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DetNet Flow Information Model
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Abstract

This document describes flow and service information model for Deterministic Networking (DetNet). These models are defined for IP and MPLS DetNet data planes

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Table of Contents

1. Introduction 3
1.1. Goals 5
1.2. Non Goals 5
2. Terminology 6
2.1. Terms Used in This Document 6
2.2. Abbreviations 6
2.3. Naming Conventions 7
3. DetNet Domain and its Modeling 7
3.1. DetNet Service Overview 7
3.2. Reference Points Used in Modeling 7
3.3. Information Elements 8
4. App-flow Related Parameters 8
4.1. App-flow Characteristics 8
4.2. App-flow Requirements 9
5. DetNet Flow Related Parameters 9
5.1. Management ID of the DetNet Flow 10
5.2. Payload type of the DetNet Flow 10
5.3. Format of the DetNet Flow 10
5.4. Identification and Specification of DetNet Flows 10
5.4.1. DetNet MPLS Flow Identification and Specification . . 10
5.4.2. DetNet IP Flow Identification and Specification . . . 11
5.5. Traffic Specification of the DetNet Flow 11
5.6. Endpoints of the DetNet Flow 12
5.7. Rank of the DetNet Flow 12
5.8. Status of the DetNet Flow 12
5.9. Requirements of the DetNet Flow 13
5.9.1. Minimum Bandwidth of the DetNet Flow 13
5.9.2. Maximum Latency of the DetNet Flow 13
5.9.3. Maximum Latency Variation of the DetNet Flow 13
5.9.4. Maximum Loss of the DetNet Flow 13
5.9.5. Maximum Consecutive Loss of the DetNet Flow 14
5.9.6. Maximum Misordering Tolerance of the DetNet Flow . . 14
5.10. BiDir requirement of the DetNet Flow 14
6. DetNet Service Related Parameters 14
6.1. Management ID of the DetNet service 14
6.2. Delivery Type of the DetNet service 15
6.3. Delivery Profile of the DetNet Service 15
6.3.1. Minimum Bandwidth of the DetNet Service 15
6.3.2. Maximum Latency of the DetNet Service 15
6.3.3. Maximum Latency Variation of the DetNet Service . . . 15
6.3.4. Maximum Loss of the DetNet Service 15

6.3.5. Maximum Consecutive Loss of the DetNet Service . . . 15
6.3.6. Maximum Misordering Tolerance of the DetNet Service . 16
6.4. Connectivity Type of the DetNet Service 16
6.5. BiDir requirement of the DetNet Service 16
6.6. Rank of the DetNet Service 16
6.7. Status of the DetNet Service 16
7. Flow Specific Operations 17
7.1. Join Operation 18
7.2. Leave Operation 18
7.3. Modify Operation 18
8. Summary 18
9. IANA Considerations 18
10. Security Considerations 19
11. References 19
11.1. Normative References 19
11.2. Informative References 19
Authors' Addresses 20

1. Introduction

Deterministic Networking (DetNet) provides a capability to carry specified unicast or multicast data flows for real-time applications with extremely low packet loss rates and assured maximum end-to-end delivery latency. A description of the general background and concepts of DetNet can be found in [RFC8655].

This document describes the Detnet Flow Service Information Model. For reference [RFC3444] describes the rational behind Information Models in general. This document describes the Flow and Service information models for operators and users to understand Detnet services, and for implementors as a guide to the functionality required by Detnet services.

The DetNet Architecture treats the DetNet related data plane functions decomposed into two sub-layers: a service sub-layer and a forwarding sub-layer. The service sub-layer is used to provide DetNet service protection and reordering. The forwarding sub-layer provides resource allocation (to ensure low loss, assured latency, and limited out-of-order delivery) and leverages Traffic Engineering mechanisms.

In the IETF DetNet service utilizes IP or MPLS and DetNet is currently defined for IP and MPLS networks as shown in Figure 1 based on Figure 2 and Figure 3 of [I-D.ietf-detnet-data-plane-framework]. IEEE 802.1 Time Sensitive Networking (TSN) utilizes Ethernet and is defined over Ethernet networks. A DetNet flow includes one or more App-flow(s) as payload. App-flows can be Ethernet, MPLS, or IP flows, which impacts which header fields are utilized to identify a

flow. DetNet flows are identified by the DetNet encapsulation of App-flow(s) (e.g., MPLS labels, IP 6-tuple etc.). In some scenarios App-flow and DetNet flow look similar on the wire (e.g., L3 App-flow over a DetNet IP network).

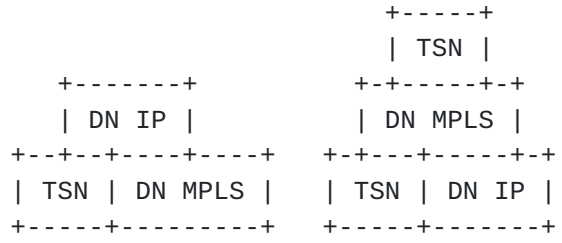


Figure 1: DetNet Service Examples as per Data Plane Framework

As shown in Figure 1 as per [I-D.ietf-detnet-data-plane-framework] a DetNet flow can be treated as an application level flow (App-flow) e.g., at DetNet flow aggregation or in a sub-network that interconnects DetNet nodes.

The DetNet flow and service information model provided by this document contains both DetNet flow and App-flow specific information in an integrated fashion.

In a given network scenario three information models can distinguished:

- Flow models that describe characteristics of data flows. These models describe in detail all relevant aspects of a flow that are needed to support the flow properly by the network between the source and the destination(s).

- Service models that describe characteristics of services being provided for data flows over a network. These models can be treated as a network operator independent information model.

- Configuration models that describe in detail the settings required on network nodes to provide a data flow proper service.

Service and flow information models are used between the user and the network operator. Configuration information models are used between the management/control plane entity of the network and the network nodes. They are shown in Figure 2.

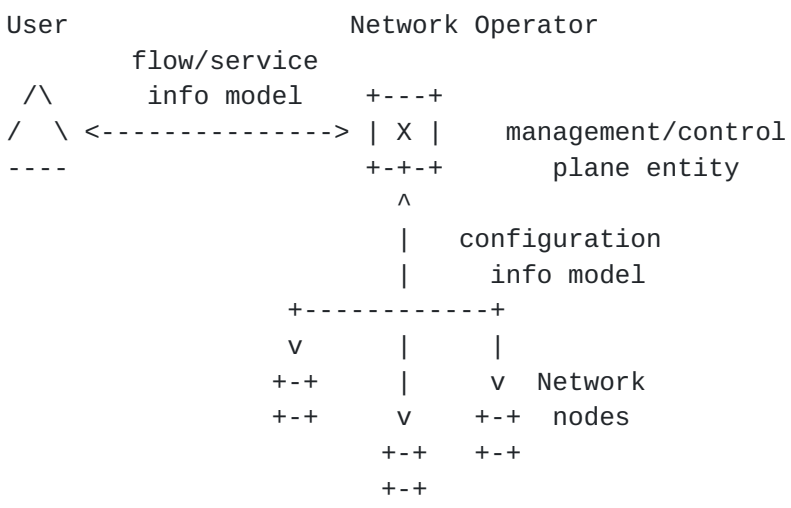


Figure 2: Usage of Information models (flow, service and configuration)

DetNet flow and service information model is based on [RFC8655] and on the concept of data model specified by [IEEE8021Qcc]. Furthermore, the origination of the DetNet flow information model was the flow identification possibilities described in Section 6. of [IEEE8021CB], which is used by [IEEE8021Qcc] as well. In addition to the TSN data model, [IEEE8021Qcc] also specifies configuration of TSN features (e.g., traffic scheduling specified by [IEEE8021Qbv]). The common architecture and flow model, allow configured features to be consistent in certain deployment scenarios, e.g., when the network that provides the DetNet service includes both L3 and L2 network segments.

1.1. Goals

As expressed in the [IETFDetNet] Charter, the DetNet WG collaborates with IEEE 802.1 TSN in order to define a common architecture for both Layer 2 and Layer 3. This is beneficial for several reasons, e.g., in order to simplify implementations and maintain consistency across diverse networks. The flow and service information models are also aligned for those reasons. Therefore, the DetNet flow and service information models described in this document are based on [IEEE8021Qcc], which is an amendment to [IEEE8021Q].

This document specifies flow and service information models only.

1.2. Non Goals

This document does not specify flow data models or DetNet configuration. Therefore, the goals of this document differ from the

goals of [IEEE8021Qcc], which also specifies the TSN data model and configuration of certain TSN features.

2. Terminology

2.1. Terms Used in This Document

This document uses the terminology established in the DetNet architecture [RFC8655] and the DetNet Data Plane Framework [I-D.ietf-detnet-data-plane-framework]. The reader is assumed to be familiar with these documents and any terminology defined therein. The DetNet <=> TSN dictionary of [RFC8655] is used to perform translation from [IEEE8021Qcc] to this document.

The following terminology is used in accordance with [RFC8655]:

App-flow The payload (data) carried over a DetNet service.

DetNet flow A DetNet flow is a sequence of packets which conform uniquely to a flow identifier, and to which the DetNet service is to be provided. It includes any DetNet headers added to support the DetNet service and forwarding sub-layers.

The following terminology is introduced in this document:

Source Reference point for an App-flow, where the flow starts.

Destination Reference point for an App-flow, where the flow terminates.

DN Ingress Reference point for the start of a DetNet flow. Networking technology specific encapsulation may be added here to the served App-flow(s).

DN Egress Reference point for the termination of a DetNet flow. Networking technology specific encapsulation may be removed here from the served App-flow(s).

2.2. Abbreviations

The following abbreviations are used in this document:

DetNet Deterministic Networking.

DN DetNet.

MPLS Multiprotocol Label Switching.

PSN Packet Switched Network.

TSN Time-Sensitive Networking.

2.3. Naming Conventions

The following naming conventions were used for naming information model components in this document. It is recommended that extensions of the model use the same conventions.

- Descriptive names are used.
- Names start with uppercase letters.
- Composed names use capital letters for the first letter of each component. All other letters are lowercase, even for acronyms. Exceptions are made for acronyms containing a mixture of lowercase and capital letters, such as IPv6. Example composed names are SourceMacAddress and DestinationIPv6Address.

3. DetNet Domain and its Modeling

3.1. DetNet Service Overview

The DetNet service can be defined as a service that provides a capability to carry a unicast or a multicast data flow for an application with constrained requirements on network performance, e.g., low packet loss rate and/or latency.

Figure 5 and Figure 8 in [RFC8655] show the DetNet service related reference points and main components.

3.2. Reference Points Used in Modeling

From service design perspective a fundamental question is the location of the service/flow endpoints, i.e., where the service/flow starts and ends.

App-flow specific reference points are the Source (where it starts) and the Destination (where it terminates). Similarly a DetNet flow has reference points termed DN Ingress (where a DetNet flow starts) and DN Egress (where a DetNet flow ends). These reference points may coexist in the same node (e.g., in a DetNet IP end system). DN Ingress and DN Egress reference points are intermediate reference points for a served App-flow.

All reference points are assumed in this document to be packet-based reference points. A DN Ingress may add and a DN Egress may remove

networking technology specific encapsulation to/from the served App-flow(s) (e.g., MPLS label(s), UDP and IP headers).

3.3. Information Elements

The DetNet flow information model and the service model relies on three groups of information elements:

- App-flow related parameters: these describe the App-flow characteristics (e.g., identification, encapsulation, traffic specification, endpoints, status, etc.) and the App-flow service expectations (e.g., delay, loss, etc.).

- DetNet flow related parameters: these describe the DetNet flow characteristics (e.g., identification, format, traffic specification, endpoints, rank, etc.).

- DetNet service related parameters: these describe the expected service characteristics (e.g., delivery type, connectivity delay/loss, status, rank, etc.).

In the information model a DetNet flow contains one or more (aggregated) App-flows (N:1 mapping). During DetNet aggregation the aggregated DetNet flows are treated simply as App-flows and the aggregate is the DetNet flow, which provides N:1 mapping. Similarly, there is an aggregated many to one relationship for the DetNet flow(s) to the DetNet Service.

4. App-flow Related Parameters

When Deterministic service is required by time/loss sensitive application(s) running on an end system during communication with its peer(s), the resulting data exchange has various requirements on delay and/or loss parameters.

4.1. App-flow Characteristics

App-flow characteristics are described by the following parameters:

- FlowID: a unique (management) identifier of the App-flow. It can be used to define the N:1 mapping of App-flows to a DetNet flow.

- FlowType: set by the encapsulation format of the flow. It can be Ethernet (TSN), MPLS, or IP.

- DataFlowSpecification: a flow descriptor, defining which packets belongs to a flow using, specific packet header fields such as src-addr, dst-addr, label, VLAN-ID, etc.

- TrafficSpecification: a flow descriptor, defining traffic parameters such as packet size, transmission time interval, and maximum packets per time interval.

- FlowEndpoints: delineate the start and termination reference points of the App-flow by pointing to the source interface/node and destination interface(s)/node(s).

- FlowStatus: indicates the status of the App-flow with respect to the establishment of the flow by the connected network, e.g., ready, failed, etc.

- FlowRank: indicates the rank of this flow relative to other flows in the connected network.

4.2. App-flow Requirements

App-flow requirements are described by the following parameters:

- FlowRequirements: defines the attributes of the App-flow regarding bandwidth, latency, latency variation, loss, and misordering tolerance.

- FlowBiDir: defines the data path requirement of the App-flow whether it must share the same data path and physical path for both directions through the network, e.g., to provide congruent paths in the two directions.

5. DetNet Flow Related Parameters

The Data model specified by [IEEE8021Qcc] describes data flows using TSN service as periodic flows with fix packet size (i.e., Constant Bit Rate (CBR) flows) or with variable packet size. The same concept is applied for flows using DetNet service.

Latency and loss parameters are correlated because the effect of late delivery can result data loss for an application. However, not all applications require hard limits on both latency and loss. For example, some real-time applications allow graceful degradation if loss happens (e.g., sample-based data processing, media distribution). Some other applications may require high-bandwidth connections that make use of packet replication techniques which are economically challenging or even impossible. Some applications may not tolerate loss, but are not delay sensitive (e.g., bufferless sensors). Time or loss sensitive applications may have somewhat special requirements especially for loss (e.g., no loss over two consecutive communication cycles; very low outage time, etc.).

DetNet flows have the following attributes:

a. DnFlowID (Section 5.1)
b. DnPayloadType (Section 5.2)
c. DnFlowFormat (Section 5.3)
d. DnFlowSpecification (Section 5.4)
e. DnTrafficSpecification (Section 5.5)
f. DnFlowEndpoints (Section 5.6)
g. DnFlowRank (Section 5.7)
h. DnFlowStatus (Section 5.8)

DetNet flows have the following requirement attributes:

o DnFlowRequirements (Section 5.9)
o DnFlowBiDir (Section 5.10)

Flow attributes are described in the following sections.

5.1. Management ID of the DetNet Flow

A unique (management) identifier is needed for each DetNet flow within the DetNet domain. It is specified by DnFlowID. It can be used to define the many to one mapping of DetNet flows to a DetNet service.

5.2. Payload type of the DetNet Flow

The DnPayloadType attribute is set according to the encapsulated App-flow format. The attribute can be Ethernet, MPLS, or IP.

5.3. Format of the DetNet Flow

The DnFlowFormat attribute is set according to the DetNet PSN technology. The attribute can be MPLS or IP.

5.4. Identification and Specification of DetNet Flows

Identification options for DetNet flows at the Ingress/Egress and within the DetNet domain are specified as follows; see Section 5.4.1 for DetNet MPLS flows and Section 5.4.2 for DetNetw IP flows.

5.4.1. DetNet MPLS Flow Identification and Specification

The identification of DetNet MPLS flows within the DetNet domain is based on the MPLS context in the service information model. The attributes are specific to the MPLS forwarding paradigm within the DetNet domain [I-D.ietf-detnet-mpls]. DetNetwork MPLS flows can be identified and specified by the following attributes:

a. SLabel
b. FLabelStack

5.4.2. DetNet IP Flow Identification and Specification

DetNet IP flows can be identified and specified by the following attributes [I-D.ietf-detnet-ip]:

a. SourceIpAddress
b. DestinationIpAddress
c. IPv6FlowLabel
d. Dscp (attribute)
e. Protocol
f. SourcePort
g. DestinationPort
h. IPSecSpi

The IP 6-tuple that is used for DetNet IP flow identification consists of items a, b, d, e, f, and g. Items c and h are additional attributes that can be used for DetNet flow identification in addition to the 6-tuple.

5.5. Traffic Specification of the DetNet Flow

DnTrafficSpecification attributes specify how the DN Ingress transmits packets for the DetNet flow. This is effectively the promise/request of the DN Ingress to the network. The network uses this traffic specification to allocate resources and adjust queue parameters in network nodes.

TrafficSpecification has the following attributes:

a. Interval: the period of time in which the traffic specification is specified.

b. MaxPacketsPerInterval: the maximum number of packets that the Ingress will transmit in one Interval.

c. MaxPayloadSize: the maximum payload size that the Ingress will transmit.

These attributes can be used to describe any type of traffic (e.g., CBR, VBR, etc.) and can be used during resource allocation to represent worst case scenarios.

Further optional attributes can be considered to achieve more efficient resource allocation. Such optional attributes might be worth for flows with soft requirements (i.e., the flow is only loss

sensitive or only delay sensitive, but not both delay-and-loss sensitive). Possible options how to extend DnTrafficSpecification attributes is for further discussion.

5.6. Endpoints of the DetNet Flow

The DnFlowEndpoints attribute defines the starting and termination reference points of the DetNet flow by pointing to the ingress interface/node and egress interface(s)/node(s). Depending on the network scenario it defines an interface or a node. Interface can be defined for example if the App-flow is a TSN Stream and it is received over a well defined UNI interface. For example, for App-flows with MPLS encapsulation defining an ingress node is more common when per platform label space is used.

5.7. Rank of the DetNet Flow

The DnFlowRank attribute provides the rank of this flow relative to other flows in the DetNet domain. Rank (range: 0-255) is used by the DetNet domain to decide which flows can and cannot exist when network resources reach their limit. Rank is used to help to determine which flows can be bumped (i.e., removed from node configuration thereby releasing its resources) if for example a port of a node becomes oversubscribed (e.g., due to network re-configuration).

5.8. Status of the DetNet Flow

DnFlowStatus provides the status of the DetNet flow with respect to the establishment of the flow by the DetNet domain.

The DnFlowStatus includes the following attributes:

a. DnIngressStatus is an enumeration for the status of the flow's Ingress reference point:

   * None: no Ingress.
   * Ready: Ingress is ready.
   * Failed: Ingress failed.
   * OutOfService: Administratively blocked.

b. DnEgressStatus is an enumeration for the status of the flow's Egress reference points:

   * None: no Egress.
   * Ready: all Egresses are ready.
   * PartialFailed: One or more Egress ready, and one or more Egress failed. The DetNet flow can be used if the Ingress is Ready.

* Failed: All Egresses failed.
* OutOfService: Administratively blocked.

c. FailureCode: A non-zero code that specifies the error if the DetNet flow encounters a failure (e.g., packet replication and elimination is requested but not possible, or DnIngressStatus is Failed, or DnEgressStatus is Failed, or DnEgressStatus is PartialFailed).

Defining FailureCodes for DetNet is out-of-scope in this document. Table 46-1 of [IEEE8021Qcc] describes TSN failure codes.

5.9. Requirements of the DetNet Flow

DnFlowRequirements specifies requirements to ensure the service level desired for the DetNet flow.

The DnFlowRequirements includes the following attributes:

a. MinBandwidth(Section 5.9.1)
b. MaxLatency(Section 5.9.2)
c. MaxLatencyVariation(Section 5.9.3)
d. MaxLoss(Section 5.9.4)
e. MaxConsecutiveLossTolerance(Section 5.9.5)
f. MaxMisordering(Section 5.9.6)

5.9.1. Minimum Bandwidth of the DetNet Flow

MinBandwidth is the minimum bandwidth that has to be guaranteed for the DetNet flow. MinBandwidth is specified in octets per second.

5.9.2. Maximum Latency of the DetNet Flow

MaxLatency is the maximum latency from Ingress to Egress(es) for a single packet of the DetNet flow. MaxLatency is specified as an integer number of nanoseconds.

5.9.3. Maximum Latency Variation of the DetNet Flow

MaxLatencyVariation is the difference between the minimum and the maximum end-to-end one-way latency. MaxLatencyVariation is specified as an integer number of nanoseconds.

5.9.4. Maximum Loss of the DetNet Flow

MaxLoss defines the maximum Packet Loss Ratio (PLR) requirement for the DetNet flow between the Ingress and Egress(es).

5.9.5. Maximum Consecutive Loss of the DetNet Flow

Some applications have special loss requirement, such as MaxConsecutiveLossTolerance. The maximum consecutive loss tolerance parameter describes the maximum number of consecutive packets whose loss can be tolerated. The maximum consecutive loss tolerance can be measured for example based on sequence number.

5.9.6. Maximum Misordering Tolerance of the DetNet Flow

MaxMisordering describes the tolerable maximum number of packets that can be received out of order. The maximum allowed misordering can be measured for example based on sequence number. The value zero for the maximum allowed misordering indicates that in order delivery is required, misordering cannot be tolerated.

5.10. BiDir requirement of the DetNet Flow

DnFlowBiDir attribute defines the requirement that the flow and the corresponding reverse direction flow must share the same path (links and nodes) through the routed or switch network in the DetNet domain, e.g., to provide congruent paths in the two directions that share fate and path characteristics.

6. DetNet Service Related Parameters

DetNet service have the following attributes:

a. DnServiceID (Section 6.1)
b. DnServiceDeliveryType (Section 6.2)
c. DnServiceDeliveryProfile (Section 6.3)
d. DNServiceConnectivity (Section 6.4)
e. DnServiceBiDir (Section 6.5)
f. DnServiceRank (Section 6.6)
g. DnServiceStatus (Section 6.7)

Service attributes are described in the following sections.

6.1. Management ID of the DetNet service

A unique (management) identifier for each DetNet service within the DetNet domain. It can be used to define the many to one mapping of DetNet flows to a DetNet service.

6.2. Delivery Type of the DetNet service

The DnServiceDeliveryType attribute is set according to the payload of the served DetNet flow (i.e., the encapsulated App-flow format). The attribute can be Ethernet, MPLS, or IP.

6.3. Delivery Profile of the DetNet Service

DnServiceDeliveryProfile specifies delivery profile to ensure proper serving of the DetNet flow.

The DnServiceDeliveryProfile includes the following attributes:

a. MinBandwidth(Section 6.3.1)
b. MaxLatency(Section 6.3.2)
c. MaxLatencyVariation(Section 6.3.3)
d. MaxLoss(Section 6.3.4)
e. MaxConsecutiveLossTolerance(Section 6.3.5)
f. MaxMisordering(Section 6.3.6)

6.3.1. Minimum Bandwidth of the DetNet Service

MinBandwidth is the minimum bandwidth that has to be guaranteed for the DetNet service. MinBandwidth is specified in octets per second.

6.3.2. Maximum Latency of the DetNet Service

MaxLatency is the maximum latency from Ingress to Egress(es) for a single packet of the DetNet flow. MaxLatency is specified as an integer number of nanoseconds.

6.3.3. Maximum Latency Variation of the DetNet Service

MaxLatencyVariation is the difference between the minimum and the maximum end-to-end one-way latency. MaxLatencyVariation is specified as an integer number of nanoseconds.

6.3.4. Maximum Loss of the DetNet Service

MaxLoss defines the maximum Packet Loss Ratio (PLR) parameter for the DetNet service between the Ingress and Egress(es) of the DetNet domain.

6.3.5. Maximum Consecutive Loss of the DetNet Service

Some applications have special loss requirement, such as MaxConsecutiveLossTolerance. The maximum consecutive loss tolerance parameter describes the maximum number of consecutive packets whose

loss can be tolerated. The maximum consecutive loss tolerance can be measured for example based on sequence number.

6.3.6. Maximum Misordering Tolerance of the DetNet Service

MaxMisordering describes the tolerable maximum number of packets that can be received out of order. The maximum allowed misordering can be measured for example based on sequence number. The value zero for the maximum allowed misordering indicates that in order delivery is required, misordering cannot be tolerated.

6.4. Connectivity Type of the DetNet Service

Two connectivity types are distinguished: point-to-point (p2p) and point-to-multipoint (p2mp). Connectivity type p2mp is created by a transport layer function (e.g., p2mp LSP). (Note: mp2mp connectivity is a superposition of p2mp connections.)

6.5. BiDir requirement of the DetNet Service

The DnServiceBiDir attribute defines the requirement that the flow and the corresponding reverse direction flow must share the same path (links and nodes) through the routed or switch network in the DetNet domain, e.g., to provide congruent paths in the two directions that share fate and path characteristics.

6.6. Rank of the DetNet Service

The DnServiceRank attribute provides the rank of a service instance relative to other services in the DetNet domain. DnServiceRank (range: 0-255) is used by the network in case of network resource limitation scenarios.

6.7. Status of the DetNet Service

DnServiceStatus information group includes elements that specify the status of the service specific state of the DetNet domain. This information group informs the user whether or not the service is ready for use.

The DnServiceStatus includes the following attributes:

a. DnServiceIngressStatus is an enumeration for the status of the service's Ingress:

   * None: no Ingress.
   * Ready: Ingress is ready.
   * Failed: Ingress failed.

* OutOfService: Administratively blocked.

b. DnServiceEgressStatus is an enumeration for the status of the service's Egress:

* None: no Egress.
* Ready: all Egresses are ready.
* PartialFailed: One or more Egress ready, and one or more Egress failed. The DetNet flow can be used if the Ingress is Ready.
* Failed: All Egresses failed.
* OutOfService: Administratively blocked.

c. DnServiceFailureCode: A non-zero code that specifies the error if the DetNet service encounters a failure (e.g., packet replication and elimination is requested but not possible, or DnServiceIngressStatus is Failed, or DnServiceEgressStatus is Failed, or DnServiceEgressStatus is PartialFailed).

Defining DnServiceFailureCodes for DetNet service is out-of-scope in this document. Table 46-1 of [IEEE8021Qcc] describes TSN failure codes.

7. Flow Specific Operations

The DetNet flow information model relies on three high level information groups:

- DnIngress: The DnIngress information group includes elements that specify the source for a single DetNet flow. This information group is applied from the user of the DetNet service to the network.

- DnEgress: The DnEgress information group includes elements that specify the destination for a single DetNet flow. This information group is applied from the user of the DetNet service to the network.

- DnFlowStatus: The status information group includes elements that specify the status of the flow in the network. This information group is applied from the network to the user of the DetNet service. This information group informs the user whether or not the DetNet flow is ready for use.

There are three possible operations for each DetNet flow with respect to its DetNet service at a DN Ingress or a DN Egress (similarly to App-flows at a Source or a Destination):

- Join: DN Ingress/DN Egress intends to join the flow.
- Leave: DN Ingress/DN Egress intends to leave the flow.
- Modify: DN Ingress/DN Egress intends to change the flow.

7.1. Join Operation

For the join operation, the DnFlowSpecification, DnFlowRank, DnFlowEndpoint, and DnTrafficSpecification are included within the DnIngress or DnEgress information group. For the join operation, the DnServiceRequirements groups can be included.

7.2. Leave Operation

For the leave operation, the DnFlowSpecification and DnFlowEndpoint are included within the DnIngress or DnEgress information group.

7.3. Modify Operation

For the modify operation, the DnFlowSpecification, DnFlowRank, DnFlowEndpoint, and DnTrafficSpecification are included within the DnIngress or DnEgress information group. For the join operation, the DnServiceRequirements groups can be included.

The Modify operation can be considered to address cases when a flow is slightly changed, e.g., only MaxPayloadSize (Section 5.5) has been changed. The advantage of having a Modify is that it allows initiation of a change of flow spec while leaving the current flow is operating until the change is accepted. If there is no linkage between the Join and the Leave, then while figuring out whether the new flow spec can be supported, the controller entity has to assume that the resources committed to the current flow are in use. By using Modify the controller entity knows that the resources supporting the current flow can be available for supporting the altered flow. Modify is considered to be an optional operation due to possible controller plane limitations.

8. Summary

This document describes the DetNet flow information model and the service information model for DetNet IP networks and DetNet MPLS networks. These models are used as input for the YANG model.

9. IANA Considerations

N/A.

10. Security Considerations

The external interfaces of the DetNet domain need to be subject to appropriate confidentiality. Additionally, knowledge of which flows/services are provided to a customer or delivered by a network operator may supply information that can be used in a variety of security attacks. Security considerations for DetNet are described in detail in [I-D.ietf-detnet-security]. General security considerations are described in [RFC8655]. This document discusses modeling the information, not how it is exchanged.

11. References

11.1. Normative References

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