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.

• Configure Interfaces Using Data Models in a gRPC Session, on page 20

gRPC Operations

You can issue the following gRPC operations:

gRPC Operation	Description
GetConfig	Retrieves a configuration
GetModels	Gets the supported Yang models on the router
MergeConfig	Appends to an existing configuration
DeleteConfig	Deletes a configuration
ReplaceConfig	Modifies a part of an existing configuration
CommitReplace	Replaces existing configuration with the new configuration file provided
GetOper	Gets operational data using JSON
CliConfig	Invokes the CLI configuration
ShowCmdTextOutput	Displays the output of show command
ShowCmdJSONOutput	Displays the JSON output of show command

gRPC Operation to Get Configuration

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

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

gRPC Request (Client to Router)	gRPC Response (Router to Client)

`rpc GetConfig`
`  {`
`   "Cisco-IOS-XR-cdp-cfg:cdp": [`
`    "cdp": "running-configuration"`
`    ]`
`  }`
	`{`
	` "Cisco-IOS-XR-cdp-cfg:cdp": {`
	`  "timer": 50,`
	`  "enable": true,`
	`  "log-adjacency": [`
	`   null`
	`  ],`
	`  "hold-time": 180,`
	`  "advertise-v1-only": [`
	`   null`
	`  ]`
	` }`
	`}`

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 Bundling of Telemetry Updates

Table 1: 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
  !
 !
!
```

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 2: Feature History Table

Feature Name	Release Information	Description
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.

RPC	Description
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.

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.
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.

RPC	Description
RevokeCertificates	Revokes specific certificates.
CanGenerateCSR	Asks a target if the certificate can be generated.

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.

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
```

gRPC Network Security Interface

Table 3: 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 15. 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 4: 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.

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 5: Types of Authentication with Configuration

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

Type	Authentication Method	Authorization Method	Configuration Requirement	Requirement From Client
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

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

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
```

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*.

For more information about configuring AAA authorization, see the System Security Configuration Guide.

How to Use Different Types of Authentication

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

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

Step 1 Metadata with TLS

Example:

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

Step 2 Metadata without TLS

Example:

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

Step 3 Metadata without Mutual TLS

Example:

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

Step 4 Certificate based Authentication

Example:

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

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
```

Configure Interfaces Using Data Models in a gRPC Session

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.

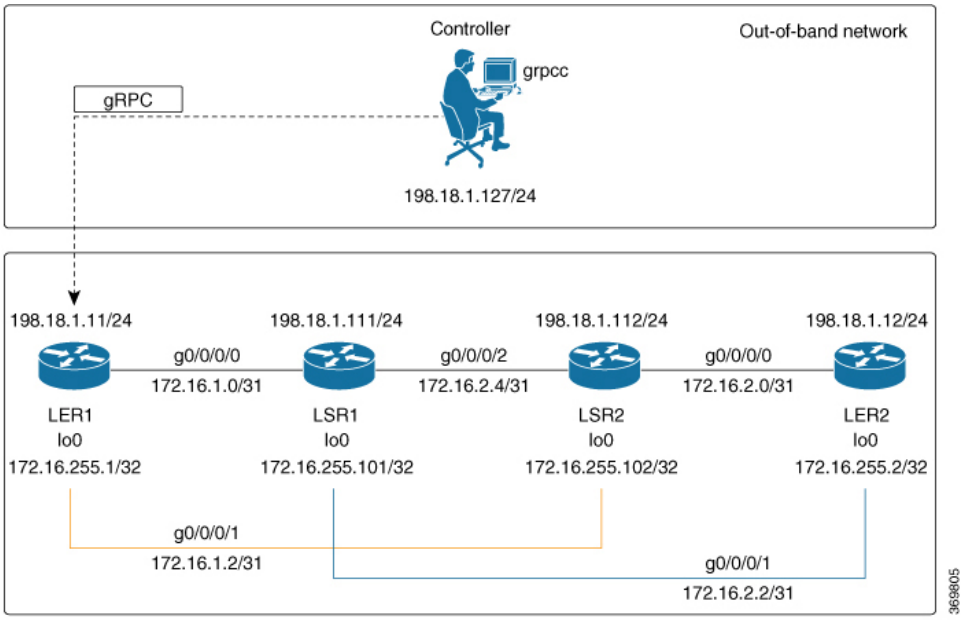
Note Configure AAA authorization to restrict users from uncontrolled access. If AAA authorization is not configured, the command and data rules associated to the groups that are assigned to the user are bypassed. An IOS-XR user can have full read-write access to the IOS-XR configuration through Network 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.

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.

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-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.