SMPTE RECOMMENDED PRACTICE

YANG Data Model for ST 2059-2 PTP Device Monitoring in Professional Broadcast Applications

Table of Contents

Page

Approved November 10, 2022

Foreword

SMPTE (the Society of Motion Picture and Television Engineers) is an internationally-recognized standards developing organization. Headquartered and incorporated in the United States of America, SMPTE has members in over 80 countries on six continents. SMPTE's Engineering Documents, including Standards, Recommended Practices, and Engineering Guidelines, are prepared by SMPTE's Technology Committees. Participation in these Committees is open to all with a bona fide interest in their work. SMPTE cooperates closely with other standards-developing organizations, including ISO, IEC and ITU.

SMPTE Engineering Documents are drafted in accordance with the rules given in its Standards Operations Manual. This SMPTE Engineering Document was prepared by Technology Committee 32NF Network/Facilities Architecture.

Normative text is text that describes elements of the design that are indispensable or contains the conformance language keywords: "shall", "should", or "may". Informative text is text that is potentially helpful to the user, but not indispensable, and can be removed, changed, or added editorially without affecting interoperability. Informative text does not contain any conformance keywords.

All text in this document is, by default, normative, except: the Introduction, any clause explicitly labeled as "Informative" or individual paragraphs that start with "Note:"

The keywords "shall" and "shall not" indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted.

The keywords "should" and "should not" indicate that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.

The keywords "may" and "need not" indicate courses of action permissible within the limits of the document.

The keyword "reserved" indicates a provision that is not defined at this time, shall not be used, and may be defined in the future. The keyword "forbidden" indicates "reserved" and in addition indicates that the provision will never be defined in the future.

A conformant implementation according to this document is one that includes all mandatory provisions ("shall") and, if implemented, all recommended provisions ("should") as described. A conformant implementation need not implement optional provisions ("may") and need not implement them as described.

Unless otherwise specified, the order of precedence of the types of normative information in this document shall be as follows: Normative prose shall be the authoritative definition; tables shall be next; then formal languages; then figures; and then any other language forms.

Introduction

This clause is entirely informative and does not form an integral part of this Engineering Document.

This Recommended Practice provides a data set for the monitoring of parameters associated with the SMPTE ST 2059-2:2021 profile of IEEE Std 1588-2019 Precision Time Protocol (PTP) in Professional Broadcast Applications.

PTP systems have several equipment elements such as Grandmaster Clock sources that may be locked to a Global Navigation Satellite System (GNSS), Boundary and Transparent Clock PTP aware switches and routers, and PTP Follower devices that are frequency or phase locked to a PTP source. PTP Follower devices include all of equipment associated with production, contribution, distribution, and broadcast, that are ultimately synchronized to the Primary PTP clock source.

The commissioning, and operational monitoring of these complex systems with such a diverse range of devices using PTP, can be simplified if PTP related information is reported in a consistent manner across the entire network.

Data Models have previously been specified by standardization bodies and equipment suppliers in Management Information Bases (MIBs). These MIBs are typically focused on retrieval of state data using Simple Network Management Protocol (SNMP) developed in the late 1980s.

Some service providers and applications now require that the management of the PTP synchronization network be flexible, and more Internet based. This has led the IETF to develop the Network Configuration Protocol NETCONF specified in IETF RFC 6241.

YANG (Yet Another Next Generation) is a data modeling language defined in IETF RFC 7950 and maintained by the IETF NETMOD working group. It is used to model configuration data, state data, remote procedure calls, and notifications for network management protocols such as NETCONF and RESTCONF. YANG can be used to define the format of status information, event notifications and telemetry from end points and network elements.

YANG Data Models have been defined by the IETF for a wide range of applications including Precision Time Protocol, System Management, Network Topologies, Routing Information, and Network Address Translation. It has also been included in work by the IEEE Std 802.3.2-2019, Cablelabs CM-SP-R-OSSI-I18-220613 Annex C, and the Broadband Forum Technical Reports TR-383 and TR-385.

At the time of publication, no notice had been received by SMPTE claiming patent rights essential to the implementation of this Engineering Document. However, attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. SMPTE shall not be held responsible for identifying any or all such patent rights.

1 Scope

This Recommended Practice defines a YANG Data Model for SMPTE ST 2059-2. The Data Model is an adaption of IETF RFC 8575, and conforms to the Network Management Datastore Architecture (NMDA) defined in IETF RFC 8342.

The additions to IETF RFC 8575 in this YANG Data Model specify only the state of the data set for monitoring purposes and do not include specifications for notifications or configuration. These additions include data sets as specified in IEEE Std 1588-2019, SMPTE ST 2059-2, IETF RFC 8173, and data sets related to the GNSS.

The Data Model provides a data set of parameters that are directly linked to published standards or published documents from technology providers, for example: a widely adopted supplier of GNSS devices that is likely to be used in a system using the SMPTE ST 2059-2 PTP profile.

The Data Model assumes that receiving devices will subsequently parse and interpret the data that has been provided and makes no assumptions as to what subsequent processing will be conducted or is required.

This document does not define a communication model or transport mechanism for the Data Model.

2 Normative References

The following standards contains provisions that, through reference in this text, constitute provisions of this standard. Dated references require that the specific edition cited shall be used as the reference. Undated citations refer to the edition of the referenced document (including any amendments) current at the date of publication of this document. All standards are subject to revision, and users of this engineering document are encouraged to investigate the possibility of applying the most recent edition of any undated reference.

IEEE Std 1588-2019 (Revision of IEEE Std 1588-2008), “IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems”, November 2019.

3 Terms and Definition

For the purposes of this document, the following terms and definitions apply:

3.1
Data Model

abstract model that organizes elements of data and standardizes how they relate to one another and to the properties of real-world entities

3.2
IEEE

Institute of Electrical and Electronic Engineers

3.3
Internet Engineering Task Force
IETF

large open international community of network engineers concerned with the evolution of Internet architecture and the smooth operation of the Internet

3.4
Global Navigation Satellite System
GNSS

satellite system that provides autonomous geospatial positioning with global coverage

3.5
Global Positioning System (GPS) service daemon
GPSD

software service daemon that monitors one or more GPS receivers attached to a host computer through serial or USB ports

3.6
Grandmaster Clock

clock within a PTP domain that is the ultimate source of time for clock synchronization using the Precision Time Protocol as defined in IEEE Std 1588-2019 Clause 3.1.17

3.7
Precision Time Protocol
PTP

time communication protocol as defined in IEEE Std 1588-2019

3.8
PTP Follower

PTP instance as defined in IEEE Std 1588-2019 Clause 3.1.72

3.9
PTP Leader

PTP instance as defined in IEEE Std 1588-2019 Clause 3.1.32

3.10
Coordinated Universal Time
UTC

timescale maintained by the Bureau International des Poids et Mesures (BIPM) and the International Earth Rotation and Reference Systems Service (IERS), which forms the basis of a coordinated dissemination of standard frequencies and time signals

It corresponds exactly in rate with International Atomic Time but differs from it by an integral number of seconds.

[Source: IEC 60050-713, item 713-05-20]

3.11
Yet Another Next Generation
YANG

data modeling language maintained by the IETF NETMOD working group, for the definition of data sent over network management protocols such as NETCONF and RESTCONF

4 YANG Data Model

Equipment conforming to this Recommended Practice shall use the Parameter Set defined in the YANG Data Model urn:smpte:yang:rp-02059-015-2023-01

The YANG Data Model defined by this Recommended Practice is rp2059-15a-2023

SHA256-Checksum:

F5C614A830FA9C3DCBC97E4FA7374C037D536D3BE9D6AC6FADAEA159522B7B5F

The entire Data Model need not be implemented; implementations may use any part of it.

Some sections of the Data Model contain parameters with both read (monitoring) and write (configuration or control) capability. Implementations conforming to this Recommended Practice are only required to implement the read or monitoring parts of the Data Model.

An informative overview of the high-level structure of the Data Model can be found in Annex A, and an informative overview of the GNSS receiver data model structure can be found in Annex C.

A simplified YANG tree diagram representation of the YANG Data Model defined by this Recommended Practice, conforming to IETF RFC 8340, is rp2059-15b-2023

SHA256-Checksum:

F9339758AEC5300E96657D147627DF1ECA530A17F6211FAE65BFA220BCCF62DC

A suggested method of reporting implemented parameters in a consistent manner based on the YANG tree diagram can be found in Annex B.

5 Message Timestamps

Messages containing Parameter Sets conforming to this Recommended Practice shall use a Timestamping Clock conforming to IEEE Std 1588-2019 Clause 7.3.4.3

Egress messages conforming to this Recommended Practice shall have an egress Timestamp that uses the Local PTP Clock of the sending device that pertains to that message. The PTP Timestamp shall be a decimal representation of the Timestamp struct defined in IEEE Std 1588-2019 Clause 5.3.3

It is recommended that messages are timestamped by the receiving device at ingress with a timestamp using a Clock that is independent of the PTP system that is being monitored.

6 Communication Model

This Recommended Practice does not define a Communication Model. Implementations may use any method for the communication of the Parameter Set defined in the Data Model of this Recommended Practice. In conjunction with YANG Data Models, IETF RFC 6241 and IETF RFC 8040 are frequently used network management communication model for such applications.

In case where a non-supported parameter is queried, a device conforming to this recommendation shall return a response for the queried parameter with an empty field containing no value. Doing so will prevent assumptions such as a communications issue. If a random, otherwise assigned, or reserved value is used this could lead to misinterpretation of the state of the queried field.

7 Performance Monitoring Measurement Periods

Performance Monitoring data defined in IEEE Std. 1588-2019 Annex J is captured and stored as a list of records. The data collection interval is a single record every 15 minutes and a single record every 24 hours. The start of such an interval is equal to the end of the previous interval.

In order to be able to compare measurement records, where possible, different pieces of equipment should provide consistent reporting intervals throughout the network based on UTC calculated from PTP. When it is not possible to provide consistent reporting intervals, e.g., when there is a fault condition, then equipment should use a best effort approach. An alignment error of less than plus or minus 10 seconds is sufficient for the purposes of aligning the 15-minute performance monitoring measurement periods.

For the purposes of Performance Monitoring Periods, if the PTP leader instance is signaling in the Announce Messages that:

- The currentUtcOffsetValid flag is TRUE
- And grandmasterClockQuality has a clockClass of 6, 7, 52, 187 or 248 in conjunction with PTP timescale TRUE
- And grandmasterClockQuality has a clockAccuracy which indicates the time is accurate to within 10 seconds
- And timeSource is not set to internal_oscillator where the epoch is determined in an arbitrary or unknown manner.

Equipment conforming to this Recommended Practice shall ensure that:

- UTC time shall be used to create the performance monitoring window timestamps.
- The UTC time shall be computed using the mechanism specified in IEEE 1588-2019 Clause 7.2.4
- The 15-minute intervals shall be aligned with the quarter of an hour, i.e. 00:00, 15:00, 30:00 45:00 UTC synthesized from PTP time.
- The 24-hour interval shall start at beginning-of-day (00:00:00) UTC synthesized from PTP time.

If the PTP leader instance is signaling in the Announce Messages that:

- The currentUtcOffsetValid flag is FALSE
- Or the grandmasterClockQuality has a clockClass of 13, 14 or 58 or 193 or 248 in conjunction with ARB timescale, where ptpTimescale is FALSE
- Or grandmasterClockQuality has a clockAccuracy which does not indicate that the time is accurate to within 10 seconds or less
- Or the timeSource is set to internal_oscillator

Equipment conforming to this Recommended Practice shall attempt to calculate UTC on a best effort basis and the measurement-valid flag shall be set to FALSE

8 YANG Timestamp

The pm-time leaf in the performance-monitoring-ds container has the type yang:timestamp. The description field in the data model indicates that the Epoch of the timestamp is to be defined by the implementation.

The YANG timestamp defined in IETF RFC 6991, represents the value of an associated YANG timeticks unsigned 32-bit modulo counter that increments every 10 milliseconds. The YANG timestamp and associated timeticks conforming to this Recommended Practice shall be initialized to zero on device boot-up. They should be locked to the local device frequency source used to derive device system time (local time), and shall increment every 10 milliseconds.

NOTE The YANG timestamp can be used in conjunction with the Message Timestamps defined in Clause 5. The Message Timestamps will be discontinuous when PTP lock is acquired or reacquired after a holdover event, and under normal operation the YANG Timestamp will wrap every 497 days. As it is unlikely that the two timestamps will be discontinuous simultaneously, the combination of the two can be used to provide continuity of sequencing of events or measurement records.

Annex A Data Structure Model Overview (Informative)

A.1 High-level Overview

At a very high level the Data Model module is made up of the following constructs:

1. module name, namespace definition, description and revision information
2. typedef definitions used within the Data Model
3. grouping definitions used within the Data Model
4. feature definitions used within the Data Model
    - unicast-negotiation
    - unicast-discovery
    - performance-monitoring
    - *gnss
    - *st-2059
    - *grandmaster
    - *rfc-8173
5. containers that contain child nodes that define the data sets (ds) of the Data Model
    1. ptp (read-write)
    2. *gnss (read only data set)
    3. *ptp-smpte (read only data set)
    4. *grandmaster (read only data set)
    5. *rfc-8173-ds (read only data set)

The features and containers marked with a '*' are defined by SMPTE specifically for the monitoring of Professional Broadcast Equipment related to PTP and contain a read only data set.

The feature definitions and the ptp container that are not marked with a '*', define generic PTP data sets that are intended for both monitoring and control. This is based on a Data Model that has been developed for submission to future work on a YANG Data Model by the IEEE based on IEEE Std. 1588-2019 in a manner that is compatible with IETF RFC 8575 which in turn is based on IEEE Std. 1588-2008. These data sets are designed for both control and monitoring and are read-write. The features and parameter set have been reduced to match the requirements of the SMPTE ST 2059-2 ptp profile. The retained features have not been amended.

A.2 Optional YANG Features

A 'feature' is a YANG mechanism that is defined in IETF RFC 7950 Clause 5.6.2. It allows a portion of the model to be conditional in a manner that is controlled by the server and is therefore optional.

This mechanism allows the model to express constructs that are not universally present in all servers. If a server supports a YANG feature, then the corresponding portions of the module are valid for that server. If the server does not support the YANG feature, those parts of the module are not valid. Applications can then adapt their behavior to match the YANG features that are supported.

In this document, four optional YANG features have been defined specifically for the monitoring of PTP related aspects of Professional Broadcast Applications and each is associated with their respective YANG container.

A.3 YANG Containers

A.3.1 About YANG Containers

The definition of the YANG ‘container’ statement in IETF RFC 7950 Clause 7.5 is that it is “used to define an interior data node in the schema tree.” It goes on to say that:

“A container node does not have a value, but it has a list of child nodes in the data tree. The child nodes are defined in the container sub-statements.”

“YANG supports two styles of containers, those that exist only for organizing the hierarchy of data nodes and those whose presence in the data tree has an explicit meaning”

The Data Model possesses five container nodes at the top level of the hierarchy:

A.3.2 ptp

This container contains all nodes for the PTP data sets. The parameters within apply to any PTP instance in a product or PTP node, be it a PTP Ordinary Clock, Boundary Clock, Transparent Clock, Leader or Follower.

Parameters from IETF RFC 8575 that are no longer supported by IEEE Std. 1588-2019 are retained but have the YANG status of ‘deprecated’. IETF RFC 7950 defines ‘deprecated’ as “indicating an obsolete definition, but it permits new/continued implementation in order to foster interoperability with older/existing implementations.”

A.3.3 gnss

This container provides monitoring access to the set of parameters associated with the GNSS Antenna and satellite lock status and is associated with the gnss-monitoring feature.

This is built on the work of the Open Source Community and includes parameters and structural elements from the GPSD.

The following child container sub-statements are defined:

a. **sky-object-ds**: provides a mechanism to describe:
    a. The list of satellites in view at a given Time and Date identified by a combination of System ID (constellation) Satellite ID (vehicle) and Signal ID
    b. The signal strength from the satellite
    c. The monitoring of the health of the satellite
    d. The carrier-to-noise ratio of the signal
    e. The health of the satellite receiver for that satellite
b. **tvp-object-ds:** Parameters relating to Time, Velocity and Position of the GNSS receiver: latitude, longitude, and altitude.
c. **osc-object-ds**: Parameters relating to the status of a GNSS-disciplined oscillator and its estimated time offset between GPS Pulse Per Second (PPS) and the oscillator PPS
d. **antenna-status-ds**: Parameters relating to the status of a GNSS reference clock and the status of the main and back-up antenna.

A.3.4 ptp-SMPTE

This container provides monitoring access to the set of parameters associated with SMPTE ST 2059-2 and is associated with the st-2059-monitoring feature.

The leaf and child container sub-statements include:

a. The reporting of SMPTE PTP Profile Communication Mode being used as defined in SMPTE ST 2059-2:2021 Clause 6.10
b. The reporting of the Variance Measurement sample period as defined in SMPTE ST 2059-2:2021 6.5.4, and IEEE Std 1588-2008 Clause 7.6.3.2
c. The reporting of parameters associated controlling with the synthesis or generation of SMPTE Time-of-Day Timecode from PTP as defined in SMPTE ST 2059-2:2021 Clause 6.12
d. Management TLV message counters
e. Current leader-follower-delay and follower-leader delay

A.3.5 grandmaster

This container defines the monitoring of parameters associated with the status of a device designed to be a Primary PTP source typically referred to in Professional Broadcast systems as a Sync Pulse Generator. It is associated with the grandmaster-monitoring feature, and includes:

a. The gm-lock-state as defined in ST 2059-2:2021 Clause 6.12 table 2 gmLockingStatus TLV
b. GNSS sub-system lock status
c. External reference locking source and status
d. Holdover status

A.3.6 rfc-8173

This container defines the monitoring of selected parameters from IETF RFC 8173 PTP MIB and is associated with the rfc-8173 feature. These include:

a. The number of associated ports: Number of associated PTP Follower sessions for a PTP Leader or the number of PTP Leaders available to a PTP Follower port. IETF RFC 8173 ptpbaseClockPortNumOfAssociatedPorts
b. A count of the number of packets sent for this clock. IETF RFC 8173 ptpbaseClockRunningPacketsSent
c. A count of the number of packets received for this clock. IETF RFC 8173 ptpbaseClockRunningPacketsReceived
d. A count of the number of errored packets associated with the associated port.
e. The PTP clock profile being used
f. The clock state of the PTP engine

Annex B (Informative) Reporting of Implemented Parameters

As specified in Clause 4 of this Recommended Practice, as there is no requirement to implement the entire Parameter Set, implementers can choose to use any part of the Data Model.

It is therefore advantageous to users of this Recommended Practice to have a method of consistently reporting parameters that have been implemented in a way that allows for straightforward comparison between implementations.

The YANG module tree diagram is specified in IETF RFC 8340 and can be automatically generated from the Data Model using the standard YANG tool chain. It can therefore be easily regenerated in a consistent manner. For convenience, the YANG tree diagram is also provided as part of the package associated with this Recommendation.

The YANG tree diagram has the property where each node in a YANG module is printed as: <status>--<flags> <name> <opts> <type> <if-features>. The <opts> uses a question mark “?” to indicate an optional leaf, choice, anydata or anyxml. The <if-feature> is printed within curly brackets and a question mark “{….}?” The presence of the question mark “?” can therefore be used as an indication that a member of the data-set is a leaf parameter or feature, both of which are of interest for the reporting of implemented parameters.

The method of reporting is to:

- Copy and Paste the YANG tree view text into a Spreadsheet. This will occupy the first column of the spreadsheet, with each line of text occupying a separate row of the spreadsheet.
- In the adjacent column of the first row, enter the product details and software version.
- Where a row contains parameter terminated by a “?”, if that parameter is supported by an implementation, enter “Yes” into the corresponding row of the adjacent column.

An example Data Model Coverage Report associated with this Recommended Practice is rp2059-15c-2023.

Annex C (Informative) The GNSS Receiver Data Model Structure

A diagrammatic representation of the GNSS Data Model and the grandmaster external reference sources is shown in Figure C.1. The Data Model allows for multiple grandmaster instances in a device.

Each grandmaster instance can derive its clock and/or time source from one or several simultaneous external reference sources including a reference derived from a GNSS Receiver. In the example shown in Figure C.1, the gm-current-external-reference-source of the first grandmaster instance is being derived from the first GNSS receiver. The second grandmaster instance is using a 10 MHz frequency reference in conjunction with SMPTE timecode.

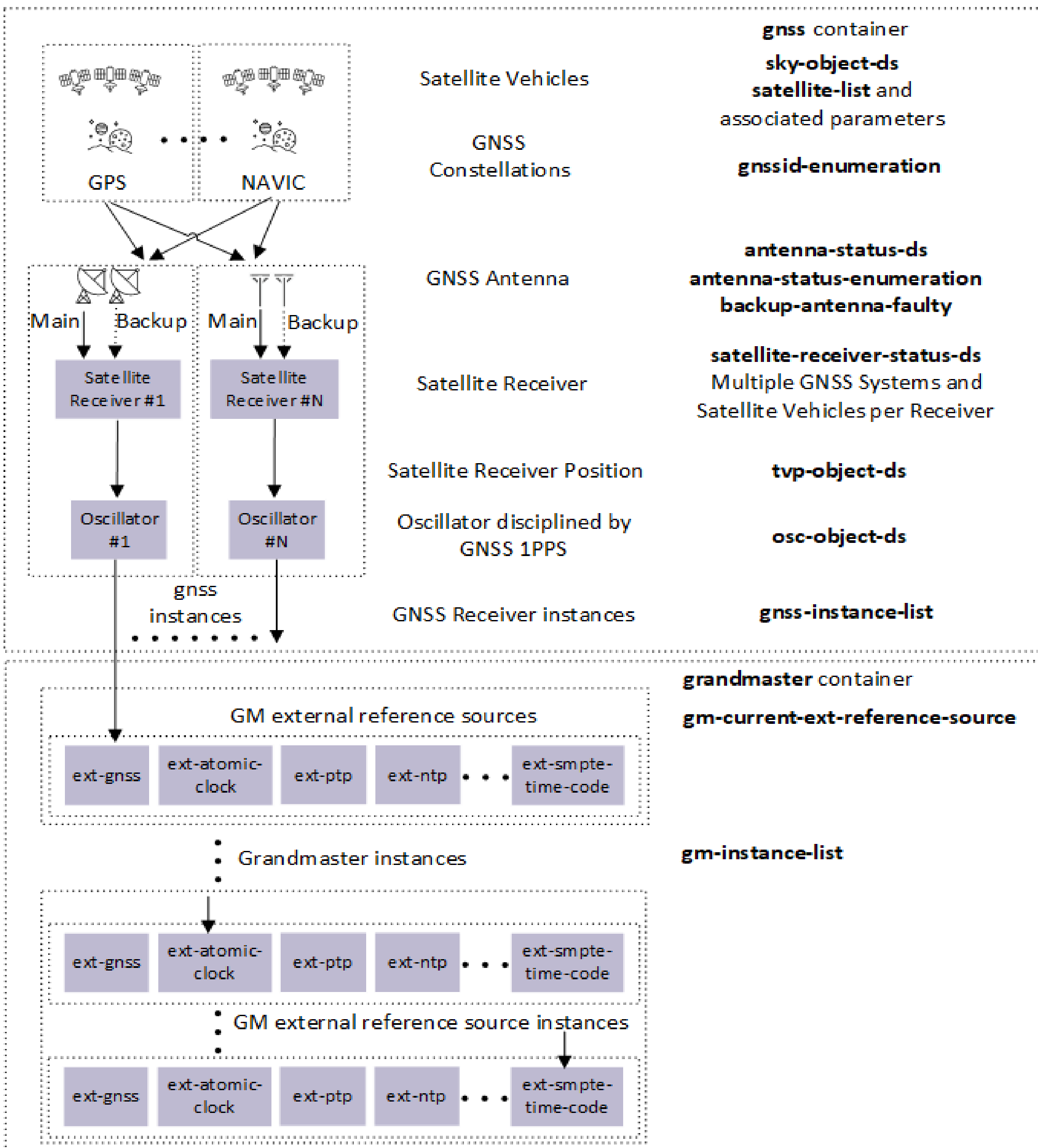

Figure C.1 — Grandmaster instances example.

The Data Model supports one or more instances of a GNSS receiver in a device. Each GNSS instance comprises a main and backup antenna, a satellite receiver and an oscillator that is disciplined by the 1PPS generated by the satellite receiver. Each GNSS instance can report:

- The Satellite Receiver status, the number of vehicles in view and the number of vehicles used in the fix for each GNSS satellite constellation.
- The status of the antenna system.
- The list of Satellite Vehicles in the skyview identified by a combination of the GNSS System ID (constellation), Satellite ID (vehicle number for that constellation) and Signal ID (frequency band).
- The Signal strength and carrier to noise ratio for each satellite vehicle (SV) and the vehicle overall health.
- The current longitude, latitude, and altitude.

NOTE The Data Model makes no assumptions as to the external reference source physical inputs to a device. E.g., SMPTE Timecode could be provided as Vertical Interval Timecode (VITC) carried on either an analog sync reference or a serial digital interface (SDI), or as Linear Timecode (LTC) on a serial communications interface. Where there are multiple physical inputs to a device or a logical mapping from a physical input to the Data Model, then the active physical interface can be signaled via the device API.

Annex D (Informative) Additional Elements

This annex lists non-prose elements of this document, as shown in Table C.1:

Table D.1 — Non-prose elements of this document.

Non-prose element	Description
a	The YANG Data Model (normative): rp2059-15a-2023.yang SHA256 checksum: F5C614A830FA9C3DCBC97E4FA7374C037D536D3BE9D6AC6FADAEA159522B7B5F
b	The YANG Tree Representation of the YANG Data Model (informative): rp2059-15b-2023.txt SHA256 checksum: F9339758AEC5300E96657D147627DF1ECA530A17F6211FAE65BFA220BCCF62DC
c	An example Data Model Coverage Report (informative): rp2059-15c-2023.xlsx

The elements pertaining to SMPTE RP 2059-15 are located in GitHub repositories at the following URLs:

- https://github.com/SMPTE/rp2059-15a
- https://github.com/SMPTE/rp2059-15b
- https://github.com/SMPTE/rp2059-15c

Bibliography (Informative)

Broadband Forum Technical Report TR-383: “Common YANG Modules for Access Networks”

Broadband Forum Technical Report TR-385: “ITU-T PON YANG Modules”

Cablelabs CM-SP-R-OSSI-I18-220613 “Data-Over-Cable Service Interface Specifications MHAv2, Remote PHY OSS Interface Specification, CM-SP-R-OSSI-I18-220613”

GPSD GPS service daemon, Raymond, E., Kuethe. C., Miller, G., et al., https://gpsd.gitlab.io/gpsd/index.html

IEEE Std 802.3.2-2019, "IEEE Standard for Ethernet - YANG Data Model Definitions," in *IEEE Std 802.3.2-2019*, vol., no., pp.1-155, 21 June 2019, doi: 10.1109/IEEESTD.2019.8737019.

IEEE Std 1588-2008, "IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems," in *IEEE Std 1588-2008 (Revision of IEEE Std 1588-2002)*, vol., no., pp.1-269, 24 July 2008, doi: 10.1109/IEEESTD.2008.4579760.

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IETF RFC 6991 Schoenwaelder, J. Ed. “Common YANG Data Types”, DOI 10.17487/RFC6991 July 2013, https://www.rfc-editor.org/info/rfc6991

IETF RFC 8040 Bierman, A., Bjorklund, M., K. Watsen, "RESTCONF Protocol", DOI 10.17487/RFC8040, January 2017, https://www.rfc-editor.org/info/rfc8040

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SMPTE ST 2059-2:2021, "ST 2059-2:2021 - SMPTE Standard - SMPTE Profile for Use of IEEE-1588 Precision Time Protocol in Professional Broadcast Applications," in *ST 2059-2:2021*, vol., no., pp.1-22, 4 June 2021, doi: 10.5594/SMPTE.ST2059-2.2021.

