IGP-TE Extensions for DetNet Information Distribution
draft-geng-detnet-info-distribution-03

Abstract

   This document extends the IGP-TE, including OSPF-TE and ISIS-TE, to
   support DetNet by specifying new information that can be placed in
   Link State Protocol Data Units (LSP). This information describes
   additional details regarding the state of the network that are useful
   for DetNet computations.

Requirements Language

   The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
   "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
   document are to be interpreted as described in RFC 2119 [RFC2119].

Status of This Memo

   This Internet-Draft is submitted in full conformance with the
   provisions of BCP 78 and BCP 79.

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   Task Force (IETF). Note that other groups may also distribute
   working documents as Internet-Drafts. The list of current Internet-
   Drafts is at https://datatracker.ietf.org/drafts/current/.

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   and may be updated, replaced, or obsoleted by other documents at any
   time. It is inappropriate to use Internet-Drafts as reference
   material or to cite them other than as "work in progress."

   This Internet-Draft will expire on April 25, 2019.

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1. Introduction

   There are many use cases from diverse industries which have the need
   in common for deterministic service, for example: audio video
   production, industrial process control and mobile access networks.
   The requirements can be summarized as:

      Deterministic minimum and maximum end-to-end latency from source
      to destination

      Extremely low packet loss rate

   Deterministic Networking (DetNet) can satisfy the requirements by the
   following techniques:

   o Congestion Protection by reserving data plane resources for DetNet
      flows in intermediate nodes along the path

   o Explicit Route that do not rapidly change with the network
      topology

   o Seamless Redundant which can distribute DetNet flow packets over
      multi paths to ensure delivery of each packet spite of the loss of
      a path

   To make the above techniques work, it's necessary to know the
   capabilities (e.g., DetNet capable or not, which congestion
   protection algorithms are supported, etc.), resources (e.g, dedicated
   bandwidth for DetNet, buffers, etc.), performance (e.g.,
   device/queue/link delay etc.) and other relevant information of each
   DetNet capable node. Then, a DetNet path computation element (e.g.,
   PCE or ingress of a DetNet flow) can use these information to compute
   a path that satisfies the requirement of a specific DetNet flow.
   Specifically, according to the requirements stated in DetNet
   architecture, the information should include:

   o Bandwidth related attributes (e.g., bandwidth reserved for
      DetNet);

   o Buffer/queue management related attributes (e.g., queue management
      algorithm, etc.);

   o PREOF (Packet Replication, Ordering and Elimination Function)
      capabilities and parameters (e.g., maximum out-of-order packets,
      etc.);

   o Delay related attributes (e.g., node processing delay, queuing
      delay, link delay, etc.);

This document defines extensions to OSPF and ISIS to distribute the above DetNet information at node and/or link granularity.

Some of information (e.g., Link delay/loss) can be distributed and collected through Traffic Engineering (TE) metric extensions [RFC7471] and [RFC7810], which are not covered by this document.

2. Terminology

All the DetNet related terminologies used in this document conform to the DetNet architecture [I-D.ietf-detnet-architecture].

3. DetNet Extensions to OSPF TE

This document defines an extension to OSPF used to advertise DetNet information.

3.1. DetNet Node Attributes Advertisement

New OSPF DetNet sub-TLVs for Node Attribute TLV[RFC5786] are defined to distribute the DetNet information of a node. These sub-TLVs include:

Type	Length	Value
TBD1	8	DetNet Processing Delay
TBD4	4	PREOF Capability

3.1.1. Packet Processing Delay Sub-TLV

In the scope of DetNet, packet processing delay, which begins after the packet goes into the input port and ends before the packet arrives the output buffer, can expected in a known range, and the value of the delay bound is specified in this sub-TLV, including:

o Maximum DetNet packet processing delay

o Minimum DetNet packet processing delay

o Maximum DetNet packet processing delay variation

The format of this sub-TLV is shown in the following diagram:

```
   0                   1                   2                   3
   0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |          Type(TBD1)           |           Length(8)           |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |    RESERVED    |       Minimum DetNet Processing Delay        |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |    RESERVED    |       Maximum DetNet Processing Delay        |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |    RESERVED    |   Maximum DetNet Processing Delay Variation  |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Type field is 2 octets in length, and the value is TBD1.

The Length field is 2 octets in length and its value is 8.

The RESERVED field is reserved for future use. It MUST be set to 0
when sent and MUST be ignored when received.

The Minimum DetNet Processing Delay field is 3 octets, and presents
the minimum delay for a DetNet flow in the device, excluding the
queuing delay in output port. The units are microsecond.

The Maximum DetNet Processing Delay field is 3 octets, and presents
the maximum delay for a DetNet flow in the device, excluding the
queuing delay in output port. The units are microsecond.

The Maximum DetNet Processing Delay Variation field is 3 octets in
length, and presents the maximum delay variation for a DetNet flow in
the device, excluding the queuing delay in output port. The units
are microsecond.

3.1.2. PREOF Capability Sub-TLV

PREOF (Packet Replication/Elimination/Ordering Function) is for
DetNet service protection, which includes:

o In-order delivery function: defined in Section 3.2.2.1 of
   [I-D.ietf-detnet-architecture]

o Packet replication function: defined in Section 3.2.2.2 of
   [I-D.ietf-detnet-architecture]

o Packet elimination function: defined in Section 3.2.2.3 of
   [I-D.ietf-detnet-architecture]

This sub-TLV specifies a set of PREOF capabilities and relevant
parameters at node granularity. PREOF can also be advertised as Link

attribute (section 3.2.3), when not all of the ports in the node
support PREOF.

The format of this sub-TLV is shown in the following diagram:

```
  0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |          Type(TBD4)            |          Length(4)           |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |      Flags     |     Maximum out-of-order Packet Number       |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Type field is 2 octets in length, and the value is TBD4.

The Length field is 2 octets in length and its value is 4.

The Flags field is 1 octet in length, and it is designed as follows:

```
  0 1 2 3 4 5 6 7 8
 +-+-+-+-+-+-+-+-+
 |R|E|O|         |
 +-+-+-+-+-+-+-+-+
```

where:

o R-flag: replication-capability flag, which indicates whether a
   link has the packet replication capability.

o E-flag: elimination-capability flag, which indicates whether a
   link has the packet elimination capability

o O-flag: in-order-capability, which indicates whether a LTP has the
   in-order delivery capability

Maximum out-of-order Packet Number field is 3 octet in length, and
presents the maximum number of out-of-order packets that this link
can support, it depends on the reserved buffer size for packet
reordering. This value is valid only when the O-flag is set.

3.2. DetNet Link Attributtes Advertisement

New OSPF DetNet sub-TLVs for Link TLV are defined to distribute
DetNet information of a link. These sub-TLVs include:

Type	Length	Value
TBD2	4	Max DetNet Reservable Bandwidth
TBD3	4	DetNet Available Bandwidth
TBD4	4	PREOF Capability
TBD5	4	Queuing Algorithm Capabilities
TBD6	10	Queue Parameters

3.2.1. Max DetNet Reservable Bandwidth Sub-TLV

This sub-TLV specifies the maximum amount of bandwidth that is
reserved for DetNet on this link. Note that this value SHOULD be
smaller than the value of Maximum Reservable Bandwidth sub-TLV
[RFC3630]. The value normally depends on the queuing management
algorithm and is user-configurable. In some particular queuing
management algorithm (e.g. Credit Based shaper in AVB), this value
will affect the calculation of maximum queuing delay of the DetNet
flow. The units are bytes per second.

The format of this sub-TLV is shown in the following diagram:

```
  0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |             Type(TBD2)         |            Length(4)          |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |    RESERVED   |     Maximum DetNet Reservable Bandwidth       |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
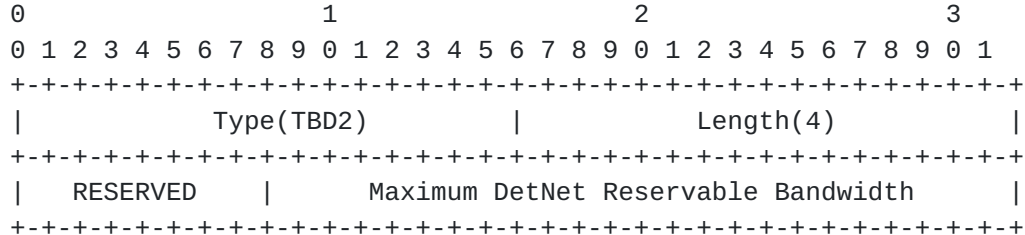
The Type field is 2 octets in length, and the value is TBD2.

The Length field is 2 octets in length and its value is 4.

The RESERVED field is reserved for future use. It MUST be set to 0
when sent and MUST be ignored when received.

This Maximum DetNet Reservable Bandwidth field is 3 octets in length,
and presents the maximum bandwidth that may be reserved for DetNet.
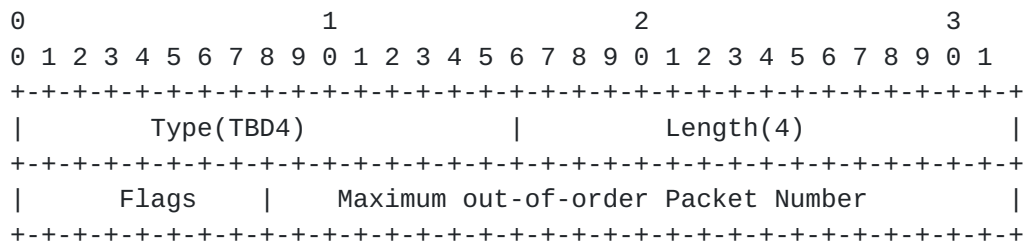The units are bytes per second.

3.2.2. DetNet Available Bandwidth Sub-TLV

This sub-TLV specifies the available bandwidth that can be reserved
for DetNet flow on this link for now. Considering that there is no
generally accepted DetNet traffic classification, this value contains
all the available DetNet Bandwidth from different DetNet traffic

classes (if there is any), which differs from the Unreserved
Bandwidth defined in [RFC3630].

The format of this sub-TLV is shown in the following diagram:

```
  0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |          Type(TBD3)            |           Length(4)           |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |    RESERVED    |         Available DetNet Bandwidth            |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Type field is 2 octets in length, and the value is TBD3.

The Length field is 2 octets in length and its value is 4.

The RESERVED field is reserved for future use. It MUST be set to 0
when sent and MUST be ignored when received.

This Available DetNet Bandwidth field is 3 octets in length, and
presents the available bandwidth for DetNet in this link. The units
are bytes per second.

3.2.3. PREOF Capability Sub-TLV

PREOF (Packet Replication/Elimination/Ordering Function) is for
DetNet service protection, which includes :

o In-order delivery function: defined in Section 3.2.2.1 of
   [I-D.ietf-detnet-architecture]

o Packet replication function: defined in Section 3.2.2.2 of
   [I-D.ietf-detnet-architecture]

o Packet elimination function: defined in Section 3.2.2.3 of
   [I-D.ietf-detnet-architecture]

This sub-TLV specifies a set of PREOF capabilities and relevant
parameters at link granularity. PREOF can also be advertised as node
attribute (section 3.1.2), when all of the ports in the node support
PREOF.

The format of this sub-TLV is shown in the following diagram:

```
      0                   1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |          Type(TBD4)            |           Length(4)           |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |     Flags     |     Maximum out-of-order Packet Number        |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
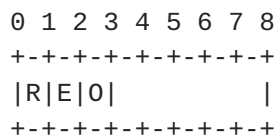
The Type field is 2 octets in length, and the value is TBD4.

The Length field is 2 octets in length and its value is 4.

The Flags field is 1 octet in length, and it is designed as follows:

```
   0 1 2 3 4 5 6 7 8
  +-+-+-+-+-+-+-+-+
  |R|E|O|         |
  +-+-+-+-+-+-+-+-+
```

where:

o R-flag: replication-capability flag, which indicates whether a
   link has the packet replication capability.

o E-flag: elimination-capability flag, which indicates whether a
   link has the packet elimination capability

o O-flag: in-order-capability, which indicates whether a LTP has the
   in-order delivery capability

Maximum out-of-order Packet Number field is 3 octet in length, and
presents the maximum number of out-of-order packets that this link
can support, it depends on the reserved buffer size for packet
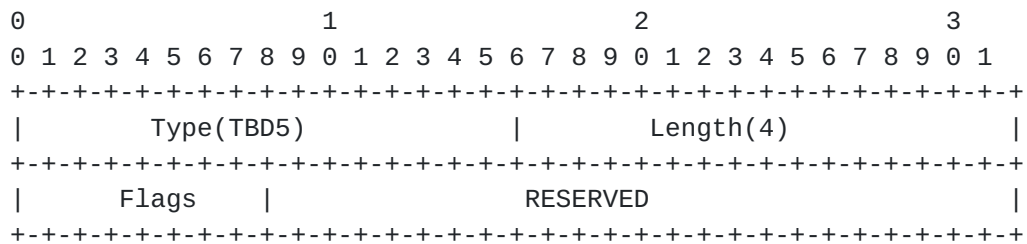reordering. This value is valid only when the O-flag is set.

3.2.4. Queuing Algorithm Capability Sub-TLV

This sub-TLV specifies queuing management algorithms capabilities to
gaurante bounded queuing latency [I-D.finn-detnet-bounded-latency].

The format of this sub-TLV is shown in the following diagram:

```
   0                   1                   2                   3
   0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |          Type(TBD5)           |            Length(4)          |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |      Flags     |                  RESERVED                    |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
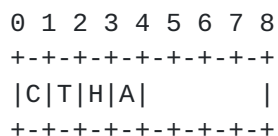
The Type field is 2 octets in length, and the value is TBD5.

The Length field is 2 octets in length and its value is 4.

The RESERVED field is reserved for future use. It MUST be set to 0
when sent and MUST be ignored when received.

The Flags field is 1 octet in length, and it is designed as follows:

```
   0 1 2 3 4 5 6 7 8
  +-+-+-+-+-+-+-+-+-+
  |C|T|H|A|         |
  +-+-+-+-+-+-+-+-+-+
```

where:

o C-flag: CBS flag, which indicates whether a link can support Time
   Aware Shaping [IIEEE802.1Qbv].

o T-flag: TAS flag, which indicate whether a link can support
   Credit Based Shaper [IEEE802.1Q-2014]

o H-flag: CQF flag, which indicate whether a link can support
   Cyclic Queuing and Forwarding [IEEE802.1Qch]

o A-flag: ATS flag, which indicate whether a link can support
   Asynchronous Traffic Shaping [IEEE802.1Qcr]

3.2.5. DetNet Queue Sub-TLV

In the context of DetNet, the delay of queuing is bounded, and the
bound depends on what queuing management method is used and how many
buffers are allocated. This sub-TLV specifies the DetNet queue
parameters.

The format of this sub-TLV is shown in the following diagram:

```
   0                   1                   2                   3
   0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |          Type(TBD6)           |            Length(10)         |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |        Queue Identifier       |       Queue Buffer Size       |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |     Flags     |            Maximum Queuing Delay              |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |   RESERVED    |            Minimum Queuing Delay              |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |   RESERVED    |        Maximum Queuing Delay Variation        |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Type field is 2 octets in length, and the value is TBD6.

The Length field is 2 octets in length and its value is 10.

The Queue Identifier field is 3 octets in length, and specifies the
identifier of a queue. It could be an internal identifier that is
only used within a node. Or it could be used by a centralized
controller to specify in which specific queue a flow/packet is
required to enter.

The Queue Buffer Size field is 3 octets in length, and specifies the
size of a queue with unit of bytes.

The Flags field is 1 octet in length, and it is designed as follows:

```
   0 1 2 3 4 5 6 7 8
  +-+-+-+-+-+-+-+-+
  |C|T|H|A|       |
  +-+-+-+-+-+-+-+-+
```

where:

o C-flag: CBS flag, which indicates whether a link can support Time
   Aware Shaping [IIEEE802.1Qbv].

o T-flag: TAS flag, which indicate whether a link can support
   Credit Based Shaper [IEEE802.1Q-2014]

o H-flag: CQF flag, which indicate whether a link can support
   Cyclic Queuing and Forwarding [IEEE802.1Qch]

o A-flag: ATS flag, which indicate whether a link can support
   Asynchronous Traffic Shaping [IEEE802.1Qcr]

The RESERVED field is reserved for future use. It MUST be set to 0
when sent and MUST be ignored when received.

Minimum Queuing Delay is 3 octets in length, and carries minimum
queuing delay value (in microseconds) encoded as an integer value.
Implementations may also add this to the value of Min Delay
Unidirectional Link Delay Sub-TLV [RFC7471] in order to advertise the
minimum delay of this link. Min Queuing Delay can be the same with
the Max Queuing Delay.

Maximum Queuing Delay is 3 octets in length, and carries the maximum
queuing delay value (in microseconds) encoded as an integer value.
Implementations may also add this to the value of Max Delay
Unidirectional Link Delay Sub-TLV [RFC7471]to order to advertise the
maximum delay of this link.

Maximum Queuing Delay variation is 3 octets in length, and carries
the maximum queuing delay variation value (in microseconds) encoded
as an integer value.

The RESERVED field is reserved for future use. It MUST be set to 0
when sent and MUST be ignored when received.

4. DetNet Extensions to ISIS TE

This document defines an extension to IS-IS used to advertise DetNet
information.

4.1. DetNet Node Attributes Advertisement

The DetNet node sub-TLVs are defined within the body of the IS-IS
Router Capability TLV [RFC7981] to carry DetNet information.

4.1.1. DetNet Processing Delay Sub-TLV

This sub-TLV specifies the DetNet packet porcessing parameters. The
reader can know more about this sub-TLV referring to section 3.1.

The format of this sub-TLV is shown in the following diagram:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Type(TBD7)  |  Length(8)   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   RESERVED   |      Minimum DetNet Processing Delay         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   RESERVED   |      Maximum DetNet Processing Delay         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   RESERVED   |   Maximum DetNet Processing Delay Variation  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Type field is 1 octets in length, and the value is TBD7.

The Length field is 1 octets in length and its value is 8.

The RESERVED field is reserved for future use. It MUST be set to 0
when sent and MUST be ignored when received.

The Minimum DetNet Processing Delay is 3 octets in length and
presents the minimum delay for a DetNet flow in the device, excluding
the queuing delay in output port. The units are microsecond.

The Maximum DetNet Processing Delay is 3 octets in length and
presents the maximum delay for a DetNet flow in the device, excluding
the queuing delay in output port. The units are microsecond.

The Maximum DetNet Processing Delay Variation is 3 octets in length
and presents the maximum delay variation for a DetNet flow in the
device, excluding the queuing delay in output port. The units are
microsecond.

4.1.2. PREOF Capability Sub-TLV

This sub-TLV specifies a set of PREOF capabilities and relevant
parameters in sub-TLV. The reader can know more about this sub-TLV
referring to section 3.4.

The format of this sub-TLV is shown in the following diagram:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Type(TBD10) |  Length(4)   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Flags    |    Maximum out-of-order Packet Number        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Type field is 1 octets in length, and the value is TBD10.

The Length field is 1 octets in length and its value is 4.

The Flags field is 1 octet in length, and it is designed as follows:

```
   0 1 2 3 4 5 6 7 8
  +-+-+-+-+-+-+-+-+
  |R|E|O|         |
  +-+-+-+-+-+-+-+-+
```

where:

o R-flag: replication-capability flag, which indicates whether a
   link has the packet replication capability.

o E-flag: elimination-capability flag, which indicates whether a
   link has the packet elimination capability

o O-flag: in-order-capability, which indicates whether a LTP has the
   in-order delivery capability

Maximum out-of-order Packet Number field is 3 octets in length and
presents the maximum number of out-of-order packets that this link
can support, it depends on the reserved buffer size for packet
reordering. This value is valid only when the O-flag is set.

4.2. DetNet Link Attributes Advertisement

This document defines new IS-IS TE sub-TLVs that can be announced in
the TLVs 22, 23, 141, 222, and 223 in order to distribute DetNet
information. The sub-TLV extensions below build on the ones provided
in [RFC5305], [RFC5316]and [RFC7310]

4.2.1. Max DetNet Reservable Bandwidth Sub-TLV

This sub-TLV specifies the maximum amount of bandwidth that is
reserved for DetNet on this link. Note that this value SHOULD be
smaller than the value of Maximum Reservable Link Bandwidth
[RFC5305]. The reader can know more about this sub-TLV referring to
section 3.2.

The format of this sub-TLV is shown in the following diagram:

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Type(TBD8)  |   Length(4)   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   RESERVED    |      Maximum DetNet Reservable Bandwidth     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Type field is 1 octets in length, and the value is TBD8.

The Length field is 1 octets in length and its value is 4.

The RESERVED field is reserved for future use. It MUST be set to 0
when sent and MUST be ignored when received.

This Maximum DetNet Reservable Bandwidth field is 3 octets in length
and presents the maximum bandwidth that may be reserved for DetNet.
The units are bytes per second.

4.2.2. DetNet Available Bandwidth Sub-TLV

This sub-TLV specifies the available bandwidth that can be reserved
for DetNet flow on this link for now. It is different from the
Unreserved Bandwidth sub-TLV defined in [RFC5305] referring to
section 3.3.

The format of this sub-TLV is shown in the following diagram:

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Type(TBD9)  |   Length(4)   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   RESERVED    |        Available DetNet Bandwidth            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Type field is 1 octets in length, and the value is TBD9.

The Length field is 1 octets in length and its value is 4.

The RESERVED field is reserved for future use. It MUST be set to 0
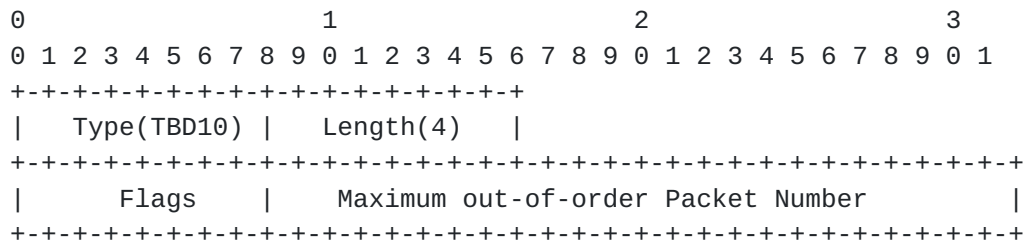when sent and MUST be ignored when received.

This Available DetNet Bandwidth field is 3 octets in length and
presents the available bandwidth for DetNet in this link. The units
are bytes per second.

4.2.3. PREOF Capability Sub-TLV

This sub-TLV specifies a set of PREOF capabilities and relevant
parameters in sub-TLV. The reader can know more about this sub-TLV
referring to section 3.4.

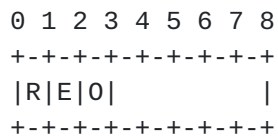The format of this sub-TLV is shown in the following diagram:

```
  0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |   Type(TBD10) |   Length(4)   |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |     Flags     |    Maximum out-of-order Packet Number         |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Type field is 1 octets in length, and the value is TBD10.

The Length field is 1 octets in length and its value is 4.

The Flags field is 1 octet in length, and it is designed as follows:

```
  0 1 2 3 4 5 6 7 8
 +-+-+-+-+-+-+-+-+-+
 |R|E|O|         |
 +-+-+-+-+-+-+-+-+-+
```

where:

o R-flag: replication-capability flag, which indicates whether a
   link has the packet replication capability.

o E-flag: elimination-capability flag, which indicates whether a
   link has the packet elimination capability

o O-flag: in-order-capability, which indicates whether a LTP has the
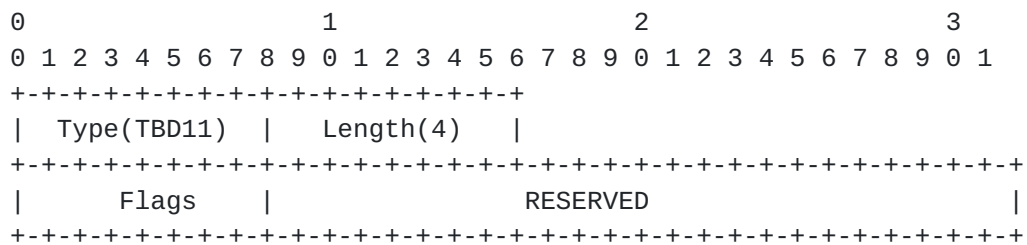   in-order delivery capability

Maximum out-of-order Packet Number field is 3 octets in length and
presents the maximum number of out-of-order packets that this link
can support, it depends on the reserved buffer size for packet
reordering. This value is valid only when the O-flag is set.

4.2.4. Queuing Algorithm Capability Sub-TLV

This sub-TLV specifies queuing management algorithms capabilities to
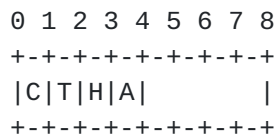gaurante bounded queuing latency [I-D.finn-detnet-bounded-latency].

The format of this sub-TLV is shown in the following diagram:

```
  0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |  Type(TBD11)  |   Length(4)   |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |     Flags     |                RESERVED                       |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Type field is 1 octets in length, and the value is TBD11.

The Length field is 1 octets in length and its value is 4.

The Flags field is 1 octet in length, and it is designed as follows:

```
  0 1 2 3 4 5 6 7 8
 +-+-+-+-+-+-+-+-+
 |C|T|H|A|       |
 +-+-+-+-+-+-+-+-+
```

where:

o C-flag: CBS flag, which indicates whether a link can support Time
   Aware Shaping [IIEEE802.1Qbv].

o T-flag: TAS flag, which indicuate whether a link can support
   Credit Based Shaper [IEEE802.1Q-2014]

o H-flag: CQF flag, which indicuate whether a link can support
   Cyclic Queuing and Forwarding [IEEE802.1Qch]

o A-flag: ATS flag, which indicuate whether a link can support
   Asynchronous Traffic Shaping [IEEE802.1Qcr]

4.2.5. DetNet Queue Sub-TLV

In the context of DetNet, the delay of queuing is bounded, and the
bound depends on what queuing management method is used and how many
buffers are allocated. This sub-TLV specifies the DetNet queue
parameters.

The format of this sub-TLV is shown in the following diagram:

```
      0                   1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Type(TBD12)  |  Length(10)   |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |       Queue Identifier        |       Queue Buffer Size       |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |     Flags     |            Maximum Queuing Delay              |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |   RESERVED    |            Minimum Queuing Delay              |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |   RESERVED    |        Maximum Queuing Delay Variation        |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   The Type field is 1 octets in length, and the value is TBD12.

   The Length field is 1 octets in length and its value is 10.

   The Queue Identifier field specifies the identifier of a queue. It
   could be an internal identifier that is only used within a node. Or
   it could be used by a centralized controller to specify in which
   specific queue a flow/packet is required to enter.

   The Queue Buffer Size field specifies the size of a queue with unit
   of bytes.

   The Flags field is 1 octet in length, and it is designed as follows:

```
     0 1 2 3 4 5 6 7 8
     +-+-+-+-+-+-+-+-+
     |C|T|H|A|       |
     +-+-+-+-+-+-+-+-+
```

   where:

   o C-flag: CBS flag, which indicates whether a link can support Time
      Aware Shaping [IIEEE802.1Qbv].

   o T-flag: TAS flag, which indicate whether a link can support
      Credit Based Shaper [IEEE802.1Q-2014]

   o H-flag: CQF flag, which indicate whether a link can support
      Cyclic Queuing and Forwarding [IEEE802.1Qch]

   o A-flag: ATS flag, which indicate whether a link can support
      Asynchronous Traffic Shaping [IEEE802.1Qcr]

The RESERVED field is reserved for future use. It MUST be set to 0
when sent and MUST be ignored when received.

Minimum Queuing Delay is 3 octets in length and presents minimum
queuing delay value (in microseconds) encoded as an integer value.
Implementations may also add this to the value of Min Delay
Unidirectional Link Delay Sub-TLV [RFC7471] in order to advertise the
minimum delay of this link. Min Queuing Delay can be the same with
the Max Queuing Delay.

Maximum Queuing Delay is 3 octets in length and presents the maximum
queuing delay value (in microseconds) encoded as an integer value.
Implementations may also add this to the value of Max Delay
Unidirectional Link Delay Sub-TLV [RFC7471]to order to advertise the
maximum delay of this link.

Maximum Queuing Delay variation is 3 octets in length and presents
the maximum queuing delay variation value (in microseconds) encoded
as an integer value.

5. IANA Considerations

5.1. Sub-TLVs for OSPF Node Attribute TLV

IANA is requested to register the OSPF sub-TLVs defined in this
document in the sub-TLVs for Node Attribute TLV registry.

```
      Type         Description
      ----         ------------------------------
      TBD1         Packet Processing Delay
      TBD2         PREOF Capability
```

5.2. Sub-TLVs for OSPF Link TLV

IANA is requested to register the OSPF sub-TLVs defined in this
document in the sub-TLVs for Link TLV registry.

```
      Type         Description
      ----         ------------------------------
      TBD3         Maximum DetNet Reservable Bandwidth
      TBD4         DetNet Available Bandwidth
      TBD5         PREOF Capability
      TBD6         Queuing Algorithm Capabilities
      TBD7         Queue Parameters
```

5.3. Sub-TLVs for ISIS Router Capability TLV

   IANA is requested to register the ISIS sub-TLVs defined in this
   document in the sub-TLVs for Router Capability TLV registry.

```
       Type          Description
       ----          ------------------------------
       TBD8          Packet Processing Delay
       TBD9          PREOF Capability
```

5.4. Sub-TLVs for IS-IS TLVs 22, 23, 141, 222, and 223

   IANA is requested to register the ISIS sub-TLVs defined in this
   document in the Sub-TLVs for TLVs 22, 23, 141, 222, and 223 registry.

```
       Type          Description
       ----          ------------------------------
       TBD10         Maximum DetNet Reservable Bandwidth
       TBD11         DetNet Available Bandwidth
       TBD12         PREOF Capability
       TBD13         Queuing Algorithm Capabilities
       TBD14         Queue Parameters
```

6. Security Considerations

   This document does not introduce security issues beyond those
   discussed in [RFC7471] and [RFC7810].

7. Acknowledgements

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