Telemetry Configuration Guide for Cisco ASR 9000 Series Routers, IOS XR Release 6.2.x

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CHAPTER 1

New and Changed Feature Information

This section lists all the new and changed features for the Programmability Configuration Guide.

New and Changed Telemetry Features

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

Feature	Description	Changed in Release	Where Documented
Support for model-driven telemetry over UDP	This feature enables configuring model-driven telemetry over UDP protocol	Release 6.2.2	Configure Dial-out Mode, on page 5
None	No new features introduced	Release 6.2.1	Not applicable

CHAPTER 2

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

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-based Telemetry

Streaming model-based telemetry data to the intended receiver involves:

- Configure Dial-out Mode, on page 5
- Configure Dial-in Mode, on page 11

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 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 17.

The process to configure a dial-out mode involves:

Create a Destination Group

The destination group specifies the destination address, port, encoding and transport that the router uses to send out telemetry data.

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

```
Router(config)#telemetry model-driven
Router(config-model-driven)#destination-group <group-name>

Router(config-model-driven-dest)#address family ipv4 <IP-address> port <port-number>
Router(config-model-driven-dest-addr)#encoding <encoding-format>
Router(config-model-driven-dest-addr)#protocol <transport>
Router(config-model-driven-dest-addr)#commit
```

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:

```
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

Note 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:

```
RP/0/RP0/CPU0:ios#run

Wed Aug 24 05:05:46.206 UTC
[xr-vm_node0_RP0_CPU0:~]$ls -l /misc/config/grpc/dialout/
total 4
-rw-r--r-- 1 root root 4017 Aug 19 19:17 dialout.pem
[xr-vm_node0_RP0_CPU0:~]$
```

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:

```
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:

```
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
```

Note If only the **protocol grpc** is configured without tls option, tls is enabled by default and tls-hostname defaults to the IP address of the destination.

What to Do Next:

Create a sensor group.

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 Dial-out

Note gRPC is supported in only 64-bit platforms.

The following example shows a sensor group `SGroup1` created for dial-out configuration with the YANG model for interface statistics:

```
Router(config)#telemetry model-driven
Router(config-model-driven)#sensor-group SGroup1
Router(config-model-driven-snsr-grp)# sensor-path
Cisco-IOS-XR-infra-statsd-oper:infra-statistics/interfaces/interface/latest/generic-counters
Router(config-model-driven-snsr-grp)# commit
```

What to Do Next:

Create a subscription.

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)#telemetry model-driven
Router(config-model-driven)#subscription <subscription-name>
Router(config-model-driven-subs)#sensor-group-id <sensor-group> sample-interval <interval>

Router(config-model-driven-subs)#destination-id <destination-group>
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
  sensor-path Cisco-IOS-XR-pfi-im-cmd-oper:interfaces/interface-xr/interface
 !

 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

Wed Aug 24 04:49:25.030 UTC
  Group Id        IP              Port    Encoding            Transport   State

  -----------------------------------------------------------------------------
  1               1.1.1.1         1111    none                grpc        ACTIVE
      TLS:1.1.1.1
  2               2.2.2.2         2222    none                grpc        ACTIVE
      TLS:2.2.2.2
  test            172.0.0.0   8801    self-describing-gpb grpc        Active
  test            172.0.0.0   8901    self-describing-gpb grpc        Active
      TLS:chkpt1.com
```

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:          Cisco-IOS-XR-pfi-im-cmd-oper:interfaces/interface-xr/interface
    Sensor Path State:    Resolved
```

```
Destination Groups:
Group Id: test
  Destination IP:       172.0.0.0
  Destination Port:     8801
  Encoding:             self-describing-gpb
  Transport:            grpc
  State:                ACTIVE
  No TLS
  Destination IP:       172.0.0.0
  Destination Port:     8901
  Encoding:             self-describing-gpb
  Transport:            grpc
  State:                ACTIVE
  TLS :                 chkpt1.com
  Total bytes sent:     120703
  Total packets sent:   11
  Last Sent time:       2016-08-24 04:49:53.52169253 +0000

Collection Groups:
------------------
  Id: 1
  Sample Interval:      10000 ms
  Encoding:             self-describing-gpb
  Num of collection:    11
  Collection time:      Min:    69 ms Max:    82 ms
  Total time:           Min:    69 ms Avg:    76 ms Max:    83 ms
  Total Deferred:       0
  Total Send Errors:    0
  Total Send Drops:     0
  Total Other Errors:   0
  Last Collection Start:2016-08-24 04:49:53.52086253 +0000
  Last Collection End:  2016-08-24 04:49:53.52169253 +0000
  Sensor Path:          Cisco-IOS-XR-pfi-im-cmd-oper:interfaces/interface-xr/interface
```

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*.

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.

   ```
   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

Address family              : ipv4
Port                        : 57300
VRF                         : global-vrf
TLS                         : enabled
TLS mutual                  : disabled
Trustpoint                  : none
Maximum requests            : 128
Maximum requests per user   : 10
Maximum streams             : 32
```

```
Maximum streams per user    : 32

TLS cipher suites
  Default                   : none
  Enable                    : none
  Disable                   : none

  Operational enable        : ecdhe-rsa-chacha20-poly1305
                            : ecdhe-ecdsa-chacha20-poly1305
                            : ecdhe-rsa-aes128-gcm-sha256
                            : ecdhe-ecdsa-aes128-gcm-sha256
                            : ecdhe-rsa-aes256-gcm-sha384
                            : ecdhe-ecdsa-aes256-gcm-sha384
                            : ecdhe-rsa-aes128-sha
                            : ecdhe-ecdsa-aes128-sha
                            : ecdhe-rsa-aes256-sha
                            : ecdhe-ecdsa-aes256-sha
                            : aes128-gcm-sha256
                            : aes256-gcm-sha384
                            : aes128-sha
                            : aes256-sha
  Operational disable       : none
```

What to Do Next:

Create a sensor group.

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

Router(config-model-driven-snsr-grp)# commit
```

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>

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

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)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:     44841
    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
  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
```

CHAPTER 4

Core Components of Model-driven Telemetry Streaming

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

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 :

- **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 in the Github repository.
  - **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**