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Subscription to YANG Datastores
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Abstract

This document describes a mechanism that allows subscriber applications to request a continuous and customized stream of updates from a YANG datastore. Providing such visibility into updates enables new capabilities based on the remote mirroring and monitoring of configuration and operational state.

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1. Introduction

Traditional approaches to provide visibility into managed entities from a remote system have been built on polling. With polling, data is periodically requested and retrieved by a client from a server to stay up-to-date. However, there are issues associated with polling-based management:

- o Polling incurs significant latency. This latency prohibits many types of application.
- o Polling cycles may be missed and requests may be delayed or get lost, often when the network is under stress and the need for the data is the greatest.
- o Polling requests may undergo slight fluctuations, resulting in intervals of different lengths. The resulting data is difficult to calibrate and compare.
- o For applications that monitor for changes, many remote polling cycles place unwanted and ultimately wasteful load on the network, devices, and applications, particularly when changes occur only infrequently.

A more effective alternative to polling is for an application to receive automatic and continuous updates from a targeted subset of a datastore. Accordingly, there is a need for a service that allows applications to subscribe to updates from a datastore and that enables the server (also referred to as publisher) to push and in effect stream those updates. The requirements for such a service have been documented in [RFC7923].

This document defines a corresponding solution that is built on top of "Custom Subscription to Event Streams" [I-D.draft-ietf-netconf-subscribed-notifications]. Supplementing that work are YANG data model augmentations, extended RPCs, and new datastore specific update notifications. Transport options for [I-D.draft-ietf-netconf-subscribed-notifications] will work seamlessly with this solution.

2. Definitions and Acronyms

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.

This document uses the terminology defined in [RFC7950], [RFC8341], [RFC8342], and [I-D.draft-ietf-netconf-subscribed-notifications]. In addition, the following terms are introduced:

- o Datastore node: A node in the instantiated YANG data tree associated with a datastore. In this document, datastore nodes are often also simply referred to as "objects"
- o Datastore node update: A data item containing the current value of a datastore node at the time the datastore node update was created, as well as the path to the datastore node.
- o Datastore subscription: A subscription to a stream of datastore node updates.
- o Datastore subtree: A datastore node and all its descendant datastore nodes
- o On-change subscription: A datastore subscription with updates that are triggered when changes in subscribed datastore nodes are detected.
- o Periodic subscription: A datastore subscription with updates that are triggered periodically according to some time interval.
- o Selection filter: Evaluation and/or selection criteria, which may be applied against a targeted set of objects.
- o Update record: A representation of one or more datastore node updates. In addition, an update record may contain which type of update led to the datastore node update (e.g., whether the datastore node was added, changed, deleted). Also included in the update record may be other metadata, such as a subscription id of the subscription as part of which the update record was generated. In this document, update records are often also simply referred to as "updates".
- o Update trigger: A mechanism that determines when an update record needs to be generated.
- o YANG-Push: The subscription and push mechanism for datastore updates that is specified in this document.

3. Solution Overview

This document specifies a solution that provides a subscription service for updates from a datastore. This solution supports dynamic as well as configured subscriptions to updates of datastore nodes. Subscriptions specify when notification messages (also referred to as "push updates") should be sent and what data to include in update records. Datastore node updates are subsequently pushed from the publisher to the receiver per the terms of the subscription.

3.1. Subscription Model

YANG-push subscriptions are defined using a YANG data model. This model enhances the subscription model defined in [I-D.draft-ietf-netconf-subscribed-notifications] with capabilities that allow subscribers to subscribe to datastore node updates, specifically to specify the update triggers defining when to generate update records as well as what to include in an update record. Key enhancements include:

- o Specification of selection filters which identify targeted YANG datastore nodes and/or datastore subtrees for which updates are to be pushed.
- o Specification of update policies contain conditions which trigger the generation and pushing of new update records. There are two types of subscriptions, distinguished by how updates are triggered: periodic and on-change.
 - * For periodic subscriptions, the update trigger is specified by two parameters that define when updates are to be pushed. These parameters are the period interval with which to report updates, and an "anchor time", i.e. a reference point in time that can be used to calculate at which points in time periodic updates need to be assembled and sent.
 - * For on-change subscriptions, an update trigger occurs whenever a change in the subscribed information is detected. Included are additional parameters that include:
 - + Dampening period: In an on-change subscription, detected object changes should be sent as quickly as possible. However it may be undesirable to send a rapid series of object changes. Such behavior has the potential to exhaust resources in the publisher or receiver. In order to protect against that, a dampening period MAY be used to specify the interval which has to pass before successive update records for the same subscription are generated for a receiver. The

dampening period collectively applies to the set of all datastore nodes selected by a single subscription. This means that when there is a change to one or more subscribed objects, an update record containing those objects is created immediately (when no dampening period is in effect) or at the end of a dampening period (when a dampening period is in fact in effect). If multiple changes to a single object occur during a dampening period, only the value that is in effect at the time when the update record is created is included. The dampening period goes into effect every time an update record completes assembly.

- + Change type: This parameter can be used to reduce the types of datastore changes for which updates are sent (e.g., you might only send an update when an object is created or deleted, but not when an object value changes).
- + Sync on start: defines whether or not a complete push-update of all subscribed data will be sent at the beginning of a subscription. Such early synchronization establishes the frame of reference for subsequent updates.
- o An encoding (using anydata) for the contents of periodic and on-change push updates.

3.2. Negotiation of Subscription Policies

A dynamic subscription request SHOULD be declined if a publisher's assessment is that it may be unable to provide update records meeting the terms of an "establish-subscription" or "modify-subscription" RPC request. In this case, a subscriber may quickly follow up with a new RPC request using different parameters.

Random guessing of different parameters by a subscriber is to be discouraged. Therefore, in order to minimize the number of subscription iterations between subscriber and publisher, a dynamic subscription supports a simple negotiation between subscribers and publishers for subscription parameters. This negotiation is in the form of supplemental information which should be inserted within error responses to a failed RPC request. This returned error response information, when considered, should increase the likelihood of success for subsequent RPC requests. Such hints include suggested periodic time intervals, acceptable dampening periods, and size estimates for the number or objects which would be returned from a proposed selection filter. However, there are no guarantees that subsequent requests which consider these hints will be accepted.

3.3. On-Change Considerations

On-change subscriptions allow receivers to receive updates whenever changes to targeted objects occur. As such, on-change subscriptions are particularly effective for data that changes infrequently, yet for which applications need to be quickly notified whenever a change does occur with minimal delay.

On-change subscriptions tend to be more difficult to implement than periodic subscriptions. Accordingly, on-change subscriptions may not be supported by all implementations or for every object.

Whether or not to accept or reject on-change subscription requests when the scope of the subscription contains objects for which on-change is not supported is up to the publisher implementation. A publisher MAY accept an on-change subscription even when the scope of the subscription contains objects for which on-change is not supported. In that case, updates are sent only for those objects within the scope that do support on-change updates, whereas other objects are excluded from update records, even if their values change. In order for a subscriber to determine whether objects support on-change subscriptions, objects are marked accordingly on a publisher. Accordingly, when subscribing, it is the responsibility of the subscriber to ensure it is aware of which objects support on-change and which do not. For more on how objects are so marked, see Section 3.10.

Alternatively, a publisher MAY decide to simply reject an on-change subscription in case the scope of the subscription contains objects for which on-change is not supported. In case of a configured subscription, the publisher MAY suspend the subscription.

To avoid flooding receivers with repeated updates for subscriptions containing fast-changing objects, or objects with oscillating values, an on-change subscription allows for the definition of a dampening period. Once an update record for a given object is generated, no other updates for this particular subscription will be created until the end of the dampening period. Values sent at the end of the dampening period are the values that are current at the end of the dampening period of all changed objects. Changed objects include those which were deleted or newly created during that dampening period. If an object has returned to its original value (or even has been created and then deleted) during the dampening-period, that value (and not the interim change) will still be sent. This will indicate churn is occurring on that object.

On-change subscriptions can be refined to let users subscribe only to certain types of changes. For example, a subscriber might only want

object creations and deletions, but not modifications of object values.

Putting it all together, following is the conceptual process for creating an update record as part of an on-change subscription:

1. Just before a change, or at the start of a dampening period, evaluate any filtering and any access control rules to ensure receiver is authorized to view all subscribed datastore nodes (filtering out any nodes for which this is not the case). The result is a set "A" of datastore nodes and subtrees.
2. Just after a change, or at the end of a dampening period, evaluate any filtering and any (possibly new) access control rules. The result is a set "B" of datastore nodes and subtrees.
3. Construct an update record, which takes the form of YANG patch record [RFC8072] for going from A to B.
4. If there were any changes made between A and B which canceled each other out, insert into the YANG patch record the last change made, even if the new value is no different from the original value (since changes that were made in the interim were canceled out). In case the changes involve creating a new datastore node, then deleting it, the YANG patch record will indicate deletion of the datastore node. Similarly, in case the changes involve deleting a new datastore node, then recreating it, the YANG patch record will indicate creation of the datastore node.
5. If the resulting patch record is non-empty, send it to the receiver.

Note: In cases where a subscriber wants to have separate dampening periods for different objects, the subscriber has the option to create multiple subscriptions with different selection filters.

3.4. Reliability Considerations

A subscription to updates from a datastore is intended to obviate the need for polling. However, in order to do so, it is critical that subscribers can rely on the subscription and have confidence that they will indeed receive the subscribed updates without having to worry about updates being silently dropped. In other words, a subscription constitutes a promise on the side of the publisher to provide the receivers with updates per the terms of the subscription.

Now, there are many reasons why a publisher may at some point no longer be able to fulfill the terms of the subscription, even if the

subscription had been entered into with good faith. For example, the volume of datastore nodes may be larger than anticipated, the interval may prove too short to send full updates in rapid succession, or an internal problem may prevent objects from being collected. For this reason, the solution that is defined in this document mandates that a publisher notifies receivers immediately and reliably whenever it encounters a situation in which it is unable to keep the terms of the subscription, and provides the publisher with the option to suspend the subscription in such a case. This includes indicating the fact that an update is incomplete as part of a push-update or push-change-update notification, as well as emitting a subscription-suspended notification as applicable. This is described further in Section 3.11.1.

A publisher SHOULD reject a request for a subscription if it is unlikely that the publisher will be able to fulfill the terms of that subscription request. In such cases, it is preferable to have a subscriber request a less resource intensive subscription than to deal with frequently degraded behavior.

The solution builds on [I-D.draft-ietf-netconf-subscribed-notifications]. As defined there, any loss of underlying transport connection will be detected and result in subscription termination (in case of dynamic subscriptions) or suspension (in case of configured subscriptions), ensuring that situations will not occur in which the loss of update notifications would go unnoticed.

3.5. Data Encodings

3.5.1. Periodic Subscriptions

In a periodic subscription, the data included as part of an update record corresponds to data that could have been read using a retrieval operation.

3.5.2. On-Change Subscriptions

In an on-change subscription, update records need to indicate not only values of changed datastore nodes but also the types of changes that occurred since the last update. Therefore, encoding rules for data in on-change updates will generally follow YANG-patch operation as specified in [RFC8072]. The YANG-patch will describe what needs to be applied to the earlier state reported by the preceding update, to result in the now-current state. Note that contrary to [RFC8072], objects encapsulated are not restricted to only configuration objects.

A publisher indicates the type of change to a datastore node using the different YANG patch operations: the "create" operation is used for newly created objects (except entries in a user-ordered list), the "delete" operation is used for deleted objects (including in user-ordered lists), the "replace" operation is used when only the object value changes, the "insert" operation is used when a new entry is inserted in a list, and the "move" operation is used when an existing entry in a user-ordered list is moved.

However, a patch must be able to do more than just describe the delta from the previous state to the current state. As per Section 3.3, it must also be able to identify whether transient changes have occurred on an object during a dampening period. To support this, it is valid to encode a YANG patch operation so that its application would result in no change between the previous and current state. This indicates that some churn has occurred on the object. An example of this would be a patch that indicates a "create" operation for a datastore node where the receiver believes one already exists, or a "replace" operation which replaces a previous value with the same value. Note that this means that the "create" and "delete" errors described in [RFC8072] section 2.5 are not errors, and are valid operations with YANG-Push.

3.6. Defining the Selection with a Datastore

A subscription must specify both the selection filters and the datastore against which these selection filters will be applied. This information is used to choose and subsequently push data from the publisher's datastore to the receivers.

Only a single selection filter can be applied to a subscription at a time. An RPC request proposing a new selection filter replaces any existing filter. The following selection filter types are included in the YANG-push data model, and may be applied against a datastore:

- o subtree: A subtree selection filter identifies one or more datastore subtrees. When specified, update records will only come from the datastore nodes of selected datastore subtree(s). The syntax and semantics correspond to that specified for [RFC6241] section 6.
- o xpath: An "xpath" selection filter is an XPath expression that returns a node set. (XPath is a query language for selecting nodes in an XML document.) When specified, updates will only come from the selected datastore nodes.

These filters are intended to be used as selectors that define which objects are within the scope of a subscription. A publisher **MUST** support at least one type of selection filter.

XPath itself provides powerful filtering constructs and care must be used in filter definition. Consider an XPath filter which only passes a datastore node when an interface is up. It is up to the receiver to understand implications of the presence or absence of objects in each update.

When the set of selection filtering criteria is applied for a periodic subscription, then they are applied whenever a periodic update record is constructed, and only datastore nodes that pass the filter and to which a receiver has access are provided to that receiver. If the same filtering criteria is applied to an on-change subscription, only the subset of those datastore nodes supporting on-change is provided. A datastore node which doesn't support on-change is never sent as part of an on-change subscription's "push-update" or "push-change-update" (see Section 3.7).

3.7. Streaming Updates

Contrary to traditional data retrieval requests, datastore subscription enables an unbounded series of update records to be streamed over time. Two generic YANG notifications for update records have been defined for this: "push-update" and "push-change-update".

A "push-update" notification defines a complete, filtered update of the datastore per the terms of a subscription. This type of YANG notification is used for continuous updates of periodic subscriptions. A "push-update" notification can also be used for the on-change subscriptions in two cases. First, it **MUST** be used as the initial "push-update" if there is a need to synchronize the receiver at the start of a new subscription. It also **MAY** be sent if the publisher later chooses to resync an on-change subscription. The "push-update" update record contains an instantiated datastore subtree with all of the subscribed contents. The content of the update record is equivalent to the contents that would be obtained had the same data been explicitly retrieved using a datastore retrieval operation using the same transport with the same filters applied.

A "push-change-update" notification is the most common type of update for on-change subscriptions. The update record in this case contains the set of changes that datastore nodes have undergone since the last notification message. In other words, this indicates which datastore nodes have been created, deleted, or have had changes to their

values. In cases where multiple changes have occurred over the course of a dampening period and the object has not been deleted, the object's most current value is reported. (In other words, for each object, only one change is reported, not its entire history. Doing so would defeat the purpose of the dampening period.)

"Push-update" and "push-change-update" are encoded and placed within notification messages, and ultimately queued for egress over the specified transport.

The following is an example of a notification message for a subscription tracking the operational status of a single Ethernet interface (per [RFC8343]). This notification message is encoded XML over NETCONF as per [I-D.draft-ietf-netconf-netconf-event-notifications].

```
<notification xmlns="urn:ietf:params:xml:ns:netconf:notification:1.0">
  <eventTime>2017-10-25T08:00:11.22Z</eventTime>
  <push-update xmlns="urn:ietf:params:xml:ns:yang:ietf-yang-push">
    <id>1011</id>
    <datastore-contents>
      <interfaces xmlns="urn:ietf:params:xml:ns:yang:ietf-interfaces">
        <interface>
          <name>eth0</name>
          <oper-status>up</oper-status>
        </interface>
      </interfaces>
    </datastore-contents>
  </push-update>
</notification>
```

Figure 1: Push example

The following is an example of an on-change notification message for the same subscription.

```
<notification xmlns="urn:ietf:params:xml:ns:netconf:notification:1.0">
  <eventTime>2017-10-25T08:22:33.44Z</eventTime>
  <push-change-update
    xmlns="urn:ietf:params:xml:ns:yang:ietf-yang-push">
    <id>89</id>
    <datastore-changes>
      <yang-patch>
        <patch-id>0</patch-id>
        <edit>
          <edit-id>edit1</edit-id>
          <operation>replace</operation>
          <target>/ietf-interfaces:interfaces</target>
          <value>
            <interfaces
              xmlns="urn:ietf:params:xml:ns:yang:ietf-interfaces">
                <interface>
                  <name>eth0</name>
                  <oper-status>down</oper-status>
                </interface>
              </interfaces>
            </value>
          </edit>
        </yang-patch>
      </datastore-changes>
    </push-change-update>
  </notification>
```

Figure 2: Push example for on change

Of note in the above example is the 'patch-id' with a value of '0'. Per [RFC8072], the 'patch-id' is an arbitrary string. With YANG Push, the publisher SHOULD put into the 'patch-id' a counter starting at '0' which increments with every 'push-change-update' generated for a subscription. If used as a counter, this counter MUST be reset to '0' anytime a resynchronization occurs (i.e., with the sending of a 'push-update'). Also if used as a counter, the counter MUST be reset to '0' after passing a maximum value of '4294967295' (i.e. maximum value that can be represented using uint32 data type). Such a mechanism allows easy identification of lost or out-of-sequence update records.

3.8. Subscription Management

The RPCs defined within [I-D.draft-ietf-netconf-subscribed-notifications] have been enhanced to support datastore subscription negotiation. Also, new error codes have been added that are able to indicate why a datastore subscription attempt has failed, along with new YANG-data that MAY be

used to include details on input parameters that might result in a successful subsequent RPC invocation.

The establishment or modification of a datastore subscription can be rejected for multiple reasons. This includes a too large subtree request, or the inability of the publisher to push update records as frequently as requested. In such cases, no subscription is established. Instead, the subscription-result with the failure reason is returned as part of the RPC response. As part of this response, a set of alternative subscription parameters MAY be returned that would likely have resulted in acceptance of the subscription request. The subscriber may consider these as part of future subscription attempts.

In the case of a rejected request for an establishment of a datastore subscription, if there are hints, the hints SHOULD be transported within a YANG-data "establish-subscription-datastore-error-info" container inserted into the RPC error response, in lieu of the "establish-subscription-stream-error-info" that is inserted in case of a stream subscription.

Below is a tree diagram for "establish-subscription-datastore-error-info". All tree diagrams used in this document follow the notation defined in [RFC8340]

```

YANG-data establish-subscription-datastore-error-info
  +--ro establish-subscription-datastore-error-info
    +--ro reason?                identityref
    +--ro period-hint?           centiseconds
    +--ro filter-failure-hint?   string
    +--ro object-count-estimate? uint32
    +--ro object-count-limit?   uint32
    +--ro kilobytes-estimate?    uint32
    +--ro kilobytes-limit?      uint32

```

Figure 3: Tree diagram for establish-subscription-datastore-error-info

Similarly, in the case of a rejected request for modification of a datastore subscription, if there are hints, the hints SHOULD be transported within a YANG-data "modify-subscription-datastore-error-info" container inserted into the RPC error response, in lieu of the "modify-subscription-stream-error-info" that is inserted in case of a stream subscription.

Below is a tree diagram for "modify-subscription-datastore-error-info".

```

YANG-data modify-subscription-datastore-error-info
  +--ro modify-subscription-datastore-error-info
    +--ro reason?                identityref
    +--ro period-hint?           centiseconds
    +--ro filter-failure-hint?   string
    +--ro object-count-estimate? uint32
    +--ro object-count-limit?   uint32
    +--ro kilobytes-estimate?    uint32
    +--ro kilobytes-limit?      uint32

```

Figure 4: Tree diagram for modify-subscription-datastore-error-info

3.9. Receiver Authorization

A receiver of subscription data MUST only be sent updates for which it has proper authorization. A publisher MUST ensure that no non-authorized data is included in push updates. To do so, it needs to apply all corresponding checks applicable at the time of a specific pushed update and if necessary silently remove any non-authorized data from datastore subtrees. This enables YANG data pushed based on subscriptions to be authorized equivalently to a regular data retrieval (get) operation.

Each "push-update" and "push-change-update" MUST have access control applied, as is depicted in the following diagram. This includes validating that read access is permitted for any new objects selected since the last notification message was sent to a particular receiver. To accomplish this, implementations SHOULD support the conceptual authorization model of [RFC8341], specifically section 3.2.4.

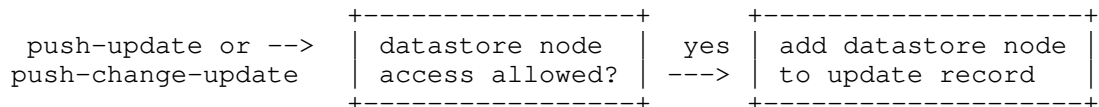


Figure 5: Updated [RFC8341] access control for push updates

A publisher MUST allow for the possibility that a subscription's selection filter references non-existent data or data that a receiver is not allowed to access. Such support permits a receiver the ability to monitor the entire lifecycle of some datastore tree without needing to explicitly enumerate every individual datastore node. If, after access control has been applied, there are no objects remaining in an update record, then (in case of a periodic subscription) only a single empty "push-update" notification MUST be sent. Empty "push-change-update" messages (in case of an on-change subscription) MUST NOT be sent. This is required to ensure that clients cannot

surreptitiously monitor objects that they do not have access to via carefully crafted selection filters. By the same token, changes to objects that are filtered MUST NOT affect any dampening intervals.

A publisher MAY choose to reject an establish-subscription request which selects non-existent data or data that a receiver is not allowed to access. As reason, the error identity "unchanging-selection" SHOULD be returned. In addition, a publisher MAY choose to terminate a dynamic subscription or suspend a configured receiver when the authorization privileges of a receiver change, or the access controls for subscribed objects change. In that case, the publisher SHOULD include the error identity "unchanging-selection" as reason when sending the "subscription-terminated" respectively "subscription-suspended" notification. Such a capability enables the publisher to avoid having to support continuous and total filtering of a subscription's content for every update record. It also reduces the possibility of leakage of access-controlled objects.

If read access into previously accessible nodes has been lost due to a receiver permissions change, this SHOULD be reported as a patch "delete" operation for on-change subscriptions. If not capable of handling such receiver permission changes with such a "delete", publisher implementations MUST force dynamic subscription re-establishment or configured subscription re-initialization so that appropriate filtering is installed.

3.10. On-Change Notifiable Datastore Nodes

In some cases, a publisher supporting on-change notifications may not be able to push on-change updates for some object types. Reasons for this might be that the value of the datastore node changes frequently (e.g., [RFC8343]'s in-octets counter), that small object changes are frequent and meaningless (e.g., a temperature gauge changing 0.1 degrees), or that the implementation is not capable of on-change notification for a particular object.

In those cases, it will be important for client applications to have a way to identify for which objects on-change notifications are supported and for which ones they are not supported. Otherwise client applications will have no way of knowing whether they can indeed rely on their on-change subscription to provide them with the change updates that they are interested in. In other words, if implementations do not provide a solution and do not support comprehensive on-change notifiability, clients of those implementations will have no way of knowing what their on-change subscription actually covers.

Implementations are therefore strongly advised to provide a solution to this problem. One solution might involve making discoverable to clients which objects are on-change notifiable, specified using another YANG data model. Such a solution is specified in [I-D.draft-ietf-netconf-notification-capabilities]. Until this solution is standardized, implementations SHOULD provide their own solution.

3.11. Other Considerations

3.11.1. Robustness and reliability

Particularly in the case of on-change updates, it is important that these updates do not get lost. In case the loss of an update is unavoidable, it is critical that the receiver is notified accordingly.

Update records for a single subscription MUST NOT be resequenced prior to transport.

It is conceivable that under certain circumstances, a publisher will recognize that it is unable to include within an update record the full set of objects desired per the terms of a subscription. In this case, the publisher MUST act as follows.

- o The publisher MUST set the "incomplete-update" flag on any update record which is known to be missing information.
- o The publisher MAY choose to suspend the subscription as per [I-D.draft-ietf-netconf-subscribed-notifications]. If the publisher does not create an update record at all, it MUST suspend the subscription.
- o When resuming an on-change subscription, the publisher SHOULD generate a complete patch from the previous update record. If this is not possible and the "sync-on-start" option is true for the subscription, then the full datastore contents MAY be sent via a "push-update" instead (effectively replacing the previous contents). If neither of these are possible, then an "incomplete-update" flag MUST be included on the next "push-change-update".

Note: It is perfectly acceptable to have a series of "push-change-update" notifications (and even "push update" notifications) serially queued at the transport layer awaiting transmission. It is not required for the publisher to merge pending update records sent at the same time.

On the receiver side, what action to take when a record with an incomplete-update flag is received depends on the application. It could simply choose to wait and do nothing. It could choose to resynch, actively retrieving all subscribed information. It could also choose to tear down the subscription and start a new one, perhaps with a lesser scope that contains less objects.

3.11.2. Publisher capacity

It is far preferable to decline a subscription request than to accept such a request when it cannot be met.

Whether or not a subscription can be supported will be determined by a combination of several factors such as the subscription update trigger (on-change or periodic), the period in which to report changes (one second periods will consume more resources than one hour periods), the amount of data in the datastore subtree that is being subscribed to, and the number and combination of other subscriptions that are concurrently being serviced.

4. A YANG Data Model for Management of Datastore Push Subscriptions

4.1. Overview

The YANG data model for datastore push subscriptions is depicted in the following figures. The tree diagram that is used follows the notation defined in [RFC8340]. New schema objects defined here (i.e., beyond those from [I-D.draft-ietf-netconf-subscribed-notifications]) are identified with "yp". For the reader's convenience, in order to compact the tree representation, some nodes that are defined in ietf-subscribed-notifications and that are not essential to the understanding of the data model defined here have been removed. This is indicated by "... " in the diagram where applicable.

Because the tree diagram is quite large, its depiction is broken up into several figures. The first figure depicts the augmentations that are introduced in module ietf-yang-push to subscription configuration specified in module ietf-subscribed-notifications.

```

module: ietf-subscribed-notifications
...
+--rw filters
|
|   ...
+--rw yp:selection-filter* [filter-id]
|   +--rw yp:filter-id                string
|   +--rw (yp:filter-spec)?
|       +--:(yp:datastore-subtree-filter)
|           +--rw yp:datastore-subtree-filter?    <anydata>
|               {sn:subtree}?
|       +--:(yp:datastore-xpath-filter)
|           +--rw yp:datastore-xpath-filter?      yang:xpath1.0
|               {sn:xpath}?
+--rw subscriptions
|   +--rw subscription* [id]
|       |
|       |   ...
+--rw (target)
|   +--:(stream)
|       |
|       |   ...
+--:(yp:datastore)
|   +--rw yp:datastore                identityref
|   +--rw (yp:selection-filter)?
|       +--:(yp:by-reference)
|           +--rw yp:selection-filter-ref
|               selection-filter-ref
|       +--:(yp:within-subscription)
|           +--rw (yp:filter-spec)?
|               +--:(yp:datastore-subtree-filter)
|                   +--rw yp:datastore-subtree-filter?
|                       <anydata> {sn:subtree}?
|               +--:(yp:datastore-xpath-filter)
|                   +--rw yp:datastore-xpath-filter?
|                       yang:xpath1.0 {sn:xpath}?
|       |
|       |   ...
+--rw (yp:update-trigger)
|   +--:(yp:periodic)
|       |
|       |   +--rw yp:periodic!
|       |       +--rw yp:period            centiseconds
|       |       +--rw yp:anchor-time?     yang:date-and-time
|       +--:(yp:on-change) {on-change}?
|           +--rw yp:on-change!
|               +--rw yp:dampening-period? centiseconds
|               +--rw yp:sync-on-start?   boolean
|               +--rw yp:excluded-change* change-type

```

Figure 6: Model structure: subscription configuration

The next figure depicts the augmentations of module `ietf-yang-push` made to RPCs specified in module `ietf-subscribed-notifications`. Specifically, these augmentations concern the `establish-subscription` and `modify-subscription` RPCs, which are augmented with parameters that are needed to specify datastore push subscriptions.

```

rpcs:
  +---x establish-subscription
  |   +---w input
  |   |   ...
  |   |   +---w (target)
  |   |   |   +---:(stream)
  |   |   |   |   ...
  |   |   |   +---:(yp:datastore)
  |   |   |   |   +---w yp:datastore
  |   |   |   |   |   identityref
  |   |   |   |   +---w (yp:selection-filter)?
  |   |   |   |   |   +---:(yp:by-reference)
  |   |   |   |   |   |   +---w yp:selection-filter-ref
  |   |   |   |   |   |   |   selection-filter-ref
  |   |   |   |   +---:(yp:within-subscription)
  |   |   |   |   |   +---w (yp:filter-spec)?
  |   |   |   |   |   |   +---:(yp:datastore-subtree-filter)
  |   |   |   |   |   |   |   +---w yp:datastore-subtree-filter?
  |   |   |   |   |   |   |   |   <anydata> {sn:subtree}?
  |   |   |   |   |   +---:(yp:datastore-xpath-filter)
  |   |   |   |   |   |   +---w yp:datastore-xpath-filter?
  |   |   |   |   |   |   |   yang:xpath1.0 {sn:xpath}?
  |   |   |   |   ...
  |   |   +---w (yp:update-trigger)
  |   |   |   +---:(yp:periodic)
  |   |   |   |   +---w yp:periodic!
  |   |   |   |   |   +---w yp:period
  |   |   |   |   |   |   centiseconds
  |   |   |   |   |   +---w yp:anchor-time?
  |   |   |   |   |   |   yang:date-and-time
  |   |   |   +---:(yp:on-change) {on-change}?
  |   |   |   |   +---w yp:on-change!
  |   |   |   |   |   +---w yp:dampening-period?
  |   |   |   |   |   |   centiseconds
  |   |   |   |   |   +---w yp:sync-on-start?
  |   |   |   |   |   |   boolean
  |   |   |   |   +---w yp:excluded-change*
  |   |   |   |   |   change-type
  |   +---ro output
  |   |   +---ro id
  |   |   |   subscription-id
  |   |   +---ro replay-start-time-revision?
  |   |   |   yang:date-and-time
  |   |   |   {replay}?
  +---x modify-subscription
  |   +---w input
  |   |   ...
  |   |   +---w (target)
  |   |   |   ...

```

```

|      +---:(yp:datastore)
|      |      +---w yp:datastore                                identityref
|      |      +---w (yp:selection-filter)?
|      |      |      +---:(yp:by-reference)
|      |      |      |      +---w yp:selection-filter-ref
|      |      |      |      |      selection-filter-ref
|      |      |      +---:(yp:within-subscription)
|      |      |      |      +---w (yp:filter-spec)?
|      |      |      |      |      +---:(yp:datastore-subtree-filter)
|      |      |      |      |      |      +---w yp:datastore-subtree-filter?
|      |      |      |      |      |      |      <anydata> {sn:subtree}?
|      |      |      |      |      +---:(yp:datastore-xpath-filter)
|      |      |      |      |      |      +---w yp:datastore-xpath-filter?
|      |      |      |      |      |      |      yang:xpath1.0 {sn:xpath}?
|      |      |      |      ...
|      |      +---w (yp:update-trigger)
|      |      |      +---:(yp:periodic)
|      |      |      |      +---w yp:periodic!
|      |      |      |      |      +---w yp:period                                centiseconds
|      |      |      |      |      +---w yp:anchor-time?                    yang:date-and-time
|      |      |      +---:(yp:on-change) {on-change}?
|      |      |      |      +---w yp:on-change!
|      |      |      |      +---w yp:dampening-period?    centiseconds
|      +---x delete-subscription
|      |      ...
|      +---x kill-subscription
|      |      ...

```

YANG-data (for placement into rpc error responses)

...

Figure 7: Model structure: RPCs

The next figure depicts augmentations of module `ietf-yang-push` to the notifications that are specified in module `ietf-subscribed-notifications`. The augmentations allow the inclusion of subscription configuration parameters that are specific to datastore push subscriptions as part of subscription-started and subscription-modified notifications.

```

notifications:
  +---n replay-completed {replay}?
  |      ...
  +---n subscription-completed
  |      ...
  +---n subscription-started {configured}?
  |      |      ...
  |      +---ro (target)

```

```

...
+---:(yp:datastore)
  +--ro yp:datastore                               identityref
  +--ro (yp:selection-filter)?
    +---:(yp:by-reference)
      |   +--ro yp:selection-filter-ref
      |       selection-filter-ref
    +---:(yp:within-subscription)
      +--ro (yp:filter-spec)?
        +---:(yp:datastore-subtree-filter)
          |   +--ro yp:datastore-subtree-filter?
          |       <anydata> {sn:subtree}?
        +---:(yp:datastore-xpath-filter)
          +--ro yp:datastore-xpath-filter?
              yang:xpath1.0 {sn:xpath}?
...
+--ro (yp:update-trigger)
  +---:(yp:periodic)
    |   +--ro yp:periodic!
    |       +--ro yp:period                centiseconds
    |       +--ro yp:anchor-time?         yang:date-and-time
  +---:(yp:on-change) {on-change}?
    +--ro yp:on-change!
      +--ro yp:dampening-period?          centiseconds
      +--ro yp:sync-on-start?             boolean
      +--ro yp:excluded-change*           change-type
+---n subscription-resumed
...
+---n subscription-modified
  ...
  +--ro (target)
    |   ...
    +---:(yp:datastore)
      +--ro yp:datastore                               identityref
      +--ro (yp:selection-filter)?
        +---:(yp:by-reference)
          |   +--ro yp:selection-filter-ref
          |       selection-filter-ref
        +---:(yp:within-subscription)
          +--ro (yp:filter-spec)?
            +---:(yp:datastore-subtree-filter)
              |   +--ro yp:datastore-subtree-filter?
              |       <anydata> {sn:subtree}?
            +---:(yp:datastore-xpath-filter)
              +--ro yp:datastore-xpath-filter?
                  yang:xpath1.0 {sn:xpath}?
...
+--ro (yp:update-trigger)?

```

```

|      +---:(yp:periodic)
|      |      +---ro yp:periodic!
|      |      |      +---ro yp:period          centiseconds
|      |      |      +---ro yp:anchor-time?    yang:date-and-time
|      +---:(yp:on-change) {on-change}?
|      |      +---ro yp:on-change!
|      |      |      +---ro yp:dampening-period?    centiseconds
|      |      |      +---ro yp:sync-on-start?      boolean
|      |      |      +---ro yp:excluded-change*    change-type
+---n subscription-terminated
|      ...
+---n subscription-suspended
|      ...

```

Figure 8: Model structure: Notifications

The final figure in this section depicts the parts of module `ietf-yang-push` that are not simply augmentations to another module, but that are newly introduced.

module: `ietf-yang-push`

rpcs:

```

+---x resync-subscription {on-change}?
|      +---w input
|      |      +---w id      sn:subscription-id

```

YANG-data: (for placement into rpc error responses)

```

+--- resync-subscription-error
|      +---ro reason?          identityref
|      +---ro period-hint?     centiseconds
|      +---ro filter-failure-hint? string
|      +---ro object-count-estimate? uint32
|      +---ro object-count-limit?   uint32
|      +---ro kilobytes-estimate?   uint32
|      +---ro kilobytes-limit?     uint32
+--- establish-subscription-error-datastore
|      +---ro reason?          identityref
|      +---ro period-hint?     centiseconds
|      +---ro filter-failure-hint? string
|      +---ro object-count-estimate? uint32
|      +---ro object-count-limit?   uint32
|      +---ro kilobytes-estimate?   uint32
|      +---ro kilobytes-limit?     uint32
+--- modify-subscription-error-datastore
|      +---ro reason?          identityref

```

```

+--ro period-hint?                centiseconds
+--ro filter-failure-hint?        string
+--ro object-count-estimate?      uint32
+--ro object-count-limit?         uint32
+--ro kilobytes-estimate?         uint32
+--ro kilobytes-limit?           uint32

notifications:
+---n push-update
|   +--ro id?                      sn:subscription-id
|   +--ro datastore-contents?      <anydata>
|   +--ro incomplete-update?       empty
+---n push-change-update {on-change}?
|   +--ro id?                      sn:subscription-id
|   +--ro datastore-changes
|   |   +--ro yang-patch
|   |   |   +--ro patch-id        string
|   |   |   +--ro comment?        string
|   |   |   +--ro edit* [edit-id]
|   |   |   |   +--ro edit-id      string
|   |   |   |   +--ro operation    enumeration
|   |   |   |   +--ro target       target-resource-offset
|   |   |   |   +--ro point?       target-resource-offset
|   |   |   |   +--ro where?       enumeration
|   |   |   |   +--ro value?       <anydata>
|   |   +--ro incomplete-update?   empty

```

Figure 9: Model structure (non-augmentation portions)

Selected components of the model are summarized below.

4.2. Subscription Configuration

Both configured and dynamic subscriptions are represented within the list "subscription". New parameters extending the basic subscription data model in [I-D.draft-ietf-netconf-subscribed-notifications] include:

- o The targeted datastore from which the selection is being made. The potential datastores include those from [RFC8341]. A platform may also choose to support a custom datastore.
- o A selection filter identifying YANG nodes of interest within a datastore. Filter contents are specified via a reference to an existing filter, or via an in-line definition for only that subscription. Referenced filters allows an implementation to avoid evaluating filter acceptability during a dynamic

subscription request. The case statement differentiates the options.

- o For periodic subscriptions, triggered updates will occur at the boundaries of a specified time interval. These boundaries can be calculated from the periodic parameters:
 - * a "period" which defines the duration between push updates.
 - * an "anchor-time"; update intervals fall on the points in time that are a multiple of a "period" from an "anchor-time". If "anchor-time" is not provided, then the "anchor-time" MUST be set with the creation time of the initial update record.
- o For on-change subscriptions, assuming any dampening period has completed, triggering occurs whenever a change in the subscribed information is detected. On-change subscriptions have more complex semantics that are guided by their own set of parameters:
 - * a "dampening-period" specifies the interval that must pass before a successive update for the subscription is sent. If no dampening period is in effect, the update is sent immediately. If a subsequent change is detected, another update is only sent once the dampening period has passed for this subscription.
 - * an "excluded-change" parameter which allows restriction of the types of changes for which updates should be sent (e.g., only add to an update record on object creation).
 - * a "sync-on-start" specifies whether a complete update with all the subscribed data is to be sent at the beginning of a subscription.

4.3. YANG Notifications

4.3.1. State Change Notifications

Subscription state notifications and mechanism are reused from [I-D.draft-ietf-netconf-subscribed-notifications]. Notifications "subscription-started" and "subscription-modified" have been augmented to include the datastore specific objects.

4.3.2. Notifications for Subscribed Content

Along with the subscribed content, there are other objects which might be part of a "push-update" or "push-change-update" notification.

An "id" (that identifies the subscription) MUST be transported along with the subscribed contents. This allows a receiver to differentiate which subscription resulted in a particular update record.

A "time-of-update" which represents the time an update record snapshot was generated. A receiver MAY assume that at this point in time a publisher's objects had the values that were pushed.

An "incomplete-update" leaf. This leaf indicates that not all changes which have occurred since the last update are actually included with this update. In other words, the publisher has failed to fulfill its full subscription obligations. (For example a datastore was unable to provide the full set of datastore nodes to a publisher process.) To facilitate re-synchronization of on-change subscriptions, a publisher MAY subsequently send a "push-update" containing a full selection snapshot of subscribed data.

4.4. YANG RPCs

YANG-Push subscriptions are established, modified, and deleted using RPCs augmented from [I-D.draft-ietf-netconf-subscribed-notifications].

4.4.1. Establish-subscription RPC

The subscriber sends an establish-subscription RPC with the parameters in section 3.1. An example might look like:

```

<netconf:rpc message-id="101"
  xmlns:netconf="urn:ietf:params:xml:ns:netconf:base:1.0">
  <establish-subscription
    xmlns="urn:ietf:params:xml:ns:yang:ietf-subscribed-notifications"
    xmlns:yp="urn:ietf:params:xml:ns:yang:ietf-yang-push">
    <yp:datastore
      xmlns:ds="urn:ietf:params:xml:ns:yang:ietf-datastores">
      ds:operational
    </yp:datastore>
    <yp:datastore-xpath-filter
      xmlns:ex="http://example.com/sample-data/1.0">
      /ex:foo
    </yp:datastore-xpath-filter>
    <yp:periodic>
      <yp:period>500</yp:period>
    </yp:periodic>
    </establish-subscription>
  </netconf:rpc>

```

Figure 10: Establish-subscription RPC

A positive response includes the "id" of the accepted subscription. In that case a publisher may respond:

```

<rpc-reply message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <id
    xmlns="urn:ietf:params:xml:ns:yang:ietf-subscribed-notifications">
    52
  </id>
</rpc-reply>

```

Figure 11: Establish-subscription positive RPC response

A subscription can be rejected for multiple reasons, including the lack of authorization to establish a subscription, no capacity to serve the subscription at the publisher, or the inability of the publisher to select datastore content at the requested cadence.

If a request is rejected because the publisher is not able to serve it, the publisher SHOULD include in the returned error hints which help a subscriber understand subscription parameters might have been accepted for the request. These hints would be included within the YANG-data structure "establish-subscription-error-datastore". However even with these hints, there are no guarantee that subsequent requests will in fact be accepted.

The specific parameters to be returned as part of the RPC error response depend on the specific transport that is used to manage the subscription. For NETCONF, those parameters are defined in [I-D.draft-ietf-netconf-netconf-event-notifications]. For example, for the following NETCONF request:

```
<rpc message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <establish-subscription
    xmlns=
      "urn:ietf:params:xml:ns:yang:ietf-subscribed-notifications"
    xmlns:yp="urn:ietf:params:xml:ns:yang:ietf-yang-push">
    <yp:datastore
      xmlns:ds="urn:ietf:params:xml:ns:yang:ietf-datastores">
      ds:operational
    </yp:datastore>
    <yp:datastore-xpath-filter
      xmlns:ex="http://example.com/sample-data/1.0">
      /ex:foo
    </yp:datastore-xpath-filter>
    <yp:on-change>
      <yp:dampening-period>100</yp:dampening-period>
    </yp:on-change>
    </establish-subscription>
  </rpc>
```

Figure 12: Establish-subscription request example 2

a publisher that cannot serve on-change updates but that can serve periodic updates might return the following NETCONF response:

```
<rpc-reply message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"
  xmlns:yp="urn:ietf:params:xml:ns:yang:ietf-subscribed-notifications">
  <rpc-error>
    <error-type>application</error-type>
    <error-tag>operation-failed</error-tag>
    <error-severity>error</error-severity>
    <error-path>/yp:periodic/yp:period</error-path>
    <error-info>
      <yp:establish-subscription-error-datastore>
        <yp:reason>yp:on-change-unsupported</yp:reason>
      </yp:establish-subscription-error-datastore>
    </error-info>
  </rpc-error>
</rpc-reply>
```

Figure 13: Establish-subscription error response example 2

4.4.2. Modify-subscription RPC

The subscriber MAY invoke the "modify-subscription" RPC for a subscription it previously established. The subscriber will include newly desired values in the "modify-subscription" RPC. Parameters not included MUST remain unmodified. Below is an example where a subscriber attempts to modify the period and datastore XPath filter of a subscription using NETCONF.

```
<rpc message-id="102"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <modify-subscription
    xmlns=
      "urn:ietf:params:xml:ns:yang:ietf-subscribed-notifications"
    xmlns:yp="urn:ietf:params:xml:ns:yang:ietf-yang-push">
    <id>1011</id>
    <yp:datastore
      xmlns:ds="urn:ietf:params:xml:ns:yang:ietf-datastores">
      ds:operational
    </yp:datastore>
    <yp:datastore-xpath-filter
      xmlns:ex="http://example.com/sample-data/1.0">
      /ex:bar
    </yp:datastore-xpath-filter>
    <yp:periodic>
      <yp:period>250</yp:period>
    </yp:periodic>
    </modify-subscription>
  </rpc>
```

Figure 14: Modify subscription request

The publisher MUST respond to the subscription modification request. If the request is rejected, the existing subscription is left unchanged, and the publisher MUST send an RPC error response. This response might have hints encapsulated within the YANG-data structure "modify-subscription-error-datastore". A subscription MAY be modified multiple times.

The specific parameters to be returned as part of the RPC error response depend on the specific transport that is used to manage the subscription. For NETCONF, those parameters are specified in [I-D.draft-ietf-netconf-netconf-event-notifications].

A configured subscription cannot be modified using "modify-subscription" RPC. Instead, the configuration needs to be edited as needed.

4.4.3. Delete-subscription RPC

To stop receiving updates from a subscription and effectively delete a subscription that had previously been established using an "establish-subscription" RPC, a subscriber can send a "delete-subscription" RPC, which takes as only input the subscription's "id". This RPC is unmodified from [I-D.draft-ietf-netconf-subscribed-notifications].

4.4.4. Resync-subscription RPC

This RPC is supported only for on-change subscriptions previously established using an "establish-subscription" RPC. For example:

```
<rpc message-id="103"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <resync-subscription
    xmlns="urn:ietf:params:xml:ns:yang:ietf-yang-push"
    <id>1011</id>
  </resync-subscription>
</netconf:rpc>
```

Figure 15: Resync subscription

On receipt, a publisher must either accept the request and quickly follow with a "push-update", or send an appropriate error within an rpc error response. Within an error response, the publisher MAY include supplemental information about the reasons within the YANG-data structure "resync-subscription-error".

4.4.5. YANG Module Synchronization

To make subscription requests, the subscriber needs to know the YANG datastore schemas used by the publisher, which are available via the YANG Library module, `ietf-yang-library.yang` from [RFC8525]. The receiver is expected to know the YANG library information before starting a subscription.

The set of modules, revisions, features, and deviations can change at run-time (if supported by the publisher implementation). For this purpose, the YANG library provides a simple "yang-library-change" notification that informs the subscriber that the library has changed. In this case, a subscription may need to be updated to take the updates into account. The receiver may also need to be informed of module changes in order to process updates regarding datastore nodes from changed modules correctly.

5. YANG Module

This YANG module imports typedefs from [RFC6991], identities from [RFC8342], the YANG-data extension from [RFC8040], and the yang-patch grouping from [RFC8072]. In addition, it imports and augments many definitions from [I-D.draft-ietf-netconf-subscribed-notifications].

```
<CODE BEGINS> file "ietf-yang-push@2019-05-21.yang"
module ietf-yang-push {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-yang-push";
  prefix yp;

  import ietf-yang-types {
    prefix yang;
    reference
      "RFC 6991: Common YANG Data Types";
  }
  import ietf-subscribed-notifications {
    prefix sn;
    reference
      "draft-ietf-netconf-subscribed-notifications:
       Customized Subscriptions to a Publisher's Event Streams
       NOTE TO RFC Editor: Please replace above reference to
       draft-ietf-netconf-subscribed-notifications with RFC number
       when published (i.e. RFC xxxx).";
  }
  import ietf-datastores {
    prefix ds;
    reference
      "RFC 8342: Network Management Datastore Architecture (NMDA)";
  }
  import ietf-restconf {
    prefix rc;
    reference
      "RFC 8040: RESTCONF Protocol";
  }
  import ietf-yang-patch {
    prefix ypatch;
    reference
      "RFC 8072: YANG Patch Media Type";
  }

  organization
    "IETF NETCONF Working Group";
  contact
    "WG Web:  <http://tools.ietf.org/wg/netconf/>"

```

```
WG List:  <mailto:netconf@ietf.org>

Editor:   Alexander Clemm
          <mailto:ludwig@clemm.org>
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Editor:   Andy Bierman
          <mailto:andy@yumaworks.com>
Editor:   Balazs Lengyel
          <mailto:balazs.lengyel@ericsson.com>";
description
  "This module contains YANG specifications for YANG push.

  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.

  Copyright (c) 2019 IETF Trust and the persons identified as
  authors of the code.  All rights reserved.

  Redistribution and use in source and binary forms, with or
  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 XXXX;
  see the RFC itself for full legal notices.";

// RFC Ed.: replace XXXX with actual RFC number and remove this
// note.

revision 2019-05-21 {
  description
    "Initial revision.
    NOTE TO RFC EDITOR:
    (1) Please replace the above revision date to
    the date of RFC publication when published.
    (2) Please replace the date in the file name
```



```
        (ietf-yang-push@2019-05-21.yang) to the date of RFC
        publication.
        (3) Please replace the following reference to
        draft-ietf-netconf-yang-push-25 with RFC number when
        published (i.e. RFC xxxx).";
    reference
        "draft-ietf-netconf-yang-push-25";
}

/*
 * FEATURES
 */

feature on-change {
    description
        "This feature indicates that on-change triggered subscriptions
        are supported.";
}

/*
 * IDENTITIES
 */

/* Error type identities for datastore subscription */

identity resync-subscription-error {
    description
        "Problem found while attempting to fulfill an
        'resync-subscription' RPC request.";
}

identity cant-exclude {
    base sn:establish-subscription-error;
    description
        "Unable to remove the set of 'excluded-changes'. This means
        the publisher is unable to restrict 'push-change-update's to
        just the change types requested for this subscription.";
}

identity datastore-not-subscribable {
    base sn:establish-subscription-error;
    base sn:subscription-terminated-reason;
    description
        "This is not a subscribable datastore.";
}

identity no-such-subscription-resync {
    base resync-subscription-error;
```

```
description
  "Referenced subscription doesn't exist. This may be as a result
  of a non-existent subscription ID, an ID which belongs to
  another subscriber, or an ID for configured subscription.";
}

identity on-change-unsupported {
  base sn:establish-subscription-error;
  description
    "On-change is not supported for any objects which are
    selectable by this filter.";
}

identity on-change-sync-unsupported {
  base sn:establish-subscription-error;
  description
    "Neither sync on start nor resynchronization are supported for
    this subscription. This error will be used for two
    reasons. First if an 'establish-subscription' RPC includes
    'sync-on-start', yet the publisher can't support sending a
    'push-update' for this subscription for reasons other than
    'on-change-unsupported' or 'sync-too-big'. And second, if the
    'resync-subscription' RPC is invoked either for an existing
    periodic subscription, or for an on-change subscription which
    can't support resynchronization.";
}

identity period-unsupported {
  base sn:establish-subscription-error;
  base sn:modify-subscription-error;
  base sn:subscription-suspended-reason;
  description
    "Requested time period or dampening-period is too short. This
    can be for both periodic and on-change subscriptions (with or
    without dampening.) Hints suggesting alternative periods may
    be returned as supplemental information.";
}

identity update-too-big {
  base sn:establish-subscription-error;
  base sn:modify-subscription-error;
  base sn:subscription-suspended-reason;
  description
    "Periodic or on-change push update datatrees exceed a maximum
    size limit. Hints on estimated size of what was too big may
    be returned as supplemental information.";
}
```

```
identity sync-too-big {
  base sn:establish-subscription-error;
  base sn:modify-subscription-error;
  base resync-subscription-error;
  base sn:subscription-suspended-reason;
  description
    "Sync-on-start or resynchronization datatree exceeds a maximum
    size limit. Hints on estimated size of what was too big may
    be returned as supplemental information.";
}

identity unchanging-selection {
  base sn:establish-subscription-error;
  base sn:modify-subscription-error;
  base sn:subscription-terminated-reason;
  description
    "Selection filter is unlikely to ever select datatree nodes.
    This means that based on the subscriber's current access
    rights, the publisher recognizes that the selection filter is
    unlikely to ever select datatree nodes which change. Examples
    for this might be that node or subtree doesn't exist, read
    access is not permitted for a receiver, or static objects that
    only change at reboot have been chosen.";
}

/*
 * TYPE DEFINITIONS
 */

typedef change-type {
  type enumeration {
    enum create {
      description
        "A change that refers to the creation of a new datastore
        node.";
    }
    enum delete {
      description
        "A change that refers to the deletion of a datastore
        node.";
    }
    enum insert {
      description
        "A change that refers to the insertion of a new
        user-ordered datastore node.";
    }
    enum move {
      description
```

```
        "A change that refers to a reordering of the target
        datastore node.";
    }
    enum replace {
        description
            "A change that refers to a replacement of the target
            datastore node's value.";
    }
}
description
    "Specifies different types of datastore changes.

    This type is based on the edit operations defined for YANG
    Patch, with the difference that it is valid for a receiver to
    process an update record which performs a create operation on
    a datastore node the receiver believes exists, or to process a
    delete on a datastore node the receiver believes is missing.";
reference
    "RFC 8072: YANG Patch Media Type, section 2.5";
}

typedef selection-filter-ref {
    type leafref {
        path "/sn:filters/yp:selection-filter/yp:filter-id";
    }
    description
        "This type is used to reference a selection filter.";
}

typedef centiseconds {
    type uint32;
    description
        "A period of time, measured in units of 0.01 seconds.";
}

/*
 * GROUP DEFINITIONS
 */

grouping datastore-criteria {
    description
        "A grouping to define criteria for which selected objects
        from a targeted datastore should be included in push
        updates.";
    leaf datastore {
        type identityref {
            base ds:datastore;
        }
    }
}
```

```
    }
    mandatory true;
    description
      "Datastore from which to retrieve data.";
  }
  uses selection-filter-objects;
}
```

grouping selection-filter-types {
 description
 "This grouping defines the types of selectors for objects
 from a datastore.";
 choice filter-spec {
 description
 "The content filter specification for this request.";
 anydata datastore-subtree-filter {
 if-feature "sn:subtree";
 description
 "This parameter identifies the portions of the
 target datastore to retrieve.";
 reference
 "RFC 6241: Network Configuration Protocol, Section 6.";
 }
 leaf datastore-xpath-filter {
 if-feature "sn:xpath";
 type yang:xpath1.0;
 description
 "This parameter contains an XPath expression identifying
 the portions of the target datastore to retrieve."

If the expression returns a node-set, all nodes in the
node-set are selected by the filter. Otherwise, if the
expression does not return a node-set, the filter
doesn't select any nodes.

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 the core function library, and the XPath functions defined in section 10 in RFC 7950.
- o The context node is the root node of the target datastore.";

```

    }
  }
}

grouping selection-filter-objects {
  description
    "This grouping defines a selector for objects from a
    datastore.";
  choice selection-filter {
    description
      "The source of the selection filter applied to the
      subscription. This will come either referenced from a global
      list, or be provided within the subscription itself.";
    case by-reference {
      description
        "Incorporate a filter that has been configured
        separately.";
      leaf selection-filter-ref {
        type selection-filter-ref;
        mandatory true;
        description
          "References an existing selection filter which is to be
          applied to the subscription.";
      }
    }
    case within-subscription {
      description
        "Local definition allows a filter to have the same
        lifecycle as the subscription.";
      uses selection-filter-types;
    }
  }
}

```

```

grouping update-policy-modifiable {
  description
    "This grouping describes the datastore specific subscription
    conditions that can be changed during the lifetime of the

```

```
    subscription.";
  choice update-trigger {
    description
      "Defines necessary conditions for sending an event record to
      the subscriber.";
    case periodic {
      container periodic {
        presence "indicates a periodic subscription";
        description
          "The publisher is requested to notify periodically the
          current values of the datastore as defined by the
          selection filter.";
        leaf period {
          type centiseconds;
          mandatory true;
          description
            "Duration of time which should occur between periodic
            push updates, in one hundredths of a second.";
        }
        leaf anchor-time {
          type yang:date-and-time;
          description
            "Designates a timestamp before or after which a series
            of periodic push updates are determined. The next
            update will take place at a whole multiple interval
            from the anchor time. For example, for an anchor time
            is set for the top of a particular minute and a period
            interval of a minute, updates will be sent at the top
            of every minute this subscription is active.";
        }
      }
    }
  }
}
case on-change {
  if-feature "on-change";
  container on-change {
    presence "indicates an on-change subscription";
    description
      "The publisher is requested to notify changes in values
      in the datastore subset as defined by a selection
      filter.";
    leaf dampening-period {
      type centiseconds;
      default "0";
      description
        "Specifies the minimum interval between the assembly of
        successive update records for a single receiver of a
        subscription. Whenever subscribed objects change, and
        a dampening period interval (which may be zero) has
```

```
        elapsed since the previous update record creation for
        a receiver, then any subscribed objects and properties
        which have changed since the previous update record
        will have their current values marshalled and placed
        into a new update record.";
    }
}
}
}

grouping update-policy {
  description
    "This grouping describes the datastore-specific subscription
    conditions of a subscription.";
  uses update-policy-modifiable {
    augment "update-trigger/on-change/on-change" {
      description
        "Includes objects not modifiable once subscription is
        established.";
      leaf sync-on-start {
        type boolean;
        default "true";
        description
          "When this object is set to false, it restricts an
          on-change subscription from sending push-update
          notifications. When false, pushing a full selection per
          the terms of the selection filter MUST NOT be done for
          this subscription. Only updates about changes,
          i.e. only push-change-update notifications are sent.
          When true (default behavior), in order to facilitate a
          receiver's synchronization, a full update is sent when
          the subscription starts using a push-update
          notification. After that, push-change-update
          notifications are exclusively sent unless the publisher
          chooses to resync the subscription via a new push-update
          notification.";
      }
      leaf-list excluded-change {
        type change-type;
        description
          "Use to restrict which changes trigger an update. For
          example, if modify is excluded, only creation and
          deletion of objects is reported.";
      }
    }
  }
}
```



```
grouping hints {
  description
    "Parameters associated with some error for a subscription
    made upon a datastore.";
  leaf period-hint {
    type centiseconds;
    description
      "Returned when the requested time period is too short. This
      hint can assert a viable period for either a periodic push
      cadence or an on-change dampening interval.";
  }
  leaf filter-failure-hint {
    type string;
    description
      "Information describing where and/or why a provided filter
      was unsupportable for a subscription.";
  }
  leaf object-count-estimate {
    type uint32;
    description
      "If there are too many objects which could potentially be
      returned by the selection filter, this identifies the
      estimate of the number of objects which the filter would
      potentially pass.";
  }
  leaf object-count-limit {
    type uint32;
    description
      "If there are too many objects which could be returned by
      the selection filter, this identifies the upper limit of
      the publisher's ability to service for this subscription.";
  }
  leaf kilobytes-estimate {
    type uint32;
    description
      "If the returned information could be beyond the capacity
      of the publisher, this would identify the data size which
      could result from this selection filter.";
  }
  leaf kilobytes-limit {
    type uint32;
    description
      "If the returned information would be beyond the capacity
      of the publisher, this identifies the upper limit of the
      publisher's ability to service for this subscription.";
  }
}
```

```
/*
 * RPCs
 */

rpc resync-subscription {
  if-feature "on-change";
  description
    "This RPC allows a subscriber of an active on-change
    subscription to request a full push of objects.

    A successful invocation results in a push-update of all
    datastore nodes that the subscriber is permitted to access.
    This RPC can only be invoked on the same session on which the
    subscription is currently active. In case of an error, a
    resync-subscription-error is sent as part of an error
    response.";
  input {
    leaf id {
      type sn:subscription-id;
      mandatory true;
      description
        "Identifier of the subscription that is to be resynced.";
    }
  }
}

rc:yang-data resync-subscription-error {
  container resync-subscription-error {
    description
      "If a 'resync-subscription' RPC fails, the subscription is
      not resynced and the RPC error response MUST indicate the
      reason for this failure. This YANG-data MAY be inserted as
      structured data within a subscription's RPC error response
      to indicate the failure reason.";
    leaf reason {
      type identityref {
        base resync-subscription-error;
      }
      mandatory true;
      description
        "Indicates the reason why the publisher has declined a
        request for subscription resynchronization.";
    }
    uses hints;
  }
}

augment "/sn:establish-subscription/sn:input" {
```

```
    description
      "This augmentation adds additional subscription parameters
      that apply specifically to datastore updates to RPC input.";
    uses update-policy;
  }

  augment "/sn:establish-subscription/sn:input/sn:target" {
    description
      "This augmentation adds the datastore as a valid target
      for the subscription to RPC input.";
    case datastore {
      description
        "Information specifying the parameters of an request for a
        datastore subscription.";
      uses datastore-criteria;
    }
  }

  rc:yang-data establish-subscription-datastore-error-info {
    container establish-subscription-datastore-error-info {
      description
        "If any 'establish-subscription' RPC parameters are
        unsupportable against the datastore, 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 within a subscription's
        RPC error response to indicate the failure reason. This
        YANG-data MUST be inserted if hints are to be provided back
        to the subscriber.";
      leaf reason {
        type identityref {
          base sn:establish-subscription-error;
        }
        description
          "Indicates the reason why the subscription has failed to
          be created to a targeted datastore.";
      }
      uses hints;
    }
  }

  augment "/sn:modify-subscription/sn:input" {
    description
      "This augmentation adds additional subscription parameters
      specific to datastore updates.";
    uses update-policy-modifiable;
  }
```

```
augment "/sn:modify-subscription/sn:input/sn:target" {
  description
    "This augmentation adds the datastore as a valid target
    for the subscription to RPC input.";
  case datastore {
    description
      "Information specifying the parameters of an request for a
      datastore subscription.";
    uses datastore-criteria;
  }
}

rc:yang-data modify-subscription-datastore-error-info {
  container modify-subscription-datastore-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 which has been made against a
      datastore. This YANG-data MUST be used if hints are to be
      provides back to the subscriber.";
    leaf reason {
      type identityref {
        base sn:modify-subscription-error;
      }
      description
        "Indicates the reason why the subscription has failed to
        be modified.";
    }
    uses hints;
  }
}

/*
 * NOTIFICATIONS
 */

notification push-update {
  description
    "This notification contains a push update, containing data
    subscribed to via a subscription. This notification is sent
    for periodic updates, for a periodic subscription. It can
    also be used for synchronization updates of an on-change
    subscription. This notification shall only be sent to
    receivers of a subscription. It does not constitute a
    general-purpose notification that would be subscribable as
    part of the NETCONF event stream by any receiver.";
  leaf id {
    type sn:subscription-id;
  }
}
```

```
    description
      "This references the subscription which drove the
        notification to be sent.";
  }
  anydata datastore-contents {
    description
      "This contains the updated data. It constitutes a snapshot
        at the time-of-update of the set of data that has been
        subscribed to. The snapshot corresponds to the same
        snapshot that would be returned in a corresponding get
        operation with the same selection filter parameters
        applied.";
  }
  leaf incomplete-update {
    type empty;
    description
      "This is a flag which indicates that not all datastore
        nodes subscribed to are included with this update. In
        other words, the publisher has failed to fulfill its full
        subscription obligations, and despite its best efforts is
        providing an incomplete set of objects.";
  }
}

notification push-change-update {
  if-feature "on-change";
  description
    "This notification contains an on-change push update. This
      notification shall only be sent to the receivers of a
      subscription. It does not constitute a general-purpose
      notification that would be subscribable as part of the
      NETCONF event stream by any receiver.";
  leaf id {
    type sn:subscription-id;
    description
      "This references the subscription which drove the
        notification to be sent.";
  }
  container datastore-changes {
    description
      "This contains the set of datastore changes of the target
        datastore starting at the time of the previous update, per
        the terms of the subscription.";
    uses ypatch yang-patch;
  }
  leaf incomplete-update {
    type empty;
    description
```

```
        "The presence of this object indicates not all changes which
        have occurred since the last update are included with this
        update.  In other words, the publisher has failed to
        fulfill its full subscription obligations, for example in
        cases where it was not able to keep up with a change
        burst.";
    }
}

augment "/sn:subscription-started" {
    description
        "This augmentation adds datastore-specific objects to
        the notification that a subscription has started.";
    uses update-policy;
}

augment "/sn:subscription-started/sn:target" {
    description
        "This augmentation allows the datastore to be included as
        part of the notification that a subscription has started.";
    case datastore {
        uses datastore-criteria {
            refine "selection-filter/within-subscription" {
                description
                    "Specifies the selection filter and where it originated
                    from.  If the 'selection-filter-ref' is populated, the
                    filter within the subscription came from the 'filters'
                    container.  Otherwise it is populated in-line as part of
                    the subscription itself.";
            }
        }
    }
}

augment "/sn:subscription-modified" {
    description
        "This augmentation adds datastore-specific objects to
        the notification that a subscription has been modified.";
    uses update-policy;
}

augment "/sn:subscription-modified/sn:target" {
    description
        "This augmentation allows the datastore to be included as
        part of the notification that a subscription has been
        modified.";
    case datastore {
        uses datastore-criteria {
```

```
    refine "selection-filter/within-subscription" {
        description
            "Specifies the selection filter and where it originated
            from. If the 'selection-filter-ref' is populated, the
            filter within the subscription came from the 'filters'
            container. Otherwise it is populated in-line as part of
            the subscription itself.";
    }
}
}
}

/*
 * DATA NODES
 */

augment "/sn:filters" {
    description
        "This augmentation allows the datastore to be included as part
        of the selection filtering criteria for a subscription.";
    list selection-filter {
        key "filter-id";
        description
            "A list of pre-configured filters that can be applied
            to datastore subscriptions.";
        leaf filter-id {
            type string;
            description
                "An identifier to differentiate between selection
                filters.";
        }
        uses selection-filter-types;
    }
}

augment "/sn:subscriptions/sn:subscription" {
    when 'yp:datastore';
    description
        "This augmentation adds many datastore specific objects to a
        subscription.";
    uses update-policy;
}

augment "/sn:subscriptions/sn:subscription/sn:target" {
    description
        "This augmentation allows the datastore to be included as
        part of the selection filtering criteria for a subscription.";
    case datastore {
```

```
        uses datastore-criteria;
    }
}
}

<CODE ENDS>
```

6. IANA Considerations

This document registers the following namespace URI in the "IETF XML Registry" [RFC3688]:

URI: urn:ietf:params:xml:ns:yang:ietf-yang-push
Registrant Contact: The IESG.
XML: N/A; the requested URI is an XML namespace.

This document registers the following YANG module in the "YANG Module Names" registry [RFC6020]:

Name: ietf-yang-push
Namespace: urn:ietf:params:xml:ns:yang:ietf-yang-push
Prefix: yp
Reference: draft-ietf-netconf-yang-push-21.txt (RFC form)

7. 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 [RFC8446].

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.

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. (It should be noted that the YANG module augments the YANG module from

[I-D.draft-ietf-netconf-subscribed-notifications]. All security considerations that are listed there are relevant also for datastore subscriptions. In the following, we focus on the data nodes that are newly introduced here.)

- o Subtree "selection-filter" under container "filters": This subtree allows to specify which objects or subtrees to include in a datastore subscription. An attacker could attempt to modify the filter. For example, the filter might be modified to result in very few objects being filtered in order to attempt to overwhelm the receiver. Alternatively, the filter might be modified to result in certain objects to be excluded from updates, in order to have certain changes go unnoticed.
- o Subtree "datastore" in choice "target" in list "subscription": Analogous to "selection filter", an attacker might attempt to modify the objects being filtered in order to overwhelm a receiver with a larger volume of object updates than expected, or to have certain changes go unnoticed.
- o Choice "update-trigger" in list "subscription": By modifying the update trigger, an attacker might alter the updates that are being sent in order to confuse a receiver, to withhold certain updates to be sent to the receiver, and/or to overwhelm a receiver. For example, an attacker might modify the period with which updates are reported for a periodic subscription, or it might modify the dampening period for an on-change subscription, resulting in greater delay of successive updates (potentially affecting responsiveness of applications that depend on the updates) or in a high volume of updates (to exhaust receiver resources).
- o RPC "resync-subscription": This RPC allows a subscriber of an on-change subscription to request a full push of objects in the subscription's scope. This can result in a large volume of data. An attacker could attempt to use this RPC to exhaust resources on the server to generate the data, and attempt to overwhelm a receiver with the resulting data volume.

NACM provides one means to mitigate these threats on the publisher side. In order to address those threats as a subscriber, a subscriber could monitor the subscription configuration for any unexpected changes. For this, it can subscribe to updates to the YANG datastore nodes that represent his datastore subscriptions. As this data volume is small, a paranoid subscriber could even revert to occasional polling to guard against a compromised subscription against subscription configuration updates itself.

8. Acknowledgments

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Appendix A. Appendix A: Subscription Errors

A.1. RPC Failures

Rejection of an RPC for any reason is indicated by via RPC error response from the publisher. Valid RPC errors returned include both existing transport layer RPC error codes, such as those seen with NETCONF in [RFC6241], as well as subscription specific errors such as those defined within the YANG model. As a result, how subscription errors are encoded within an RPC error response is transport dependent.

References to specific identities in the ietf-subscribed-notifications YANG model or the ietf-yang-push YANG model may be returned as part of the error responses resulting from failed attempts at datastore subscription. For errors defined as part of ietf-subscribed-notifications, please refer to

[I-D.draft-ietf-netconf-subscribed-notifications]. The errors introduced in this document, grouped per RPC, are as follows:

establish-subscription	modify-subscription
-----	-----
cant-exclude	period-unsupported
datastore-not-subscribable	update-too-big
on-change-unsupported	sync-too-big
on-change-sync-unsupported	unchanging-selection
period-unsupported	
update-too-big	resync-subscription
sync-too-big	-----
unchanging-selection	no-such-subscription-resync
	sync-too-big

There is one final set of transport independent RPC error elements included in the YANG model. These are the following four YANG-data structures for failed datastore subscriptions:

1. YANG-data establish-subscription-error-datastore
This MUST be returned if information identifying the reason for an RPC error has not been placed elsewhere within the transport portion of a failed "establish-subscription" RPC response. This MUST be sent if hints are included.
2. YANG-data modify-subscription-error-datastore
This MUST be returned if information identifying the reason for an RPC error has not been placed elsewhere within the transport portion of a failed "modify-subscription" RPC response. This MUST be sent if hints are included.
3. YANG-data sn:delete-subscription-error
This MUST be returned if information identifying the reason for an RPC error has not been placed elsewhere within the transport portion of a failed "delete-subscription" or "kill-subscription" RPC response.
4. YANG-data resync-subscription-error
This MUST be returned if information identifying the reason for an RPC error has not been placed elsewhere within the transport portion of a failed "resync-subscription" RPC response.

A.2. Notifications of Failure

A subscription may be unexpectedly terminated or suspended independent of any RPC or configuration operation. In such cases, indications of such a failure MUST be provided. To accomplish this, a number of errors can be returned as part of the corresponding subscription state change notification. For this purpose, the following error identities have been introduced in this document, in addition to those that were already defined in [I-D.draft-ietf-netconf-subscribed-notifications]:

subscription-terminated -----	subscription-suspended -----
datastore-not-subscribable unchanging-selection	period-unsupported update-too-big synchronization-size

Appendix B. Changes Between Revisions

(To be removed by RFC editor prior to publication)

v24 - v25

- o Minor updates to address IESG review comment regarding referencing the draft which addresses the notification capabilities problem.

v23 - v24

- o Minor updates to address IESG review comments. Moving five of the coauthors to contributors as requested.

v22 - v23

- o Minor updates to address IESG review comments.

v21 - v22

- o Minor updates per Martin Bjorklund's YANG doctor review.

v20 - v21

- o Minor updates, simplifying RPC input conditions.

v19 - v20

- o Minor updates per WGLC comments.

v18 - v19

- o Minor updates per WGLC comments.

v17 - v18

- o Minor updates per WGLC comments.

v16 - v17

- o Minor updates to YANG module, incorporating comments from Tom Petch.
- o Updated references.

v15 - v16

- o Updated security considerations.
- o Updated references.
- o Addressed comments from last call review, specifically comments received from Martin Bjorklund.

v14 - v15

- o Minor text fixes. Includes a fix to on-change update calculation to cover churn when an object changes to and from a value during a dampening period.

v13 - v14

- o Minor text fixes.

v12 - v13

- o Hint negotiation models now show error examples.
- o yang-data structures for rpc errors.

v11 - v12

- o Included Martin's review clarifications.
- o QoS moved to subscribed-notifications
- o time-of-update removed as it is redundant with RFC5277's eventTime, and other times from notification-messages.

- o Error model moved to match existing implementations
- o On-change notifiable removed, how to do this is implementation specific.
- o NMDA model supported. Non NMDA version at <https://github.com/netconf-wg/yang-push/>

v10 - v11

- o Promise model reference added.
- o Error added for no-such-datastore
- o Inherited changes from subscribed notifications (such as optional feature definitions).
- o scrubbed the examples for proper encodings

v09 - v10

- o Returned to the explicit filter subtyping of v00-v05
- o identityref to ds:datastore made explicit
- o Returned ability to modify a selection filter via RPC.

v08 - v09

- o Minor tweaks cleaning up text, removing appendices, and making reference to revised-datastores.
- o Subscription-id (now:id) optional in push updates, except when encoded in RFC5277, Section 4 one-way notification.
- o Finished adding the text describing the resync subscription RPC.
- o Removed relationships to other drafts and future technology appendices as this work is being explored elsewhere.
- o Deferred the multi-line card issue to new drafts
- o Simplified the NACM interactions.

v07 - v08

- o Updated YANG models with minor tweaks to accommodate changes of ietf-subscribed-notifications.

v06 - v07

- o Clarifying text tweaks.
- o Clarification that filters act as selectors for subscribed datastore nodes; support for value filters not included but possible as a future extension
- o Filters don't have to be matched to existing YANG objects

v05 - v06

- o Security considerations updated.
- o Base YANG model in [subscribe] updated as part of move to identities, YANG augmentations in this doc matched up
- o Terms refined and text updates throughout
- o Appendix talking about relationship to other drafts added.
- o Datastore replaces stream
- o Definitions of filters improved

v04 to v05

- o Referenced based subscription document changed to Subscribed Notifications from 5277bis.
- o Getting operational data from filters
- o Extension notifiable-on-change added
- o New appendix on potential futures. Moved text into there from several drafts.
- o Subscription configuration section now just includes changed parameters from Subscribed Notifications
- o Subscription monitoring moved into Subscribed Notifications
- o New error and hint mechanisms included in text and in the YANG model.
- o Updated examples based on the error definitions
- o Groupings updated for consistency

- o Text updates throughout v03 to v04
- o Updates-not-sent flag added
- o Not notifiable extension added
- o Dampening period is for whole subscription, not single objects
- o Moved start/stop into rfc5277bis
- o Client and Server changed to subscriber, publisher, and receiver
- o Anchor time for periodic
- o Message format for synchronization (i.e. sync-on-start)
- o Material moved into 5277bis
- o QoS parameters supported, by not allowed to be modified by RPC
- o Text updates throughout

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