following example shows a wildcard search that returns all fields with a description available under `/interfaces` path.

```
path {
  elem {
    name: "interfaces"
  }
```

```
      elem {
        name: "..."
      }
      elem {
        name: "description"
      }
    }
```

Example: gNMI Get Request with Unique Path to a Leaf

The following is a sample `Get` request to fetch the operational state of `GigabitEthernet0/0/0/0` interface in particular.

```
path: <
    origin: "Cisco-IOS-XR-pfi-im-cmd-oper"
        elem: <
            name: "interfaces"
        >
        elem: <
            name: "interface-xr"
        >
        elem: <
            name: "interface"
            key: <
                key: "interface-name"
                value: "\"GigabitEthernet0/0/0/0\""
            >
        >
        elem: <
            name: "state"
        >
>
type: OPERATIONAL
encoding: JSON_IETF
```

The following is a sample `Get` response:

```
notification: <
  timestamp: 1597974202517298341
  update: <
    path: <
      origin: "Cisco-IOS-XR-pfi-im-cmd-oper"
       elem: <
          name: "interfaces"
       >
       elem: <
          name: "interface-xr"
       >
       elem: <
          name: "interface"
          key: <
            key: "interface-name"
            value: "\"GigabitEthernet0/0/0/0\""
           >
        >
        elem: <
            name: "state"
           >
       >
       val: <
          json_ietf_val: im-state-admin-down
       >
    >
>
```

```
error: <
>
```

Example: gNMI Get Request Without a Key Specified in the Schema Path

The following is a sample `Get` request to fetch the operational state of all interfaces.

```
path: <
    origin: "Cisco-IOS-XR-pfi-im-cmd-oper"
        elem: <
            name: "interfaces"
        >
        elem: <
            name: "interface-xr"
        >
        elem: <
            name: "interface"
        >
        elem: <
            name: "state"
        >
>
type: OPERATIONAL
encoding: JSON_IETF
```

The following is a sample `Get` response:

```
path: <
    origin: "Cisco-IOS-XR-pfi-im-cmd-oper"
        elem: <
            name: "interfaces"
        >
        elem: <
            name: "interface-xr"
        >
        elem: <
            name: "interface"
        >
        elem: <
            name: "state"
        >
>
type: OPERATIONAL
encoding: JSON_IETF
  notification: <
  timestamp: 1597974202517298341
  update: <
    path: <
      origin: "Cisco-IOS-XR-pfi-im-cmd-oper"
      elem: <
        name: "interfaces"
      >
      elem: <
        name: "interface-xr"
      >
      elem: <
        name: "interface"
        key: <
          key: "interface-name"
          value: "\"GigabitEthernet0/0/0/0\""
        >
      >
      elem: <
        name: "state"
```

```
      >
    >
    val: <
      json_ietf_val: im-state-admin-down
    >
  >
  update: <
    path: <
      origin: "Cisco-IOS-XR-pfi-im-cmd-oper"
      elem: <
        name: "interfaces"
      >
      elem: <
        name: "interface-xr"
      >
      elem: <
        name: "interface"
        key: <
          key: "interface-name"
          value: "\"GigabitEthernet0/0/0/1\""
        >
      >
      elem: <
        name: "state"
      >
    >
    val: <
      json_ietf_val: im-state-admin-down
    >
  >
  update: <
    path: <
      origin: "Cisco-IOS-XR-pfi-im-cmd-oper"
      elem: <
        name: "interfaces"
      >
      elem: <
        name: "interface-xr"
      >
      elem: <
        name: "interface"
        key: <
          key: "interface-name"
          value: "\"GigabitEthernet0/0/0/2\""
        >
      >
      elem: <
        name: "state"
      >
    >
    val: <
      json_ietf_val: im-state-admin-down
    >
  >
  update: <
    path: <
      origin: "Cisco-IOS-XR-pfi-im-cmd-oper"
      elem: <
        name: "interfaces"
      >
      elem: <
        name: "interface-xr"
      >
      elem: <
```

```
        name: "interface"
        key: <
          key: "interface-name"
          value: "\"MgmtEth0/RP0/CPU0/0\""
        >
      >
      elem: <
        name: "state"
      >
    >
    val: <
      json_ietf_val: im-state-admin-down
    >
  >
```

Example: gNMI Get Request with Unique Path to a CLI

The following is a sample `Get` request to fetch the system updates through CLI.

```
path: <
  origin: "cli"
  elem: <
    name: "show version"
  >
>
type: ALL
encoding: ASCII
```

The following is a sample `Get` response.

```
path: <
  origin: "cli"
  elem: <
    name: "show version"
  >
>

type: ALL
...
...

[
  {
    "source": "unix:///var/run/test_env.sock",
    "timestamp": 1730123328800447525,
    "time": "2024-10-28T06:48:48.800447525-07:00",
    "updates": [
      {
        "Path": "show version",
        "values": {
          "show version":
"-------------------------------- show version ---------------------------------
Cisco IOS XR Software, Version 24.4.1.37I
Copyright (c) 2013-2024 by Cisco Systems, Inc.
Build Information:\n Built By     : swtools
Built On     : Mon Oct 21 03:16:32 PDT 2024
Built Host   : iox-lnx-121\n Workspace    :
/auto/iox-lnx-121-san2/prod/24.4.1.37I.SIT_IMAGE/ncs5500/ws
Version      : 24.4.1.37I\n Location     : /opt/cisco/XR/packages/
Label        : 24.4.1.37I-EFT2LabOnly
cisco NCS-5500 () processor
System uptime is 3 days 22 hours 54 minutes\n\n\n"
        }
      }
    ]
```

```
   }
]
```

gNMI Bundling of Telemetry Updates

Table 6: Feature History Table

Feature Name	Release Information	Description
gNMI Bundling Size Enhancement	Release 7.8.1	With gRPC Network Management Interface (gNMI) bundling, the router internally bundles multiple gNMI `Update` messages meant for the same client into a single gNMI `Notification` message and sends it to the client over the interface. You can now optimize the interface bandwidth utilization by accommodating more gNMI updates in a single notification message to the client. We have now increased the gNMI bundling size from 32768 to 65536 bytes, and enabled gNMI bundling size configuration through Cisco native data model. Prior releases allowed only a maximum bundling size of 32768 bytes, and you could configure only through CLI. The feature introduces new XPaths to the `Cisco-IOS-XR-telemetry-model-driven-cfg.yang` Cisco native data model to configure gNMI bundling size. To view the specification of gNMI bundling, see Github repository.

To send fewer number of bytes over the gNMI interface, multiple gNMI `Update` messages pertained to the same client are bundled and sent to the client to achieve optimized bandwidth utilization.

The router internally bundles multiple gNMI `Update` messages in a single gNMI `Notification` message of gNMI `SubscribeResponse` message. Cisco IOS XR software Release 7.8.1 supports gNMI bundling size up to 65536 bytes.

Router bundles multiple instances of the same client. For example, a router bundles interfaces `MgmtEth0/RP0/CPU0/0`, `FourHundredGigE0/0/0/0`, `FourHundredGigE0/0/0/1`, and so on, of the following path.

- `Cisco-IOS-XR-infra-statsd-oper:infra-statistics/interfaces/interface/latest/generic-counters`

Router does not bundle messages of different client in a single gNMI `Notification` message. For example,

- `Cisco-IOS-XR-infra-statsd-oper:infra-statistics/interfaces/interface/latest/generic-counters`
- `Cisco-IOS-XR-infra-statsd-oper:infra-statistics/interfaces/interface/latest/protocols`

  Data under the container of the client path cannot be split into different bundles.

The gNMI `Notification` message contains a timestamp at which an event occurred or a sample is taken. The bundling process assigns a single timestamp for all bundled `Update` values. The notification timestamp is the first message of the bundle.

Note

- ON-CHANGE subscription mode does not support gNMI bundling.
- Router does not enforce bundling size in the following scenarios:
  - At the end of (N-1) message processing, if the notification message size is less than the configured bundling size, router allows one extra instance which could result in exceeding the bundling size.
  - Data of a single instance exceeding the bundling size.
- The XPath: `network-instances/network-instance/afts` does not support bundling.

Configure gNMI Bundling Size

gNMI bundling is disabled by default and the default bundling size is 32,768 bytes. gNMI bundling size ranges from 1024 to 65536 bytes. Prior to Cisco IOS XR software Release 7.8.1 the range was 1024 to 32768 bytes. You can enable gNMI bundling to all gNMI subscribe sessions and specify the bundling size.

Configuration Example

This example shows how to enable gNMI bundling and configure bundling size.

```
Router# configure
Router(config)# telemetry model-driven
Router(config-model-driven)# gnmi
Router(config-gnmi)# bundling
Router(config-gnmi-bdl)# size 2000
Router(config-gnmi-bdl)# commit
```

Running configuration

This example shows the running configuration of gNMI bundle.

```
Router# show running-config
telemetry model-driven
 gnmi
  bundling
   size 2000
  !
 !
!
```

Replace Router Configuration at Sub-tree Level Using gNMI

Table 7: Feature History Table

Feature Name	Release Information	Description
Replace Router Configuration at Sub-tree Level Using gNMI	Release 7.8.1	Using the gNMI `SetRequest` message, you can replace the router's existing configuration with a new set of configurations at the subtree level within the same model. Earlier you could replace router configurations at the data tree root level. To view the specification of gNMI replace, see Github repository.

The gNMI replace feature replaces the existing configuration on the router with the new configuration using a `SetRequest` RPC message. It allows you to specify a `path` (a structured format for path elements, and any associated key values) as the root prompt to perform a `replace` operation. Cisco IOS XR software Release 7.8.1 supports subtree-level replace operation. Prior to this release replace operation was performed at datatree-level.

Replace operation either includes all the path elements which are defined under the root or only few of them. If the omitted path elements are configured with default values, they are reverted to its default values during the replace operation. If the omitted path elements are not configured with default values, they are deleted from the data tree during the replace operation, and returned to its original unconfigured state. Consider the following example:

In the following data tree schema, `b` has a default value of `true` and `c` has no default value. Both `b` and `c` are set as `False`.

```
root +
     |
     + a --+
     |     |
     |     +-- b
     |     |
     |     +-- c
     |
     |
     + d --+
           +-- e
           |
           +-- f
```

When a `replace` operation is performed with `e` and `f` as set, and all other elements are omitted, `b` is reverted to its default setting true, and `c` is deleted from the tree, and returned to its original unconfigured state.

Following example shows the `SetRequest` and `SetResponse` of gNMI replace operation.

gNMI Replace Example

This example shows the gNMI replace request and response messages.

```
Request Message:
replace: <
  path: <
    elem: <
      name: "system"
    >
```

```
    elem: <
      name: "config"
    >
    elem: <
      name: "hostname"
    >
  >
  val: <
    json_ietf_val: "\"testing123\""
  >
>

Response Message:
  path: <
    elem: <
      name: "system"
    >
    elem: <
      name: "config"
    >
    elem: <
      name: "hostname"
    >
  >
  op: REPLACE
>
message: <
>
timestamp: 1662873319202107537
```

gNMI Union Replace Operation

Table 8: Feature History Table

Feature Name	Release Information	Description
gNMI Union Replace Operation	Release 24.2.11	You can now update your router's entire configuration in one go to ensure that the actual settings of your network operating system align with the intended setup. The update includes OpenConfig (OC), Native YANG (NY), and CLI configurations and is done using the gRPC Network Management Interface (gNMI). The update is possible with the gNMI union-replace operation in a `gNMI SetRequest` RPC message which supports mixing of the configuration schemas. The supported schema combinations are: • OpenConfig (OC) and CLI • OC and native YANG (NY) To view the specification of gNMI union-replace, see the Github repository.

Routers can be configured using different schemas including native YANG (NY) models, the command-line interface (CLI), or OpenConfig (OC) YANG models. You can now update your router's entire configuration in one go to ensure that the actual settings of your network operating system align with the intended setup.

The router update can be done by merging these different schemas and directly replace the existing router settings using the gNMI union-replace operation.

gNMI Union-Replace Operation-Supported Schema Combinations

gNMI union-replace operation in a `gNMI SetRequest` RPC message supports the following two schema combinations:

- OC and CLI
- OC and NY

gNMI union-replace operation Guidelines and Limitations

Using gNMI when a client sends the `gNMI SetRequest` RPC message with union-replace operations to a target router:

- The state of the target router must not be changed until all the changes have been accepted successfully.
- If a particular path-value is specified in the gNMI request, the value replaces the current value in the target router.
- If a particular path-value isn't specified in the gNMI request and the path doesn't have a default value in the corresponding schema, it's deleted.
- If a path-value isn't specified in the gNMI request and the path does have a default value, the default value is applied on the target router.
- A `gNMI SetRequest` RPC message containing union_replace operations must not contain delete, replace, and update operations.

The origin field in the path message of a gNMI union-replace operation is set to one of the following:

- **openconfig**: Path and content are part of OC YANG models.
- **cisco_native**: Path and content are part of Cisco's network operating system YANG models.
- **cisco_cli**: This origin represents an ASCII text or CLI configuration defined as command-line interface (CLI) text.

If the origin field is unspecified, the origin value is set to OpenConfig.

gNMI Union Replace Operation Examples

The following schema combination examples show the union_replace operation in the `gNMI SetRequest` RPC message:

- OC and CLI Origin, on page 25
- OC and NY Origin, on page 27

OC and CLI Origin

gNMI union_replace operation in `gNMI SetRequest` RPC message with OC and CLI origin schema combination example is as follows:

```
union_replace: {
  path: {
    origin: "cisco_cli"
  }
  val: {
    ascii_val: "hostname myhost"
  }
}
union_replace: {
  path:  {
    elem:  {
      name:  "interfaces"
    }
    elem:  {
      name:  "interface"
      key: {
          key: "name"
          value: "FourHundredGigE0/0/0/0"
      }
    }
    elem:  {
      name:  "config"
    }
    elem:  {
      name: "description"
    }
  }
  val:  {
    json_ietf_val:  "\"true\""
  }
}
```

Replacement Sequence for the OC and CLI Origin Schema Combination

The configurations from both the schemas are merged and the merged configuration replaces the router's existing configuration.

Note If the CLI and OC configuration values overlap, the CLI configuration takes higher precedence and overwrites the value set by OC.

Guidelines for OC and CLI Origin

Ensure that you don't use a union-replace operation with an empty path under OC or CLI origins. Doing so removes all the content of the respective origin on the target router.

A union-replace operation with OC and CLI schema combination containing bootz configuration, the processing order of the configuration application on the target router is as follows: OC->CLI->bootz.

OC and NY Origin

A gNMI union_replace operation in the `gNMI SetRequest` RPC message with OC and NY origin schema combination example is as follows.

```
union_replace: {

  path: {

    origin: "cisco_native"

    elem: {

      name: "Cisco-IOS-XR-shellutil-cfg:host-names"

    }

    elem: {

      name: "host-name"

    }

  }

  val: {

    json_ietf_val: "\"abc\""

  }

}

union_replace: {

  path:  {

    elem:  {

      name:  "interfaces"

    }
```

```
      elem:  {
        name:  "interface"
        key: {
            key: "name"
                   value: "FourHundredGigE0/0/0/0"
        }
      }
      elem:  {
        name:  "config"
      }
      elem:  {
        name: "description"
      }
    }
    val:  {
      json_ietf_val:  "\"true\""
    }
  }
```

Guidelines for OC and NY Origin

The configurations from both the schemas are merged and the merged configuration replaces the router's existing configuration.

If the OC and NY schema configuration values overlap, the NY configuration takes higher precedence and overwrites the value set by OC.

If an OC and NY union-replace requests explicitly set configuration items that are overlapping, the RPC doesn't return INVALID_ARGUMENT.

RPC Error Scenarios

The RPC message returns INVALID_ARGUMENT if:

- One of the origins from the supported schema combinations is missing or if the union_replace operation has no specified path value for one of the origins.
- Union-replace operations for all three origins (“cisco_native”, “cisco_cli”, and “openconfig”) are present in the `gNMI SetRequest` RPC message.
- A `gNMI SetRequest` RPC message with union_replace operations contain delete, replace, or update operations.

gNMI XPath-Based Authorization

Table 9: Feature History Table

Feature Name	Release Information	Description
gNMI XPath-Based Authorization	Release 24.2.11	We've introduced gNMI authorization through the gNSI pathz policy which is adding authorization of a user or a group to access a specified YANG XPath through gNMI. The policy configurations can be done on the router either when the router boots up or dynamically when the router is up and running. When a user or a group sends a `gNMI SetRequest` message using a certain XPath, the system validates the request against the permissions specified in the policies associated with that user or the group. To view the specification of gNSI for the OpenConfig XPath-based Authorization, see the Github repository. The feature introduces these changes: **CLI:** • show gnsi path authorization policy • show gnsi path authorization counters • show gnsi trace pathz • show gnsi path authorization statistics • show tech-support gnsi • clear gnsi path authorization counters

How gNSI pathz Policy Works

Upon receiving a `gNMI SetRequest` message for a configuration change, the router applies an XPath-based pathz policy to determine the request's authorization. The pathz policy originates from a gNSI RPC within the router. The policy configurations can be established during the router's boot process or dynamically adjusted while the router is operational.

The router securely receives the initial pathz policy either through Secure Zero Touch Provisioning (sZTP) or a secure bootstrapping protocol like bootz when booting up. The policy includes the user or group name and a list of rules defining XPaths and their associated access permissions. The policy is enforced before processing any gNMI requests.

Authorization by the gNSI pathz policy is granted or denied based on user or group credentials, permitting or declining the `gNMI SetRequest` accordingly.

gNMI Authorization Using gNSI pathz Policy

Starting from Release 24.2.11, you can perform gNMI XPath-based authorization using gNSI pathz policies.

The gnsi-pathz YANG model defines the following counters and timestamps for each configured rule READ, WRITE, PERMIT, and DENY.

- access-rejects: 64-bit
- last-access-reject: timestamp
- access-accepts: 64-bit
- last-access-accept: timestamp

The counters get incremented per accepted or rejected XPath (Example, per gNMI request).

Define Authorization Policy for a gNSI Pathz

The authorization policy for gNSI Pathz consists of three components.

Table 10: Authorization Policy Components

Authorization Policy Component	Details
Users	Individuals named in rules or group definitions.
Groups of users	A group of users in the administrative domain, such as operators or administrators. • The matching policy gives precedence to a specific user over a group. • Match rules enable authorization against either a user or a group, but not both simultaneously.

Policy rules	Each rule defines a single authorization policy.
	• Authorization (how the policy is defined) is performed for a specific user in a predefined group of users on a specific gNMI path and a specific access methodology (example: READ or WRITE).
	  • The wildcard character (*):
	    • Replaces the missing keys in keyed path elements. Absence of keys implies a wildcard by default.
	    • Masks all the values entirely, it doesn't permit partial value masking (Example: /this/is/a/keyed[name=Ethernet1/*/3]/things is invalid).

How Authorization Policy Matching Rules Work

Policy Matching Rule	Description
Multiple rules	The authorization process evaluates the rule with the longest match when granting access, rather than defaulting to the first rule encountered.

Policy Matching Rule	Description
A defined KEY and wildcard in a keyed path	The defined KEY in the keyed path is preferred over the wildcard. For example, the router prefers /a/b[key=FOO]/c/d over /a/b[key=*]/c/d due to its more precise key match.
A user-specific rule and a corresponding group rule for the same user	The rule that corresponds to a specific user is prioritized over the one that matches with a user's group.
Permission mode	A mode that matches with the request (READ or WRITE) is considered.
DENY or PERMIT	DENY takes priority over PERMIT when other conditions are equal, and multiple matching rules are present.

Policy evaluation results with a single best match rule for the provided {user, path, or mode}. If multiple best matches emerge, an error is logged, and the evaluation fails.

If no matching rule is found, an implicit DENY is applied and detailed in a log entry.

The authorization evaluation process results in a PERMIT or DENY decision, along with the version of the policy and the identifier of the rule applied.

Scenario for Authorization Policy Rules

Rule	User	Group	Path	Action	Mode
1	Bob	—	/interfaces/interface[FourHundredGigE0/0/0/0]	PERMIT	READ
2	Bob	—	/interfaces/interface[FourHundredGigE0/0/0/0]	PERMIT	WRITE
3	Bob	—	/interfaces/interface[FourHundredGigE1/1/1/1]	DENY	WRITE
4	—	Admin	/interfaces/interface[*]	PERMIT	WRITE
5	Bob	—	/interfaces	PERMIT	READ
6	—	Admin	/interfaces/interface[FourHundredGigE0/0/0/0]	PERMIT	WRITE
7	Jim	—	/interfaces/interface[FourHundredGigE0/0/0/0]	DENY	WRITE

For user Bob, the following authorization rules apply:

- READ or WRITE (gNMI request) access to the XPath /interfaces/interface[FourHundredGigE0/0/0/0] is granted under rules 1 and 2.
- READ access to the XPath /interfaces/interface[FourHundredGigE1/1/1/1] is granted under rule 5 due to the longest match criterion, which specifies READ mode. WRITE access to this path is denied by rule 3.
- WRITE access to the XPath /interfaces/interface[FourHundredGigE2/2/2/2] is granted being a member of the Admins group as specified by rule 4. Without the Admin membership, access is denied by the default deny all rule.

- READ access to the XPath /interfaces/interface[FourHundredGigE2/2/2/2] is granted under rule 5, independent of group affiliation.

For user Jim, the following authorization rule applies:

- Access to the XPath /interfaces/interface[FourHundredGigE0/0/0/0] is controlled by a policy that favors personal user permissions over group permissions. As a result, although the admins group is allowed access, Jim is individually denied access because the policy emphasizes user-specific rules.

gNSI Pathz Authorization Policy Configuration

To set a gNSI pathz authorization policy, you can perform either of the following methods:

- Load gNSI Pathz Policies at Boot-time, on page 32
- Rotate, Finalize, and Get the gNSI Pathz Policy, on page 32

Load gNSI Pathz Policies at Boot-time

To load gNSI pathz policies at boot-time into the router, you can use either sZTP or bootstrapping.

For details on loading gNSI pathz policy through sZTP, refer to *Secure Zero Touch Provisioning* section of *Cisco IOS XR Setup and Upgrade Guide for Cisco 8000 Series Routers* guide.

Rotate, Finalize, and Get the gNSI Pathz Policy

When the router is up and running, you can rotate (update), finalize (commit), and get (read) the gNSI pathz policy using the gNSI pathz gRPC operations. To view the specification of gNSI pathz policy rotation, see the Github repository.

gNSI pathz supports the following policy instances:

- Active policy—Used for authorizing gNMI requests.
- Potential or candidate policy—Used to test a policy before rotation.

Rules for Authorization Policy Rotation

- The node holds on to the candidate policy indefinitely until either:
  - The candidate is committed or again rotated, or
  - The RPC session is closed (this event removes the candidate instance).
- A single policy rotation RPC can be active at any given time. Concurrent RPC requests for policy rotation is rejected with the gRPC error code `UNAVAILABLE`.
  - gNMI allows different encodings, including JSON. IOS XR applies the gNSI pathz policy based on each leaf of the flattened JSON model for authorizing the gNMI request.

Metrics of gNSI Authorization Rules

IOS-XR pathz supports the following statistics, counters, diagnostics, and trace data commands for the gNSI authorization rules:

- gNSI Pathz Policy and Statistics
- gNSI Path Authorization Counters
- gNSI Pathz Trace Data
- gNSI State Details

gNSI Path Authorization Counters

The gNSI path authorization counters show the counters for a given gRPC server-name for all XPaths, or the specified XPath. Providing the XPath and server-name is optional. To view the gNSI Path Authorization counters, use the **show gnsi path authorization counters** command.

-
```
Router# show gnsi path authorization counters
Mon Apr  1 08:05:46.297 UTC
----------------Pathz Counters Info--------------

/system/config/hostname:
                                        Read                              Write
Rejects :                                  0                                  0
   Last :                                N/A                                N/A
Accepts :                                  0                                  3
   Last :                                N/A    Mon, 01 Apr 2024 08:05:25 +0000
Total path records received 1


Router# show gnsi path authorization counters server-name 64.103.223.33
Mon Apr  1 08:33:25.194 UTC
----------------Pathz Counters Info--------------

/:
                                        Read                              Write
Rejects :                                  0                                  2
   Last :                                N/A    Mon, 01 Apr 2024 08:32:37 +0000
Accepts :                                  0                                  0
   Last :                                N/A                                N/A

/system/config/hostname:
                                        Read                              Write
Rejects :                                  0                                  6
   Last :                                N/A    Mon, 01 Apr 2024 08:32:36 +0000
Accepts :                                  0                                  0
   Last :                                N/A                                N/A
Total path records received 2
Router#
```

```
Router# show gnsi path authorization counters path /system/config/hostname
Mon Apr  1 08:32:46.468 UTC
----------------Pathz Counters Info--------------

/system/config/hostname:
                                        Read                              Write
Rejects :                                  0                                  6
   Last :                                N/A    Mon, 01 Apr 2024 08:32:36 +0000
Accepts :                                  0                                  0
   Last :                                N/A                                N/A
Total path records received 1
Router#
```

- To clear the gNSI path authorization counters, use the **clear gnsi path authorization counters** command.

```
Router# clear gnsi path authorization counters
Router#
```

gNSI Pathz Policy and Statistics

To display the configured gNSI policy and statistics, use the are following commands:

- **show gnsi path authorization policy**—Shows the running gNSI path authorization policy.
- **show gnsi path authorization statistics**—Shows gNSI path authorization statistics.

```
Router# show gnsi path authorization policy
Mon Apr  1 04:29:37.905 UTC
version:"1" created_on:1711946719670313 policy:{rules:{user:"cafyauto"
path:{origin:"openconfig" elem:{name:"system"} elem:{name:"config"} elem:{name:"hostname"}}
 action:ACTION_PERMIT mode:MODE_WRITE}}
Router#
```

```
Router# show gnsi path authorization statistics
Mon Apr  1 04:29:23.259 UTC
----------------Pathz Info--------------
Engine:

  State:
    Active Policy:
      Version                   : 1
      Created On (UTC)          : Wed, 09 Dec 54251401 07:58:33 +0000
    Sandbox Policy:
      Version                   : N/A
      Created On (UTC)          : N/A
    Policy Rotation in Progress: False

  Stats:
    Rotations in Progress Count: 0
    Policy Rotations            : 0
    Policy Rotation Errors      : 0
    Policy Upload Requests      : 0
    Policy Upload Errors        : 0
    Policy Finalize             : 0
    Policy Finalize Errors      : 0
    Probe Requests              : 0
    Probe Errors                : 0
    Get Requests                : 0
    Get Errors                  : 0
    Policy Unmarshall Errors    : 0
    Sandbox Policy Errors       : 0

  Counters:
    No Policy Auth Requests     : 0
    gNMI Path Leaves            : 0
    gNMI Authorizations         : 0
    gNMI Set Path Permit        : 0
    gNMI Set Path Deny          : 0
    gNMI Get Path Permit        : 0
    gNMI Get Path Deny          : 0

  Errors:
    Path To String              : 0
    Origin Type                 : 0
    Bad Mode                    : 0
    Bad Action                  : 0
    JSON Flatten                : 0
    String To Path              : 0
    Join Paths                  : 0
    Nil Path                    : 0
    Nil SetRequest              : 0
    Empty User                  : 0
```

```
    Probe Internal              : 0
    Path Counters:
      Increment                 : 0
      Find                      : 0
      Clear                     : 0
      Walk                      : 0
```

gNSI Pathz Trace Data

To trace the configured gNSI policy, use the **show gnsi trace pathz** command.

```
Router# show gnsi trace pathz all
Mon Apr  1 04:31:26.689 UTC
61 wrapping entries (21760 possible, 512 allocated, 0 filtered, 61 total)
Apr  1 04:07:09.681 gnsi/pathz 0/RP0/CPU0 t11383 Pathz: Code(178) 'Trying to load policy'
'/mnt/rdsfs/ems/gnsi/pathz_policy.txt'
Apr  1 04:07:09.685 gnsi/pathz 0/RP0/CPU0 t11383 Pathz: Code(173) 'Set Sandbox policy'
'1(54251382-02-18 11:34:58 +0000 UTC)'
Apr  1 04:07:09.685 gnsi/pathz 0/RP0/CPU0 t11383 Pathz: Code(179) 'Set Policy from'
'/mnt/rdsfs/ems/gnsi/pathz_policy.txt'
Apr  1 04:07:09.685 gnsi/pathz 0/RP0/CPU0 t11383 Pathz: Code(249) 'Pathz Policy Clearing
Counters' ' '
Apr  1 04:07:09.685 gnsi/pathz 0/RP0/CPU0 t11383 Pathz: Code (79): 'Engine Initialized'
Apr  1 04:08:05.761 gnsi/pathz 0/RP0/CPU0 t11794 Pathz: Code(63) 'Pathz.Get()'
'5.38.4.111:52126'
Apr  1 04:08:05.761 gnsi/pathz_err 0/RP0/CPU0 t11794 Pathz ERROR: Code (65): 'Nil Policy'
Apr  1 04:08:05.788 gnsi/pathz 0/RP0/CPU0 t11480 Pathz: Code(63) 'Pathz.Get()'
'5.38.4.111:52126'
Apr  1 04:08:05.788 gnsi/pathz 0/RP0/CPU0 t11480 Pathz: Code(176) 'Get'
'POLICY_INSTANCE_ACTIVE 1(1711946094752098)'
Apr  1 04:08:05.791 gnsi/pathz_deny 0/RP0/CPU0 t11481 Pathz DENY: Code(235) 'Upd/Rep Denied
 path' 'cafyauto@/system/config/hostname,|1,1711946094752098'
Apr  1 04:08:05.808 gnsi/pathz_deny 0/RP0/CPU0 t11383 Pathz DENY: Code(234) 'Del Denied
path' 'cafyauto@/system/config/hostname,|1,1711946094752098'
Apr  1 04:08:05.821 gnsi/pathz_deny 0/RP0/CPU0 t11480 Pathz DENY: Code(235) 'Upd/Rep Denied
 path' 'cafyauto@/system/config/hostname,|1,1711946094752098'
Apr  1 04:08:07.348 gnsi/pathz_deny 0/RP0/CPU0 t11383 Pathz DENY: Code(235) 'Upd/Rep Denied
 path' 'cafyauto@/lldp/config/enabled,|1,1711946094752098'
Apr  1 04:08:08.205 gnsi/pathz 0/RP0/CPU0 t11383 Pathz: Code(63) 'Pathz.Get()'
'5.38.4.111:52126'
Apr  1 04:08:08.205 gnsi/pathz_err 0/RP0/CPU0 t11383 Pathz ERROR: Code (65): 'Nil Policy'
Apr  1 04:08:08.221 gnsi/pathz 0/RP0/CPU0 t11480 Pathz: Code(63) 'Pathz.Get()'
'5.38.4.111:52126'
Apr  1 04:08:08.221 gnsi/pathz 0/RP0/CPU0 t11480 Pathz: Code(176) 'Get'
'POLICY_INSTANCE_ACTIVE 1(1711946094752098)'
Apr  1 04:08:08.238 gnsi/pathz_deny 0/RP0/CPU0 t11481 Pathz DENY: Code(235) 'Upd/Rep Denied
 path' 'cafyauto@/system/config/hostname,|1,1711946094752098'
Apr  1 04:08:08.281 gnsi/pathz_deny 0/RP0/CPU0 t11480 Pathz DENY: Code(234) 'Del Denied
path' 'cafyauto@/system/config/hostname,|1,1711946094752098'
Router#
```

gNSI State Details

To collect diagnostic information of gNSI, use the **show tech-support gnsi** command.

```
Router# show tech-support gnsi
Mon Apr  1 06:55:51.482 UTC
++ Show tech start time: 2024-Apr-01.065551.UTC ++
Mon Apr  1 06:55:52 UTC 2024 Waiting for gathering to complete
...
Mon Apr  1 06:56:01 UTC 2024 Compressing show tech output
Show tech output available at Router#:
/harddisk:/showtech/showtech-mtb_sf2-gnsi-2024-Apr-01.065551.UTC.tgz
++ Show tech end time: 2024-Apr-01.065601.UTC ++
```

show tech-support gnsi command places the collected diagnostic information in a file, example **Router#: /harddisk: /showtech/showtech-mtb_sf2-gnsi-2024-Apr-01.065551**.

gRPC Network Operations Interface

gRPC Network Operations Interface (gNOI) defines a set of gRPC-based microservices for executing operational commands on network devices. These services are to be used in conjunction with gRPC network management interface (gNMI) for all target state and operational state of a network. gNOI uses gRPC as the transport protocol and the configuration is same as that of gRPC. For more information about gNOI, see the Github repository.

gNOI RPCs

To send gNOI RPC requests, you need a client that implements the gNOI client interface for each RPC.

All messages within the gRPC service definition are defined as protocol buffer (.proto) files. gNOI OpenConfig proto files are located in the Github repository.

Table 11: Feature History Table

Feature Name	Release Information	Description
gNOI MPLS Proto	Release 7.5.4	The RPCs defined in the proto file can be used to perform Multiprotocol Label Switching (MPLS) operations on the router.
gNOI OS Proto	Release 7.9.1	The RPCs defined in the proto file can be used to install the software, activate the software version and verify that the installation is successful.
gNOI System Proto	Release 7.8.1	You can now avail the services of `CancelReboot` to terminate outstanding reboot request, and `KillProcess` RPCs to restart the process on device.

gNOI supports the following remote procedure calls (RPCs):

System RPCs

The RPCs are used to perform key operations at the system level such as upgrading the software, rebooting the device, and troubleshooting the network. The **system.proto** file is available in the Github repository.

RPC	Description
Reboot	Reboots the target. The router supports the following reboot options: • COLD = 1; Shutdown and restart OS and all hardware • POWERDOWN = 2; Halt and power down • HALT = 3; Halt • POWERUP = 7; Apply power
RebootStatus	Returns the status of the target reboot.
SetPackage	Places a software package including bootable images on the target device.
Ping	Pings the target device and streams the results of the ping operation.
Traceroute	Runs the traceroute command on the target device and streams the result. The default hop count is 30.
Time	Returns the current time on the target device.
SwitchControlProcessor	Switches from the current route processor to the specified route processor. If the target does not exist, the RPC returns an error message.
CancelReboot	Cancels any pending reboot request.
KillProcess	Stops an OS process and optionally restarts it.

File RPCs

The RPCs are used to perform key operations at the file level such as reading the contents if a file and its metadata. The **file.proto** file is available in the Github repository.

RPC	Description
Get	Reads and streams the contents of a file from the target device. The RPC streams the file as sequential messages with 64 KB of data.
Remove	Removes the specified file from the target device. The RPC returns an error if the file does not exist or permission is denied to remove the file.
Stat	Returns metadata about a file on the target device. **Note** gNOI File.Stat returns only the filename in the response, which can cause incorrect handling, especially during recursive processing, as the file might be mistakenly treated as a directory.

RPC	Description
Put	Streams data into a file on the target device.
TransferToRemote	Transfers the contents of a file from the target device to a specified remote location. The response contains the hash of the transferred data. The RPC returns an error if the file does not exist, the file transfer fails or an error when reading the file. This is a blocking call until the file transfer is complete.

Certificate Management (Cert) RPCs

The RPCs are used to perform operations on the certificate in the target device. The **cert.proto** file is available in the Github repository.

RPC	Description
Rotate	Replaces an existing certificate on the target device by creating a new CSR request and placing the new certificate on the target device. If the process fails, the target rolls back to the original certificate.
Install	Installs a new certificate on the target by creating a new CSR request and placing the new certificate on the target based on the CSR.
GetCertificates	Gets the certificates on the target.
RevokeCertificates	Revokes specific certificates.
CanGenerateCSR	Asks a target if the certificate can be generated.
LoadCertificateAuthorityBundle	Loads a bundle of CA certificates on the target. This CA certificate bundle is used to verify the client certificate when mutual TLS is enabled.

Interface RPCs

The RPCs are used to perform operations on the interfaces. The **interface.proto** file is available in the Github repository.

RPC	Description
SetLoopbackMode	Sets the loopback mode on an interface.
GetLoopbackMode	Gets the loopback mode on an interface.
ClearInterfaceCounters	Resets the counters for the specified interface.

Layer2 RPCs

The RPCs are used to perform operations on the Link Layer Discovery Protocol (LLDP) layer 2 neighbor discovery protocol. The **layer2.proto** file is available in the Github repository.

Feature Name	Description
ClearLLDPInterface	Clears all the LLDP adjacencies on the specified interface.

BGP RPCs

The RPCs are used to perform operations on the Link Layer Discovery Protocol (LLDP) layer 2 neighbor discovery protocol. The **bgp.proto** file is available in the Github repository.

Feature Name	Description
ClearBGPNeighbor	Clears a BGP session.

Diagnostic (Diag) RPCs

The RPCs are used to perform diagnostic operations on the target device. You assign each bit error rate test (BERT) operation a unique ID and use this ID to manage the BERT operations. The **diag.proto** file is available in the Github repository.

Feature Name	Description
StartBERT	Starts BERT on a pair of connected ports between devices in the network.
StopBERT	Stops an already in-progress BERT on a set of ports.
GetBERTResult	Gets the BERT results during the BERT or after the operation is complete.

MPLS RPCs

The RPCs are used to perform MPLS operations on the target device. The **mpls.proto** file is available in the Github repository.

Feature Name	Description
MPLSPing	Checks basic connectivity using MPLS ping operation. See RFC 4379. In Cisco IOS XR Release 7.5.4, the RPC supports `ldp_fec` and `rsvpte_lsp_name` destination types. The destination types `fec129_pwe` and `rsvpte_lsp` are not supported.
ClearLSP	Clears a single tunnel.
ClearLSPCounters	Clears the MPLS counters for the specified Label Switched Path (LSP).

Operating System (OS) RPCs

The OS service provides an interface for the OS installation on a target device. The RPCs replace the router software to upgrade the system. No concurrent installation is allowed on the same target. The **os.proto** file is available in the Github repository.

Feature Name	Description
Install	Transfers an OS package onto the target. **Note** Only Golden ISO installation is supported; RPM installation is not supported.
Activate	Sets the requested OS version as the version that is used at the next reboot. If booting up the requested OS version fails, the system recovers by rolling back to the previously running OS package.
Verify	Verifies the running OS version. The following gNOI OS verify information returns based on the install state: • If `success`, verify returns the installed version. • If `failure`, verify the version returned by install and set the activation_fail_message to the error returned by the install. • If `in-progress`, verify returns version returned by install and set the activation_fail_message to `in-progress`. • If the install state was not retrieved, verify that the version returned is `unknown` and set the activaiton_fail_message to `Failed to verify the current version`.

gNOI RPCs

The following examples show the representation of few gNOI RPCs:

Get RPC

Streams the contents of a file from the target.

```
RPC to 10.105.57.106:57900
RPC start time: 20:58:27.513638
---------------------File Get Request---------------------
RPC start time: 20:58:27.513668
remote_file: "harddisk:/giso_image_repo/test.log"

---------------------File Get Response---------------------
RPC end time: 20:58:27.518413
contents: "GNOI \n\n"

hash {
method: MD5
hash: "D\002\375h\237\322\024\341\370\3619k\310\333\016\343"
}
```

Remove RPC

Remove the specified file from the target.

```
RPC to 10.105.57.106:57900
RPC start time: 21:07:57.089554
---------------------File Remove Request---------------------
remote_file: "harddisk:/sample.txt"

---------------------File Remove Response---------------------
RPC end time: 21:09:27.796217
File removal harddisk:/sample.txt successful
```

Reboot RPC

Reloads a requested target.

```
RPC to 10.105.57.106:57900
RPC start time: 21:12:49.811536
---------------------Reboot Request---------------------
RPC start time: 21:12:49.811561
method: COLD
message: "Test Reboot"
subcomponents {
origin: "openconfig-platform"
elem {
name: "components"
}
elem {
name: "component"
key {
key: "name"
value: "0/RP0"
}
}
elem {
name: "state"
}
elem {
name: "location"
}
}
---------------------Reboot Request---------------------
RPC end time: 21:12:50.023604
```

Set Package RPC

Places software package on the target.

```
RPC to 10.105.57.106:57900
RPC start time: 21:12:49.811536
---------------------Set Package Request---------------------
RPC start time: 15:33:34.378745
Sending SetPackage RPC
package {
filename: "harddisk:/giso_image_repo/<platform-version>-giso.iso"
activate: true
}
method: MD5
hash: "C\314\207\354\217\270=\021\341y\355\240\274\003\034\334"
RPC end time: 15:47:00.928361
```

Reboot Status RPC

Returns the status of reboot for the target.

```
RPC to 10.105.57.106:57900
RPC start time: 22:27:34.209473
---------------------Reboot Status Request---------------------
subcomponents {
origin: "openconfig-platform"
elem {
name: "components"
}
elem {
name: "component"
key {
key: "name"
value: "0/RP0"
}
}
elem {
name: "state"
}
elem
name: "location"
}
}

RPC end time: 22:27:34.319618

---------------------Reboot Status Response---------------------
Active : False
Wait : 0
When : 0
Reason : Test Reboot
Count : 0
```

CancelReboot RPC

Cancels any outstanding reboot

```
Request :
CancelRebootRequest
subcomponents {
origin: "openconfig-platform"
elem {
name: "components"
}
elem {
name: "component"
key {
key: "name"
value: "0/RP0/CPU0"
}
}
elem {
name: "state"
}
elem {
name: "location"
}
}

CancelRebootResponse

(rhel7-22.24.10) -bash-4.2$
```

KillProcess RPC

Kills the executing process. Either a PID or process name must be specified, and a termination signal must be specified.

```
KillProcessRequest
pid: 3451
signal: SIGNAL_TERM

KillProcessResponse
-bash-4.2$
```

gNOI Packet Link Qualification

Table 12: Feature History Table

Feature Name	Release Information	Feature Description
gNOI Packet Link Qualification	Release 24.2.11	You can now check and assess the reliability of the link speed and packet drops between the two network devices (generator and the reflector) by performing the gNOI packet-based link qualification service. This can be achieved by sending the packets from the generator to the reflector, and receiving the looped back packets from the reflector within a certain tolerance limit. The link transimmision rate and the link's capacity range for that interface can be obtained from the following gNSI Packet Link Qualification RPC messages: • `Capabilities`—Minimum and maximum rate of the transmission link • `Get`—Expected rate and actual rate of link transmission

The gRPC Network Operations Interface (gNOI) Packet Link Qualification service provides a way to certify link quality between a generator and a reflector device. The generator device generates test traffic and sends it out of the requested interface, maintaining counters of the sent, received, errored, and dropped packets. The reflector device loops back the traffic on the requested interface. The Packet-Based Link Qualification service verifies that the packets are sent and received on the requested interface. You can obtain the transmission rate and the link's capacity range for that interface from the gNSI Packet Link Qualification RPC messages: `Capabilities` and `Get`.

To view the packet link qualification specification, see the Github repository.

Table 13: Packet Link Qualification (PLQ) RPCs

RPC	Description
Capabilities	Fetches the capabilities of the device as a link qualification service. The capabilities result includes: • The roles supported on the device (Packet generator, Physical Medium Dependent (PMD) loopback reflector) • Information on whether the NTP synchronization is supported or not. • Information on whether the current device time is synchronized through NTP or not. • The Maximum number of results stored per interface
Create	Creates a set of link qualifications on the device. Each element in a `Create` message specifies the following parameters: • A unique qualification ID • The interface on which to run the qualification • The endpoint type (the role of the device) • Role-specific configuration • Timing information in the form of either NTP-based or RPC-based timing For more information, see `Link Qualifications Based on Timing` table. **Note** Packet generator and PMD loopback roles are supported The packet injector and ASIC loopback roles are not supported.
Delete	Deletes a set of qualifications by their IDs. Stops all the running qualification tests listed and deletes their records from the device. The qualifications are automatically deleted from the device 24 hours either after successful completion or in the event of any error.
Get	Gets the status of each of the unique qualification IDs that you specify. For generator qualifications, it returns the number of packets sent, received, errored, dropped, and the expected and achieved rate in bytes per second. This data isn't present for reflector qualifications.
List	This RPC lists all the qualifications on the device.

Link Qualifications Based on Timing

When you run the `Create RPC` (see table `Packet Link Qualification (PLQ) RPCs`), it creates a set of link qualifications based on either it's NTP-based or RPC-based timing.

For both NTP-based and RPC-based timings, the qualification start time must be set no earlier than the minimum setup duration from the current time, as specified in the `Capabilities` RPC (see table `Packet Link Qualification (PLQ) RPCs`) response message.

NTP-based timing specifies:

- Specific start time
- Specific end time
- Teardown time

RPC-based timing specifies:

- Presync duration (duration from the current time to when the setup should start)
- Setup duration
- Qualification duration
- Postsync duration (duration from the end of the qualification to when the teardown should start)
- Teardown duration

gRPC Network Security Interface

Table 14: Feature History Table

Feature Name	Release Information	Feature Description
gRPC Network Security Interface	Release 7.11.1	This release implements authorization mechanisms to restrict access to gRPC applications and services based on client permissions. This is made possible by introducing an authorization protocol buffer service for gRPC Network Security Interface (gNSI). Prior to this release, the gRPC services in the gNSI systems could be accessed by unauthorized users. This feature introduces the following change: **CLI**: • **gnsi load service authorization policy** • **show gnsi service authorization policy** To view the specification of gNSI, see Github repository.

gRPC Network Security Interface (gNSI) is a repository which contains security infrastructure services necessary for safe operations of an OpenConfig platform. The services such as authorization protocol buffer manage a network device's certificates and authorization policies.

This feature introduces a new authorization protocol buffer under gRPC gNSI. It contains gNSI.authz policies which prevent unauthorized users to access sensitive information. It defines an API that allows the configuration of the RPC service on a router. It also controls the user access and restricts authorization to update specific RPCs.

By default, gRPC-level authorization policy is provisioned using Secure ZTP. If the router is in zero-policy mode that is, in the absence of any policy, you can use gRPC authorization policy configuration to restrict access to specific users. The default authorization policy at the gRPC level can permit access to all RPCs except for the gNSI.authz RPCs.

If there is no policy specified or the policy is invalid, the router will fall back to zero-policy mode, in which the default behavior allows access to all gRPC services to all the users if their profiles are configured. If an invalid policy is configured, you can revert it by loading a valid policy using exec command **gnsi load service authorization policy.** For more information on how to create user profiles and update authorization policy for these user profiles, see How to Update gRPC-Level Authorization Policy, on page 47. Using **show gnsi service authorization policy** command, you can see the active policy in a router.

We have introduced the following commands in this release :

- **gnsi load service authorization policy**: To load and update the gRPC-level authorization policy in a router.
- **show gnsi service authorization policy**: To see the active policy applied in a router.

Note When both gNSI and gNOI are configured, gNSI takes precedence over gNOI. If niether gNSI nor gNOI is configured, then tls trsutpoint's data is considered for certificate management.

The following RPCs are used to perform key operations at the system level such as updating and displaying the current status of the authorization policy in a router.

Table 15: Operations

RPC	Description
gNSI.authz.Rotate()	Updates the gRPC-level authorization policy.
gNSI.authz.Probe()	Verifies the authenticity of a user based on the defined policy of the gRPC-level authorization policy engine.
gNSI.authz.Get()	Shows the current instance of the gRPC-level authorization policy, including the version and date of creation of the policy.

How to Update gRPC-Level Authorization Policy

gRPC-level authorization policy is configured by default at the time of router deployment using secure ZTP. You can update the same gRPC-level authorization policy using any of two the following methods:

- Using gNSI Client.
- Using exec command.

Updating the gRPC-Level Authorization Policy in the Router Using gNSI Client

Before you start

When a router boots for the first time, it should have the following prerequisites:

- The gNSI.authz service is up and running.
- The default gRPC-level authorization policy is added for all gRPC services.
- The default gRPC-level authorization policy allows access to all RPCs.

The following steps are used to update the gRPC-level authorization policy:

1. Initiate the **gNSI.authz.Rotate()** streaming RPC. This step creates a streaming connection between the router and management application (client).

Note Only one `gNSI.authz.Rotate()` must be in progress at a time. Any other RPC request is rejected by the server.

2. The client uploads new gRPC-level authorization policy using the **UploadRequest** message.

Note
- There must be only one gRPC-level authorization policy in the router. All the policies must be defined in the same gRPC-level authorization policy which is being updated. As `gNSI.authz.Rotate()` method replaces all previously defined or used policies once the **finalize** message is sent.
- The upgrade information is passed to the version and the created_on fields. These information are not used by the gNSI.authz service. It is designed to help you to track the active gRPC-level authorization policy on a particular router.

3. The router activates the gRPC-level authorization policy.
4. The router sends the `UploadResponse` message back to the client after activating the new policy.
5. The client verifies the new gRPC-level authorization policy using separate **gNSI.authz.Probe()** RPCs.
6. The client sends the **FinalizeRequest** message, indicating the previous gRPC-level authorization policy is replaced.

Note It is not recommended to close the stream without sending the **finalize** message. It results in the abandoning of the uploaded policy and rollback to the one that was active before the `gNSI.authz.Rotate()` RPC started.

Below is an example of a gRPC-level authorization policy that allows admins, V1,V2,V3 and V4, access to all RPCs that are defined by the gNSI.ssh interface. All the other users won't have access to call any of the gNSI.ssh RPCs:

```
{
  "version": "version-1",
  "created_on": "1632779276520673693",
  "policy": {
    "name": "gNSI.ssh policy",
    "allow_rules": [{
      "name": "admin-access",
      "source": {
        "principals": [
          "spiffe://company.com/sa/V1",
          "spiffe://company.com/sa/V2"
        ]
      },
      "request": {
        "paths": [
          "/gnsi.ssh.Ssh/*"
        ]
      }
    }],
    "deny_rules": [{
      "name": "sales-access",
```

```
        "source": {
          "principals": [
            "spiffe://company.com/sa/V3",
            "spiffe://company.com/sa/V4"
          ]
        },
        "request": {
          "paths": [
            "/gnsi.ssh.Ssh/MutateAccountCredentials",
            "/gnsi.ssh.Ssh/MutateHostCredentials"
          ]
        }
      }]
    }
  }
```

Updating the gRPC-Level Authorization Policy file Using Exec Command

Use the following steps to update the authorization policy in the router.

1. Create the users profiles for the users who need to be added in the authorization policy. You can skip this step if you have already defined the user profiles.

   The following example creates three users who are added in the authorization policy.

   ```
   Router(config)#username V1
   Router(config-un)#group root-lr
   Router(config-un)#group cisco-support
   Router(config-un)#secret x
   Router(config-un)#exit
   Router(config)#username V2
   Router(config-un)#group root-lr
   Router(config-un)#password x
   Router(config-un)#exit
   Router(config)#username V3
   Router(config-un)#group root-lr
   Router(config-un)#password x
   Router(config-un)#commit
   ```

2. Enable **tls-mutual** to establish the secure mutual between the client and the router.

   ```
   Router(config)#grpc
   Router(config-grpc)#port 0
   Router(config-grpc)#tls-mutual
   Router(config-grpc)#certificate-authentication
   Router(config-grpc)#commit
   ```

3. Define the gRPC-level authorization policy.

   The following sample gRPC-level authorization policy defines authorization policy for the users V1, V2 and V3.

   ```
   {
       "name": "authz",
       "allow_rules": [
           {
               "name": "allow all gNMI for all users",
               "source": {
                   "principals": [
                       "*"
                   ]
   ```

```
            },
            "request": {
                "paths": [
                    "*"
                ]
            }
        }
    ],
    "deny_rules": [
         {
            "name": "deny gNMI set for oper users",
            "source": {
                "principals": [
                    "V1"
                ]
            },
            "request": {
                "paths": [
                    "/gnmi.gNMI/Get".
                ]
            }
        },

        {
            "name": "deny gNMI set for oper users",
            "source": {
                "principals": [
                    "V2"
                ]
            },
            "request": {
                "paths": [
                    "/gnmi.gNMI/Get"
                ]
            }
        },
        {
            "name": "deny gNMI set for oper users",
            "source": {
                "principals": [
                    "V3"
                ]
            },
            "request": {
                "paths": [
                    "/gnmi.gNMI/Set"
                ]
            }
        }
    ]
}
```

4. Copy the gRPC-level authorization policy to the router.

   The following example copies the gNSI Authz policy to the router:

```
-bash-4.2$ scp test.json V1@192.0.2.255:/disk0:/
Password:
test.json
                                   100%  993   161.4KB/s   00:00
-bash-4.2$
```

5. Activate the gRPC-level authorization policy to the router.

The following example loads the policy to the router.

```
Router(config)#gnsi load service authorization policy /disk0:/test.json
Successfully loaded policy
```

Verification

Use the **show gnsi service authorization policy** to verify if the policy is active in the router.

```
Router#show gnsi service authorization policy
Wed Jul 19 10:56:14.509 UTC{
    "version": "1.0",
    "created_on": 1700816204,
    "policy": {
        "name": "authz",
        "allow_rules": [
            {
                "name": "allow all gNMI for all users",
                "request": {
                    "paths": [
                        "*"
                    ]
                },
                "source": {
                    "principals": [
                        "*"
                    ]
                }
            }
        ],
        "deny_rules": [
            {
                "name": "deny gNMI set for oper users",
                "request": {
                    "paths": [
                        "/gnmi.gNMI/*"
                    ]
                },
                "source": {
                    "principals": [
                        "User1"
                    ]
                }
            }
        ]
    }
}
```

In the following example, User1 user tries to access the **get** RPC request for which the permission is denied in the above authorization policy.

```
bash-4.2$ ./gnmi_cli -address 198.51.100.255 -ca_crt
certs/certs/ca.cert -client_crt certs/certs/User1.pem -client_key
certs/certs/User1.key -server_name ems.cisco.com -get -proto get-oper.proto
```

Output

```
E0720 14:49:42.277504   26473 gnmi_cli.go:195]
target returned RPC error for Get("path:{origin:"openconfig-interfaces"
elem:{name:"interfaces"}
 elem:{name:"interface" key:{key:"name" value:"HundredGigE0/0/0/0"}}}
 type:OPERATIONAL encoding:JSON_IETF"):
rpc error: code = PermissionDenied desc = unauthorized RPC request rejected
```

gNSI Credentialz Update

Table 16: Feature History Table

Feature Name	Release Information	Description
gNSI Credentialz Update	Release 24.2.11	To improve communication confidentiality and security, you can now update or rotate account-specific and host-specific SSH credentials on a router. You can access the latest SSH credentials through the gNMI credentialz RPC. The updated SSH credentials encompass passwords, host keys, and certificates. To view the specification of gNSI credentialz RPCs and messages, see the Github repository.

Rotation is the process of changing or updating SSH credentials such as passwords, keys, or certificates in a network. You can now update the account-related and host-related SSH credentials through the gNSI credentialz RPC when the router is up and running.

gNSI Rotate Credentialz RPC

Starting from Release 24.2.1, Cisco IOS XR supports four RPCs to change the existing SSH credentials.

gNSI Rotate Credentialz RPC	Run This When	For More Information
RotateAccountCredentials	You want to specify an SSH authentication service policy for the network element. If the policy is valid, it replaces the existing policy.	See, Rotate Account Credentials
RotateHostParameters	You want to change both the Certificate Authority (CA) public key and the key and certificate used by the SSH server.	See, Rotate Host Parameters
CanGenerateKey	You want to check whether the target can generate a public or private key pair.	See, CanGenerateKey
GetPublicKeys	You want to get the current public keys from the host. It returns each configured key in the provided list.	See, GetPublicKey

Rotate Account Credentials

This RPC automates secure credential rotation on routers, updating passwords and SSH keys to enforce security and prevent unauthorized access. It updates the user-specific authorized keys, authorized principles, invalidates old credentials, logs activities, and notifies stakeholders, enhancing overall network security.

Prerequisites

- Configure a user account on your router.
- Configure SSH Version 2.

The following table outlines the messages that `Rotate Account Credentials` RPC supports, along with their descriptions.

Message	Description
AuthorizedKeysRequest	This message defines the authorized key list for password-less SSH accepted by the router's SSH service. The gNSI client dispatches an `AuthorizedKeysRequest` to the router to update or replace credentials on the SSH service. The router responds with a `AuthorizedKeysResponse` message to the gNSI client. It supports the following keys: • RSA 2048, RSA 4096 bits • ECDSA-p-256, ECDSA-p-521 • Ed25519
AuthorizedUsersRequest	This message performs a user authorization check. User authorization can be done using both static and dynamic methods. Static Authorization: You can perform static authorization based on a principal name (unique identifier for a user) using Cisco SSH. For static authorization, use the `AuthorizedUsersRequest` message. Dynamic authorization: For dynamic authorization, use the `AuthorizedPrincipalCheckRequest` message. For details, see Rotate Host Parameters, on page 53 CiscoSSH supports the user authorization using AuthorizedPrincipalsFile. AuthorizedPrincipalsFile contains pairs of account names and their corresponding principal names that the router recognizes for certificate-based authentication. For more details, see AuthorizedPrincipalsFile

Rotate Host Parameters

The `RotateHostParameters` RPC updates and verifies host account credentials on network devices to enhance security and ensure stable SSH access. If updates fail, the system either adopts new credentials after successful validation or reverts to the old ones to maintain uninterrupted access. The router automatically falls back to prevent lockouts and preserve network integrity.

Prerequisites

- Configure a user account on your router.
- Configure SSH Version 2.

The following table outlines the messages that `Rotate Host Parameters` RPC supports, along with their descriptions.

Message	Description
CA public key	The SSH server uses the `CA public key` message to verify the gNSI client certificates presented during connection establishment. Without Host Identity Based Authorization (HIBA), the following keys are supported: • RSA 2048, RSA 4096 bits • ECDSA-p-256, ECDSA-p-521 • Ed25519

Server keys	The `Server keys` message includes host keys and router certificates that serve as credentialz for the gNSI client.
	If the host keys are generated externally, they must be specified in the `Server keys` request.
	It supports the following keys:
	• RSA 2048, RSA 4096 bits
	• ECDSA-p-256, ECDSA-p-521
	• Ed25519
	It supports the following router certificates:
	• Router certificates with HIBA Support
	  • ssh-rsa-cert-v01@openssh.com
	• Router certificates without HIBA support:
	  • ecdsa-sha2-nistp256-cert-v01@openssh.com
	  • ecdsa-sha2-nistp521-cert-v01@openssh.com
	  • ssh-ed25519-cert-v01@openssh.com
	  • rsa-sha2-256-cert-v01@openssh.com
	  • rsa-sha2-512-cert-v01@openssh.com

Generate key	The `Generate Key` message is used for host key management in SSH. When the host keys are generated by the router, this message triggers the creation of new host keys for SSH host key management. The `Generate key` message supports the following keys: It supports the following keys: • RSA 2048, RSA 4096 bits • ECDSA-p-256, ECDSA-p-521 • Ed25519

Message	Description

AllowedAuthenticationRequest	The `AllowedAuthenticationRequest` message specifies the permissible authentication methods for the gNSI client authentication.
	The supported authentication methods are as follows:
	• Keyboard interactive
	• Password-based
	• Pubkey-based
	  • OpenSSH certificate-based
	  • Public key-based
	By default, the SSH server allows all authentication methods.

AuthorizedPrincipalCheckRequest	The `AuthorizedPrincipalCheckRequest` message supports the dynamic authorization of the user against the principal name using the OpenSSH or CiscoSSH. Setting the TOOL_HIBA_DEFAULT flag prompts the router to use the HIBA binary for dynamic authorization. Un setting the HIBA_DEFAULT flag switches the router to use a static authorization. Dynamic Authorization: You can enforce the user for authorization check using HIBA. **Note** The support is only for ssh-rsa-cert-v01@openssh.com CiscoSSH supports AuthorizedPrincipalCheck using `AuthorizedPrincipalsCommand` and `AuthorizedPrincipalsCommandUser` AuthorizedPrincipalsCommand: This command generates the list of allowed certificate principals by executing a HIBA binary (By setting the TOOL_HIBA_DEFAULT flag). AuthorizedPrincipalsCommandUser: This command specifies the user account under which the system executes the `AuthorizedPrincipalsCommand`. For more details on the specification, see AuthorizedPrincipalsCommandUser

CanGenerateKey

This RPC checks if the router can generate a public or private key pair.

It supports the following key pairs:

- RSA 2048, RSA 4096 bits
- ECDSA-p-256, ECDSA-p-521
- Ed25519

GetPublicKey

This RPC gets the available public keys from the router and displays them. It supports the following keys:

- RSA 2048, RSA 4096 bits
- ECDSA-p-256, ECDSA-p-521
- Ed25519

Manage certificates using Certz.proto

Table 17: Feature History Table

Feature Name	Release Information	Feature Description
Manage certificates using Certz.proto	Release 24.1.1	Instead of using multiple RPCs, Certz.proto provides a bidirectional Rotate RPC to replace, revoke, or load a certificate. It also provides additional APIs to install Public Key Infrastructure (PKI) entities such as like identity certificates, trust-bundles, and Certificate Revocation Lists (CRLs) for a gRPC Server. This feature introduces the following changes: CLI: • **grpc gnsi service certz ssl-profile-id** • **show grpc certificate** Yang Data Models: • Cisco-IOS-XR-man-ems-cfg.yang (see Github, YANG Data Models Navigator)

Certz RPCs

The Certz RPCs are specific methods used for executing operations on the certificate that resides in the target device. The **certz.proto** file is available in the Github repository.

In cert.proto, a certificate identifier differentiates between leaf certificates. However, the CA bundle lacks an identifier, meaning a new request to load a bundle could overwrite the existing one. On the other hand, in certz.proto, entities like Certificate, CA bundle, key, CRL, and authentication policy are tied to a unique SSL profile.

In cert.proto, a certificate identifier differentiates between leaf certificates. However, the CA bundle lacks an identifier, meaning a new request to load a bundle could overwrite the existing one. On the other hand, in certz.proto, entities like Certificate, CA bundle, key, CRL, and authentication policy are tied to a unique SSL profile.

The certz.proto differs from the cert.proto in the way that it handles the upload of all entities. While in cert.proto, separate RPCs are used to replace, load, and revoke a certificate, in certz.proto, a single Rotate() RPC is used to upload all entities at once. This includes the certificate, the key, the CA bundle, and the CRL.

In addition to these features, certz.proto also provides support for different cryptographic algorithms, including Rivest-Shamir-Adleman (RSA), Elliptic Curve Digital Signature Algorithm (ECDSA), and ED25519, a public-key signature system.

These functionalities make certz.proto a comprehensive solution for managing SSL profiles, providing a streamlined process for handling cryptographic entities and algorithms.

Note If neither cert.proto nor certz.proto is configured, then tls trustpoint data is considered for certificate management.

The following table describes the RPCs supported under Certz.proto.

Table 18: Certz RPCs

RPC	Description
AddProfile	AddProfile is part of SSL profile management. It allows adding a new SSL profile. When an SSL profile is added, all its elements, that is, certificate, CA trusted bundle and a set of certificate revocation lists are NULL/Empty. So, before an SSL profile can be used these entities have to be 'rotated' using the `Rotate()` RPC. **Note** An attempt to add an already existing profile is rejected with an error.
Rotate	Rotate replaces/adds an existing device certificate and/or CA certificates (trust bundle) or/and a certificate revocation list bundle on the target. The new device certificate can be created from a target-generated or client-generated CSR (Certificate Signing Request). In the latter case, the client must provide the corresponding private key with the signed certificate.
DeleteProfile	DeleteProfile is part of SSL profile management. It allows for removing an existing SSL profile. **Note** An attempt to delete a not existing profile results in an error. The profile used by the gRPC server can’t be deleted and an attempt to remove it will be rejected with an error.
GetProfileList	GetProfileList is part of SSL profile management. It allows for retrieving a list of IDs of SSL profiles present on the target.
CanGenerateCSR	An RPC to ask a target if it can generate a CSR.

SSL Profile

An SSL profile is a named set of SSL settings that determine how end-user systems connect to or from SSL-based applications or interfaces. The settings in an SSL profile include information about the version of SSL/TLS to be used, certificates, keys, and other parameters related to SSL/TLS communication. By using profiles, administrators can manage and apply these settings more easily across multiple applications or connections.

Here are some key-points regarding SSL profile:

- SSL profiles logically groups certificate, private key, Certificate Authority chain of certificates (a.k.a. a CA trust bundle) and a list of Certificate Revocation Lists into a single set that then can be assigned to a gRPC server.
- There’s at least one profile present on a target - the one that is used by the gRPC server. Its ID is gNxI but when the ssl_profile_id field in the RotateCertificateRequest message isn’t set (or set to an empty string) it also refers to this SSL profile by default.
- You can’t remove the gRPC SSL profile (gNxI).

Configure gNSI Certz

Before you begin

- Ensure you've created and stored SSL-Profile at `cd/misc/config/grpc/gnsi/certz/ssl_profiles/`

Procedure

Step 1 Create SSL-Profile using AddProfile RPC.

Step 2 Rotate SSL-profile using Rotate RPC. You can't rotate SSL-profile using a command line interface.

Step 3 Activate the profile using **grpc gnsi service certz ssl-profile-id.**

Example:

Router (config-grpc) #**`gnsi service certz profile ssl-profile id <ssl-profile-name>`**

Step 4 Verify that certz.proto is configured using the **show grpc certificate**.

Example:

```
Router#show grpc certificate
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number: 32 (0x20)
        Signature Algorithm: sha256WithRSAEncryption
        Issuer: CN=localhost,O=OpenConfig,C=US
        Validity
            Not Before: Nov  8 08:49:38 2023 GMT
            Not After : Mar 22 08:49:38 2025 GMT
        Subject: CN=ems,O=OpenConfig,C=US
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                RSA Public-Key: (4096 bit)
                Modulus:
                    00:ea:6a:6c:25:be:9f:15:71:ce:74:89:03:ec:ef:
                    0b:3b:de:58:a8:7e:28:b8:cf:b3:82:91:b4:5c:42:
```

```
                    e7:d8:28:98:35:bd:35:60:a7:4e:f8:77:02:46:5f:
                    27:a4:16:cf:3c:e3:24:28:69:9c:22:1e:e3:52:96:
                    71:87:7c:40:0c:1f:dd:30:ea:dc:40:ca:93:00:54:
                    5e:de:20:54:5b:f4:2f:9f:19:6f:71:61:28:69:3d:
                    97:26:ab:e1:5f:53:3c:f1:a2:c3:14:f4:01:90:1a:
                    e3:08:7b:51:c9:5d:aa:6d:eb:99:a4:08:97:d3:72:
                    8c:86:a3:f3:b3:77:10:72:e7:a9:3b:fc:38:65:3d:
                    41:1a:f5:cf:3e:a0:d8:17:d6:d5:53:86:49:a3:dc:
                    cc:3a:d9:6d:46:25:b0:f9:3b:98:fa:2f:98:09:08:
                    51:ac:2c:b1:43:c4:b7:96:3e:4e:4e:a6:a5:36:1f:
                    1f:0f:6a:6a:1a:ea:72:6e:74:90:21:05:fb:26:df:
                    81:0d:96:e7:13:94:62:2b:ce:3c:7c:de:32:f4:d9:
                    fa:24:ce:f5:b2:0f:d3:f7:4b:6b:ee:bd:cf:ac:a6:
                    ed:69:37:fc:d3:4f:3b:46:8b:1b:62:4d:3b:60:30:
                    74:68:50:4e:48:35:5f:15:66:9a:01:7c:37:1f:e1:
                    5a:8a:d9:c0:2c:3e:12:fd:71:30:13:b8:b7:16:98:
                    03:27:6d:45:c4:0f:34:fd:f1:aa:29:8e:c1:63:ac:
                    57:04:f6:a7:83:83:06:45:dc:0f:f9:de:f9:1e:b6:
                    d8:5a:bc:3a:98:f8:ac:b0:be:3f:87:df:8c:5e:47:
                    12:ca:77:70:26:14:02:14:79:fa:6f:1f:ab:ee:06:
                    2c:83:93:e4:22:db:37:83:90:c1:72:5b:36:78:1b:
                    6d:0a:06:72:76:dc:89:df:86:89:43:54:03:55:bd:
                    fc:a0:9a:d6:8e:5d:22:87:a2:32:19:35:c8:17:4e:
                    1c:1b:5e:81:9d:a5:67:9e:a7:ed:06:e8:e2:91:f1:
                    ae:f9:19:b1:ae:a8:e6:66:14:2c:6d:a6:c3:0f:8b:
                    7f:ef:c0:60:cb:c2:52:a5:46:1e:a4:20:52:f8:93:
                    93:2b:02:23:98:90:81:b3:e6:c4:4e:8f:85:a6:ff:
                    4e:8e:dd:6c:12:ea:db:58:7f:3c:66:c4:38:96:44:
                    d1:5b:da:c2:66:6a:4e:97:4d:99:59:9f:24:a0:4a:
                    57:b6:9d:69:22:f7:5a:10:cb:96:bc:58:ca:96:0e:
                    ab:b0:4d:14:da:03:e1:d3:24:c1:f2:bd:40:32:20:
                    82:66:4d:78:4b:13:c6:bd:66:a9:83:2f:15:29:7e:
                    11:95:37
                Exponent: 65537 (0x10001)
        X509v3 extensions:
            X509v3 Key Usage: critical
                Digital Signature
            X509v3 Extended Key Usage:
                TLS Web Client Authentication, TLS Web Server Authentication
            X509v3 Authority Key Identifier:
                keyid:0A:A8:9A:6A:23:34:AE:CA:96:00:2C:F3:04:38:14:E3:D4:8D:77:BD

            X509v3 Subject Alternative Name:
                DNS, IP Address:64.103.223.56
    Signature Algorithm: sha256WithRSAEncryption
         b9:89:ec:60:3d:8d:7d:9c:dc:08:56:89:99:44:92:98:45:b6:
         97:ba:e3:e5:f2:48:b2:44:8d:db:23:bb:a1:c0:62:79:78:18:
         d7:55:f6:4a:67:5b:75:e0:c0:0b:52:51:07:36:d5:6c:c7:67:
         48:86:8d:dd:70:1c:9f:7c:a1:7b:aa:a5:4e:e1:ad:cf:4c:e5:
         81:db:92:cf:88:70:5a:1c:8d:de:0d:e8:b3:05:de:b9:04:4d:
         23:e1:de:66:e5:08:bd:2e:31:0a:07:a6:c0:00:3a:38:2f:00:
         cd:cf:be:e2:1f:12:9f:8a:44:8d:2d:24:d5:d3:bb:9e:db:70:
         bf:89:ea:0c:31:b4:b2:fc:3d:73:f5:17:09:07:54:ab:2f:23:
         cb:66:0e:0e:7a:9e:21:bf:1e:bf:07:f1:fc:09:88:23:4e:2d:
         5d:08:35:16:cd:07:df:25:34:7f:42:0a:dc:6f:d0:ec:9d:99:
         72:d8:5f:d6:7e:6f:cc:67:4d:d7:b9:b8:c8:56:75:db:56:1e:
         03:1b:6d:37:21:4d:e0:f1:e2:80:99:40:24:24:f2:e4:9b:7e:
         6c:bc:f7:f9:3a:b6:fc:8e:dd:9a:cd:dd:88:15:d7:46:71:d2:
         11:20:86:8f:ea:c5:a8:e8:4e:b6:ef:9b:06:5b:b1:c4:11:36:
         38:7a:63:8e:1a:a6:a8:f8:bb:7d:0b:a6:f2:89:49:94:ac:0c:
         8b:c4:fc:02:e8:b2:b8:27:bc:70:95:32:83:09:f5:de:68:34:
         3f:a4:5a:73:dc:92:15:2c:0e:ab:46:dd:13:06:98:aa:08:2d:
         b8:37:a0:52:4b:ba:f7:be:ed:68:cd:fb:67:3b:66:ea:16:85:
         61:75:cf:06:85:a0:06:e8:4a:3e:63:72:c1:79:c7:fd:d4:85:
```

```
74:d8:ea:66:d3:42:74:e2:fb:7c:9e:93:4b:24:2f:ad:c5:13:
bc:eb:83:f7:6d:3e:53:9a:ec:16:85:b7:b5:6c:77:48:53:7e:
19:2e:48:2d:83:35:7b:b9:66:5e:12:b4:f3:ee:e8:b2:3b:ba:
18:46:91:b0:f9:6f:b0:d5:17:a8:de:5c:a0:0e:35:85:7b:c0:
e3:79:06:fa:ad:8e:f2:28:ab:09:19:b7:f0:f3:9e:cb:94:93:
b7:04:63:74:82:c3:71:3b:16:8b:58:c7:fa:ff:ff:2a:97:91:
e7:1d:06:ab:0a:6c:cc:a0:41:31:54:f2:e7:db:a3:b5:22:c4:
ab:ec:e2:5d:86:e6:ac:a5:c6:e2:0e:15:44:a2:32:42:3d:07:
65:0a:0d:58:2e:22:3c:7b:e3:e8:8e:2e:60:47:f0:60:04:89:
64:65:fc:fc:74:dd:4d:7f
```


P4Runtime

Table 19: Feature History Table

Feature Name	Release Information	Description
P4Runtime to Manage Traffic Operations	Release 7.10.1	With this release, the router supports Programming Protocol-Independent Packet Processors Runtime (P4), a gRPC-based service, to program the data plane elements for network operations such as sending and receiving packets between the router and the P4Runtime controller using packet I/O messages. This feature introduces the following commands: **CLI:** • **grpc p4rt** • **grpc p4rt interface** • **grpc p4rt location** • **show p4rt devices** • **show p4rt interfaces** • **show p4rt state** • **show p4rt stats** • **show p4rt trace** **YANG Data Model:** `openconfig-p4rt.yang` OpenConfig data model (see GitHub, YANG Data Models Navigator)

P4Runtime is a control plane specification to manage the data plane elements of a device. It defines the navigation and management of packets through data plane blocks using P4Runtime APIs. These blocks can be managed to perform the following set of traffic operations between the P4Runtime controller and the router:

- Send or receive packets using PacketOut and PacketIn I/O messages—`StreamMessageRequest`, `StreamMessageResponse` and `StreamError` messages.
- Elect the primary controller using the `MasterArbitrationUpdate` message.
- Read and write forwarding table entries, protocol headers, counters, and other P4 entities.

For more information about how controllers can connect to the router and program P4-defined functionalities, see P4RT specification.

Configure P4RT to Manage Packets

Configure P4RT to send or receive packets between one or more controllers and the router.

Procedure

Step 1 Enable P4Runtime.

Example:

```
Router#config
Router(config)#grpc
Router(config-grpc)#p4rt
Router(config-grpc-p4rt)#commit
```

Step 2 Assign a unique P4 numeric identifier to the required physical port on the router. The controller uses this port ID as an alias to identify the interface through which the packets are sent or received with ingress or egress metadata.

Example:

```
Router(config-grpc-p4rt)#interface HundredGigE0/0/0/24 port-id 3
Router(config-grpc-p4rt)#interface HundredGigE0/0/0/25 port-id 6
Router(config-grpc-p4rt)#interface HundredGigE0/0/0/26 port-id 7
```

The `port-id` is a unique 32-bit identifier. The range is 1 to 4294967039.

Step 3 Assign a unique P4 device identifier to each Network Processing Unit (NPU) in the system.

Example:

```
Router(config-grpc-p4rt)#location 0/0/CPU0 npu-id 0 device-id 1000000
Router(config-grpc-p4rt)#location 0/0/CPU0 npu-id 1 device-id 1000001
Router(config-grpc-p4rt)#location 0/1/CPU0 npu-id 0 device-id 1000002
Router(config-grpc-p4rt)#location 0/1/CPU0 npu-id 1 device-id 1000011
Router(config-grpc-p4rt)#commit
Router(config-grpc-p4rt)#end
```

The `device-id` is a unique 64-bit identifier. The range is 1 to 18446744073709551615. The `npu-id` represents a NPU identifier within a line card and the value ranges from 0 to 7.

The controller or the P4Runtime agent, which can be external or internal to the router, can use the `port-id` and `device-id` to inject packets and request to send certain packet types. For example, P4Runtime supports the ability to configure Access Control Lists (ACLs) in order to redirect packets with TTL value 1 to the controller. When the router receives a

packet with that TTL value, the packet is sent to the controller with the details such as packet received from `device-id x`, `port-id y` and the packet is being sent to `port-id z`.

For more information about programming the router using P4Runtime, see P4RT specification.

IANA Port Numbers For gRPC Services

Table 20: Feature History Table

Feature Name	Release Information	Description
IANA Port Numbers For gRPC Services	Release 24.1.1	You can now efficiently manage and customize port assignments for gNMI, gRIBI, and P4RT services without port conflicts. This is possible because Cisco IOS XR now supports the Internet Assigned Numbers Authority (IANA)-assigned specific ports for P4RT (Port 9559), gRIBI (Port 9340), and gNMI (Port 9339). You can now use both IANA-assigned and user-specified ports for these gRPC services across any specified IPv4 or IPv6 addresses. As part of this support, a new submode for gNMI in gRPC is introduced. This feature introduces the following changes: **CLI:** • **port (gRPC)** • **gnmi**

IANA (Internet Assigned Numbers Authority) manages the allocation of port numbers for various protocols. These port numbers help in distinguishing different services on a network. Service names and port numbers are used to distinguish between different services that run over transport protocols such as TCP, UDP, DCCP, and SCTP. Port numbers are assigned in various ways, based on three ranges: System Ports (0-1023), User Ports (1024-49151), and the Dynamic and/or Private Ports (49152-65535).

Earlier, the gRPC server configuration on IOS-XR allowed a usable port range of 10000-57999, with a default listening port of 57400 and all services registered to the gRPC server utilized this port for connectivity. Service-based filtering of requests on any of the ports was unavailable. Hence, the request for a specific service sent on a port designated to another service (for example, gRIBI request on gNMI port) was accepted.

From Cisco IOS XR Release 24.1.1, a new submode for gNMI is introduced in the configuration model to allow for service-level port customization. The existing gRPC configuration model includes submodes for P4RT and gRIBI. This submode will enable you to configure specific ports for gNMI, gRIBI, and P4RT services independently. You can configure gNMI, gRIBI, and P4RT services using the gRPC submode command to set the default port for each service. The **port** command under service submode, allows you to modify the port as needed, while adhering to the defined port range.

Disabling the **port** command will cause the service to use the default or IANA port.

You can set custom ports for gNMI, gRIBI, and P4RT services within the defined range, including default IANA ports like 9339, 9340, and 9559 (respectively). The gRPC service will continue to maintain its default port within the specified range (57344-57999). Any changes made to the gRPC default port will not impact the service port configurations for gNMI, gRIBI, and P4RT. Requests which are sent on a port designated for a specific service (example, gRIBI request on gNMI port) will be accepted. This flexibility allows for seamless communication across different service ports and the general gRPC port.

Starting from Release 24.2.1, the allowed port range is 1024-65535.

Configure gRPC Service-Level Port

To configure a default listening port for the gRPC services such as gNMI, gRIBI, and P4RT, use the respective service command (**gnmi**, **gribi**, or **p4rt**) under the gRPC configuration mode.

To specify a port number for gRPC, gNMI, gRIBI, and P4RT services within the defined range, use the **port** command under respective submodes.

Note The IANA port ranges are:

- System ports (Reserved): 0—1023
- Registered ports: 1024—49151
- Dynamic or Private or Ephemeral ports: 49152—65535

XR Ephemeral port range: 15232–57343

If the configured port is in the range of IANA registered ports (1024-49151) or XR ephemeral ports (15232-57343), a syslog is generated with a NOTICE to warn the user for a possible application conflict.

Resetting the port reverts to the default service port, and disabling the service stops listening on that port.

Procedure

Configure the port number for a service.

The following examples display the service-level port configurations.

- **For gRPCservice:**

  This configuration creates a gRPC listener with the default or IANA ratified port of 57400.

  The allowed range is 1024-65535.

  ```
  Router#config
  Router(config)#grpc
  Router(config-grpc)# commit
  ```

  Verify the listening port created for gRPC service.

  ```
  Router#show running-config grpc
  grpc
  !
  ```

  The **port** command under gRPC submode allows the port to be modified in the port range or IANA ratified port.

```
Router# config
Router(config)# grpc port 2000
Router(config)# commit
```

Verify the port number.

```
Router#show running-config grpc
grpc
  port 2000
!
```

- **For gNMI service:**

  This configuration creates a gRPC listener with the default or IANA ratified gNMI port of 9339.

  The allowed range is 1024-65535.

```
Router(config-grpc)#gnmi
Router(config-grpc-gnmi)#commit
```

  Verify the listening port created for gNMI service.

```
Router#show running-config grpc
grpc
  gnmi
!
```

  The **port** command under gNMI submode allows the port to be modified in the port range or IANA ratified port.

```
Router(config-grpc)#gnmi
Router(config-grpc-gnmi)#port 9339
Router(config-grpc-gnmi)#commit
```

  Verify the port number.

```
Router#show running-config grpc
grpc
  gnmi
    port 9339
!
```

- **For P4RT service:**

  This configuration creates a gRPC listener with the default or IANA ratified P4RT port of 9559.

  The allowed range is 1024-65535.

```
Router(config-grpc)#p4rt
Router(config-grpc-p4rt)#commit
```

  Verify the listening port created for P4RT service.

```
Router#show running-config grpc
grpc
  p4rt
!
```

  The **port** command under P4RT submode allows the port to be modified in the port range or IANA ratified port.

```
Router(config-grpc)#p4rt
Router(config-grpc-p4rt)#port 9559
Router(config-grpc-p4rt)#commit
```

  Verify the port number.

```
Router#show running-config grpc
grpc
  p4rt
```

```
    port 9559
!
```

- **For gRIBI service:**

  This configuration creates a gRPC listener with the default or IANA ratified gRIBI port of 9340.

  The allowed range is 1024-65535.

  ```
  Router(config-grpc)#gribi
  Router(config-grpc-gribi)#commit
  ```

  Verify the listening port created for gRIBI service.

  ```
  Router#show running-config grpc
  grpc
    gribi
  !
  ```

  The **port** command under gRIBI submode allows the port to be modified in the port range or IANA ratified port.

  ```
  Router(config-grpc)#gribi
  Router(config-grpc-gribi)#port 9340
  Router(config-grpc-gribi)#commit
  ```

  Verify the port number.

  ```
  Router#show running-config grpc
  grpc
    gribi
      port 9340
  !
  ```

Unconfiguring the port command in a service

and

Unconfiguring a service under gRPC

- Unconfiguring the **port** command results in using the default port for the respective service.

  Example:

  Unconfiguring the **port** command will result in a gNMI service using the default gNMI port.

  ```
  Router(config-grpc)#gnmi
  Router(config-grpc-gnmi)#no port
  Router(config-grpc-gnmi)#commit
  ```

  Verify the service port configuration.

  ```
  Router#show running-config grpc
  grpc
    gnmi
  !
  ```

- Unconfiguring a service removes the listener for the respective port and no requests will be accepted on that port.

  Example:

  Unconfiguring gNMI disables the requests on port 9339.

  ```
  Router(config-grpc)#no gnmi
  Router(config-grpc-gnmi)#commit
  ```

  Verify the port configuration.

```
Router#show running-config grpc
grpc
!
```

Configure Interfaces Using Data Models in a gRPC Session

Table 21: Feature History Table

Feature Name	Release Information	Description
Set Limit on Concurrent Streams for gRPC Server	Release 24.1.1	You can prevent potential security attacks by disallowing any single gRPC server client on Cisco IOS XR from consuming excessive resources and monopolizing connection resources, both of which can be potential attack vectors. Such prevention is possible because you now have the option to configure the gRPC server to limit the number of concurrent streams per gRPC connection. The feature introduces the **grpc max-concurrent-streams** command. **YANG Data Models:** • `Cisco-IOS-XR-man-ems-oper.yang` • `Cisco-IOS-XR-man-ems-cfg.yang` (see GitHub, YANG Data Models Navigator)

Google-defined remote procedure call () is an open-source RPC framework. gRPC supports IPv4 and IPv6 address families. The client applications use this protocol to request information from the router, and make configuration changes to the router.

The process for using data models involves:

- Obtain the data models.
- Establish a connection between the router and the client using gRPC communication protocol.
- Manage the configuration of the router from the client using data models.

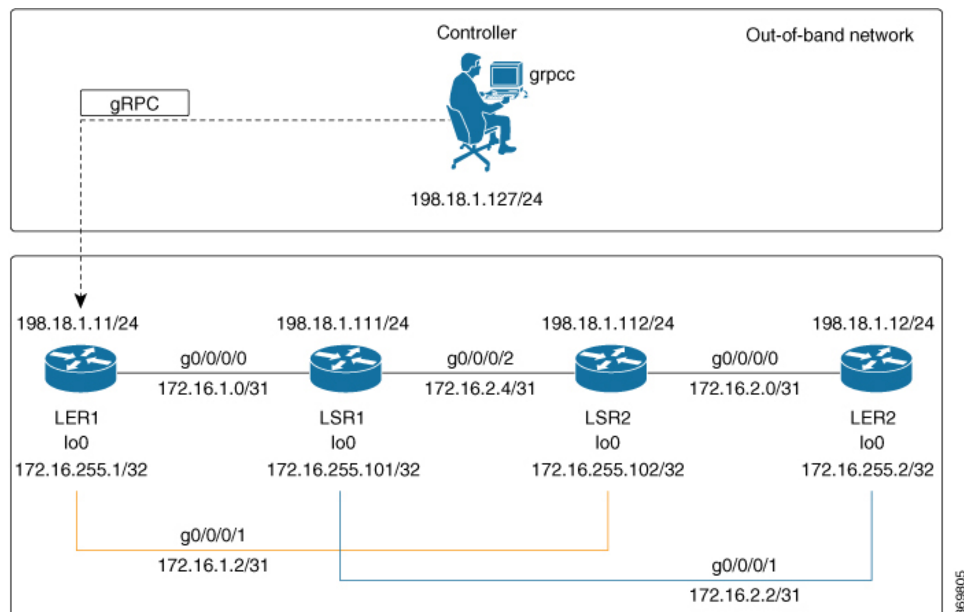
Note Configure AAA authorization to restrict users from uncontrolled access. If AAA authorization is not configured, the command and data rules associated to the groups that are assigned to the user are bypassed. An IOS-XR user can have full read-write access to the IOS-XR configuration through Network Configuration Protocol (NETCONF), google-defined Remote Procedure Calls (gRPC) or any YANG-based agents. In order to avoid granting uncontrolled access, enable AAA authorization using **aaa authorization exec** command before setting up any configuration. For more information about configuring AAA authorization, see the *System Security Configuration Guide*.

In this section, you use native data models to configure loopback and ethernet interfaces on a router using a gRPC session.

Consider a network topology with four routers and one controller. The network consists of label edge routers (LER) and label switching routers (LSR). Two routers LER1 and LER2 are label edge routers, and two routers LSR1 and LSR2 are label switching routers. A host is the controller with a gRPC client. The controller communicates with all routers through an out-of-band network. All routers except LER1 are pre-configured with proper IP addressing and routing behavior. Interfaces between routers have a point-to-point configuration with `/31` addressing. Loopback prefixes use the format `172.16.255.x/32`.

The following image illustrates the network topology:

Figure 1: Network Topology for gRPC session



You use Cisco IOS XR native model `Cisco-IOS-XR-ifmgr-cfg.yang` to programmatically configure router LER1.

Before you begin

- Retrieve the list of YANG modules on the router using NETCONF monitoring RPC. For more information
- Configure Transport Layer Security (TLS). Enabling gRPC protocol uses the default HTTP/2 transport with no TLS. gRPC mandates AAA authentication and authorization for all gRPC requests. If TLS is

not configured, the authentication credentials are transferred over the network unencrypted. Enabling TLS ensures that the credentials are secure and encrypted. Non-TLS mode can only be used in secure internal network.

Procedure

Step 1 Enable gRPC Protocol

To configure network devices and view operational data, gRPC proptocol must be enabled on the server. In this example, you enable gRPC protocol on LER1, the server.

Note
Cisco IOS XR 64-bit platforms support gRPC protocol. The 32-bit platforms do not support gRPC protocol.

a) Enable gRPC over an HTTP/2 connection.

Example:

```
Router#configure
Router(config)#grpc
Router(config-grpc)#port <port-number>
```

The port number ranges from 57344 to 57999. If a port number is unavailable, an error is displayed.

Starting Release 24.1.1, you can now configure IANA port numbers for specified gRPC services. To see the port numbers for the various gRPC services, see *Support IANA Port Numbers*.

b) Set the session parameters.

Example:

```
Router(config)#grpc {address-family | certificate-authentication | dscp | max-concurrent-streams
 | max-request-per-user | max-request-total | max-streams |
max-streams-per-user | no-tls | tlsv1-disable | tls-cipher | tls-mutual | tls-trustpoint |
service-layer | vrf}
```

where:

- `address-family:` set the address family identifier type.
- `certificate-authentication:` enables certificate based authentication
- `dscp:` set QoS marking DSCP on transmitted gRPC.
- `max-concurrent-streams:` set the limit on the maximum concurrent streams per gRPC connection to be applied on the server.
- `max-request-per-user:` set the maximum concurrent requests per user.
- `max-request-total:` set the maximum concurrent requests in total.
- `max-streams:` set the maximum number of concurrent gRPC requests. The maximum subscription limit is 128 requests. The default is 32 requests.
- `max-streams-per-user:` set the maximum concurrent gRPC requests for each user. The maximum subscription limit is 128 requests. The default is 32 requests.
- `no-tls:` disable transport layer security (TLS). The TLS is enabled by default

- `tlsv1-disable:` disable TLS version 1.0
- `service-layer:` enable the grpc service layer configuration.

  This parameter is not supported in Cisco ASR 9000 Series Routers, Cisco NCS560 Series Routers, , and Cisco NCS540 Series Routers.
- `tls-cipher:` enable the gRPC TLS cipher suites.
- `tls-mutual:` set the mutual authentication.
- `tls-trustpoint:` configure trustpoint.
- `server-vrf:` enable server vrf.

After gRPC is enabled, use the YANG data models to manage network configurations.

Step 2 Configure the interfaces.

In this example, you configure interfaces using Cisco IOS XR native model `Cisco-IOS-XR-ifmgr-cfg.yang`. You gain an understanding about the various gRPC operations while you configure the interface. For the complete list of operations, see gRPC Operations, on page 4. In this example, you merge configurations with `merge-config` RPC, retreive operational statistics using `get-oper` RPC, and delete a configuration using `delete-config` RPC. You can explore the structure of the data model using YANG validator tools such as pyang.

LER1 is the gRPC server, and a command line utility `grpcc` is used as a client on the controller. This utility does not support YANG and, therefore, does not validate the data model. The server, LER1, validates the data mode.

Note
The OC interface maps all IP configurations for parent interface under a VLAN with index 0. Hence, do not configure a sub interface with tag 0.

a) Explore the XR configuration model for interfaces and its IPv4 augmentation.

Example:

```
controller:grpc$ pyang --format tree --tree-depth 3 Cisco-IOS-XR-ifmgr-cfg.yang
Cisco-IOS-XR-ipv4-io-cfg.yang
module: Cisco-IOS-XR-ifmgr-cfg
    +--rw global-interface-configuration
    | +--rw link-status? Link-status-enum
    +--rw interface-configurations
        +--rw interface-configuration* [active interface-name]
            +--rw dampening
            | ...
            +--rw mtus
            | ...
            +--rw encapsulation
            | ...
            +--rw shutdown? empty
            +--rw interface-virtual? empty
            +--rw secondary-admin-state? Secondary-admin-state-enum
            +--rw interface-mode-non-physical? Interface-mode-enum
            +--rw bandwidth? uint32
            +--rw link-status? empty
            +--rw description? string
            +--rw active Interface-active
            +--rw interface-name xr:Interface-name
            +--rw ipv4-io-cfg:ipv4-network
            | ...
            +--rw ipv4-io-cfg:ipv4-network-forwarding ...
```

b) Configure a loopback0 interface on LER1.

Example:

```
controller:grpc$ more xr-interfaces-lo0-cfg.json
{
 "Cisco-IOS-XR-ifmgr-cfg:interface-configurations":
  { "interface-configuration": [
    {
      "active": "act",
      "interface-name": "Loopback0",
      "description": "LOCAL TERMINATION ADDRESS",
      "interface-virtual": [
        null
       ],
       "Cisco-IOS-XR-ipv4-io-cfg:ipv4-network": {
        "addresses": {
            "primary": {
              "address": "172.16.255.1",
              "netmask": "255.255.255.255"
       }
      }
     }
    }
   ]
 }
}
```

c) Merge the configuration.

Example:

```
controller:grpc$ grpcc -username admin -password admin -oper merge-config
-server_addr 198.18.1.11:57400 -json_in_file xr-interfaces-gi0-cfg.json
emsMergeConfig: Sending ReqId 1
emsMergeConfig: Received ReqId 1, Response '
'
```

d) Configure the ethernet interface on LER1.

Example:

```
controller:grpc$ more xr-interfaces-gi0-cfg.json
{
 "Cisco-IOS-XR-ifmgr-cfg:interface-configurations": {
   "interface-configuration": [
    {
     "active": "act",
     "interface-name": "GigabitEthernet0/0/0/0",
     "description": "CONNECTS TO LSR1 (g0/0/0/0)",
     "Cisco-IOS-XR-ipv4-io-cfg:ipv4-network": {
        "addresses": {
         "primary": {
            "address": "172.16.1.0",
            "netmask": "255.255.255.254"
      }
     }
    }
   }
  ]
 }
}
```

e) Merge the configuration.

Example:

```
controller:grpc$ grpcc -username admin -password admin -oper merge-config
-server_addr 198.18.1.11:57400 -json_in_file xr-interfaces-gi0-cfg.json
emsMergeConfig: Sending ReqId 1
emsMergeConfig: Received ReqId 1, Response '
'
```

f) Enable the ethernet interface `GigabitEthernet 0/0/0/0` on LER1 to bring up the interface. To do this, delete `shutdown` configuration for the interface.

Example:

```
controller:grpc$ grpcc -username admin -password admin -oper delete-config
-server_addr 198.18.1.11:57400 -yang_path "$(< xr-interfaces-gi0-shutdown-cfg.json )"
emsDeleteConfig: Sending ReqId 1, yangJson {
 "Cisco-IOS-XR-ifmgr-cfg:interface-configurations": {
   "interface-configuration": [
   {
    "active": "act",
    "interface-name": "GigabitEthernet0/0/0/0",
    "shutdown": [
      null
    ]
   }
  ]
 }
}
emsDeleteConfig: Received ReqId 1, Response ''
```

Step 3 Verify that the loopback interface and the ethernet interface on router LER1 are operational.

Example:

```
controller:grpc$ grpcc -username admin -password admin -oper get-oper
-server_addr 198.18.1.11:57400 -oper_yang_path "$(< xr-interfaces-briefs-oper-filter.json )"
emsGetOper: Sending ReqId 1, yangPath {
  "Cisco-IOS-XR-pfi-im-cmd-oper:interfaces": {
    "interface-briefs": [
      null
     ]
  }
}
{ "Cisco-IOS-XR-pfi-im-cmd-oper:interfaces": {
  "interface-briefs": {
    "interface-brief": [
    {
      "interface-name": "GigabitEthernet0/0/0/0",
      "interface": "GigabitEthernet0/0/0/0",
      "type": "IFT_GETHERNET",
      "state": "im-state-up",
      "actual-state": "im-state-up",
      "line-state": "im-state-up",
      "actual-line-state": "im-state-up",
      "encapsulation": "ether",
      "encapsulation-type-string": "ARPA",
      "mtu": 1514,
      "sub-interface-mtu-overhead": 0,
      "l2-transport": false,
      "bandwidth": 1000000
     },
     {
```

```
      "interface-name": "GigabitEthernet0/0/0/1",
      "interface": "GigabitEthernet0/0/0/1",
      "type": "IFT_GETHERNET",
      "state": "im-state-up",
      "actual-state": "im-state-up",
      "line-state": "im-state-up",
      "actual-line-state": "im-state-up",
      "encapsulation": "ether",
      "encapsulation-type-string": "ARPA",
      "mtu": 1514,
      "sub-interface-mtu-overhead": 0,
      "l2-transport": false,
      "bandwidth": 1000000
     },
     {
      "interface-name": "Loopback0",
      "interface": "Loopback0",
      "type": "IFT_LOOPBACK",
      "state": "im-state-up",
      "actual-state": "im-state-up",
      "line-state": "im-state-up",
      "actual-line-state": "im-state-up",
      "encapsulation": "loopback",
      "encapsulation-type-string": "Loopback",
      "mtu": 1500,
      "sub-interface-mtu-overhead": 0,
      "l2-transport": false,
      "bandwidth": 0
   },
   {
      "interface-name": "MgmtEth0/RP0/CPU0/0",
      "interface": "MgmtEth0/RP0/CPU0/0",
      "type": "IFT_ETHERNET",
      "state": "im-state-up",
      "actual-state": "im-state-up",
      "line-state": "im-state-up",
      "actual-line-state": "im-state-up",
      "encapsulation": "ether",
      "encapsulation-type-string": "ARPA",
      "mtu": 1514,
      "sub-interface-mtu-overhead": 0,
      "l2-transport": false,
      "bandwidth": 1000000
   },
   {
      "interface-name": "Null0",
      "interface": "Null0",
      "type": "IFT_NULL",
      "state": "im-state-up",
      "actual-state": "im-state-up",
      "line-state": "im-state-up",
      "actual-line-state": "im-state-up",
      "encapsulation": "null",
      "encapsulation-type-string": "Null",
      "mtu": 1500,
      "sub-interface-mtu-overhead": 0,
      "l2-transport": false,
      "bandwidth": 0
    }
   ]
  }
 }
}
emsGetOper: ReqId 1, byteRecv: 2325
```

In summary, router LER1, which had minimal configuration, is now programmatically configured using data models with an ethernet interface and is assigned a loopback address. Both these interfaces are operational and ready for network provisioning operations.