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Subscription to YANG Notifications

Abstract

This document defines a YANG data model and associated mechanisms enabling subscriber-specific subscriptions to a publisher's event streams. Applying these elements allows a subscriber to request and receive a continuous, customized feed of publisher-generated information.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 7841.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at https://www.rfc-editor.org/info/rfc8639.

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1. Introduction

This document defines a YANG data model and associated mechanisms enabling subscriber-specific subscriptions to a publisher's event streams. This effectively enables a "subscribe, then publish" capability where the customized information needs and access permissions of each target receiver are understood by the publisher before subscribed event records are marshaled and pushed. The receiver then gets a continuous, customized feed of publisher-generated information.

While the functionality defined in this document is transport agnostic, transports like the Network Configuration Protocol (NETCONF) [RFC6241] or RESTCONF [RFC8040] can be used to configure or dynamically signal subscriptions. Bindings for subscribed event record delivery for NETCONF and RESTCONF are defined in [RFC8640] and [RESTCONF-Notif], respectively.

The YANG data model defined in this document conforms to the Network Management Datastore Architecture defined in [RFC8342].

1.1. Motivation

Various limitations to subscriptions as described in [RFC5277] were alleviated to some extent by the requirements provided in [RFC7923]. Resolving any remaining issues is the primary motivation for this work. Key capabilities supported by this document include:

- multiple subscriptions on a single transport session
- support for dynamic and configured subscriptions
- modification of an existing subscription in progress
- per-subscription operational counters
- negotiation of subscription parameters (through the use of hints returned as part of declined subscription requests)
- subscription state change notifications (e.g., publisher-driven suspension, parameter modification)
- independence from transport

1.2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

- Client: Defined in [RFC8342].
- Configuration: Defined in [RFC8342].
- Configuration datastore: Defined in [RFC8342].

- Configured subscription: A subscription installed via configuration into a configuration datastore.

- Dynamic subscription: A subscription created dynamically by a subscriber via a Remote Procedure Call (RPC).

- Event: An occurrence of something that may be of interest. Examples include a configuration change, a fault, a change in status, crossing a threshold, or an external input to the system.

- Event occurrence time: A timestamp matching the time an originating process identified as when an event happened.

- Event record: A set of information detailing an event.

- Event stream: A continuous, chronologically ordered set of events aggregated under some context.

- Event stream filter: Evaluation criteria that may be applied against event records in an event stream. Event records pass the filter when specified criteria are met.

- Notification message: Information intended for a receiver indicating that one or more events have occurred.

- Publisher: An entity responsible for streaming notification messages per the terms of a subscription.

- Receiver: A target to which a publisher pushes subscribed event records. For dynamic subscriptions, the receiver and subscriber are the same entity.

- Subscriber: A client able to request and negotiate a contract for the generation and push of event records from a publisher. For dynamic subscriptions, the receiver and subscriber are the same entity.

- Subscription: A contract with a publisher, stipulating the information that one or more receivers wish to have pushed from the publisher without the need for further solicitation.

All YANG tree diagrams used in this document follow the notation defined in [RFC8340].

1.3. Solution Overview

This document describes a transport-agnostic mechanism for subscribing to and receiving content from an event stream in a publisher. This mechanism operates through the use of a subscription.

Two types of subscriptions are supported:

1. Dynamic subscriptions, where a subscriber initiates a subscription negotiation with a publisher via an RPC. If the publisher is able to serve this request, it accepts it and then starts pushing notification messages back to the subscriber. If the publisher is not able to serve it as requested, then an error response is returned. This response MAY include hints for subscription parameters that, had they been present, may have enabled the dynamic subscription request to be accepted.

2. Configured subscriptions, which allow the management of subscriptions via a configuration so that a publisher can send notification messages to a receiver. Support for configured subscriptions is optional, with its availability advertised via a YANG feature.

Additional characteristics differentiating configured from dynamic subscriptions include the following:

- The lifetime of a dynamic subscription is bound by the transport session used to establish it. For connection-oriented stateful transports like NETCONF, the loss of the transport session will result in the immediate termination of any associated dynamic subscriptions. For connectionless or stateless transports like HTTP, a lack of receipt acknowledgment of a sequential set of notification messages and/or keep-alives can be used to trigger a termination of a dynamic subscription. Contrast this to the lifetime of a configured subscription. This lifetime is driven by relevant configuration being present in the publisher's applied configuration. Being tied to configuration operations implies that (1) configured subscriptions can be configured to persist across reboots and (2) a configured subscription can persist even when its publisher is fully disconnected from any network.

- Configured subscriptions can be modified by any configuration client with write permission on the configuration of the subscription. Dynamic subscriptions can only be modified via an RPC request made by the original subscriber or by a change to configuration data referenced by the subscription.

Note that there is no mixing and matching of dynamic and configured operations on a single subscription. Specifically, a configured subscription cannot be modified or deleted using RPCs defined in this document. Similarly, a dynamic subscription cannot be directly modified or deleted by configuration operations. It is, however, possible to perform a configuration operation that indirectly impacts a dynamic subscription. By changing the value of a preconfigured filter referenced by an existing dynamic subscription, the selected event records passed to a receiver might change.

Also note that transport-specific specifications based on this specification MUST detail the lifecycle of dynamic subscriptions as well as the lifecycle of configured subscriptions (if supported).

A publisher MAY terminate a dynamic subscription at any time. Similarly, it MAY decide to temporarily suspend the sending of notification messages for any dynamic subscription, or for one or more receivers of a configured subscription. Such termination or suspension is driven by internal considerations of the publisher.

1.4. Relationship to RFC 5277

This document is intended to provide a superset of the subscription capabilities initially defined in [RFC5277]. It is important to understand what has been reused and what has been replaced, especially when extending an existing implementation that is based on [RFC5277]. Key relationships between these two documents include the following:

- This document defines a transport-independent capability; [RFC5277] is specific to NETCONF.
- For the new operations, the data model defined in this document is used instead of the data model defined in Section 3.4 of [RFC5277].
- The RPC operations in this document replace the operation <create-subscription> as defined in [RFC5277], Section 4.
- The <notification> message of [RFC5277], Section 4 is used.
- The included contents of the "NETCONF" event stream are identical between this document and [RFC5277].
- A publisher MAY implement both the Notification Management Schema and RPCs defined in [RFC5277] and this document concurrently.

- Unlike [RFC5277], this document enables a single transport session to intermix notification messages and RPCs for different subscriptions.

- A subscription "stop-time" can be specified as part of a notification replay. This supports a capability analogous to the <stopTime> parameter of [RFC5277]. However, in this specification, a "stop-time" parameter can also be applied without replay.

2. Solution

Per the overview provided in Section 1.3, this section details the overall context, state machines, and subsystems that may be assembled to allow the subscription of events from a publisher.

2.1. Event Streams

An event stream is a named entity on a publisher; this entity exposes a continuously updating set of YANG-defined event records. An event record is an instantiation of a "notification" YANG statement. If the "notification" is defined as a child to a data node, the instantiation includes the hierarchy of nodes that identifies the data node in the datastore (see Section 7.16.2 of [RFC7950]). Each event stream is available for subscription. Identifying a) how event streams are defined (other than the NETCONF stream), b) how event records are defined/generated, and c) how event records are assigned to event streams is out of scope for this document.

There is only one reserved event stream name in this document: "NETCONF". The "NETCONF" event stream contains all NETCONF event record information supported by the publisher, except where an event record has explicitly been excluded from the stream. Beyond the "NETCONF" stream, implementations MAY define additional event streams.

As YANG-defined event records are created by a system, they may be assigned to one or more streams. The event record is distributed to a subscription’s receiver(s) where (1) a subscription includes the identified stream and (2) subscription filtering does not exclude the event record from that receiver.

Access control permissions may be used to silently exclude event records from an event stream for which the receiver has no read access. See [RFC8341], Section 3.4.6 for an example of how this might be accomplished. Note that per Section 2.7 of this document, subscription state change notifications are never filtered out.

If no access control permissions are in place for event records on an event stream, then a receiver MUST be allowed access to all the event records. If subscriber permissions change during the lifecycle of a subscription and event stream access is no longer permitted, then the subscription MUST be terminated.

Event records MUST NOT be delivered to a receiver in a different order than the order in which they were placed on an event stream.

2.2. Event Stream Filters

This document defines an extensible filtering mechanism. The filter itself is a boolean test that is placed on the content of an event record. A "false" filtering result causes the event record to be excluded from delivery to a receiver. A filter never results in information being stripped from an event record prior to that event record being encapsulated in a notification message. The two optional event stream filtering syntaxes supported are [XPATH] and subtree [RFC6241].

If no event stream filter is provided in a subscription, all event records on an event stream are to be sent.

2.3. QoS

This document provides for several Quality of Service (QoS) parameters. These parameters indicate the treatment of a subscription relative to other traffic between publisher and receiver. Included are:

- A "dscp" marking to differentiate prioritization of notification messages during network transit.
- A "weighting" so that bandwidth proportional to this weighting can be allocated to this subscription relative to other subscriptions.
- A "dependency" upon another subscription.

If the publisher supports the "dscp" feature, then a subscription with a "dscp" leaf MUST result in a corresponding Differentiated Services Code Point (DSCP) marking [RFC2474] being placed in the IP header of any resulting notification messages and subscription state change notifications. A publisher MUST respect the DSCP markings for subscription traffic egressing that publisher.

Different DSCP code points require different transport connections. As a result, where TCP is used, a publisher that supports the "dscp" feature must ensure that a subscription's notification messages are returned in a single TCP transport session where all traffic shares the subscription's "dscp" leaf value. If this cannot be guaranteed, any "establish-subscription" RPC request SHOULD be rejected with a "dscp-unavailable" error.

For the "weighting" parameter, when concurrently dequeuing notification messages from multiple subscriptions to a receiver, the publisher MUST allocate bandwidth to each subscription proportional to the weights assigned to those subscriptions. "Weighting" is an optional capability of the publisher; support for it is identified via the "qos" feature.

If a subscription has the "dependency" parameter set, then any buffered notification messages containing event records selected by the parent subscription MUST be dequeued prior to the notification messages of the dependent subscription. If notification messages have dependencies on each other, the notification message queued the longest MUST go first. If a "dependency" included in an RPC references a subscription that does not exist or is no longer accessible to that subscriber, that "dependency" MUST be silently removed. "Dependency" is an optional capability of the publisher; support for it is identified via the "qos" feature.

"Dependency" and "weighting" parameters will only be respected and enforced between subscriptions that share the same "dscp" leaf value.

There are additional types of publisher capacity overload that this specification does not address, as they are out of scope. For example, the prioritization of which subscriptions have precedence when the publisher CPU is overloaded is not discussed. As a result, implementation choices will need to be made to address such considerations.

2.4. Dynamic Subscriptions

Dynamic subscriptions are managed via protocol operations (in the form of RPCs, per [RFC7950], Section 7.14) made against targets located in the publisher. These RPCs have been designed extensibly so that they may be augmented for subscription targets beyond event streams. For examples of such augmentations, see the RPC augmentations in the YANG data model provided in [RFC8641].

2.4.1. Dynamic Subscription State Machine

Below is the publisher's state machine for a dynamic subscription. Each state is shown in its own box. It is important to note that such a subscription doesn't exist at the publisher until an "establish-subscription" RPC is accepted. The mere request by a subscriber to establish a subscription is not sufficient for that subscription to be externally visible. Start and end states are depicted to reflect subscription creation and deletion events.

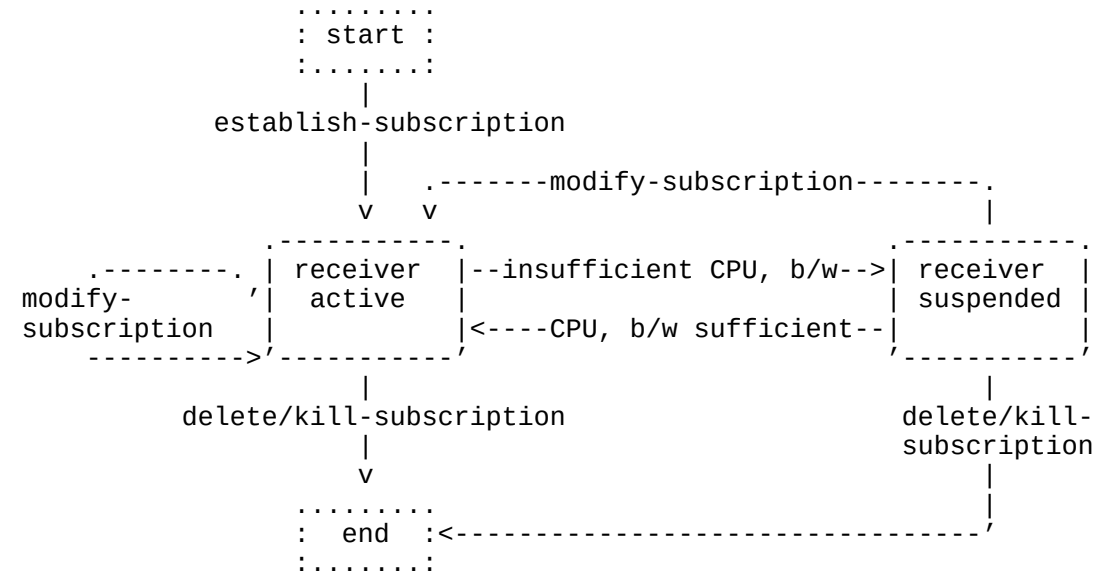


Figure 1: Publisher's State Machine for a Dynamic Subscription

Of interest in this state machine are the following:

- Successful "establish-subscription" or "modify-subscription" RPCs move the subscription to the "active" state.
- Failed "modify-subscription" RPCs will leave the subscription in its previous state, with no visible change to any streaming updates.
- A "delete-subscription" or "kill-subscription" RPC will end the subscription, as will reaching a "stop-time".

- A publisher may choose to suspend a subscription when there is not sufficient CPU or bandwidth available to service the subscription. This is announced to the subscriber via the "subscription-suspended" subscription state change notification.

- A suspended subscription may be modified by the subscriber (for example, in an attempt to use fewer resources). Successful modification returns the subscription to the "active" state.

- Even without a "modify-subscription" request, a publisher may return a subscription to the "active" state when sufficient resources are again available. This is announced to the subscriber via the "subscription-resumed" subscription state change notification.

2.4.2. Establishing a Dynamic Subscription

The "establish-subscription" RPC allows a subscriber to request the creation of a subscription.

The input parameters of the operation are:

- A "stream" name, which identifies the targeted event stream against which the subscription is applied.

- An event stream filter, which may reduce the set of event records pushed.

- If the transport used by the RPC supports multiple encodings, an optional "encoding" for the event records pushed. If no "encoding" is included, the encoding of the RPC MUST be used.

- An optional "stop-time" for the subscription. If no "stop-time" is present, notification messages will continue to be sent until the subscription is terminated.

- An optional "replay-start-time" for the subscription. The "replay-start-time" MUST be in the past and indicates that the subscription is requesting a replay of previously generated information from the event stream. For more on replay, see Section 2.4.2.1. If there is no "replay-start-time", the subscription starts immediately.

If the publisher can satisfy the "establish-subscription" request, it replies with an identifier for the subscription and then immediately starts streaming notification messages.

Below is a tree diagram for "establish-subscription". All objects contained in this tree are described in the YANG module in Section 4.

```
    +---x establish-subscription
       +---w input
       |  +---w (target)
       |  |  +--:(stream)
       |  |     +---w (stream-filter)?
       |  |     |  +--:(by-reference)
       |  |     |  |  +---w stream-filter-name
       |  |     |  |          stream-filter-ref
       |  |     |  +--:(within-subscription)
       |  |     |     +---w (filter-spec)?
       |  |     |        +--:(stream-subtree-filter)
       |  |     |        |  +---w stream-subtree-filter?   <anydata>
       |  |     |        |          {subtree}?
       |  |     |        +--:(stream-xpath-filter)
       |  |     |           +---w stream-xpath-filter?
       |  |     |                   yang:xpath1.0 {xpath}?
       |  |     +---w stream                                stream-ref
       |  |     +---w replay-start-time?
       |  |             yang:date-and-time {replay}?
       |  +---w stop-time?
       |  |       yang:date-and-time
       |  +---w dscp?                                       inet:dscp
       |  |       {dscp}?
       |  +---w weighting?                                  uint8
       |  |       {qos}?
       |  +---w dependency?
       |  |       subscription-id {qos}?
       |  +---w encoding?                                   encoding
       +--ro output
          +--ro id                             subscription-id
          +--ro replay-start-time-revision?    yang:date-and-time
                  {replay}?
```

Figure 2: "establish-subscription" RPC Tree Diagram

A publisher MAY reject the "establish-subscription" RPC for many reasons, as described in Section 2.4.6. The contents of the resulting RPC error response MAY include details on input parameters that, if considered in a subsequent "establish-subscription" RPC, may result in successful subscription establishment. Any such hints MUST be transported in a yang-data "establish-subscription-stream-error-info" container included in the RPC error response.

Below is a tree diagram for "establish-subscription-stream-error-info" RPC yang-data. All objects contained in this tree are described in the YANG module in Section 4.

```
yang-data establish-subscription-stream-error-info
  +--ro establish-subscription-stream-error-info
     +--ro reason?                   identityref
     +--ro filter-failure-hint?      string
```

Figure 3: "establish-subscription-stream-error-info" RPC yang-data Tree Diagram

2.4.2.1. Requesting a Replay of Event Records

Replay provides the ability to establish a subscription that is also capable of passing event records generated in the recent past. In other words, as the subscription initializes itself, it sends any event records in the target event stream that meet the filter criteria that have an event time that is after the "replay-start-time" and also have an event time before the "stop-time" should this "stop-time" exist. The end of these historical event records is identified via a "replay-completed" subscription state change notification. Any event records generated since the subscription establishment may then follow. For a particular subscription, all event records will be delivered in the order in which they are placed in the event stream.

Replay is an optional feature that is dependent on an event stream supporting some form of logging. This document puts no restrictions on the size or form of the log, where it resides in the publisher, or when event record entries in the log are purged.

The inclusion of a "replay-start-time" in an "establish-subscription" RPC indicates a replay request. If the "replay-start-time" contains a value that is earlier than what a publisher’s retained history supports, then if the subscription is accepted, the actual publisher’s revised start time MUST be set in the returned "replay-start-time-revision" object.

A "stop-time" parameter may be included in a replay subscription. For a replay subscription, the "stop-time" MAY be earlier than the current time but MUST be later than the "replay-start-time".

If the given "replay-start-time" is later than the time marked in any event records retained in the replay buffer, then the publisher MUST send a "replay-completed" notification immediately after a successful "establish-subscription" RPC response.

If an event stream supports replay, the "replay-support" leaf is present in the "/streams/stream" list entry for the event stream. An event stream that does support replay is not expected to have an unlimited supply of saved notifications available to accommodate any given replay request. To assess the timeframe available for replay, subscribers can read the leafs "replay-log-creation-time" and "replay-log-aged-time". See Figure 18 for the YANG tree and Section 4 for the YANG module describing these elements. The actual size of the replay log at any given time is a publisher-specific matter. Control parameters for the replay log are outside the scope of this document.

2.4.3. Modifying a Dynamic Subscription

The "modify-subscription" operation permits changing the terms of an existing dynamic subscription. Dynamic subscriptions can be modified any number of times. Dynamic subscriptions can only be modified via this RPC using a transport session connecting to the subscriber. If the publisher accepts the requested modifications, it acknowledges success to the subscriber, then immediately starts sending event records based on the new terms.

Subscriptions created by configuration cannot be modified via this RPC. However, configuration may be used to modify objects referenced by the subscription (such as a referenced filter).

Below is a tree diagram for "modify-subscription". All objects contained in this tree are described in the YANG module in Section 4.

```
    +---x modify-subscription
       +---w input
          +---w id
          |       subscription-id
          +---w (target)
          |  +--:(stream)
          |     +---w (stream-filter)?
          |        +--:(by-reference)
          |        |  +---w stream-filter-name
          |        |          stream-filter-ref
          |        +--:(within-subscription)
          |           +---w (filter-spec)?
          |              +--:(stream-subtree-filter)
          |              |  +---w stream-subtree-filter?   <anydata>
          |              |          {subtree}?
          |              +--:(stream-xpath-filter)
          |                 +---w stream-xpath-filter?
          |                         yang:xpath1.0 {xpath}?
          +---w stop-time?
                  yang:date-and-time
```

Figure 4: "modify-subscription" RPC Tree Diagram

If the publisher accepts the requested modifications on a currently suspended subscription, the subscription will immediately be resumed (i.e., the modified subscription is returned to the "active" state). The publisher MAY immediately suspend this newly modified subscription through the "subscription-suspended" notification before any event records are sent.

If the publisher rejects the RPC request, the subscription remains as it was prior to the request. That is, the request has no impact whatsoever. Rejection of the RPC for any reason is indicated via an RPC error as described in Section 2.4.6. The contents of such a rejected RPC MAY include hints on inputs that (if considered) may result in a successfully modified subscription. These hints MUST be transported in a yang-data "modify-subscription-stream-error-info" container inserted into the RPC error response.

Below is a tree diagram for "modify-subscription-stream-error-info" RPC yang-data. All objects contained in this tree are described in the YANG module in Section 4.

```
yang-data modify-subscription-stream-error-info
  +--ro modify-subscription-stream-error-info
     +--ro reason?                identityref
     +--ro filter-failure-hint?   string
```

Figure 5: "modify-subscription-stream-error-info" RPC yang-data Tree Diagram

2.4.4. Deleting a Dynamic Subscription

The "delete-subscription" operation permits canceling an existing subscription. If the publisher accepts the request and the publisher has indicated success, the publisher MUST NOT send any more notification messages for this subscription.

Below is a tree diagram for "delete-subscription". All objects contained in this tree are described in the YANG module in Section 4.

```
+---x delete-subscription
   +---w input
      +---w id     subscription-id
```

Figure 6: "delete-subscription" RPC Tree Diagram

Dynamic subscriptions can only be deleted via this RPC using a transport session connecting to the subscriber. Configured subscriptions cannot be deleted using RPCs.

2.4.5. Killing a Dynamic Subscription

The "kill-subscription" operation permits an operator to end a dynamic subscription that is not associated with the transport session used for the RPC. A publisher MUST terminate any dynamic subscription identified by the "id" parameter in the RPC request, if such a subscription exists.

Configured subscriptions cannot be killed using this RPC. Instead, configured subscriptions are deleted as part of regular configuration operations. Publishers MUST reject any RPC attempt to kill a configured subscription.

Below is a tree diagram for "kill-subscription". All objects contained in this tree are described in the YANG module in Section 4.

```
    +---x kill-subscription
       +---w input
          +---w id     subscription-id
```

Figure 7: "kill-subscription" RPC Tree Diagram

2.4.6. RPC Failures

Whenever an RPC is unsuccessful, the publisher returns relevant information as part of the RPC error response. Transport-level error processing MUST be done before the RPC error processing described in this section. In all cases, RPC error information returned by the publisher will use existing transport-layer RPC structures, such as those seen with NETCONF (Appendix A of [RFC6241]) or RESTCONF (Section 7.1 of [RFC8040]). These structures MUST be able to encode subscription-specific errors identified below and defined in this document's YANG data model.

As a result of this variety, how subscription errors are encoded in an RPC error response is transport dependent. Valid errors that can occur for each RPC are as follows:

establish-subscription	modify-subscription
dscp-unavailable	filter-unsupported
encoding-unsupported	insufficient-resources
filter-unsupported	no-such-subscription
insufficient-resources	
replay-unsupported	

delete-subscription	kill-subscription
no-such-subscription	no-such-subscription

To see a NETCONF-based example of an error response from the list above, see the "no-such-subscription" error response illustrated in [RFC8640], Figure 10.

There is one final set of transport-independent RPC error elements included in the YANG data model defined in this document: three yang-data structures that enable the publisher to provide to the receiver any error information that does not fit into existing transport-layer RPC structures. These structures are:

1. "establish-subscription-stream-error-info": This MUST be returned with the leaf "reason" populated if an RPC error reason has not been placed elsewhere in the transport portion of a failed "establish-subscription" RPC response. This MUST be sent if hints on how to overcome the RPC error are included.

2. "modify-subscription-stream-error-info": This MUST be returned with the leaf "reason" populated if an RPC error reason has not been placed elsewhere in the transport portion of a failed "modify-subscription" RPC response. This MUST be sent if hints on how to overcome the RPC error are included.

3. "delete-subscription-error-info": This MUST be returned with the leaf "reason" populated if an RPC error reason has not been placed elsewhere in the transport portion of a failed "delete-subscription" or "kill-subscription" RPC response.

2.5. Configured Subscriptions

A configured subscription is a subscription installed via configuration. Configured subscriptions may be modified by any configuration client with the proper permissions. Subscriptions can be modified or terminated via configuration at any point during their lifetime. Multiple configured subscriptions MUST be supportable over a single transport session.

Configured subscriptions have several characteristics distinguishing them from dynamic subscriptions:

- persistence across publisher reboots,

- persistence even when transport is unavailable, and

- an ability to send notification messages to more than one receiver. (Note that receivers are unaware of the existence of any other receivers.)

On the publisher, support for configured subscriptions is optional and advertised using the "configured" feature. On a receiver of a configured subscription, support for dynamic subscriptions is optional. However, if replaying missed event records is required for

a configured subscription, support for dynamic subscription is highly recommended. In this case, a separate dynamic subscription can be established to retransmit the missing event records.

In addition to the subscription parameters available to dynamic subscriptions as described in Section 2.4.2, the following additional parameters are also available to configured subscriptions:

- A "transport", which identifies the transport protocol to use to connect with all subscription receivers.

- One or more receivers, each intended as the destination for event records. Note that each individual receiver is identifiable by its "name".

- Optional parameters to identify where traffic should egress a publisher:

  * A "source-interface", which identifies the egress interface to use from the publisher. Publisher support for this parameter is optional and advertised using the "interface-designation" feature.

  * A "source-address" address, which identifies the IP address to stamp on notification messages destined for the receiver.

  * A "source-vrf", which identifies the Virtual Routing and Forwarding (VRF) instance on which to reach receivers. This VRF is a network instance as defined in [RFC8529]. Publisher support for VRFs is optional and advertised using the "supports-vrf" feature.

  If none of the above parameters are set, notification messages MUST egress the publisher's default interface.

A tree diagram that includes these parameters is provided in Figure 20 in Section 3.3. These parameters are described in the YANG module in Section 4.

2.5.1. Configured Subscription State Machine

Below is the state machine for a configured subscription on the publisher. This state machine describes the three states ("valid", "invalid", and "concluded") as well as the transitions between these states. Start and end states are depicted to reflect configured subscription creation and deletion events. The creation or modification of a configured subscription initiates an evaluation by the publisher to determine if the subscription is in the

"valid" state or the "invalid" state. The publisher uses its own criteria in making this determination. If in the "valid" state, the subscription becomes operational. See (1) in the diagram below.

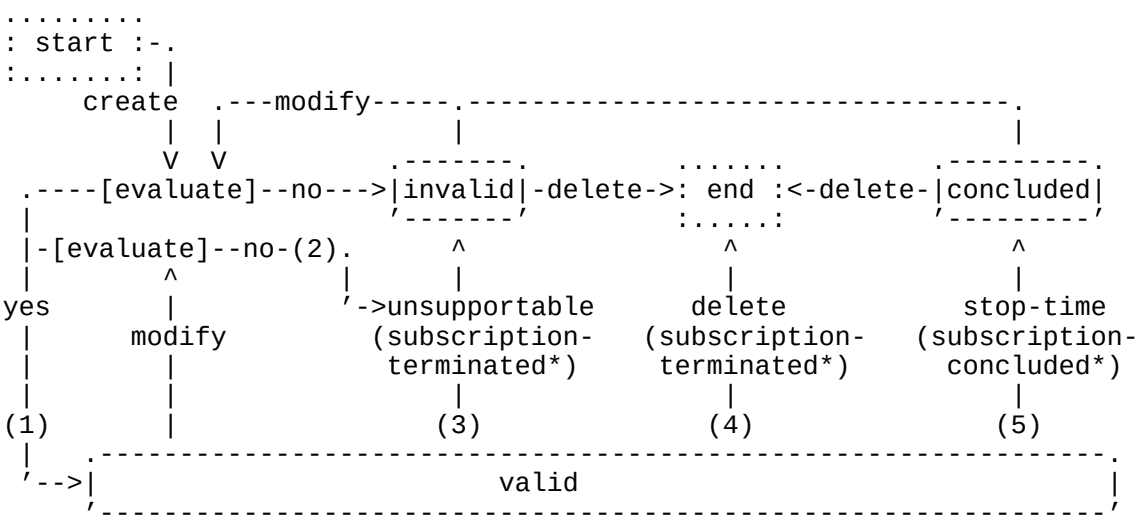
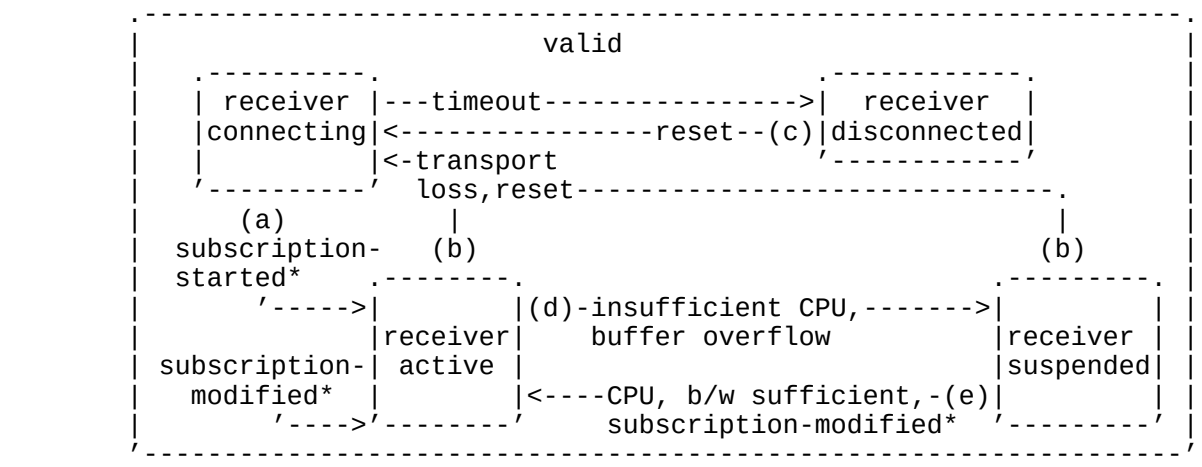


Figure 8: Publisher's State Machine for a Configured Subscription

A subscription in the "valid" state may move to the "invalid" state in one of two ways. First, it may be modified in a way that fails a re-evaluation. See (2) in the diagram. Second, the publisher might determine that the subscription is no longer supportable. This could be because of an unexpected but sustained increase in an event stream's event records, degraded CPU capacity, a more complex referenced filter, or other subscriptions that have usurped resources. See (3) in the diagram. No matter the case, a "subscription-terminated" notification is sent to any receivers in the "active" or "suspended" state. A subscription in the "valid" state may also transition to the "concluded" state via (5) if a configured stop time has been reached. In this case, a "subscription-concluded" notification is sent to any receivers in the "active" or "suspended" state. Finally, a subscription may be deleted by configuration (4).

When a subscription is in the "valid" state, a publisher will attempt to connect with all receivers of a configured subscription and deliver notification messages. Below is the state machine for each receiver of a configured subscription. This receiver state machine is fully contained in the state machine of the configured subscription and is only relevant when the configured subscription is in the "valid" state.



Legend:
Dashed boxes that include the word "receiver" show the possible states for an individual receiver of a valid configured subscription.

* indicates a subscription state change notification

Figure 9: Receiver State Machine for a Configured Subscription on a Publisher

When a configured subscription first moves to the "valid" state, the "state" leaf of each receiver is initialized to the "connecting" state. If transport connectivity is not available to any receivers and there are any notification messages to deliver, a transport session is established (e.g., per [RFC8071]). Individual receivers are moved to the "active" state when a "subscription-started" subscription state change notification is successfully passed to that receiver (a). Event records are only sent to active receivers. Receivers of a configured subscription remain active on the publisher if both (1) transport connectivity to the receiver is active and (2) event records are not being dropped due to a publisher's sending capacity being reached. In addition, a configured subscription's receiver MUST be moved to the "connecting" state if the receiver is

reset via the "reset" action (b), (c). For more on the "reset" action, see Section 2.5.5. If transport connectivity cannot be achieved while in the "connecting" state, the receiver MAY be moved to the "disconnected" state.

A configured subscription's receiver MUST be moved to the "suspended" state if there is transport connectivity between the publisher and receiver but (1) delivery of notification messages is failing due to a publisher's buffer capacity being reached or (2) notification messages cannot be generated for that receiver due to insufficient CPU (d). This is indicated to the receiver by the "subscription-suspended" subscription state change notification.

A configured subscription's receiver MUST be returned to the "active" state from the "suspended" state when notification messages can be generated, bandwidth is sufficient to handle the notification messages, and a receiver has successfully been sent a "subscription-resumed" or "subscription-modified" subscription state change notification (e). The choice as to which of these two subscription state change notifications is sent is determined by whether the subscription was modified during the period of suspension.

Modification of a configured subscription is possible at any time. A "subscription-modified" subscription state change notification will be sent to all active receivers, immediately followed by notification messages conforming to the new parameters. Suspended receivers will also be informed of the modification. However, this notification will await the end of the suspension for that receiver (e).

The mechanisms described above are mirrored in the RPCs and notifications defined in this document. It should be noted that these RPCs and notifications have been designed to be extensible and allow subscriptions into targets other than event streams. For instance, the YANG module defined in Section 5 of [RFC8641] augments "/sn:modify-subscription/sn:input/sn:target".

2.5.2. Creating a Configured Subscription

Configured subscriptions are established using configuration operations against the top-level "subscriptions" subtree.

Because there is no explicit association with an existing transport session, configuration operations MUST include additional parameters beyond those of dynamic subscriptions. These parameters identify each receiver, how to connect with that receiver, and possibly whether the notification messages need to come from a specific egress

interface on the publisher. Receiver-specific transport connectivity parameters MUST be configured via transport-specific augmentations to this specification. See Section 2.5.7 for details.

After a subscription is successfully established, the publisher immediately sends a "subscription-started" subscription state change notification to each receiver. It is quite possible that upon configuration, reboot, or even steady-state operations, a transport session may not be currently available to the receiver. In this case, when there is something to transport for an active subscription, transport-specific "call home" operations [RFC8071] will be used to establish the connection. When transport connectivity is available, notification messages may then be pushed.

With active configured subscriptions, it is allowable to buffer event records even after a "subscription-started" has been sent. However, if events are lost (rather than just delayed) due to replay buffer capacity being reached, a new "subscription-started" must be sent. This new "subscription-started" indicates an event record discontinuity.

To see an example of subscription creation using configuration operations over NETCONF, see Appendix A.

2.5.3. Modifying a Configured Subscription

Configured subscriptions can be modified using configuration operations against the top-level "subscriptions" subtree.

If the modification involves adding receivers, added receivers are placed in the "connecting" state. If a receiver is removed, the subscription state change notification "subscription-terminated" is sent to that receiver if that receiver is active or suspended.

If the modification involves changing the policies for the subscription, the publisher sends to currently active receivers a "subscription-modified" notification. For any suspended receivers, a "subscription-modified" notification will be delayed until the receiver’s subscription has been resumed. (Note: In this case, the "subscription-modified" notification informs the receiver that the subscription has been resumed, so no additional "subscription-resumed" need be sent. Also note that if multiple modifications have occurred during the suspension, only the "subscription-modified" notification describing the latest one need be sent to the receiver.)

2.5.4. Deleting a Configured Subscription

Subscriptions can be deleted through configuration against the top-level "subscriptions" subtree.

Immediately after a subscription is successfully deleted, the publisher sends to all receivers of that subscription a subscription state change notification stating that the subscription has ended (i.e., "subscription-terminated").

2.5.5. Resetting a Configured Subscription's Receiver

It is possible that a configured subscription to a receiver needs to be reset. This is accomplished via the "reset" action in the YANG module at "/subscriptions/subscription/receivers/receiver/reset". This action may be useful in cases where a publisher has timed out trying to reach a receiver. When such a reset occurs, a transport session will be initiated if necessary, and a new "subscription-started" notification will be sent. This action does not have any effect on transport connectivity if the needed connectivity already exists.

2.5.6. Replay for a Configured Subscription

It is possible to do replay on a configured subscription. This is supported via the configuration of the "configured-replay" object on the subscription. The setting of this object enables the streaming of the buffered event records for the subscribed event stream. All buffered event records that have been retained since the last publisher restart will be sent to each configured receiver.

Replay of event records created since restart is useful. It allows event records generated before transport connectivity establishment to be passed to a receiver. Setting the restart time as the earliest configured replay time precludes the possibility of resending event records that were logged prior to publisher restart. It also ensures that the same records will be sent to each configured receiver, regardless of the speed of transport connectivity establishment to each receiver. Finally, by establishing restart as the earliest potential time for event records to be included in notification messages, a well-understood timeframe for replay is defined.

As a result, when any configured subscription's receivers become active, buffered event records will be sent immediately after the "subscription-started" notification. If the publisher knows the last event record sent to a receiver and the publisher has not rebooted, the next event record on the event stream that meets filtering criteria will be the leading event record sent. Otherwise, the

leading event record will be the first event record meeting filtering criteria subsequent to the latest of three different times: the "replay-log-creation-time", the "replay-log-aged-time", or the most recent publisher boot time. The "replay-log-creation-time" and "replay-log-aged-time" are discussed in Section 2.4.2.1. The most recent publisher boot time ensures that duplicate event records are not replayed from a previous time the publisher was booted.

It is quite possible that a receiver might want to retrieve event records from an event stream prior to the latest boot. If such records exist where there is a configured replay, the publisher MUST send the time of the event record immediately preceding the "replay-start-time" in the "replay-previous-event-time" leaf. Through the existence of the "replay-previous-event-time", the receiver will know that earlier events prior to reboot exist. In addition, if the subscriber was previously receiving event records with the same subscription "id", the receiver can determine if there was a time gap where records generated on the publisher were not successfully received. And with this information, the receiver may choose to dynamically subscribe to retrieve any event records placed in the event stream before the most recent boot time.

All other replay functionality remains the same as with dynamic subscriptions as described in Section 2.4.2.1.

2.5.7. Transport Connectivity for a Configured Subscription

This specification is transport independent. However, supporting a configured subscription will often require the establishment of transport connectivity. And the parameters used for this transport connectivity establishment are transport specific. As a result, the YANG module defined in Section 4 is not able to directly define and expose these transport parameters.

It is necessary for an implementation to support the connection establishment process. To support this function, the YANG data model defined in this document includes a node where transport-specific parameters for a particular receiver may be augmented. This node is "/subscriptions/subscription/receivers/receiver". By augmenting transport parameters from this node, system developers are able to incorporate the YANG objects necessary to support the transport connectivity establishment process.

The result of this is the following requirement. A publisher supporting the feature "configured" MUST also support at least one YANG data model that augments transport connectivity parameters on "/subscriptions/subscription/receivers/receiver". For an example of such an augmentation, see Appendix A.

2.6. Event Record Delivery

Whether dynamic or configured, once a subscription has been set up, the publisher streams event records via notification messages per the terms of the subscription. For dynamic subscriptions, notification messages are sent over the session used to establish the subscription. For configured subscriptions, notification messages are sent over the connections specified by the transport and each receiver of a configured subscription.

A notification message is sent to a receiver when an event record is not blocked by either the specified filter criteria or receiver permissions. This notification message MUST include an <eventTime> object, as shown in [RFC5277], Section 4. This <eventTime> MUST be at the top level of a YANG structured event record.

The following example of XML [W3C.REC-xml-20081126], adapted from Section 4.2.10 of [RFC7950], illustrates a compliant message:

```
<notification
       xmlns="urn:ietf:params:xml:ns:netconf:notification:1.0">
    <eventTime>2007-09-01T10:00:00Z</eventTime>
    <link-failure xmlns="https://acme.example.com/system">
        <if-name>so-1/2/3.0</if-name>
        <if-admin-status>up</if-admin-status>
        <if-oper-status>down</if-oper-status>
    </link-failure>
</notification>
```

Figure 10: Subscribed Notification Message

[RFC5277], Section 2.2.1 states that a notification message is to be sent to a subscriber that initiated a <create-subscription>. With this document, this statement from [RFC5277] should be more broadly interpreted to mean that notification messages can also be sent to a subscriber that initiated an "establish-subscription" or to a configured receiver that has been sent a "subscription-started".

When a dynamic subscription has been started or modified with "establish-subscription" or "modify-subscription", respectively, event records matching the newly applied filter criteria MUST NOT be sent until after the RPC reply has been sent.

When a configured subscription has been started or modified, event records matching the newly applied filter criteria MUST NOT be sent until after the "subscription-started" or "subscription-modified" notification has been sent, respectively.

2.7. Subscription State Change Notifications

In addition to sending event records to receivers, a publisher MUST also send subscription state change notifications when events related to subscription management have occurred.

Subscription state change notifications are unlike other notifications in that they are never included in any event stream. Instead, they are inserted (as defined in this section) into the sequence of notification messages sent to a particular receiver. Subscription state change notifications cannot be dropped or filtered out, they cannot be stored in replay buffers, and they are delivered only to impacted receivers of a subscription. The identification of subscription state change notifications is easy to separate from other notification messages through the use of the YANG extension "subscription-state-notif". This extension tags a notification as a subscription state change notification.

The complete set of subscription state change notifications is described in the following subsections.

2.7.1. "subscription-started"

This notification indicates that a configured subscription has started, and event records may be sent. Included in this subscription state change notification are all the parameters of the subscription, except for (1) transport connection information for one or more receivers and (2) origin information indicating where notification messages will egress the publisher. Note that if a referenced filter from the "filters" container has been used in the subscription, the notification still provides the contents of that referenced filter under the "within-subscription" subtree.

Note that for dynamic subscriptions, no "subscription-started" notifications are ever sent.

Below is a tree diagram for "subscription-started". All objects contained in this tree are described in the YANG module in Section 4.

```
    +---n subscription-started {configured}?
       +--ro id
       |       subscription-id
       +--ro (target)
       |  +--:(stream)
       |     +--ro (stream-filter)?
       |     |  +--:(by-reference)
       |     |  |  +--ro stream-filter-name
       |     |  |          stream-filter-ref
       |     |  +--:(within-subscription)
       |     |     +--ro (filter-spec)?
       |     |        +--:(stream-subtree-filter)
       |     |        |  +--ro stream-subtree-filter?   <anydata>
       |     |        |          {subtree}?
       |     |        +--:(stream-xpath-filter)
       |     |           +--ro stream-xpath-filter?     yang:xpath1.0
       |     |                   {xpath}?
       |     +--ro stream                                stream-ref
       |     +--ro replay-start-time?
       |     |       yang:date-and-time {replay}?
       |     +--ro replay-previous-event-time?
       |             yang:date-and-time {replay}?
       +--ro stop-time?
       |       yang:date-and-time
       +--ro dscp?                                       inet:dscp
       |       {dscp}?
       +--ro weighting?                                  uint8 {qos}?
       +--ro dependency?
       |       subscription-id {qos}?
       +--ro transport?                                  transport
       |       {configured}?
       +--ro encoding?                                   encoding
       +--ro purpose?                                    string
               {configured}?
```

Figure 11: "subscription-started" Notification Tree Diagram

2.7.2. "subscription-modified"

This notification indicates that a subscription has been modified by configuration operations. It is delivered directly after the last event records processed using the previous subscription parameters, and before any event records processed after the modification.

Below is a tree diagram for "subscription-modified". All objects contained in this tree are described in the YANG module in Section 4.

```
    +---n subscription-modified
       +--ro id
       |       subscription-id
       +--ro (target)
       |  +--:(stream)
       |     +--ro (stream-filter)?
       |     |  +--:(by-reference)
       |     |  |  +--ro stream-filter-name
       |     |  |          stream-filter-ref
       |     |  +--:(within-subscription)
       |     |     +--ro (filter-spec)?
       |     |        +--:(stream-subtree-filter)
       |     |        |  +--ro stream-subtree-filter?   <anydata>
       |     |        |          {subtree}?
       |     |        +--:(stream-xpath-filter)
       |     |           +--ro stream-xpath-filter?     yang:xpath1.0
       |     |                   {xpath}?
       |     +--ro stream                                stream-ref
       |     +--ro replay-start-time?
       |             yang:date-and-time {replay}?
       +--ro stop-time?
       |       yang:date-and-time
       +--ro dscp?                                       inet:dscp
       |       {dscp}?
       +--ro weighting?                                  uint8 {qos}?
       +--ro dependency?
       |       subscription-id {qos}?
       +--ro transport?                                  transport
       |       {configured}?
       +--ro encoding?                                   encoding
       +--ro purpose?                                    string
               {configured}?
```

Figure 12: "subscription-modified" Notification Tree Diagram

A publisher most often sends this notification directly after the modification of any configuration parameters impacting a configured subscription. But it may also be sent at two other times:

1. If a configured subscription has been modified during the suspension of a receiver, the notification will be delayed until the receiver’s suspension is lifted. In this situation, the notification indicates that the subscription has been both modified and resumed.

2. A "subscription-modified" subscription state change notification MUST be sent if the contents of the filter identified by the subscription's "stream-filter-ref" leaf have changed. This state change notification is to be sent for a filter change impacting any active receivers of a configured or dynamic subscription.

2.7.3. "subscription-terminated"

This notification indicates that no further event records for this subscription should be expected from the publisher. A publisher may terminate the sending of event records to a receiver for the following reasons:

1. Configuration that removes a configured subscription, or a "kill-subscription" RPC that ends a dynamic subscription. These are identified via the reason "no-such-subscription".

2. A referenced filter is no longer accessible. This reason is identified by the "filter-unavailable" identity.

3. The event stream referenced by a subscription is no longer accessible by the receiver. This reason is identified by the "stream-unavailable" identity.

4. A suspended subscription has exceeded some timeout. This reason is identified by the "suspension-timeout" identity.

Each reason listed above derives from the "subscription-terminated-reason" base identity specified in the YANG data model in this document.

Below is a tree diagram for "subscription-terminated". All objects contained in this tree are described in the YANG module in Section 4.

```
    +---n subscription-terminated
       +--ro id        subscription-id
       +--ro reason    identityref
```

Figure 13: "subscription-terminated" Notification Tree Diagram

Note: This subscription state change notification MUST be sent to a dynamic subscription's receiver when the subscription ends unexpectedly. This might happen when a "kill-subscription" RPC is successful or when some other event, not including reaching the subscription's "stop-time", results in a publisher choosing to end the subscription.

2.7.4. "subscription-suspended"

This notification indicates that a publisher has suspended the sending of event records to a receiver and also indicates the possible loss of events. Suspension happens when capacity constraints stop a publisher from serving a valid subscription. The two conditions where this is possible are:

1. "insufficient-resources", when a publisher is unable to produce the requested event stream of notification messages, and

2. "unsupportable-volume", when the bandwidth needed to get generated notification messages to a receiver exceeds a threshold.

These conditions are encoded in the "reason" object. No further notifications will be sent until the subscription resumes or is terminated.

Below is a tree diagram for "subscription-suspended". All objects contained in this tree are described in the YANG module in Section 4.

```
+---n subscription-suspended
   +--ro id        subscription-id
   +--ro reason    identityref
```

Figure 14: "subscription-suspended" Notification Tree Diagram

2.7.5. "subscription-resumed"

This notification indicates that a previously suspended subscription has been resumed under the unmodified terms previously in place. Subscribed event records generated after the issuance of this subscription state change notification may now be sent.

Below is a tree diagram for "subscription-resumed". All objects contained in this tree are described in the YANG module in Section 4.

```
+---n subscription-resumed
   +--ro id    subscription-id
```

Figure 15: "subscription-resumed" Notification Tree Diagram

2.7.6. "subscription-completed"

This notification indicates that a subscription that includes a "stop-time" has successfully finished passing event records upon reaching that time.

Below is a tree diagram for "subscription-completed". All objects contained in this tree are described in the YANG module in Section 4.

```
+---n subscription-completed {configured}?
   +--ro id    subscription-id
```

Figure 16: "subscription-completed" Notification Tree Diagram

2.7.7. "replay-completed"

This notification indicates that all of the event records prior to the current time have been passed to a receiver. It is sent before any notification messages containing an event record with a timestamp later than (1) the "stop-time" or (2) the subscription's start time.

If a subscription does not contain a "stop-time" or has a "stop-time" that has not been reached, then after the "replay-completed" notification has been sent, additional event records will be sent in sequence as they arise naturally on the publisher.

Below is a tree diagram for "replay-completed". All objects contained in this tree are described in the YANG module in Section 4.

```
+---n replay-completed {replay}?
   +--ro id    subscription-id
```

Figure 17: "replay-completed" Notification Tree Diagram

2.8. Subscription Monitoring

In the operational state datastore, the "subscriptions" container maintains the state of all dynamic subscriptions as well as all configured subscriptions. Using datastore retrieval operations [RFC8641] or subscribing to the "subscriptions" container (Section 3.3) allows the state of subscriptions and their connectivity to receivers to be monitored.

Each subscription in the operational state datastore is represented as a list element. Included in this list are event counters for each receiver, the state of each receiver, and the subscription parameters currently in effect. The appearance of the leaf "configured-subscription-state" indicates that a particular subscription came

into being via configuration. This leaf also indicates whether the current state of that subscription is "valid", "invalid", or "concluded".

To understand the flow of event records in a subscription, there are two counters available for each receiver. The first counter is "sent-event-records", which shows the number of events identified for sending to a receiver. The second counter is "excluded-event-records", which shows the number of event records not sent to a receiver. "excluded-event-records" shows the combined results of both access control and per-subscription filtering. For configured subscriptions, counters are reset whenever the subscription's state is evaluated as "valid" (see (1) in Figure 8).

Dynamic subscriptions are removed from the operational state datastore once they expire (reaching "stop-time") or when they are terminated. While many subscription objects are shown as configurable, dynamic subscriptions are only included in the operational state datastore and as a result are not configurable.

2.9. Support for the "ietf-subscribed-notifications" YANG Module

Publishers supporting this document MUST indicate support of the YANG module "ietf-subscribed-notifications" in the YANG library of the publisher. In addition, if supported, the optional features "encode-xml", "encode-json", "configured", "supports-vrf", "qos", "xpath", "subtree", "interface-designation", "dscp", and "replay" MUST be indicated.

3. YANG Data Model Tree Diagrams

This section contains tree diagrams for nodes defined in Section 4. For tree diagrams of subscription state change notifications, see Section 2.7. For the tree diagrams for the RPCs, see Section 2.4.

3.1. The "streams" Container

A publisher maintains a list of available event streams as operational data. This list contains both standardized and vendor-specific event streams. This enables subscribers to discover what streams a publisher supports.

Below is a tree diagram for the "streams" container. All objects contained in this tree are described in the YANG module in Section 4.

```
  +--ro streams
     +--ro stream* [name]
        +--ro name                          string
        +--ro description                   string
        +--ro replay-support?               empty {replay}?
        +--ro replay-log-creation-time      yang:date-and-time
        |       {replay}?
        +--ro replay-log-aged-time?         yang:date-and-time
                {replay}?
```

Figure 18: "streams" Container Tree Diagram

3.2. The "filters" Container

The "filters" container maintains a list of all subscription filters that persist outside the lifecycle of a single subscription. This enables predefined filters that may be referenced by more than one subscription.

Below is a tree diagram for the "filters" container. All objects contained in this tree are described in the YANG module in Section 4.

```
  +--rw filters
     +--rw stream-filter* [name]
        +--rw name                              string
        +--rw (filter-spec)?
           +--:(stream-subtree-filter)
           |  +--rw stream-subtree-filter?      <anydata> {subtree}?
           +--:(stream-xpath-filter)
              +--rw stream-xpath-filter?        yang:xpath1.0 {xpath}?
```

Figure 19: "filters" Container Tree Diagram

3.3. The "subscriptions" Container

The "subscriptions" container maintains a list of all subscriptions on a publisher, both configured and dynamic. It can be used to retrieve information about the subscriptions that a publisher is serving.

Below is a tree diagram for the "subscriptions" container. All objects contained in this tree are described in the YANG module in Section 4.

```
  +--rw subscriptions
     +--rw subscription* [id]
        +--rw id
        |       subscription-id
        +--rw (target)
        |  +--:(stream)
        |     +--rw (stream-filter)?
        |     |  +--:(by-reference)
        |     |  |  +--rw stream-filter-name
        |     |  |          stream-filter-ref
        |     |  +--:(within-subscription)
        |     |     +--rw (filter-spec)?
        |     |        +--:(stream-subtree-filter)
        |     |        |  +--rw stream-subtree-filter?   <anydata>
        |     |        |          {subtree}?
        |     |        +--:(stream-xpath-filter)
        |     |           +--rw stream-xpath-filter?
        |     |                   yang:xpath1.0 {xpath}?
        |     +--rw stream                                stream-ref
        |     +--ro replay-start-time?
        |     |       yang:date-and-time {replay}?
        |     +--rw configured-replay?                    empty
        |             {configured,replay}?
        +--rw stop-time?
        |       yang:date-and-time
        +--rw dscp?                                       inet:dscp
        |       {dscp}?
        +--rw weighting?                                  uint8 {qos}?
        +--rw dependency?
        |       subscription-id {qos}?
        +--rw transport?                                  transport
        |       {configured}?
        +--rw encoding?                                   encoding
        +--rw purpose?                                    string
        |       {configured}?
```

```
           +--rw (notification-message-origin)? {configured}?
           |  +--:(interface-originated)
           |  |  +--rw source-interface?
           |  |          if:interface-ref {interface-designation}?
           |  +--:(address-originated)
           |     +--rw source-vrf?
           |     |       -> /ni:network-instances/network-instance/name
           |     |       {supports-vrf}?
           |     +--rw source-address?
           |             inet:ip-address-no-zone
           +--ro configured-subscription-state?             enumeration
           |       {configured}?
           +--rw receivers
              +--rw receiver* [name]
                 +--rw name                       string
                 +--ro sent-event-records?
                 |       yang:zero-based-counter64
                 +--ro excluded-event-records?
                 |       yang:zero-based-counter64
                 +--ro state                      enumeration
                 +---x reset {configured}?
                    +--ro output
                       +--ro time    yang:date-and-time
```

Figure 20: "subscriptions" Container Tree Diagram

4. Event Notification Subscription YANG Module

This module imports typedefs from [RFC6991], [RFC8343], [RFC8341], [RFC8529], and [RFC8040]. It references [RFC6241], [XPATH] ("XML Path Language (XPath) Version 1.0"), [RFC7049], [RFC8259], [RFC7950], [RFC7951], and [RFC7540].

```
<CODE BEGINS> file "ietf-subscribed-notifications@2019-09-09.yang"
module ietf-subscribed-notifications {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-subscribed-notifications";
  prefix sn;

  import ietf-inet-types {
    prefix inet;
    reference
      "RFC 6991: Common YANG Data Types";
  }
  import ietf-interfaces {
    prefix if;
    reference
      "RFC 8343: A YANG Data Model for Interface Management";
```

```
  }
  import ietf-netconf-acm {
    prefix nacm;
    reference
      "RFC 8341: Network Configuration Access Control Model";
  }
  import ietf-network-instance {
    prefix ni;
    reference
      "RFC 8529: YANG Data Model for Network Instances";
  }
  import ietf-restconf {
    prefix rc;
    reference
      "RFC 8040: RESTCONF Protocol";
  }
  import ietf-yang-types {
    prefix yang;
    reference
      "RFC 6991: Common YANG Data Types";
  }

  organization
    "IETF NETCONF (Network Configuration) Working Group";
  contact
    "WG Web:  <https:/datatracker.ietf.org/wg/netconf/>
     WG List: <mailto:netconf@ietf.org>

     Author:  Alexander Clemm
              <mailto:ludwig@clemm.org>

     Author:  Eric Voit
              <mailto:evoit@cisco.com>

     Author:  Alberto Gonzalez Prieto
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              <mailto:ambtripa@cisco.com>";
  description
    "This module defines a YANG data model for subscribing to event
     records and receiving matching content in notification messages.

     The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL', 'SHALL
     NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED', 'NOT RECOMMENDED',
```

```
     'MAY', and 'OPTIONAL' in this document are to be interpreted as
     described in BCP 14 (RFC 2119) (RFC 8174) when, and only when,
     they appear in all capitals, as shown here.

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     authors of the code.  All rights reserved.

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     without modification, is permitted pursuant to, and subject to
     the license terms contained in, the Simplified BSD License set
     forth in Section 4.c of the IETF Trust's Legal Provisions
     Relating to IETF Documents
     (https://trustee.ietf.org/license-info).

     This version of this YANG module is part of RFC 8639; see the
     RFC itself for full legal notices.";

  revision 2019-09-09 {
    description
      "Initial version.";
    reference
      "RFC 8639: A YANG Data Model for Subscriptions to
                 Event Notifications";
  }

  /*
   * FEATURES
   */

  feature configured {
    description
      "This feature indicates that configuration of subscriptions is
       supported.";
  }

  feature dscp {
    description
      "This feature indicates that a publisher supports the ability
       to set the Differentiated Services Code Point (DSCP) value in
       outgoing packets.";
  }

  feature encode-json {
    description
      "This feature indicates that JSON encoding of notification
       messages is supported.";
  }
```

```
  feature encode-xml {
    description
      "This feature indicates that XML encoding of notification
       messages is supported.";
  }

  feature interface-designation {
    description
      "This feature indicates that a publisher supports sourcing all
       receiver interactions for a configured subscription from a
       single designated egress interface.";
  }

  feature qos {
    description
      "This feature indicates that a publisher supports absolute
       dependencies of one subscription's traffic over another
       as well as weighted bandwidth sharing between subscriptions.
       Both of these are Quality of Service (QoS) features that allow
       differentiated treatment of notification messages between a
       publisher and a specific receiver.";
  }

  feature replay {
    description
      "This feature indicates that historical event record replay is
       supported.  With replay, it is possible for past event records
       to be streamed in chronological order.";
  }

  feature subtree {
    description
      "This feature indicates support for YANG subtree filtering.";
    reference
      "RFC 6241: Network Configuration Protocol (NETCONF),
                 Section 6";
  }

  feature supports-vrf {
    description
      "This feature indicates that a publisher supports VRF
       configuration for configured subscriptions.  VRF support for
       dynamic subscriptions does not require this feature.";
    reference
      "RFC 8529: YANG Data Model for Network Instances,
                 Section 6";
  }
```

```
  feature xpath {
    description
      "This feature indicates support for XPath filtering.";
    reference
      "XML Path Language (XPath) Version 1.0
       (https://www.w3.org/TR/1999/REC-xpath-19991116)";
  }

  /*
   * EXTENSIONS
   */

  extension subscription-state-notification {
    description
      "This statement applies only to notifications.  It indicates
       that the notification is a subscription state change
       notification.  Therefore, it does not participate in a regular
       event stream and does not need to be specifically subscribed
       to in order to be received.  This statement can only occur as
       a substatement of the YANG 'notification' statement.  This
       statement is not for use outside of this YANG module.";
  }

  /*
   * IDENTITIES
   */
  /* Identities for RPC and notification errors */

  identity delete-subscription-error {
    description
      "Base identity for the problem found while attempting to
       fulfill either a 'delete-subscription' RPC request or a
       'kill-subscription' RPC request.";
  }

  identity establish-subscription-error {
    description
      "Base identity for the problem found while attempting to
       fulfill an 'establish-subscription' RPC request.";
  }

  identity modify-subscription-error {
    description
      "Base identity for the problem found while attempting to
       fulfill a 'modify-subscription' RPC request.";
  }

  identity subscription-suspended-reason {
```

```
    description
      "Base identity for the problem condition communicated to a
       receiver as part of a 'subscription-suspended'
       notification.";
  }

  identity subscription-terminated-reason {
    description
      "Base identity for the problem condition communicated to a
       receiver as part of a 'subscription-terminated'
       notification.";
  }

  identity dscp-unavailable {
    base establish-subscription-error;
    if-feature "dscp";
    description
      "The publisher is unable to mark notification messages with
       prioritization information in a way that will be respected
       during network transit.";
  }

  identity encoding-unsupported {
    base establish-subscription-error;
    description
      "Unable to encode notification messages in the desired
       format.";
  }

  identity filter-unavailable {
    base subscription-terminated-reason;
    description
      "Referenced filter does not exist.  This means a receiver is
       referencing a filter that doesn't exist or to which it
       does not have access permissions.";
  }

  identity filter-unsupported {
    base establish-subscription-error;
    base modify-subscription-error;
    description
      "Cannot parse syntax in the filter.  This failure can be from
       a syntax error or a syntax too complex to be processed by the
       publisher.";
  }

  identity insufficient-resources {
    base establish-subscription-error;
```

```
    base modify-subscription-error;
    base subscription-suspended-reason;
    description
      "The publisher does not have sufficient resources to support
       the requested subscription.  An example might be that
       allocated CPU is too limited to generate the desired set of
       notification messages.";
  }

  identity no-such-subscription {
    base modify-subscription-error;
    base delete-subscription-error;
    base subscription-terminated-reason;
    description
      "Referenced subscription doesn't exist.  This may be as a
       result of a nonexistent subscription ID, an ID that belongs to
       another subscriber, or an ID for a configured subscription.";
  }

  identity replay-unsupported {
    base establish-subscription-error;
    if-feature "replay";
    description
      "Replay cannot be performed for this subscription.  This means
       the publisher will not provide the requested historic
       information from the event stream via replay to this
       receiver.";
  }

  identity stream-unavailable {
    base subscription-terminated-reason;
    description
      "Not a subscribable event stream.  This means the referenced
       event stream is not available for subscription by the
       receiver.";
  }

  identity suspension-timeout {
    base subscription-terminated-reason;
    description
      "Termination of a previously suspended subscription.  The
       publisher has eliminated the subscription, as it exceeded a
       time limit for suspension.";
  }

  identity unsupportable-volume {
    base subscription-suspended-reason;
    description
```

```
      "The publisher does not have the network bandwidth needed to
       get the volume of generated information intended for a
       receiver.";
  }

  /* Identities for encodings */

  identity configurable-encoding {
    description
      "If a transport identity derives from this identity, it means
       that it supports configurable encodings.  An example of a
       configurable encoding might be a new identity such as
       'encode-cbor'.  Such an identity could use
       'configurable-encoding' as its base.  This would allow a
       dynamic subscription encoded in JSON (RFC 8259) to request
       that notification messages be encoded via the Concise Binary
       Object Representation (CBOR) (RFC 7049).  Further details for
       any specific configurable encoding would be explored in a
       transport document based on this specification.";
    reference
      "RFC 8259: The JavaScript Object Notation (JSON) Data
                 Interchange Format
       RFC 7049: Concise Binary Object Representation (CBOR)";
  }

  identity encoding {
    description
      "Base identity to represent data encodings.";
  }

  identity encode-xml {
    base encoding;
    if-feature "encode-xml";
    description
      "Encode data using XML as described in RFC 7950.";
    reference
      "RFC 7950: The YANG 1.1 Data Modeling Language";
  }

  identity encode-json {
    base encoding;
    if-feature "encode-json";
    description
      "Encode data using JSON as described in RFC 7951.";
    reference
      "RFC 7951: JSON Encoding of Data Modeled with YANG";
  }
```

```
  /* Identities for transports */

  identity transport {
    description
      "An identity that represents the underlying mechanism for
       passing notification messages.";
  }

  /*
   * TYPEDEFs
   */

  typedef encoding {
    type identityref {
      base encoding;
    }
    description
      "Specifies a data encoding, e.g., for a data subscription.";
  }

  typedef stream-filter-ref {
    type leafref {
      path "/sn:filters/sn:stream-filter/sn:name";
    }
    description
      "This type is used to reference an event stream filter.";
  }

  typedef stream-ref {
    type leafref {
      path "/sn:streams/sn:stream/sn:name";
    }
    description
      "This type is used to reference a system-provided
       event stream.";
  }

  typedef subscription-id {
    type uint32;
    description
      "A type for subscription identifiers.";
  }

  typedef transport {
    type identityref {
      base transport;
    }
    description
```

```
      "Specifies the transport used to send notification messages
       to a receiver.";
  }

  /*
   * GROUPINGS
   */

  grouping stream-filter-elements {
    description
      "This grouping defines the base for filters applied to event
       streams.";
    choice filter-spec {
      description
        "The content filter specification for this request.";
      anydata stream-subtree-filter {
        if-feature "subtree";
        description
          "Event stream evaluation criteria encoded in the syntax of
           a subtree filter as defined in RFC 6241, Section 6.

           The subtree filter is applied to the representation of
           individual, delineated event records as contained in the
           event stream.

           If the subtree filter returns a non-empty node set, the
           filter matches the event record, and the event record is
           included in the notification message sent to the
           receivers.";
        reference
          "RFC 6241: Network Configuration Protocol (NETCONF),
                     Section 6";
      }
      leaf stream-xpath-filter {
        if-feature "xpath";
        type yang:xpath1.0;
        description
          "Event stream evaluation criteria encoded in the syntax of
           an XPath 1.0 expression.

           The XPath expression is evaluated on the representation of
           individual, delineated event records as contained in
           the event stream.

           The result of the XPath expression is converted to a
           boolean value using the standard XPath 1.0 rules.  If the
           boolean value is 'true', the filter matches the event
           record, and the event record is included in the
```

```
            notification message sent to the receivers.

            The expression is evaluated in the following XPath
            context:

               o  The set of namespace declarations is the set of
                  prefix and namespace pairs for all YANG modules
                  implemented by the server, where the prefix is the
                  YANG module name and the namespace is as defined by
                  the 'namespace' statement in the YANG module.

                  If the leaf is encoded in XML, all namespace
                  declarations in scope on the 'stream-xpath-filter'
                  leaf element are added to the set of namespace
                  declarations.  If a prefix found in the XML is
                  already present in the set of namespace
                  declarations, the namespace in the XML is used.

               o  The set of variable bindings is empty.

               o  The function library is comprised of the core
                  function library and the XPath functions defined in
                  Section 10 in RFC 7950.

               o  The context node is the root node.";
          reference
            "XML Path Language (XPath) Version 1.0
             (https://www.w3.org/TR/1999/REC-xpath-19991116)
             RFC 7950: The YANG 1.1 Data Modeling Language,
                       Section 10";
        }
      }
    }

    grouping update-qos {
      description
        "This grouping describes QoS information concerning a
         subscription.  This information is passed to lower layers
         for transport prioritization and treatment.";
      leaf dscp {
        if-feature "dscp";
        type inet:dscp;
        default "0";
        description
          "The desired network transport priority level.  This is the
           priority set on notification messages encapsulating the
           results of the subscription.  This transport priority is
           shared for all receivers of a given subscription.";
```

```
    }
    leaf weighting {
      if-feature "qos";
      type uint8 {
        range "0 .. 255";
      }
      description
        "Relative weighting for a subscription.  Larger weights get
         more resources.  Allows an underlying transport layer to
         perform informed load-balance allocations between various
         subscriptions.";
      reference
        "RFC 7540: Hypertext Transfer Protocol Version 2 (HTTP/2),
                   Section 5.3.2";
    }
    leaf dependency {
      if-feature "qos";
      type subscription-id;
      description
        "Provides the 'subscription-id' of a parent subscription.
         The parent subscription has absolute precedence should
         that parent have push updates ready to egress the publisher.
         In other words, there should be no streaming of objects from
         the current subscription if the parent has something ready
         to push.

         If a dependency is asserted via configuration or via an RPC
         but the referenced 'subscription-id' does not exist, the
         dependency is silently discarded.  If a referenced
         subscription is deleted, this dependency is removed.";
      reference
        "RFC 7540: Hypertext Transfer Protocol Version 2 (HTTP/2),
                   Section 5.3.1";
    }
  }

  grouping subscription-policy-modifiable {
    description
      "This grouping describes all objects that may be changed
       in a subscription.";
    choice target {
      mandatory true;
      description
        "Identifies the source of information against which a
         subscription is being applied as well as specifics on the
         subset of information desired from that source.";
      case stream {
        choice stream-filter {
```

```
          description
            "An event stream filter can be applied to a subscription.
             That filter will either come referenced from a global
             list or be provided in the subscription itself.";
          case by-reference {
            description
              "Apply a filter that has been configured separately.";
            leaf stream-filter-name {
              type stream-filter-ref;
              mandatory true;
              description
                "References an existing event stream filter that is
                 to be applied to an event stream for the
                 subscription.";
            }
          }
          case within-subscription {
            description
              "A local definition allows a filter to have the same
               lifecycle as the subscription.";
            uses stream-filter-elements;
          }
        }
      }
    }
    leaf stop-time {
      type yang:date-and-time;
      description
        "Identifies a time after which notification messages for a
         subscription should not be sent.  If 'stop-time' is not
         present, the notification messages will continue until the
         subscription is terminated.  If 'replay-start-time' exists,
         'stop-time' must be for a subsequent time.  If
         'replay-start-time' doesn't exist, 'stop-time', when
         established, must be for a future time.";
    }
  }

  grouping subscription-policy-dynamic {
    description
      "This grouping describes the only information concerning a
       subscription that can be passed over the RPCs defined in this
       data model.";
    uses subscription-policy-modifiable {
      augment "target/stream" {
        description
          "Adds additional objects that can be modified by an RPC.";
        leaf stream {
```

```
          type stream-ref {
            require-instance false;
          }
          mandatory true;
          description
            "Indicates the event stream to be considered for
             this subscription.";
        }
        leaf replay-start-time {
          if-feature "replay";
          type yang:date-and-time;
          config false;
          description
            "Used to trigger the 'replay' feature for a dynamic
             subscription, where event records that are selected
             need to be at or after the specified starting time.  If
             'replay-start-time' is not present, this is not a replay
             subscription and event record push should start
             immediately.  It is never valid to specify start times
             that are later than or equal to the current time.";
        }
      }
    }
    uses update-qos;
  }

  grouping subscription-policy {
    description
      "This grouping describes the full set of policy information
       concerning both dynamic and configured subscriptions, with the
       exclusion of both receivers and networking information
       specific to the publisher, such as what interface should be
       used to transmit notification messages.";
    uses subscription-policy-dynamic;
    leaf transport {
      if-feature "configured";
      type transport;
      description
        "For a configured subscription, this leaf specifies the
         transport used to deliver messages destined for all
         receivers of that subscription.";
    }
    leaf encoding {
      when 'not(../transport) or derived-from(../transport,
      "sn:configurable-encoding")';
      type encoding;
      description
        "The type of encoding for notification messages.  For a
```

```
          dynamic subscription, if not included as part of an
          'establish-subscription' RPC, the encoding will be populated
          with the encoding used by that RPC.  For a configured
          subscription, if not explicitly configured, the encoding
          will be the default encoding for an underlying transport.";
      }
      leaf purpose {
        if-feature "configured";
        type string;
        description
          "Open text allowing a configuring entity to embed the
           originator or other specifics of this subscription.";
      }
    }

    /*
     * RPCs
     */

    rpc establish-subscription {
      description
        "This RPC allows a subscriber to create (and possibly
         negotiate) a subscription on its own behalf.  If successful,
         the subscription remains in effect for the duration of the
         subscriber's association with the publisher or until the
         subscription is terminated.  If an error occurs or the
         publisher cannot meet the terms of a subscription, an RPC
         error is returned, and the subscription is not created.
         In that case, the RPC reply's 'error-info' MAY include
         suggested parameter settings that would have a higher
         likelihood of succeeding in a subsequent
         'establish-subscription' request.";
      input {
        uses subscription-policy-dynamic;
        leaf encoding {
          type encoding;
          description
            "The type of encoding for the subscribed data.  If not
             included as part of the RPC, the encoding MUST be set by
             the publisher to be the encoding used by this RPC.";
        }
      }
      output {
        leaf id {
          type subscription-id;
          mandatory true;
          description
            "Identifier used for this subscription.";
```

```
      }
      leaf replay-start-time-revision {
        if-feature "replay";
        type yang:date-and-time;
        description
          "If a replay has been requested, this object represents
           the earliest time covered by the event buffer for the
           requested event stream.  The value of this object is the
           'replay-log-aged-time' if it exists.  Otherwise, it is
           the 'replay-log-creation-time'.  All buffered event
           records after this time will be replayed to a receiver.
           This object will only be sent if the starting time has
           been revised to be later than the time requested by the
           subscriber.";
      }
    }
  }

  rc:yang-data establish-subscription-stream-error-info {
    container establish-subscription-stream-error-info {
      description
        "If any 'establish-subscription' RPC parameters are
         unsupportable against the event stream, a subscription
         is not created and the RPC error response MUST indicate the
         reason why the subscription failed to be created.  This
         yang-data MAY be inserted as structured data in a
         subscription's RPC error response to indicate the reason for
         the failure.  This yang-data MUST be inserted if hints are
         to be provided back to the subscriber.";
      leaf reason {
        type identityref {
          base establish-subscription-error;
        }
        description
          "Indicates the reason why the subscription has failed to
           be created to a targeted event stream.";
      }
      leaf filter-failure-hint {
        type string;
        description
          "Information describing where and/or why a provided
           filter was unsupportable for a subscription.  The
           syntax and semantics of this hint are
           implementation specific.";
      }
    }
  }
```

```
  rpc modify-subscription {
    description
      "This RPC allows a subscriber to modify a dynamic
       subscription's parameters.  If successful, the changed
       subscription parameters remain in effect for the duration of
       the subscription, until the subscription is again modified, or
       until the subscription is terminated.  In the case of an error
       or an inability to meet the modified parameters, the
       subscription is not modified and the original subscription
       parameters remain in effect.  In that case, the RPC error MAY
       include 'error-info' suggested parameter hints that would have
       a high likelihood of succeeding in a subsequent
       'modify-subscription' request.  A successful
       'modify-subscription' will return a suspended subscription to
       the 'active' state.";
    input {
      leaf id {
        type subscription-id;
        mandatory true;
        description
          "Identifier to use for this subscription.";
      }
      uses subscription-policy-modifiable;
    }
  }

  rc:yang-data modify-subscription-stream-error-info {
    container modify-subscription-stream-error-info {
      description
        "This yang-data MAY be provided as part of a subscription's
         RPC error response when there is a failure of a
         'modify-subscription' RPC that has been made against an
         event stream.  This yang-data MUST be used if hints are to
         be provided back to the subscriber.";
      leaf reason {
        type identityref {
          base modify-subscription-error;
        }
        description
          "Information in a 'modify-subscription' RPC error response
           that indicates the reason why the subscription to an event
           stream has failed to be modified.";
      }
      leaf filter-failure-hint {
        type string;
        description
          "Information describing where and/or why a provided
           filter was unsupportable for a subscription.  The syntax
```

```
            and semantics of this hint are
            implementation specific.";
        }
      }
    }

    rpc delete-subscription {
      description
        "This RPC allows a subscriber to delete a subscription that
         was previously created by that same subscriber using the
         'establish-subscription' RPC.

         If an error occurs, the server replies with an 'rpc-error'
         where the 'error-info' field MAY contain a
         'delete-subscription-error-info' structure.";
      input {
        leaf id {
          type subscription-id;
          mandatory true;
          description
            "Identifier of the subscription that is to be deleted.
             Only subscriptions that were created using
             'establish-subscription' from the same origin as this RPC
             can be deleted via this RPC.";
        }
      }
    }

    rpc kill-subscription {
      nacm:default-deny-all;
      description
        "This RPC allows an operator to delete a dynamic subscription
         without restrictions on the originating subscriber or
         underlying transport session.

         If an error occurs, the server replies with an 'rpc-error'
         where the 'error-info' field MAY contain a
         'delete-subscription-error-info' structure.";
      input {
        leaf id {
          type subscription-id;
          mandatory true;
          description
            "Identifier of the subscription that is to be deleted.
             Only subscriptions that were created using
             'establish-subscription' can be deleted via this RPC.";
        }
      }
```

```
  }

  rc:yang-data delete-subscription-error-info {
    container delete-subscription-error-info {
      description
        "If a 'delete-subscription' RPC or a 'kill-subscription' RPC
         fails, the subscription is not deleted and the RPC error
         response MUST indicate the reason for this failure.  This
         yang-data MAY be inserted as structured data in a
         subscription's RPC error response to indicate the reason
         for the failure.";
      leaf reason {
        type identityref {
          base delete-subscription-error;
        }
        mandatory true;
        description
          "Indicates the reason why the subscription has failed to be
           deleted.";
      }
    }
  }

  /*
   * NOTIFICATIONS
   */

  notification replay-completed {
    sn:subscription-state-notification;
    if-feature "replay";
    description
      "This notification is sent to indicate that all of the replay
       notifications have been sent.";
    leaf id {
      type subscription-id;
      mandatory true;
      description
        "This references the affected subscription.";
    }
  }

  notification subscription-completed {
    sn:subscription-state-notification;
    if-feature "configured";
    description
      "This notification is sent to indicate that a subscription has
       finished passing event records, as the 'stop-time' has been
       reached.";
```

```
    leaf id {
      type subscription-id;
      mandatory true;
      description
        "This references the gracefully completed subscription.";
    }
  }

  notification subscription-modified {
    sn:subscription-state-notification;
    description
      "This notification indicates that a subscription has been
       modified.  Notification messages sent from this point on will
       conform to the modified terms of the subscription.  For
       completeness, this subscription state change notification
       includes both modified and unmodified aspects of a
       subscription.";
    leaf id {
      type subscription-id;
      mandatory true;
      description
        "This references the affected subscription.";
    }
    uses subscription-policy {
      refine "target/stream/stream-filter/within-subscription" {
        description
          "Filter applied to the subscription.  If the
           'stream-filter-name' is populated, the filter in the
           subscription came from the 'filters' container.
           Otherwise, it is populated in-line as part of the
           subscription.";
      }
    }
  }

  notification subscription-resumed {
    sn:subscription-state-notification;
    description
      "This notification indicates that a subscription that had
       previously been suspended has resumed.  Notifications will
       once again be sent.  In addition, a 'subscription-resumed'
       indicates that no modification of parameters has occurred
       since the last time event records have been sent.";
    leaf id {
      type subscription-id;
      mandatory true;
      description
        "This references the affected subscription.";
```

```
    }
  }

  notification subscription-started {
    sn:subscription-state-notification;
    if-feature "configured";
    description
      "This notification indicates that a subscription has started
       and notifications will now be sent.";
    leaf id {
      type subscription-id;
      mandatory true;
      description
        "This references the affected subscription.";
    }
    uses subscription-policy {
      refine "target/stream/replay-start-time" {
        description
          "Indicates the time that a replay is using for the
           streaming of buffered event records.  This will be
           populated with the most recent of the following:
           the event time of the previous event record sent to a
           receiver, the 'replay-log-creation-time', the
           'replay-log-aged-time', or the most recent publisher
           boot time.";
      }
      refine "target/stream/stream-filter/within-subscription" {
        description
          "Filter applied to the subscription.  If the
           'stream-filter-name' is populated, the filter in the
           subscription came from the 'filters' container.
           Otherwise, it is populated in-line as part of the
           subscription.";
      }
      augment "target/stream" {
        description
          "This augmentation adds additional parameters specific to a
           'subscription-started' notification.";
        leaf replay-previous-event-time {
          when '../replay-start-time';
          if-feature "replay";
          type yang:date-and-time;
          description
            "If there is at least one event in the replay buffer
             prior to 'replay-start-time', this gives the time of
             the event generated immediately prior to the
             'replay-start-time'.
```

```
            If a receiver previously received event records for
            this configured subscription, it can compare this time
            to the last event record previously received.  If the
            two are not the same (perhaps due to a reboot), then a
            dynamic replay can be initiated to acquire any missing
            event records.";
        }
      }
    }
  }

  notification subscription-suspended {
    sn:subscription-state-notification;
    description
      "This notification indicates that a suspension of the
       subscription by the publisher has occurred.  No further
       notifications will be sent until the subscription resumes.
       This notification shall only be sent to receivers of a
       subscription; it does not constitute a general-purpose
       notification.";
    leaf id {
      type subscription-id;
      mandatory true;
      description
        "This references the affected subscription.";
    }
    leaf reason {
      type identityref {
        base subscription-suspended-reason;
      }
      mandatory true;
      description
        "Identifies the condition that resulted in the suspension.";
    }
  }

  notification subscription-terminated {
    sn:subscription-state-notification;
    description
      "This notification indicates that a subscription has been
       terminated.";
    leaf id {
      type subscription-id;
      mandatory true;
      description
        "This references the affected subscription.";
    }
    leaf reason {
```

```
      type identityref {
        base subscription-terminated-reason;
      }
      mandatory true;
      description
        "Identifies the condition that resulted in the termination.";
    }
  }

  /*
   * DATA NODES
   */

  container streams {
    config false;
    description
      "Contains information on the built-in event streams provided by
       the publisher.";
    list stream {
      key "name";
      description
        "Identifies the built-in event streams that are supported by
         the publisher.";
      leaf name {
        type string;
        description
          "A handle for a system-provided event stream made up of a
           sequential set of event records, each of which is
           characterized by its own domain and semantics.";
      }
      leaf description {
        type string;
        description
          "A description of the event stream, including such
           information as the type of event records that are
           available in this event stream.";
      }
      leaf replay-support {
        if-feature "replay";
        type empty;
        description
          "Indicates that event record replay is available on this
           event stream.";
      }
      leaf replay-log-creation-time {
        when '../replay-support';
        if-feature "replay";
        type yang:date-and-time;
```

```
        mandatory true;
        description
          "The timestamp of the creation of the log used to support
           the replay function on this event stream.  This time
           might be earlier than the earliest available information
           contained in the log.  This object is updated if the log
           resets for some reason.";
      }
      leaf replay-log-aged-time {
        when '../replay-support';
        if-feature "replay";
        type yang:date-and-time;
        description
          "The timestamp associated with the last event record that
           has been aged out of the log.  This timestamp identifies
           how far back in history this replay log extends, if it
           doesn't extend back to the 'replay-log-creation-time'.
           This object MUST be present if replay is supported and any
           event records have been aged out of the log.";
      }
    }
  }
  container filters {
    description
      "Contains a list of configurable filters that can be applied to
       subscriptions.  This facilitates the reuse of complex filters
       once defined.";
    list stream-filter {
      key "name";
      description
        "A list of preconfigured filters that can be applied to
         subscriptions.";
      leaf name {
        type string;
        description
          "A name to differentiate between filters.";
      }
      uses stream-filter-elements;
    }
  }
  container subscriptions {
    description
      "Contains the list of currently active subscriptions, i.e.,
       subscriptions that are currently in effect, used for
       subscription management and monitoring purposes.  This
       includes subscriptions that have been set up via
       RPC primitives as well as subscriptions that have been
       established via configuration.";
```

```
    list subscription {
      key "id";
      description
        "The identity and specific parameters of a subscription.
         Subscriptions in this list can be created using a control
         channel or RPC or can be established through configuration.

         If the 'kill-subscription' RPC or configuration operations
         are used to delete a subscription, a
         'subscription-terminated' message is sent to any active or
         suspended receivers.";
      leaf id {
        type subscription-id;
        description
          "Identifier of a subscription; unique in a given
           publisher.";
      }
      uses subscription-policy {
        refine "target/stream/stream" {
          description
            "Indicates the event stream to be considered for this
             subscription.  If an event stream has been removed
             and can no longer be referenced by an active
             subscription, send a 'subscription-terminated'
             notification with 'stream-unavailable' as the reason.
             If a configured subscription refers to a nonexistent
             event stream, move that subscription to the
             'invalid' state.";
        }
        refine "transport" {
          description
            "For a configured subscription, this leaf specifies the
             transport used to deliver messages destined for all
             receivers of that subscription.  This object is
             mandatory for subscriptions in the configuration
             datastore.  This object (1) is not mandatory for dynamic
             subscriptions in the operational state datastore and
             (2) should not be present for other types of dynamic
             subscriptions.";
        }
        augment "target/stream" {
          description
            "Enables objects to be added to a configured stream
             subscription.";
          leaf configured-replay {
            if-feature "configured";
            if-feature "replay";
            type empty;
```

```
            description
              "The presence of this leaf indicates that replay for
               the configured subscription should start at the
               earliest time in the event log or at the publisher
               boot time, whichever is later.";
          }
        }
      }
      choice notification-message-origin {
        if-feature "configured";
        description
          "Identifies the egress interface on the publisher
           from which notification messages are to be sent.";
        case interface-originated {
          description
            "When notification messages are to egress a specific,
             designated interface on the publisher.";
          leaf source-interface {
            if-feature "interface-designation";
            type if:interface-ref;
            description
              "References the interface for notification messages.";
          }
        }
        case address-originated {
          description
            "When notification messages are to depart from a
             publisher using a specific originating address and/or
             routing context information.";
          leaf source-vrf {
            if-feature "supports-vrf";
            type leafref {
              path "/ni:network-instances/ni:network-instance/ni:name";
            }
            description
              "VRF from which notification messages should egress a
               publisher.";
          }
          leaf source-address {
            type inet:ip-address-no-zone;
            description
              "The source address for the notification messages.
               If a source VRF exists but this object doesn't, a
               publisher's default address for that VRF must
               be used.";
          }
        }
      }
```

```
      leaf configured-subscription-state {
        if-feature "configured";
        type enumeration {
          enum valid {
            value 1;
            description
              "The subscription is supportable with its current
               parameters.";
          }
          enum invalid {
            value 2;
            description
              "The subscription as a whole is unsupportable with its
               current parameters.";
          }
          enum concluded {
            value 3;
            description
              "A subscription is inactive, as it has hit a
               stop time.  It no longer has receivers in the
               'active' or 'suspended' state, but the subscription
               has not yet been removed from configuration.";
          }
        }
        config false;
        description
          "The presence of this leaf indicates that the subscription
           originated from configuration, not through a control
           channel or RPC.  The value indicates the state of the
           subscription as established by the publisher.";
      }
      container receivers {
        description
          "Set of receivers in a subscription.";
        list receiver {
          key "name";
          min-elements 1;
          description
            "A host intended as a recipient for the notification
             messages of a subscription.  For configured
             subscriptions, transport-specific network parameters
             (or a leafref to those parameters) may be augmented to a
             specific receiver in this list.";
          leaf name {
            type string;
            description
              "Identifies a unique receiver for a subscription.";
          }
```

```
          leaf sent-event-records {
            type yang:zero-based-counter64;
            config false;
            description
              "The number of event records sent to the receiver.  The
               count is initialized when a dynamic subscription is
               established or when a configured receiver
               transitions to the 'valid' state.";
          }
          leaf excluded-event-records {
            type yang:zero-based-counter64;
            config false;
            description
              "The number of event records explicitly removed via
               either an event stream filter or an access control
               filter so that they are not passed to a receiver.
               This count is set to zero each time
               'sent-event-records' is initialized.";
          }
          leaf state {
            type enumeration {
              enum active {
                value 1;
                description
                  "The receiver is currently being sent any
                   applicable notification messages for the
                   subscription.";
              }
              enum suspended {
                value 2;
                description
                  "The receiver state is 'suspended', so the
                   publisher is currently unable to provide
                   notification messages for the subscription.";
              }
              enum connecting {
                value 3;
                if-feature "configured";
                description
                  "A subscription has been configured, but a
                   'subscription-started' subscription state change
                   notification needs to be successfully received
                   before notification messages are sent.

                   If the 'reset' action is invoked for a receiver of
                   an active configured subscription, the state
                   must be moved to 'connecting'.";
              }
```

```
              enum disconnected {
                value 4;
                if-feature "configured";
                description
                  "A subscription has failed to send a
                   'subscription-started' state change to the
                   receiver.  Additional connection attempts are not
                   currently being made.";
              }
            }
            config false;
            mandatory true;
            description
              "Specifies the state of a subscription from the
               perspective of a particular receiver.  With this
               information, it is possible to determine whether a
               publisher is currently generating notification
               messages intended for that receiver.";
          }
          action reset {
            if-feature "configured";
            description
              "Allows the reset of this configured subscription's
               receiver to the 'connecting' state.  This enables the
               connection process to be reinitiated.";
            output {
              leaf time {
                type yang:date-and-time;
                mandatory true;
                description
                  "Time at which a publisher returned the receiver to
                   the 'connecting' state.";
              }
            }
          }
        }
      }
    }
  }
}
<CODE ENDS>
```

5. IANA Considerations

IANA has registered one URI in the "ns" subregistry of the "IETF XML Registry" [RFC3688] maintained at <https://www.iana.org/assignments/xml-registry>. The following registration has been made per the format in [RFC3688]:

URI: urn:ietf:params:xml:ns:yang:ietf-subscribed-notifications
Registrant Contact: The NETCONF WG of the IETF.
XML: N/A; the requested URI is an XML namespace.

IANA has registered one YANG module in the "YANG Module Names" registry [RFC6020] maintained at <https://www.iana.org/assignments/yang-parameters>. The following registration has been made per the format in [RFC6020]:

Name: ietf-subscribed-notifications
Namespace: urn:ietf:params:xml:ns:yang:ietf-subscribed-notifications
Prefix: sn
Reference: RFC 8639

6. Implementation Considerations

To support deployments that include both configured and dynamic subscriptions, it is recommended that the subscription "id" domain be split into static and dynamic halves. This will eliminate the possibility of collisions if the configured subscriptions attempt to set a "subscription-id" that might have already been dynamically allocated. A best practice is to use the lower half of the "id" object's integer space when that "id" is assigned by an external entity (such as with a configured subscription). This leaves the upper half of the subscription integer space available to be dynamically assigned by the publisher.

If a subscription is unable to marshal a series of filtered event records into transmittable notification messages, the receiver should be suspended with the reason "unsupportable-volume".

For configured subscriptions, operations are performed against the set of receivers using the subscription "id" as a handle for that set. But for streaming updates, subscription state change notifications are local to a receiver. In the case of this specification, receivers do not get any information from the publisher about the existence of other receivers. But if a network operator wants to let the receivers correlate results, it is useful to use the subscription "id" across the receivers to allow that

correlation. Note that due to the possibility of different access control permissions per receiver, each receiver may actually get a different set of event records.

For configured replay subscriptions, the receiver is protected from duplicated events being pushed after a publisher is rebooted. However, it is possible that a receiver might want to acquire event records that failed to be delivered just prior to the reboot. Delivering these event records can be accomplished by leveraging the <eventTime> [RFC5277] from the last event record received prior to the receipt of a "subscription-started" subscription state change notification. With this <eventTime> and the "replay-start-time" from the "subscription-started" notification, an independent dynamic subscription can be established that retrieves any event records that may have been generated but not sent to the receiver.

7. Transport Requirements

This section provides requirements for any subscribed notification transport supporting the solution presented in this document.

The transport selected by the subscriber to reach the publisher MUST be able to support multiple "establish-subscription" requests made in the same transport session.

For both configured and dynamic subscriptions, the publisher MUST authenticate a receiver via some transport-level mechanism before sending any event records that the receiver is authorized to see. In addition, the receiver MUST authenticate the publisher at the transport level. The result is mutual authentication between the two.

A secure transport is highly recommended. Beyond this, the publisher MUST ensure that the receiver has sufficient authorization to perform the function it is requesting against the specific subset of content involved.

A specification for a transport built upon this document may or may not choose to require the use of the same logical channel for the RPCs and the event records. However, the event records and the subscription state change notifications MUST be sent on the same transport session to ensure properly ordered delivery.

A specification for a transport MUST identify any encodings that are supported. If a configured subscription’s transport allows different encodings, the specification MUST identify the default encoding.

A subscriber that includes a "dscp" leaf in an "establish-subscription" request will need to understand and consider what the corresponding DSCP value represents in the domain of the publisher.

Additional transport requirements will be dictated by the choice of transport used with a subscription. For an example of such requirements, see [RFC8640].

8. Security Considerations

The YANG module specified in this document defines a schema for data that is designed to be accessed via network management protocols such as NETCONF [RFC6241] or RESTCONF [RFC8040]. The lowest NETCONF layer is the secure transport layer, and the mandatory-to-implement secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC5246].

The Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

With configured subscriptions, one or more publishers could be used to overwhelm a receiver. To counter this, notification messages SHOULD NOT be sent to any receiver that does not support this specification. Receivers that do not want notification messages need only terminate or refuse any transport sessions from the publisher.

When a receiver of a configured subscription gets a new "subscription-started" message for a known subscription where it is already consuming events, it may indicate that an attacker has done something that has momentarily disrupted receiver connectivity. To acquire events lost during this interval, the receiver SHOULD retrieve any event records generated since the last event record was received. This can be accomplished by establishing a separate dynamic replay subscription with the same filtering criteria with the publisher, assuming that the publisher supports the "replay" feature.

For dynamic subscriptions, implementations need to protect against malicious or buggy subscribers that may send a large number of "establish-subscription" requests and thereby use up system resources. To cover this possibility, operators SHOULD monitor for such cases and, if discovered, take remedial action to limit the resources used, such as suspending or terminating a subset of the subscriptions or, if the underlying transport is session based, terminating the underlying transport session.

The replay mechanisms described in Sections 2.4.2.1 and 2.5.6 provide access to historical event records. By design, the access control model that protects these records could enable subscribers to view data to which they were not authorized at the time of collection.

Using DNS names for configured subscription's receiver "name" lookups can cause situations where the name resolves differently than expected on the publisher, so the recipient would be different than expected.

An attacker that can cause the publisher to use an incorrect time can induce message replay by setting the time in the past and can introduce a risk of message loss by setting the time in the future.

There are a number of data nodes defined in this YANG module that are writable/creatable/deletable (i.e., config true, which is the default). These data nodes may be considered sensitive or vulnerable in some network environments. Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative effect on network operations. These are the subtrees and data nodes and their sensitivity/vulnerability:

Container: "/filters"

- "stream-subtree-filter": Updating a filter could increase the computational complexity of all referencing subscriptions.

- "stream-xpath-filter": Updating a filter could increase the computational complexity of all referencing subscriptions.

Container: "/subscriptions"

The following considerations are only relevant for configuration operations made upon configured subscriptions:

- "configured-replay": Can be used to send a large number of event records to a receiver.

- "dependency": Can be used to force important traffic to be queued behind updates that are not as important.

- "dscp": If unvalidated, can result in the sending of traffic with a higher-priority marking than warranted.

- "id": Can overwrite an existing subscription, perhaps one configured by another entity.

- "name": Adding a new key entry can be used to attempt to send traffic to an unwilling receiver.

- "replay-start-time": Can be used to push very large logs, wasting resources.

- "source-address": The configured address might not be able to reach a desired receiver.

- "source-interface": The configured interface might not be able to reach a desired receiver.

- "source-vrf": Can place a subscription in a virtual network where receivers are not entitled to view the subscribed content.

- "stop-time": Could be used to terminate content at an inopportune time.

- "stream": Could set a subscription to an event stream that does not contain content permitted for the targeted receivers.

- "stream-filter-name": Could be set to a filter that is not relevant to the event stream.

- "stream-subtree-filter": A complex filter can increase the computational resources for this subscription.

- "stream-xpath-filter": A complex filter can increase the computational resources for this subscription.

- "weighting": Allocating a large weight can overwhelm the dequeuing of other subscriptions.

Some of the readable data nodes in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control read access (e.g., via get, get-config, or notification) to these data nodes. These are the subtrees and data nodes and their sensitivity/vulnerability:

Container: "/streams"

- "name": If access control is not properly configured, can expose system internals to those who should not have access to this information.

- "replay-support": If access control is not properly configured, can expose logs to those who should not have access.

Container: "/subscriptions"

- "excluded-event-records": This leaf can provide information about filtered event records. A network operator should have the proper permissions to know about such filtering. However, exposing the count of excluded events to a receiver could leak information about the presence of access control filters that might be in place for that receiver.

- "subscription": Different operational teams might have a desire to set varying subsets of subscriptions. Access control should be designed to permit read access to just the allowed set.

Some of the RPC operations in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control access to these operations. These are the operations and their sensitivity/vulnerability:

RPC: all

- If a malicious or buggy subscriber sends an unexpectedly large number of RPCs, the result might be an excessive use of system resources on the publisher just to determine that these subscriptions should be declined. In such a situation, subscription interactions MAY be terminated by terminating the transport session.

RPC: "delete-subscription"

- No special considerations.

RPC: "establish-subscription"

- Subscriptions could overload a publisher’s resources. For this reason, publishers MUST ensure that they have sufficient resources to fulfill this request; otherwise, they MUST reject the request.

RPC: "kill-subscription"

- The "kill-subscription" RPC MUST be secured so that only connections with administrative rights are able to invoke this RPC.

RPC: "modify-subscription"

- Subscriptions could overload a publisher’s resources. For this reason, publishers MUST ensure that they have sufficient resources to fulfill this request; otherwise, they MUST reject the request.

9. References

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Appendix A. Example Configured Transport Augmentation

This appendix provides a non-normative example of how the YANG module defined in Section 4 may be enhanced to incorporate the configuration parameters needed to support the transport connectivity process. This example is not intended to be a complete transport model. In this example, connectivity via an imaginary transport type of "foo" is explored. For more on the overall objectives behind configuring transport connectivity for a configured subscription, see Section 2.5.7.

The YANG module example defined in this appendix contains two main elements. First is a transport identity "foo". This transport identity allows a configuration agent to define "foo" as the selected type of transport for a subscription. Second is a YANG case augmentation "foo", which is made to the "/subscriptions/subscription/receivers/receiver" node of Section 4. In this augmentation are the transport configuration parameters "address" and "port", which are necessary to make the connection to the receiver.

```
module example-foo-subscribed-notifications {
  yang-version 1.1;
  namespace
    "urn:example:foo-subscribed-notifications";

  prefix fsn;

  import ietf-subscribed-notifications {
    prefix sn;
  }
  import ietf-inet-types {
    prefix inet;
  }

  description
    "Defines 'foo' as a supported type of configured transport for
     subscribed event notifications.";

  identity foo {
    base sn:transport;
    description
      "Transport type 'foo' is available for use as a configured
       subscription's transport protocol for subscribed
       notifications.";
  }
```

```
    augment
      "/sn:subscriptions/sn:subscription/sn:receivers/sn:receiver" {
      when 'derived-from(../../../transport, "fsn:foo")';
      description
        "This augmentation makes transport parameters specific to 'foo'
         available for a receiver.";
      leaf address {
        type inet:host;
        mandatory true;
        description
          "Specifies the address to use for messages destined for a
           receiver.";
      }
      leaf port {
        type inet:port-number;
        mandatory true;
        description
          "Specifies the port number to use for messages destined for a
           receiver.";
      }
    }
  }
```

Figure 21: Example Transport Augmentation
for the Fictitious Protocol "foo"

This example YANG module for transport "foo" will not be seen in a real-world deployment. For a real-world deployment supporting an actual transport technology, a similar YANG module must be defined.

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