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New and Changed Feature Information

This section lists all the new and changed features for the Telemetry Configuration Guide for Cisco NCS 5500 Series Routers.

- New and Changed Telemetry Features, on page 1

New and Changed Telemetry Features

Table 1: Telemetry Features Added or Modified in IOS XR Release 6.2.x

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
<th>Changed in Release</th>
<th>Where Documented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support for model-driven telemetry over UDP</td>
<td>This feature enables configuring model-driven telemetry over UDP protocol</td>
<td>Release 6.2.2</td>
<td>Configure Dial-out Mode, on page 8</td>
</tr>
<tr>
<td>None</td>
<td>No new features introduced</td>
<td>Release 6.2.1</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
Stream Telemetry Data

This document will help you understand the process of streaming telemetry data and its core components.

- Video: Telemetry in Cisco IOS XR, on page 3
- Scope, on page 3
- Need, on page 4
- Benefits, on page 4
- Methods of Telemetry, on page 4

Video: Telemetry in Cisco IOS XR

Watch Video: Cisco IOS XR Telemetry Video Series.

This series has three videos:

- **Telemetry**: Unlock the intelligence of data in a network by streaming telemetry data in real-time to proactively predict and troubleshoot issues.

- **Model-driven telemetry**: Discover the power of real-time network management using model-driven telemetry to define and consume data of interest with data models.

- **Configure model-driven telemetry**: Configure model-driven telemetry to take advantage of data models, open source collectors, encodings and integrate into monitoring tools.

Scope

Streaming telemetry lets users direct data to a configured receiver. This data can be used for analysis and troubleshooting purposes to maintain the health of the network. This is achieved by leveraging the capabilities of machine-to-machine communication.

The data is used by development and operations (DevOps) personnel who plan to optimize networks by collecting analytics of the network in real-time, locate where problems occur, and investigate issues in a collaborative manner.
**Need**

Collecting data for analyzing and troubleshooting has always been an important aspect in monitoring the health of a network.

IOS XR provides several mechanisms such as SNMP, CLI and Syslog to collect data from a network. These mechanisms have limitations that restrict automation and scale. One limitation is the use of the pull model, where the initial request for data from network elements originates from the client. The pull model does not scale when there is more than one network management station (NMS) in the network. With this model, the server sends data only when clients request it. To initiate such requests, continual manual intervention is required. This continual manual intervention makes the pull model inefficient.

Network state indicators, network statistics, and critical infrastructure information are exposed to the application layer, where they are used to enhance operational performance and to reduce troubleshooting time. A push model uses this capability to continuously stream data out of the network and notify the client. Telemetry enables the push model, which provides near-real-time access to monitoring data.

Streaming telemetry provides a mechanism to select data of interest from IOS XR routers and to transmit it in a structured format to remote management stations for monitoring. This mechanism enables automatic tuning of the network based on real-time data, which is crucial for its seamless operation. The finer granularity and higher frequency of data available through telemetry enables better performance monitoring and therefore, better troubleshooting. It helps a more service-efficient bandwidth utilization, link utilization, risk assessment and control, remote monitoring and scalability. Streaming telemetry, thus, converts the monitoring process into a Big Data proposition that enables the rapid extraction and analysis of massive data sets to improve decision-making.

**Benefits**

Streamed real-time telemetry data is useful in:

- **Traffic optimization**: When link utilization and packet drops in a network are monitored frequently, it is easier to add or remove links, re-direct traffic, modify policing, and so on. With technologies like fast reroute, the network can switch to a new path and re-route faster than the SNMP poll interval mechanism. Streaming telemetry data helps in providing quick response time for faster traffic.

- **Preventive troubleshooting**: Helps to quickly detect and avert failure situations that result after a problematic condition exists for a certain duration.

**Methods of Telemetry**

Telemetry data can be streamed using these methods:

- **Model-driven telemetry**: provides a mechanism to stream data from an MDT-capable device to a destination. The data to be streamed is driven through subscription. There are two methods of configuration:
  - **Cadence-based telemetry**: Cadence-based Telemetry (CDT) continuously streams data (operational statistics and state transitions) at a configured cadence. The streamed data helps users closely identify patterns in the networks. For example, streaming data about interface counters and so on.
• **Policy-based telemetry**: streams telemetry data to a destination using a policy file. A policy file defines the data to be streamed and the frequency at which the data is to be streamed.

---

**Note**

Model-driven telemetry supersedes policy-based telemetry.
CHAPTER 3

Configure Model-driven Telemetry

Model-driven Telemetry (MDT) provides a mechanism to stream data from an MDT-capable device to a destination. The data to be streamed is defined through subscription.

The data to be streamed is subscribed from a data set in a YANG model. The data from the subscribed data set is streamed out to the destination either at a configured periodic interval or only when an event occurs. This behavior is based on whether MDT is configured for cadence-based telemetry.

The following YANG models are used to configure and monitor MDT:

- Cisco-IOS-XR-telemetry-model-driven-cfg.yang and openconfig-telemetry.yang: configure MDT using NETCONF or merge-config over grpc.
- Cisco-IOS-XR-telemetry-model-driven-oper.yang: get the operational information about MDT.

The process of streaming MDT data uses these components:

- **Destination**: specifies one or more destinations to collect the streamed data.
- **Sensor path**: specifies the YANG path from which data has to be streamed.
- **Subscription**: binds one or more sensor-paths to destinations, and specifies the criteria to stream data.
  In cadence-based telemetry, data is streamed continuously at a configured frequency.
- **Transport and encoding**: represents the delivery mechanism of telemetry data.

For more information about the core components, see Core Components of Model-driven Telemetry Streaming, on page 19.

The options to initialize a telemetry session between the router and destination is based on two modes:

- **Dial-out mode**: The router initiates a session to the destinations based on the subscription.
- **Dial-in mode**: The destination initiates a session to the router and subscribes to data to be streamed.

---

Note

Dial-in mode is supported only over gRPC.
Configure Dial-out Mode

In a dial-out mode, the router initiates a session to the destinations based on the subscription.

All 64-bit IOS XR platforms (except for NCS 6000 series routers) support gRPC, UDP and TCP protocols. All 32-bit IOS XR platforms support only TCP.

For more information about the dial-out mode, see Dial-out Mode, on page 19.

The process to configure a dial-out mode involves:

1. Identify the destination address, port, transport, and encoding format.
2. Create a destination group.

Example: Destination Group for TCP Dial-out

The following example shows a destination group DGroup1 created for TCP dial-out configuration with key-value Google Protocol Buffers (also called self-describing-gpb) encoding:

```
Router(config)#telemetry model-driven
Router(config-model-driven)#destination-group DGroup1
Router(config-model-driven-dest)#address family ipv4 172.0.0.0 port 5432
Router(config-model-driven-dest-addr)#encoding self-describing-gpb
Router(config-model-driven-dest-addr)#protocol tcp
Router(config-model-driven-dest-addr)#commit
```
Example: Destination Group for UDP Dial-out

The following example shows a destination group **DGroup1** created for UDP dial-out configuration with key-value Google Protocol Buffers (also called self-describing-gpb) encoding:

```plaintext
Router(config)#telemetry model-driven
Router(config-model-driven)#destination-group DGroup1
Router(config-model-driven-dest)#address family ipv4 172.0.0.0 port 5432
Router(config-model-driven-dest-addr)#encoding self-describing-gpb
Router(config-model-driven-dest-addr)#protocol udp
Router(config-model-driven-dest-addr)#commit
```

The UDP destination is shown as **Active** irrespective of the state of the collector because UDP is connectionless. Model-driven Telemetry with UDP is not suitable for a busy network. There is no retry if a message is dropped by the network before it reaches the collector.

Example: Destination Group for gRPC Dial-out

**gRPC** is supported in only 64-bit platforms.

gRPC protocol supports TLS and model-driven telemetry uses TLS to dial-out by default. The certificate must be copied to `/misc/config/grpc/dialout/`. To by-pass the TLS option, use `protocol grpc no-tls`.

The following is an example of a certificate to which the server certificate is connected:

```plaintext
RP/0/RP0/CP0:ios#run
Wed Aug 24 05:05:46.206 UTC
[xr-vr_node0_RP0_CPU0:~]$ls -l /misc/config/grpc/dialout/
total 4
-rw-r--r-- 1 root root 4017 Aug 19 19:17 dialout.pem
[xr-vr_node0_RP0_CPU0:~]$
```

The **CN (CommonName)** used in the certificate must be configured as `protocol grpc tls-hostname <>`. The following example shows a destination group **DGroup2** created for gRPC dial-out configuration with key-value GPB encoding, and with tls disabled:

```plaintext
Router(config)#telemetry model-driven
Router(config-model-driven)#destination-group DGroup2
Router(config-model-driven-dest)#address family ipv4 172.0.0.0 port 57500
Router(config-model-driven-dest-addr)#encoding self-describing-gpb
Router(config-model-driven-dest-addr)#protocol grpc no-tls
Router(config-model-driven-dest-addr)#commit
```

The following example shows a destination group **DGroup2** created for gRPC dial-out configuration with key-value GPB encoding, and with tls hostname:

```plaintext
Configuration with tls-hostname:
Router(config)#telemetry model-driven
Router(config-model-driven)#destination-group DGroup2
Router(config-model-driven-dest)#address family ipv4 172.0.0.0 port 57500
Router(config-model-driven-dest-addr)#encoding self-describing-gpb
Router(config-model-driven-dest-addr)#protocol grpc tls-hostname hostname.com
Router(config-model-driven-dest-addr)#commit
```
Create a Sensor Group

The sensor-group specifies a list of YANG models that are to be streamed.

1. Identify the sensor path for XR YANG model.
2. Create a sensor group.

Example: Sensor Group for Dial-out

Create a Subscription

The subscription associates a destination-group with a sensor-group and sets the streaming method.

A source interface in the subscription group specifies the interface that will be used for establishing the session to stream data to the destination. If both VRF and source interface are configured, the source interface must be in the same VRF as the one specified under destination group for the session to be established.
Router(config-model-driven-subs)#source-interface <source-interface>
Router(config-mdt-subscription)#commit

**Example: Subscription for Cadence-based Dial-out Configuration**
The following example shows a subscription Sub1 that is created to associate the sensor-group and destination-group, and configure an interval of 30 seconds to stream data:

Router(config)#telemetry model-driven
Router(config-model-driven)#subscription Sub1
Router(config-model-driven-subs)#sensor-group-id SGroup1 sample-interval 30000
Router(config-model-driven-subs)#destination-id DGroup1
Router(config-mdt-subscription)# commit

**Validate Dial-out Configuration**
Use the following command to verify that you have correctly configured the router for dial-out.

Router#show telemetry model-driven subscription <subscription-group-name>

**Example: Validation for TCP Dial-out**
Router#show telemetry model-driven subscription Sub1
Thu Jul 21 15:42:27.751 UTC
Subscription: Sub1 State: ACTIVE
-------------
Sensor groups:
Id Interval(ms) State
SGroup1 30000 Resolved

Destination Groups:
Id Encoding Transport State Port IP
DGroup1 self-describing-gpb tcp Active 5432 172.0.0.0

**Example: Validation for gRPC Dial-out**

```
Note

gRPC is supported in only 64-bit platforms.
```

Router#show telemetry model-driven subscription Sub2
Thu Jul 21 21:14:08.636 UTC
Subscription: Sub2 State: ACTIVE
-------------
Sensor groups:
Id Interval(ms) State
SGroup2 30000 Resolved

Destination Groups:
Id Encoding Transport State Port IP
DGroup2 self-describing-gpb grpc ACTIVE 57500 172.0.0.0

The telemetry data starts steaming out of the router to the destination.
Example: Configure model-driven telemetry with different sensor groups

RP/0/RP0/CPU0:ios#sh run telemetry model-driven

Wed Aug 24 04:49:19.309 UTC
telemetry model-driven
destination-group 1
  address family ipv4 1.1.1.1 port 1111
  protocol grpc
!

destination-group 2
  address family ipv4 2.2.2.2 port 2222
!

destination-group test
  address family ipv4 172.0.0.0 port 8801
    encoding self-describing-gpb
    protocol grpc no-tls
!
  address family ipv4 172.0.0.0 port 8901
    encoding self-describing-gpb
    protocol grpc tls-hostname chkpt1.com
!

sensor-group 1
  sensor-path Cisco-IOS-XR-plat-chas-invmgr-oper:platform-inventory/racks/rack
!
sensor-group mdt
  sensor-path Cisco-IOS-XR-telemetry-model-driven-oper:telemetry-model-driven
!
sensor-group generic
  sensor-path Cisco-IOS-XR-infra-statsd-oper:infra-statistics/interfaces/interface/latest/generic-counters
!
sensor-group if-oper
!
subscription mdt
  sensor-group-id mdt sample-interval 10000
!
subscription generic
  sensor-group-id generic sample-interval 10000
!
subscription if-oper
  sensor-group-id if-oper sample-interval 10000
  destination-id test
!

A sample output from the destination with TLS certificate chkpt1.com:

RP/0/RP0/CPU0:ios#sh telemetry model-driven dest
<table>
<thead>
<tr>
<th>Group Id</th>
<th>IP</th>
<th>Port</th>
<th>Encoding</th>
<th>Transport</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.1.1.1</td>
<td>1111</td>
<td>none</td>
<td>grpc</td>
<td>ACTIVE</td>
</tr>
<tr>
<td></td>
<td>TLS:1.1.1.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2.2.2.2</td>
<td>2222</td>
<td>none</td>
<td>grpc</td>
<td>ACTIVE</td>
</tr>
<tr>
<td></td>
<td>TLS:2.2.2.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>test</td>
<td>172.0.0.0</td>
<td>8801</td>
<td>self-describing-gpb</td>
<td>grpc</td>
<td>Active</td>
</tr>
<tr>
<td>test</td>
<td>172.0.0.0</td>
<td>8901</td>
<td>self-describing-gpb</td>
<td>grpc</td>
<td>Active</td>
</tr>
<tr>
<td></td>
<td>TLS:chkpt1.com</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A sample output from the subscription:

```
RP/0/RP0/CPU0:ios#sh telemetry model-driven subscription

Wed Aug 24 04:49:48.002 UTC
Subscription: mdt State: ACTIVE
-------------
Sensor groups:
Id      Interval(ms) State
mdt 10000 Resolved

Subscription: generic State: ACTIVE
-------------
Sensor groups:
Id      Interval(ms) State
generic 10000 Resolved

Subscription: if-oper State: ACTIVE
-------------
Sensor groups:
Id      Interval(ms) State
if-oper 10000 Resolved

Destination Groups:
Id      Encoding    Transport State Port IP
test self-describing-gpb grpc ACTIVE 8801 172.0.0.0

No TLS :

test self-describing-gpb grpc Active 8901 172.0.0.0
TLS : chkpt1.com
```

RP/0/RP0/CPU0:ios#sh telemetry model-driven subscription if-oper

Wed Aug 24 04:50:02.295 UTC
Subscription: if-oper
-------------
State: ACTIVE
Sensor groups:
Id: if-oper
Sample Interval: 10000 ms
Sensor Path State: Resolved

Destination Groups:
Group Id: test
Destination IP: 172.0.0.0
Destination Port: 8801
Encoding: self-describing-gpb
Transport: grpc
Configure Dial-in Mode

In a dial-in mode, the destination initiates a session to the router and subscribes to data to be streamed.

Note

Dial-in mode is supported over gRPC in only 64-bit platforms.

For more information about dial-in mode, see Dial-in Mode, on page 19.

The process to configure a dial-in mode involves these tasks:

- Enable gRPC
- Create a sensor group
- Create a subscription
- Validate the configuration

Enable gRPC

Configure the gRPC server on the router to accept incoming connections from the collector.

1. Enable gRPC over an HTTP/2 connection.

```text
Router# configure
Router (config)# grpc
```
2. Enable access to a specified port number.

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

   The `<port-number>` range is from 57344 to 57999. If a port number is unavailable, an error is displayed.

3. In the configuration mode, set the session parameters.

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

   where:

   • **address-family**: set the address family identifier type
   • **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.
   • **service-layer**: enable the grpc service layer configuration
   • **tls-cipher**: enable the gRPC TLS cipher suites
   • **tls-mutual**: set the mutual authentication
   • **tls-trustpoint**: configure trustpoint
   • **server-vrf**: enable server vrf

4. Commit the configuration.

   `Router(config-grpc)#commit`

The following example shows the output of `show grpc` command. The sample output displays the gRPC configuration when TLS is enabled on the router.

   `Router#show grpc`

<table>
<thead>
<tr>
<th>Address family</th>
<th>Port</th>
<th>VRF</th>
<th>TLS</th>
<th>TLS mutual</th>
<th>Trustpoint</th>
<th>Maximum requests</th>
<th>Maximum requests per user</th>
<th>Maximum streams</th>
<th>Maximum streams per user</th>
</tr>
</thead>
<tbody>
<tr>
<td>ipv4</td>
<td>57300</td>
<td>global-vrf</td>
<td>enabled</td>
<td>disabled</td>
<td>none</td>
<td>128</td>
<td>10</td>
<td>32</td>
<td>32</td>
</tr>
</tbody>
</table>

   `TLS cipher suites
   Default : none
   Enable : none`
Create a Sensor Group

The sensor group specifies a list of YANG models that are to be streamed.

1. Identify the sensor path for XR YANG model.
2. Create a sensor group.

```
Router(config)#telemetry model-driven
Router(config-model-driven)#sensor-group <group-name>
Router(config-model-driven-snsr-grp)# sensor-path <XR YANG model>
Router(config-model-driven-snsr-grp)# commit
```

Example: Sensor Group for gRPC Dial-in

The following example shows a sensor group SGroup3 created for gRPC dial-in configuration with the YANG model for interfaces:

```
Router(config)#telemetry model-driven
Router(config-model-driven)#sensor-group SGroup3
Router(config-model-driven-snsr-grp)# sensor-path openconfig-interfaces:interfaces/interface
```

What to Do Next:
Create a subscription.

Create a Subscription

The subscription associates a sensor-group with a streaming interval. The collector requests the subscription to the sensor paths when it establishes a connection with the router.

```
Router(config)#telemetry model-driven
Router(config-model-driven)#subscription <subscription-name>
Router(config-model-driven-subs)#sensor-group-id <sensor-group> sample-interval <interval>
```
Example: Subscription for gRPC Dial-in

The following example shows a subscription Sub3 that is created to associate the sensor-group with an interval of 30 seconds to stream data:

Router(config-model-driven-subs)#destination-id <destination-group>
Router(config-mdt-subscription)#commit

Example: Subscription for gRPC Dial-in

Router(config)telemetry model-driven
Router(config-model-driven)#subscription Sub3
Router(config-model-driven-subs)#sensor-group-id SGroup3 sample-interval 30000
Router(config-mdt-subscription)#commit

What to Do Next:
Validate the configuration.

Validate Dial-in Configuration

Use the following command to verify that you have correctly configured the router for gRPC dial-in.

Router#show telemetry model-driven subscription

Example: Validation for gRPC Dial-in

RP/0/RP0/CPU0:SunC#show telemetry model-driven subscription Sub3
Thu Jul 21 21:32:45.365 UTC
Subscription: Sub3
-------------
State: ACTIVE
Sensor groups:
Id: SGroup3
  Sample Interval: 30000 ms
  Sensor Path: openconfig-interfaces:interfaces/interface
  Sensor Path State: Resolved

Destination Groups:
Group Id: DialIn_1002
  Destination IP: 172.30.8.4
  Destination Port: 48481
  Encoding: self-describing-gpb
  Transport: dialin
  State: Active
  Total bytes sent: 13909
  Total packets sent: 14
  Last Sent time: 2016-07-21 21:32:25.231964501 +0000

Collection Groups:
--------------
Id: 2
  Sample Interval: 30000 ms
  Encoding: self-describing-gpb
  Num of collection: 7
  Collection time: Min: 32 ms Max: 39 ms
  Total time: Min: 34 ms Avg: 37 ms Max: 40 ms
  Total Deferred: 0
  Total Send Errors: 0
  Total Send Drops: 0
Validate Dial-in Configuration

Total Other Errors: 0
Last Collection Start: 2016-07-21 21:32:25.231930501 +0000
Last Collection End: 2016-07-21 21:32:25.231969501 +0000
Sensor Path: openconfig-interfaces:interfaces/interface
Core Components of Model-driven Telemetry Streaming

The core components used in streaming model-driven telemetry data are:

- Session, on page 19
- Sensor Path, on page 20
- Subscription, on page 20
- Transport and Encoding, on page 20

Session

A telemetry session can be initiated using:

Dial-in Mode

In a dial-in mode, an MDT receiver dials in to the router, and subscribes dynamically to one or more sensor paths or subscriptions. The router acts as the server and the receiver is the client. The router streams telemetry data through the same session. The dial-in mode of subscriptions is dynamic. This dynamic subscription terminates when the receiver cancels the subscription or when the session terminates.

There are two methods to request sensor-paths in a dynamic subscription:

- **OpenConfig RPC model:** The `subscribe` RPC defined in the model is used to specify sensor-paths and frequency. In this method, the subscription is not associated with an existing configured subscription. A subsequent `cancel` RPC defined in the model removes an existing dynamic subscription.

- **IOS XR MDT RPC:** IOS XR defines RPCs to subscribe and to cancel one or more configured subscriptions. The sensor-paths and frequency are part of the telemetry configuration on the router. A subscription is identified by its configured subscription name in the RPCs.

Dial-out Mode

In a dial-out mode, the router dials out to the receiver. This is the default mode of operation. The router acts as a client and receiver acts as a server. In this mode, sensor-paths and destinations are configured and bound together into one or more subscriptions. The router continually attempts to establish a session with each destination in the subscription, and streams data to the receiver. The dial-out mode of subscriptions is persistent.
When a session terminates, the router continually attempts to re-establish a new session with the receiver every 30 seconds.

**Sensor Path**

The sensor path describes a YANG path or a subset of data definitions in a YANG model with a container. In a YANG model, the sensor path can be specified to end at any level in the container hierarchy.

An MDT-capable device, such as a router, associates the sensor path to the nearest container path in the model. The router encodes and streams the container path within a single telemetry message. A receiver receives data about all the containers and leaf nodes at and below this container path.

The router streams telemetry data for one or more sensor-paths, at the configured frequency (cadence-based streaming) to one or more receivers through subscribed sessions.

**Subscription**

A subscription binds one or more sensor paths and destinations. An MDT-capable device streams data for each sensor path at the configured frequency (cadence-based streaming) to the destination.

**Transport and Encoding**

The router streams telemetry data using a transport mechanism. The generated data is encapsulated into the desired format using encoders.

Model-Driven Telemetry (MDT) data is streamed through these supported transport mechanisms:

- **Google Protocol RPC (gRPC):** used for both dial-in and dial-out modes.
- **Transmission Control Protocol (TCP):** used for only dial-out mode.
- **User Datagram Protocol (UDP):** used for only dial-out mode.

The data to be streamed can be encoded into Google Protocol Buffers (GPB) or JavaScript Object Notation (JSON) encoding. In GPB, the encoding can either be compact GPB (for optimising the network bandwidth usage) or self-describing GPB. The encodings supported are:

- **GPB encoding:** configuring for GPB encoding requires metadata in the form of compiled .proto files. A .proto file describes the GPB message format, which is used to stream data. The .proto files are available at https://github.com/cisco/bigmuddy-network-telemetry-proto/tree/master/proto_archive.
  - **Compact GPB encoding:** data is streamed in compressed and non self-describing format. A .proto file corresponding to each sensor-path must be used by the receiver to decode the streamed data.
  - **Key-value (KV-GPB) encoding:** data of each sensor path streamed is in a self-describing formatted ASCII text. A single .proto file telemetry.proto is used by the receiver to decode any sensor path data. Because the key names are included in the streamed data, the data on the wire is much larger as compared to compact GPB encoding.
- **JSON encoding**
CHAPTER 5

Configure Policy-based Telemetry

Policy-based telemetry (PBT) streams telemetry data to a destination using a policy file. A policy file defines the data to be streamed and the frequency at which the data is to be streamed.

ASR9000 series routers and CRS routers do not support PBT.

The process of streaming telemetry data uses three core components:

- **Telemetry Policy File** specifies the kind of telemetry data to be generated, at a specified frequency.
- **Telemetry Encoder** encapsulates the generated data into the desired format and transmits to the receiver.
- **Telemetry Receiver** is the remote management system that stores the telemetry data.

For more information about the three core components, see Core Components of Policy-based Telemetry Streaming, on page 27.

Model-driven telemetry supersedes policy-based telemetry.

Streaming policy-based telemetry data to the intended receiver involves these tasks:

- Create Policy File, on page 21
- Copy Policy File, on page 23
- Configure Encoder, on page 23
- Verify Policy Activation, on page 25

Create Policy File

You define a telemetry policy file to specify the kind of telemetry data to be generated and pushed to the receiver. Defining the policy files requires a path to stream data. The paths can be schemas, native YANG or allowed list entries.

For more information on the schema paths associated with a corresponding CLI command, see Schema Paths, on page 28.

For more information on policy files, see Telemetry Policy File, on page 27.

1. Determine the schema paths to stream data.

   For example, the schema path for interfaces is:
2. Create a policy file that contains these paths.

**Example: Policy File**

The following example shows a sample policy file for streaming the generic counters of an interface:

```yaml
{
  "Name": "Test",
  "Metadata": {
    "Version": 25,
    "Description": "This is a sample policy",
    "Comment": "This is the first draft",
    "Identifier": "<data that may be sent by the encoder to the mgmt stn"
  },
  "CollectionGroups": {
    "FirstGroup": {
      "Period": 10,
      "Paths": [
        "RootOper.InfraStatistics.Interface(*).Latest.GenericCounters"
      ]
    }
  }
}
```

The following example shows the paths with allowed list entries in the policy file. Instead of streaming all the data for a particular entry, only specific items can be streamed using allowed list entries. The entries are allowed using `IncludeFields` in the policy file. In the example, the entry within the `IncludeFields` section streams only the latest applied AutoBW value for that TE tunnel, which is nested two levels down from the top level of the path:

```yaml
{
  "Name": "RSVPTEPolicy",
  "Metadata": {
    "Version": 1,
    "Description": "This policy collects auto bw stats",
    "Comment": "This is the first draft"
  },
  "CollectionGroups": {
    "FirstGroup": {
      "Period": 10,
      "Paths": {
        "RootOper.MPLS_TE.P2P_P2MPTunnel.TunnelHead({'TunnelName': 'tunnel-te10'})": {
          "IncludeFields": {
            "P2PInfo": {
              "AutoBandwidthOper": {
                "LastBandwidthApplied" : "" }
            }
          }
        }
      }
    }
  }
}
```
The following example shows the paths with native YANG entry in the policy file. This entry will stream the generic counters of the interface:

"Paths": [
    "/Cisco-IOS-XR-infra-statsd-oper:infra-statistics/interfaces/interface=*/latest/generic-counters"
]

**What to Do Next:**

Copy the policy file to the router. You may copy the same policy file to multiple routers.

---

**Copy Policy File**

Run the Secure Copy Protocol (SCP) command to securely copy the policy file from the server where it is created. For example:

```
$ scp Test.policy <ip-address-of-router>:/telemetry/policies
```

For example, to copy the `Test.policy` file to the `/telemetry/policies` folder of a router with IP address 10.0.0.1:

```
$ scp Test.policy cisco@10.0.0.1:/telemetry/policies
```

cisco@10.0.0.1's password:

100% 779 0.8KB/s 00:00
Connection to 10.0.0.1 closed by remote host.

**Verify Policy Installation**

In this example, the policy is installed in the `/telemetry/policies/` folder in the router file system. Run the `show telemetry policies brief` command to verify that the policy is successfully copied to the router.

```
Router# show telemetry policy-driven policies brief
Wed Aug 26 02:24:40.556 PDT

Name | Active? | Version | Description
-------------------------------------|--------|---------|-------------------------------------
Test | N      | 1       | This is a sample policy
```

**What to Do Next:**

Configure the telemetry encoder to activate and stream data.

---

**Configure Encoder**

An encoder calls the streaming Telemetry API to:

- Specify policies to be explicitly defined
- Register all policies of interest
Configure the encoder to activate the policy and stream data. More than one policy and destination can be specified. Multiple policy groups can be specified under each encoder and each group can be streamed to multiple destinations. When multiple destinations are specified, the data is streamed to all destinations.

Configure an encoder based on the requirement.

**Configure JSON Encoder**

The JavaScript Object Notation (JSON) encoder is packaged with the IOS XR software and provides the default format for streaming telemetry data.

To stream data in JavaScript Object Notation (JSON) format, specify the encoder, policies, policy group, destination, and port:

```
Router# configure
Router(config)# telemetry policy-driven encoder json
Router(config-telemetry-json)# policy group FirstGroup
Router(config-policy-group)# policy Test
Router(config-policy-group)# destination ipv4 10.0.0.1 port 5555
Router(config-policy-group)# commit
```

The names of the policy and the policy group must be identical to the policy and its definition that you create. For more information on policy files, see Create Policy File, on page 21.

For more information about the message format of JSON encoder, see JSON Message Format, on page 31

**Configure GPB Encoder**

Configuring the GPB (Google Protocol Buffer) encoder requires metadata in the form of compiled `.proto` files. A `.proto` file describes the GPB message format, which is used to stream data.

Two encoding formats are supported:

- **Compact encoding** stores data in a compressed and non-self-describing format. A `.proto` file must be generated for each path in the policy file to be used by the receiver to decode the resulting data.

- **Key-value encoding** uses a single `.proto` file to encode data in a self-describing format. This encoding does not require a `.proto` file for each path. The data on the wire is much larger because key names are included.

To stream GPB data, complete these steps:

1. For compact encoding, create `.proto` files for all paths that are to be streamed using the following tool:

   ```
   telemetry generate gpb-encoding path <path> [file <output_file>]
   or
   telemetry generate gpb-encoding policy <policy_file> directory <output_dir>
   ```

   A parser limitation does not support the use of quotes within paths in the tool. For example, for use in the tool, change this policy path,

   ```
   ```

   to

   ```
   ```
2. Copy the policy file to the router.
3. Configure the telemetry policy specifying the encoder, policies, policy group, destination, and port:

```
Router# configure
Router(config)# telemetry policy-driven encoder gpb
Router(config-telemetry-json)# policy group FirstGroup
Router(config-policy-group)# policy Test
Router(config-policy-group)# destination ipv4 10.0.0.1 port 5555
Router(config-policy-group)# commit
```

For more information about the message format of GPB encoder, see GPB Message Format, on page 33

**Verify Policy Activation**

Verify that the policy is activated using the `show telemetry policies` command.

```
Router# show telemetry policy-driven policies
Wed Aug 26 02:24:40.556 PDT
Filename: Test.policy
Version: 25
Description: This is a sample policy to demonstrate the syntax
Status: Active
CollectionGroup: FirstGroup
  Cadence: 10s
  Total collections: 2766
  Latest collection: 2015-08-26 02:25:07
  Min collection time: 0.000s
  Max collection time: 0.095s
  Avg collection time: 0.000s
  Min total time: 0.022s
  Max total time: 0.903s
  Avg total time: 0.161s
  Collection errors: 0
  Missed collections: 0
```

<table>
<thead>
<tr>
<th>Path</th>
<th>Avg (s)</th>
<th>Max (s)</th>
<th>Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>RootOper.InfraStatistics.Interface(*).Latest.GenericCounters</td>
<td>0.000</td>
<td>0.000</td>
<td>0</td>
</tr>
</tbody>
</table>

After the policy is validated, the telemetry encoder starts streaming data to the receiver. For more information on the receiver, see Telemetry Receiver, on page 36.
Verify Policy Activation
Core Components of Policy-based Telemetry Streaming

The core components used in streaming policy-based telemetry data are:

- Telemetry Policy File, on page 27
- Telemetry Encoder, on page 29
- Telemetry Receiver, on page 36

Telemetry Policy File

A telemetry policy file is defined by the user to specify the kind of telemetry data that is generated and pushed to the receiver. The policy must be stored in a text file with a .policy extension. Multiple policy files can be defined and installed in the /telemetry/policies/ folder in the router file system.

A policy file:

- Contains one or more collection groups; a collection group includes different types of data to be streamed at different intervals
- Includes a period in seconds for each group
- Contains one or more paths for each group
- Includes metadata that contains version, description, and other details about the policy

Policy file syntax

The following example shows a sample policy file:

```json
{
  "Name": "NameOfPolicy",
  "Metadata": {
    "Version": 25,
    "Description": "This is a sample policy to demonstrate the syntax",
    "Comment": "This is the first draft",
    "Identifier": "<data that may be sent by the encoder to the mgmt stn"
  },
  "CollectionGroups": {
    "FirstGroup": {
      "Period": 10,
      "Paths": [}
```
The syntax of the policy file includes:

- **Name** the name of the policy. In the previous example, the policy is stored in a file named `NameOfPolicy.policy`. The name of the policy must match the filename (without the .policy extension). It can contain uppercase alphabets, lower-case alphabets, and numbers. The policy name is case sensitive.

- **Metadata** information about the policy. The metadata can include the version number, date, description, author, copyright information, and other details that identify the policy. The following fields have significance in identifying the policy:
  - Description is displayed in the `show policies` command.
  - Version and Identifier are sent to the receiver as part of the message header of the telemetry messages.

- **CollectionGroups** an encoder object that maps the group names to information about them. The name of the collection group can contain uppercase alphabets, lowercase alphabets, and numbers. The group name is case sensitive.

- **Period** the cadence for each collection group. The period specifies the frequency in seconds at which data is queried and sent to the receiver. The value must be within the range of 5 and 86400 seconds.

- **Paths** one or more schema paths, allowed list entries or native YANG paths (for a container) for the data to be streamed and sent to the receiver. For example,
  - Schema path:
    ```
    ```
  - YANG path:
    ```
    /Cisco-IOS-XR-infra-statsd-oper:infra-statistics/interfaces/interface=*/latest/generic-counters
    ```
  - Allowed list entry:
    ```
    "RootOper.Interfaces.Interface(*)":
    {
      "IncludeFields": ["State"]
    }
    ```

### Schema Paths

A schema path is used to specify where the telemetry data is collected. A few paths are listed in the following table for your reference:
### Telemetry Encoder

The telemetry encoder encapsulates the generated data into the desired format and transmits to the receiver. An encoder calls the streaming Telemetry API to:

- Specify policies to be explicitly defined
- Register all policies of interest

Telemetry supports two types of encoders:

- **JavaScript Object Notation (JSON) encoder**
  
  This encoder is packaged with the IOS XR software and provides the default method of streaming telemetry data. It can be configured by CLI and XML to register for specific policies. Configuration is grouped into policy groups, with each policy group containing one or more policies and one or more destinations. JSON encoding is supported over only TCP transport service.

  JSON encoder supports two encoding formats:

  - **Restconf-style encoding** is the default JSON encoding format.
  - **Embedded-keys encoding** treats naming information in the path as keys.

- **Google Protocol Buffers (GPB) encoder**
  
  This encoder provides an alternative encoding mechanism, streaming the data in GPB format over UDP or TCP. It can be configured by CLI and XML and uses the same policy files as those of JSON.

---

**Table 2: Schema Paths**

<table>
<thead>
<tr>
<th>Operation</th>
<th>Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface Operational data</td>
<td>RootOper.Interfaces.Interface(*)</td>
</tr>
<tr>
<td>Packet/byte rates</td>
<td>RootOper.InfraStatistics.Interface(*).Latest.DataRate</td>
</tr>
<tr>
<td>MPLS stats</td>
<td>• RootOper.MPLS_TE.Tunnels.TunnelAutoBandwidth</td>
</tr>
<tr>
<td></td>
<td>• RootOper.MPLS_TE.P2P_P2MP_Tunnel.TunnelHead</td>
</tr>
<tr>
<td></td>
<td>• RootOper.MPLS_TE.SignallingCounters.HeadSignallingCounters</td>
</tr>
<tr>
<td>QOS Stats</td>
<td>• RootOper.QOS.Interface(*).Input.Statistics</td>
</tr>
<tr>
<td></td>
<td>• RootOper.QOS.Interface(*).Output.Statistics</td>
</tr>
<tr>
<td>BGP Data</td>
<td>RootOper.BGP.Instance({'InstanceName': 'default'}).InstanceActive.DefaultVRF.Neighbor[*]</td>
</tr>
<tr>
<td>Inventory data</td>
<td>RootOper.PlatformInventory.Rack(*).Attributes.BasicInfo</td>
</tr>
<tr>
<td></td>
<td>RootOper.PlatformInventory.Rack(<em>).Slot(</em>).Card(<em>).Sensor(</em>).Attributes.BasicInfo</td>
</tr>
</tbody>
</table>
Additionally, a GPB encoder requires metadata in the form of compiled .proto files to translate the data into GPB format.

GPB encoder supports two encoding formats:

- **Compact encoding** stores data in a compact GPB structure that is specific to the policy that is streamed. This format is available over both UDP and TCP transport services. A .proto file must be generated for each path in the policy file to be used by the receiver to decode the resulting data.

- **Key-value encoding** stores data in a generic key-value format using a single .proto file. The encoding is self-describing as the keys are contained in the message. This format is available over UDP and TCP transport service. A .proto file is not required for each policy file because the receiver can interpret the data.

### TCP Header

Streaming data over a TCP connection either with a JSON or a GPB encoder and having it optionally compressed by zlib ensures that the stream is flushed at the end of each batch of data. This helps the receiver to decompress the data received. If data is compressed using zlib, the compression is done at the policy group level. The compressor resets when a new connection is established from the receiver because the decompressor at the receiver has an empty initial state.

Header of each TCP message:

<table>
<thead>
<tr>
<th>Type</th>
<th>Flags</th>
<th>Length</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 bytes</td>
<td>4 bytes</td>
<td>4 bytes</td>
<td>Variable</td>
</tr>
<tr>
<td></td>
<td>• <strong>default</strong> - Use 0x0 value to set no flags.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• <strong>zlib compression</strong> - Use 0x1 value to set zlib compression on the message.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

where:

- The Type is encoded as a big-endian value.
- The Length (in bytes) is encoded as a big-endian value.
- The flags indicates modifiers (such as compression) in big-endian format.
- The message contains the streamed data in either JSON or GPB object.

Type of messages:

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Length</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reset Compressor</td>
<td>0</td>
<td>No value</td>
</tr>
<tr>
<td>2</td>
<td>JSON Message</td>
<td>Variable</td>
<td>JSON message (any format)</td>
</tr>
<tr>
<td>3</td>
<td>GPB compact</td>
<td>Variable</td>
<td>GPB message in compact format</td>
</tr>
</tbody>
</table>
### JSON Message Format

JSON messages are sent over TCP and use the header message described in TCP Header, on page 30.

The message consists of the following JSON objects:

```json
{
    "Policy": "<name-of-policy>",
    "Version": "<policy-version>",
    "Identifier": "<data from policy file>",
    "CollectionID": <id>,
    "Path": <Policy Path>,
    "CollectionStartTime": <timestamp>,
    "Data": { ... object as above ... },
    "CollectionEndTime": <timestamp>
}
```

where:

- **Policy**, **Version** and **Identifier** are specified in the policy file.
- **CollectionID** is an integer that allows messages to be grouped together if data for a single path is split over multiple messages.
- **Path** is the base path of the corresponding data as specified in the policy file.
- **CollectionStartTime** and **CollectionEndTime** are the timestamps that indicate when the data was collected.

The JSON message reflects the hierarchy of the router's data model. The hierarchy consists of:

- containers: a container has nodes that can be of different types.
- tables: a table also contains nodes, but the number of child nodes may vary, and they must be of the same type.
- leaf node: a leaf contains a data value, such as integer or string.

The schema objects are mapped to JSON in this manner:

- Each container maps to a JSON object. The keys are strings that represent the schema names of the nodes; the values represent the values of the nodes.
- JSON objects are also used to represent tables. In this case, the keys are based on naming information that is converted to string format. Two options are provided for encoding the naming information:
  - The default is restconf-style encoding, where naming parameters are contained within the child node to which it refers.
  - The embedded-keys option uses the naming information as keys in a JSON dictionary, with the corresponding child node forming the value.
- Leaf data types are mapped in this manner:
- Simple strings, integers, and booleans are mapped directly.
- Enumeration values are stored as the string representation of the value.
- Other simple data types, such as IP addresses, are mapped as strings.

**Example: Rest-conf Encoding**

For example, consider the path -

```
Interfaces(*).Counters.Protocols("IPv4")
```

This has two naming parameters - the interface name and the protocol name - and represents a container holding leaf nodes which are packet and byte counters. This would be represented as follows:

```json
{
    "Interfaces": [
        {
            "Name": "GigabitEthernet0/0/0/1",
            "Counters": {
                "Protocols": [
                    {
                        "ProtoName": "IPv4",
                        "CollectionTime": 12345678,
                        "InputPkt": 100,
                        "InputBytes": 200,
                    }
                ]
            }
        },
        {
            "Name": "GigabitEthernet0/0/0/2",
            "Counters": {
                "Protocols": [
                    {
                        "ProtoName": "IPv4",
                        "CollectionTime": 12345678,
                        "InputPkt": 400,
                        "InputBytes": 500,
                    }
                ]
            }
        }
    ]
}
```

A naming parameter with multiple keys, for example Foo.Destination(IPAddress=1.1.1.1, Port=2000) would be represented as follows:

```json
{
    "Foo": {
        "Destination": [
            {
                "IPAddress": 1.1.1.1,
                "Port": 2000,
                "CollectionTime": 12345678,
                "Leaf1": 100,
            }
        ]
    }
}
```
Example: Embedded Keys Encoding

The embedded-keys encoding treats naming information in the path as keys in the JSON dictionary. The key name information is lost and there are extra levels in the hierarchy but it is clearer which data constitutes the key which may aid collectors when parsing it. This option is provided primarily for backwards-compatibility with 6.0.

```json
{
  "Interfaces": {
    "GigabitEthernet0/0/0/1": {
      "Counters": {
        "Protocols": {
          "IPv4": {
            "CollectionTime": 12345678,
            "InputPkts": 100,
            "InputBytes": 200,
          }
        }
      }
    },
    "GigabitEthernet0/0/0/2": {
      "Counters": {
        "Protocols": {
          "IPv4": {
            "CollectionTime": 12345678,
            "InputPkts": 400,
            "InputBytes": 500,
          }
        }
      }
    }
  }
}

A naming parameter with multiple keys, for example Foo.Destination(IPAddress=1.1.1.1, Port=2000), would be represented by nesting each key in order:

```json
{
  "Foo": {
    "Destination": {
      1.1.1.1: {
        2000: {
          "Leaf1": 100,
        }
      }
    }
  }
}
```

GPB Message Format

The output of the GPB encoder consists entirely of GPBs and allows multiple tables in a single packet for scalability.

GPB (Google Protocol Buffer) encoder requires metadata in the form of compiled .proto files. A .proto file describes the GPB message format, which is used to stream data.

For UDP, the data is simply a GPB. Only the compact format is supported so the message can be interpreted as a TelemetryHeader message.
For TCP, the message body is either a Telemetry message or a TelemetryHeader message, depending on which of the following encoding types is configured:

- **Compact GPB format** stores data in a compressed and non-self-describing format. A .proto file must be generated for each path in the policy file to be used by the receiver to decode the resulting data.

- **Key-value GPB format** uses a single .proto file to encode data in a self-describing format. This encoding does not require a .proto file for each path. The data on the wire is much larger because key names are included.

In the following example, the policy group, alpha uses the default configuration of compact encoding and UDP transport. The policy group, beta uses compressed TCP and key-value encoding. The policy group, gamma uses compact encoding over uncompressed TCP.

```plaintext
telemetry policy-driven encoder gpb
  policy group alpha
    policy foo
      destination ipv4 192.168.1.1 port 1234
      destination ipv4 10.0.0.1 port 9876
  policy group beta
    policy bar
    policy whizz
      destination ipv4 10.20.30.40 port 3333
      transport tcp
      compression zlib
  policy group gamma
    policy bang
      destination ipv4 11.1.1.1 port 4444
      transport tcp
      encoding-format gpb-compact
```

### Compact GPB Format

The compact GPB format is intended for streaming large volumes of data at frequent intervals. The format minimizes the size of the message on the wire. Multiple tables can be sent in a single packet for scalability.

**Note**

The tables can be split over multiple packets but fragmenting a row is not supported. If a row in the table is too large to fit in a single UDP frame, it cannot be streamed. Instead either switch to TCP, increase the MTU, or modify the .proto file.

The following .proto file shows the header, which is common to all packets sent by the encoder:

```plaintext
message TelemetryHeader {
  optional uint32 encoding = 1
  optional string policy_name = 2;
  optional string version = 3;
  optional string identifier = 4;
  optional uint64 start_time = 5;
  optional uint64 end_time = 6;
  repeated TelemetryTable tables = 7;
}
message TelemetryTable {
  optional string policy_path = 1;
}
repeated bytes row = 2;
"
where:

- encoding is used by receivers to verify that the packet is valid.
- policy name, version and identifier are metadata taken from the policy file.
- start time and end time indicate the duration when the data is collected.
- tables is a list of tables within the packet. This format indicates that it is possible to receive results for multiple schema paths in a single packet.
- For each table:
  - policy path is the schema path.
  - row is one or more byte arrays that represents an encoded GPB.

### Key-value GPB Format

The self-describing key-value GPB format uses a generic .proto file. This file encodes data as a sequence of key-value pairs. The field names are included in the output for the receiver to interpret the data.

The following .proto file shows the field containing the key-value pairs:

```proto
message Telemetry {
  uint64 collection_id = 1;
  string base_path = 2;
  string subscription_identifier = 3;
  string model_version = 4;
  uint64 collection_start_time = 5;
  uint64 msg_timestamp = 6;
  repeated TelemetryField fields = 14;
  uint64 collection_end_time = 15;
}
```

```proto
message TelemetryField {
  uint64 timestamp = 1;
  string name = 2;
  bool augment_data = 3;
  oneof value_by_type {
    bytes bytes_value = 4;
    string string_value = 5;
    bool bool_value = 6;
    uint32 uint32_value = 7;
    uint64 uint64_value = 8;
    sint32 sint32_value = 9;
    sint64 sint64_value = 10;
    double double_value = 11;
    float float_value = 12;
  }
  repeated TelemetryField fields = 15;
}
```

where:

- collection_id, base_path, collection_start_time and collection_end_time provide streaming details.
- subscription_identifier is a fixed value for cadence-driven telemetry. This is used to distinguish from event-driven data.
• model_version contains a string used for the version of the data model, as applicable.

Telemetry Receiver

A telemetry receiver is used as a destination to store streamed data.

A sample receiver that handles both JSON and GPB encodings is available at https://github.com/cisco/bigmuddy-network-telemetry-collector.

A copy of the cisco.proto file is required to compile code for a GPB receiver. The cisco.proto file is available at http://github.com/cisco/logstash-codec-bigmuddy-network-telemetry-gpb/tree/master/resources/xr6.0.0.

If you are building your own collector, use the standard protoc compiler. For example, for the GPB compact encoding:

protoc --python_out . -I=/sw/packages/protoc/current/google/include/:. generic_counters.proto ipv4_counters.proto

where:

• --python_out <out_dir> specifies the location of the resulting generated files. These files are of the form <name>_pb2.py.

• -I <import_path> specifies the path to look for imports. This must include the location of descriptor.proto from Google. (in /sw/packages) and cisco.proto and the .proto files that are compiled.

All files shown in the above example are located in the local directory.