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**DetNet Enhanced Data Plane**

## Abstract

Aiming at providing the bounded latency to DetNet services, DetNet data plane is required to be enhanced. This document provides a method to extend DetNet data plane by introducing the Bounded Latency Information (BLI), which facilitates DetNet transit nodes to guarantee the bounded latency transmission in data plane.

## 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 .

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## 1. Introduction

DetNet [[RFC8655](#)] provides the capability to carry specified unicast or multicast data flows with extremely low data loss rates and bounded end-to-end latency within a network domain. Three primary goals of DetNet QoS are defined in section 3.1 of [[RFC8655](#)]:

\*Minimum and maximum end-to-end latency from source to destination, timely delivery, and bounded jitter (packet delay variation) derived from these constraints.

\*Packet loss ratio under various assumptions as to the operational states of the nodes and links.

\*An upper bound on out-of-order packet delivery. It is worth noting that some DetNet applications are unable to tolerate any out-of-order delivery.

To fulfill the goals of DetNet QoS, DetNet architecture [[RFC8655](#)] defines a DetNet data plane protocol stack, which includes DetNet forwarding and service sub-layers. Specifically, DetNet data plane framework [[RFC8938](#)] specifies two metadata of flow identity and sequence number to be encoded in data plane. Flow-ID is used for identification of the flow or aggregate flow to decide the DetNet traffic treatment and PREOF in both sub-layers. At the same time, sequence number is only used for PREOF in service sub-layer.

For IP DetNet data plane, [[RFC8939](#)] specifies a method of using 6-tuple to identify DetNet flows. Management and control information defined in DetNet YANG module [[I-D.ietf-detnet-yang](#)] is used to select the forwarding outgoing interface and next hop. It is stated that the allocation of system resources and provisioning of related parameters is used for DetNet traffic treatment. However, [[RFC8939](#)] doesn't further specify the related parameters used in data plane.

In [[RFC8964](#)], DetNet Control Word (d-CW), DetNet service label (S-Label), and DetNet MPLS forwarding label(s) (F-Label) are defined for the MPLS-based DetNet data plane encapsulation, where the first two information is mainly used for the DetNet service sub-layer functions, the last information is used for the DetNet forwarding sub-layer functions. DetNet controller plane takes the responsibility to provision both flow identification information and the flow-specific resources needed to provide traffic treatment to meet each flow's service requirements. There is no specification in MPLS DetNet data plane to empower the packet treatment capabilities.

There are also other specifications of DetNet data planes such as [[RFC9023](#)], [[RFC9024](#)], [[RFC9025](#)], [[RFC9037](#)], and [[RFC9056](#)]. These documents specifies the DetNet data planes and interworking technologies of one type of network operating over another sub-network in order to extend the DetNet service range. However, these documents do not introduce new procedure or process, but to follow the specifications defined in [[RFC8939](#)] and [[RFC8964](#)].

To meet the requirements for large-scale deterministic networks and support the bounded latency objective specified in

[[I-D.liu-detnet-large-scale-requirements](#)], DetNet data plane is required to be enhanced in the following aspects:

- \*Explicit inclusion of the metadata used for traffic treatment, especially for bounded latency and jitter, when considering the support of DetNet flows scalability in large scale DetNet networks
- \*Compatibility to different options of queuing, shaping, policing or any other underlying network technologies, in order to provide bounded latency
- \*Minimize the end-to-end delay difference of multiple forwarding paths that are used for packet replication and elimination
- \*DetNet data plane processing of DetNet flow coexists with the non-DetNet flows

This document provides a method to extend DetNet data plane by introducing Bounded Latency Information (BLI), which facilitates DetNet transit nodes to guarantee the bounded latency transmission in data plane. The resources include the QoS mechanisms, scheduling mechanisms, or any other mechanisms from underlying network layer so as to support bounded latency. This document also proposes a format of bounded latency information and its encapsulations on DetNet data planes.

## **2. Terminology and Conventions**

### **2.1. Requirement Language**

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.

### **2.2. Terminology**

The abbreviations used in this document are:

BLI: Bounded Latency Information

PREOF: Packet Replication, Elimination, and Ordering Functions

## **3. Design of DetNet Enhanced Data Plane**

In order to support the enhanced traffic treatment functions, such as bounded latency, DetNet data plane is enhanced by carrying a new

defined metadata information in DetNet service packets: Bounded Latency Information (BLI).

DetNet uses either one or combination of QoS related and resource allocation technologies to ensure the end-to-end bounded latency. [\[I-D.ietf-detnet-bounded-latency\]](#) introduces a set of scheduling mechanisms can be used to assure the bounded latency. [\[I-D.stein-srtsn\]](#) uses a single stack data structure to provide a unified approach to forwarding and deadline based scheduling. Noted that in most scheduling process, an ancillary information is required to be transmitted between DetNet nodes to facilitate local scheduling. In this document, this ancillary information is named bounded latency information. Bounded latency information is transmitted across multiple DetNet transit nodes and used by the DetNet forwarding sub-layer.

To cope with a variety of scheduling mechanisms and transfer different information in a uniform format in data plane, the bounded latency information is abstracted and classified into two categories: requirement and resource.

### **3.1. Category 1: Requirement**

Bounded latency information in the requirement category may include the information like the end-to-end delay budget, local delay budget, local deadline, delay variation budget, local delay variation budget etc. For example, end-to-end delay budget describes the upper bounded latency value of DetNet flow in network. Then DetNet node may use this information to determine the packet priority or which queue can be used to transmit this packet. Local delay budget is a variation of end-to-end delay budget when multiple DetNet nodes may have same or different delay budget time of each in DetNet network. Deadline is straightforward to indicate how much time is left for this packet to meet the upper bounded latency requirement. Similar practice in 6LoWPANs is given by [\[RFC9034\]](#). The usage of this information is similar to the delay budget information when DetNet node decides the priority or queue for the packet forwarding. Delay variation [\[I-D.mohammadpour-detnet-bounded-delay-variation\]](#) is another deterministic goal required by DetNet and should be considered in scheduling process when it is required. Priority can also be a type of requirement. DetNet application may assign its priority by different meanings and formats, which may not be equivalently fulfilled by existing QoS priority.

### **3.2. Category 2: Resource**

Bounded latency information in the resource category includes the information like cycle ID, queue ID, and time slot ID etc. Since

cycles, queues, or time slots are the real resources can be allocated for DetNet flow, they are named as the time resource ID. For example, time resource ID can represent a cycle ID when cyclic queuing mechanism is used on DetNet node. Time resource ID can also represent a queue ID when queue based scheduling mechanism is locally used on DetNet node. Time resource ID can represent a time slot ID too, when a time slot based mechanism like [\[RFC9030\]](#) is used.

#### 4. Data Field of Bounded Latency Information

This section introduces the data field of bounded latency information in DetNet data plane. The format of the data field is shown as follows.

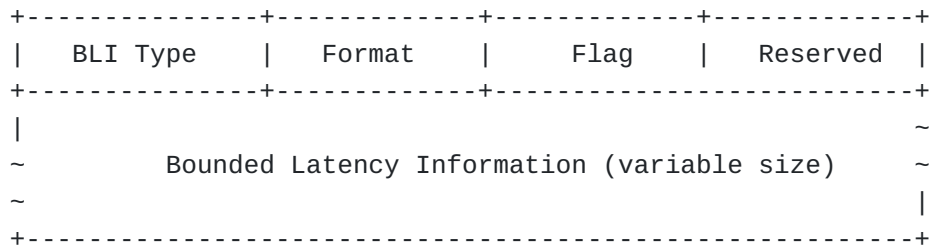


Figure 1: Data Field of Bounded Latency Information

where:

\*Bounded Latency Information Type: 8-bit identifier to represent the type of bounded latency information. A new registry is expected to be created and the value is assigned by IANA. Table 1 lists the value of BLI Type and the corresponding Bounded Latency Information defined so far,

BLI Type Value	Bounded Latency Information
0	Reserved
1	Time resource ID
2	Priority
3	End-to-end delay budget
4	Local delay budget
5	End-to-end deadline
6	Local deadline
7	End-to-end delay variation budget
8	Local delay variation budget

Table 1: Bounded Latency Information Type and Value

\*Format: 8-bit value to indicate the format of bounded latency information. For example, the format could be 16-bit unsigned integer, 32-bit unsigned integer, PTP or NTP timestamp, and other pre-configured formats. Table 2 lists the value of Format and the corresponding Format defined so far,

Format Value	Format
1	32-bit unsigned Integer
2	16-bit unsigned Integer
3	8-bit unsigned Integer
4	PTP 80-bit Timestamp
5	PTP 64-bit Timestamp
6	NTP 64-bit Timestamp
7	NTP 32-bit Timestamp

Table 2: Format

Bounded Latency Information Type and Format are used together to specify the type, length and format of the bounded latency information.

Reserved: Reserved for future usage.

Time resource ID: the identifier to indicate the underlying resources used for bounded latency. The format is 32-bit unsigned integer.

Priority: QoS priority of the DetNet service packet. As six bits of the Differentiated Services Field [[RFC2474](#)] are used as a codepoint (DSCP), the format of priority is 8-bit unsigned integer.

End-to-end delay budget: the end-to-end delay requirement of DetNet service packet. The format is 32-bit unsigned Integer.

Local delay budget: the per hop delay requirement of DetNet service packet on this network node. The format is 32-bit unsigned Integer.

End-to-end deadline: the time when the packet must arrive at the final destination or exit the DetNet network. This time is usually the birth time plus the end-to-end delay budget. The format is the timestamp with proper length.

Local deadline: the time when the packet must exit this network node. The format is the timestamp with proper length.

End-to-end delay variation budget: the end-to-end delay variation requirement of DetNet service packet. The format is 16-bit unsigned Integer.

Local delay variation budget: the per hop delay variation requirement of DetNet service packet on this network node. The format is 16-bit unsigned Integer.

\*Flags: 8 bits of flags. A new registry "Bounded Latency Flags" is expected to be created. At the writing time, all flags are unused and undefined.

```
0 1 2 3 4 5 6 7
+--+--+--+--+--+
|U U U U U U U U|
+--+--+--+--+--+
```

Figure 2: Flag

\*Reserved: Keeps zero when it is not specified.



\*Bounded Latency Information: indicates the bounded latency information used for local scheduling processing. Table 1 shows the bounded latency information type and the corresponding values. The bounded latency information is different depending on the type of bounded latency information.

## 5. Encapsulation of Bounded Latency Information

BLI data field can be encapsulated in different DetNet data planes.

### 5.1. DetNet Data Plane of IP

For IPv6 based DetNet data plane, the data field of bounded latency information is recommended to be carried in IPv6 Extension Header Options, called Bounded Latency Information Option, shown in the following Figure.

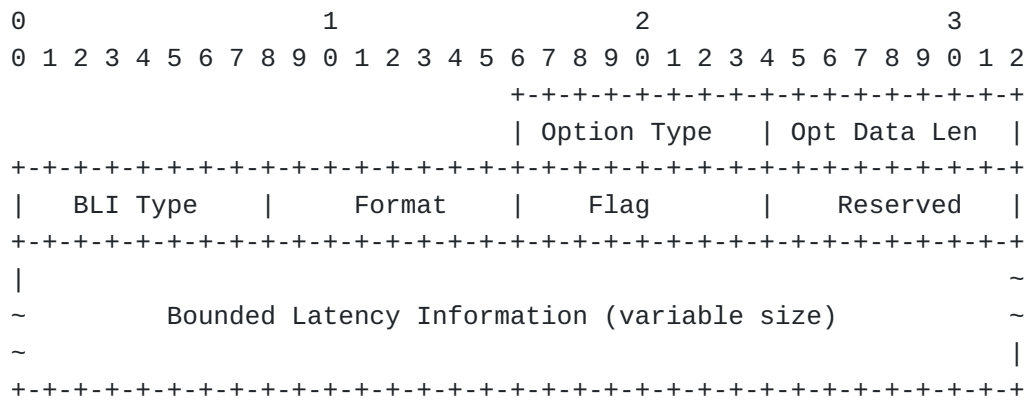


Figure 3: Bounded Latency Information Option

\*Option Type: 8-bit identifier of the type of option. Value TBD by IANA; the highest-order 3 bits of this field is 001 to skip over this option and continue processing the header if the processing IPv6 node does not recognize the Option Type and to permit the Option Data may change en route to the destination of packet.

\*Opt Data Len: 8-bit unsigned integer. Length of the Option Data field of this option, in octets.

\*For Bounded Latency Information data field, see section 4 for details.

Bounded latency information data field is encapsulated in either IPv6 Hop-by-Hop Options header or IPv6 Destination Options header depending on the processing happens at each hop or at the last hop. More than one bounded latency information can appear in one Bounded Latency Information Option. The Option Data Length and the Format are used to locate every bounded latency information. The

encapsulation of Bounded Latency Information Option is shown in Figure 4 and Figure 5.

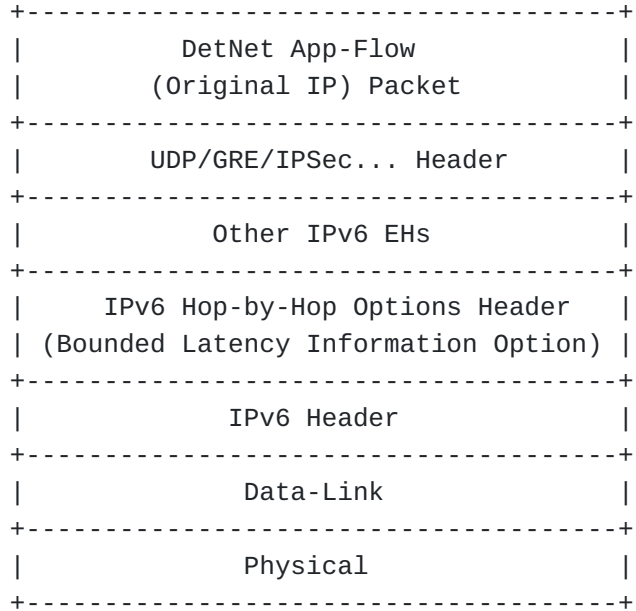


Figure 4: Encapsulation of BLI Option in IPv6 Hop-by-Hop Options Headers

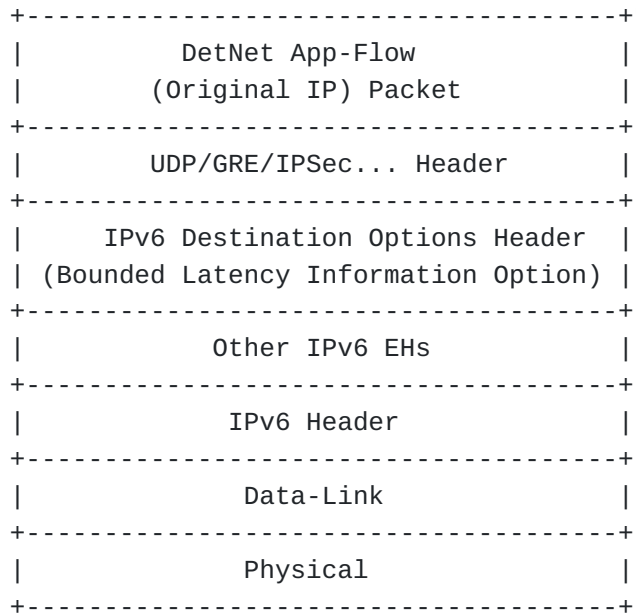


Figure 5: Encapsulation of BLI Option in IPv6 Destination Options Headers

## 5.2. DetNet Data Plane of MPLS

An MPLS extension header is proposed in [[I-D.song-mpls-extension-header](#)]. An MPLS Extension Header (EH)

encapsulated with the format of bounded latency information is called Bounded Latency Information Extension Header (BLIEH) and shown in Figure 6.

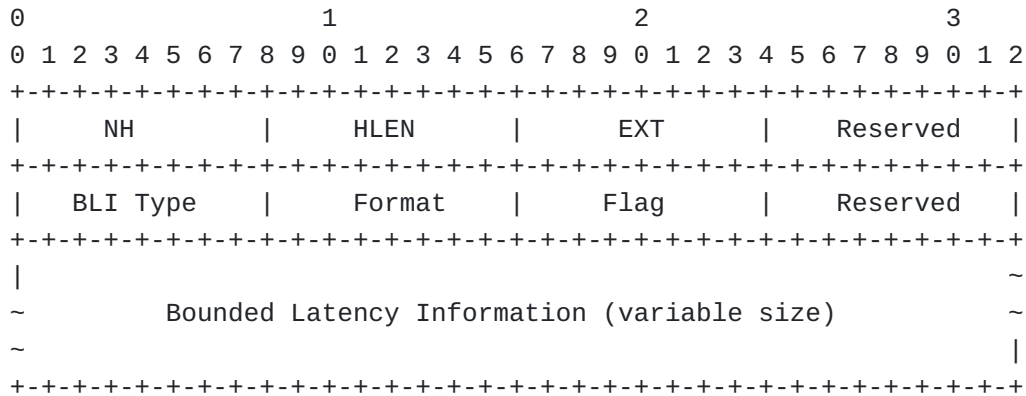


Figure 6: Bounded Latency Information Extension Header

\*NH: 8-bit indicator for the Next Header. This field identifies the type of the EH immediately following this EH.

\*HLEN: 8-bit unsigned integer for the Extension Header Length in 4-octet units, not including the first 4 octets.

\*EXT: 8-bit optional type extension.

The encapsulation of bounded latency information in MPLS extension headers with MPLS label stack is shown in the following figure. More than one BLI can be carried in one Bounded Latency Information Extension Header (BLIEH).

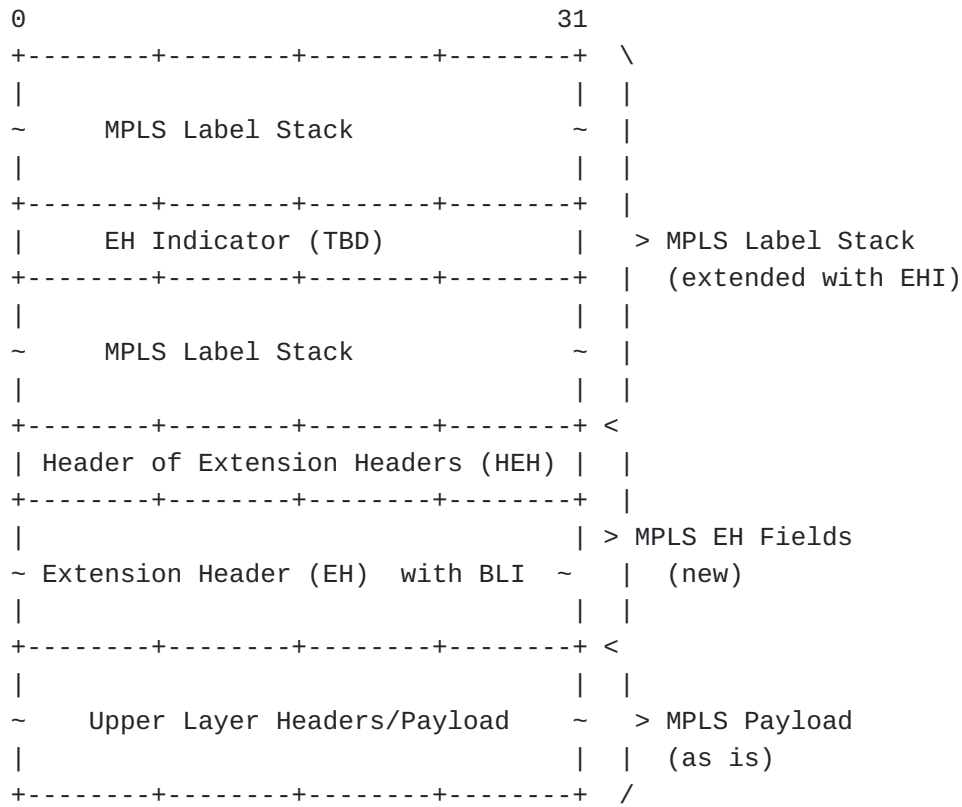


Figure 7: MPLS Encapsulation of Bounded Latency Information Extension Header

### 5.3. DetNet Data Plane of MPLS over UDP/IP

This document describes a DetNet IP encapsulation that includes the bounded latency information based on the DetNet MPLS over UDP/IP data plane [[RFC9025](#)], i.e., leveraging the MPLS-over-UDP technology. The bounded latency guarantee capable DetNet IP encapsulation builds on encapsulating DetNet PW over an IP/UDP tunnel [RFC7510]. It is noted that the format of MPLS Bounded Latency Extension Header (BLIEH) after UDP header is the same with the format of MPLS Bounded Latency Extension Header (BLIEH) defined in section 5.2, as well as without using any MPLS forwarding labels. The encapsulation of bounded latency information in DetNet Data Plane of MPLS over UDP/IP is shown in the following figure.

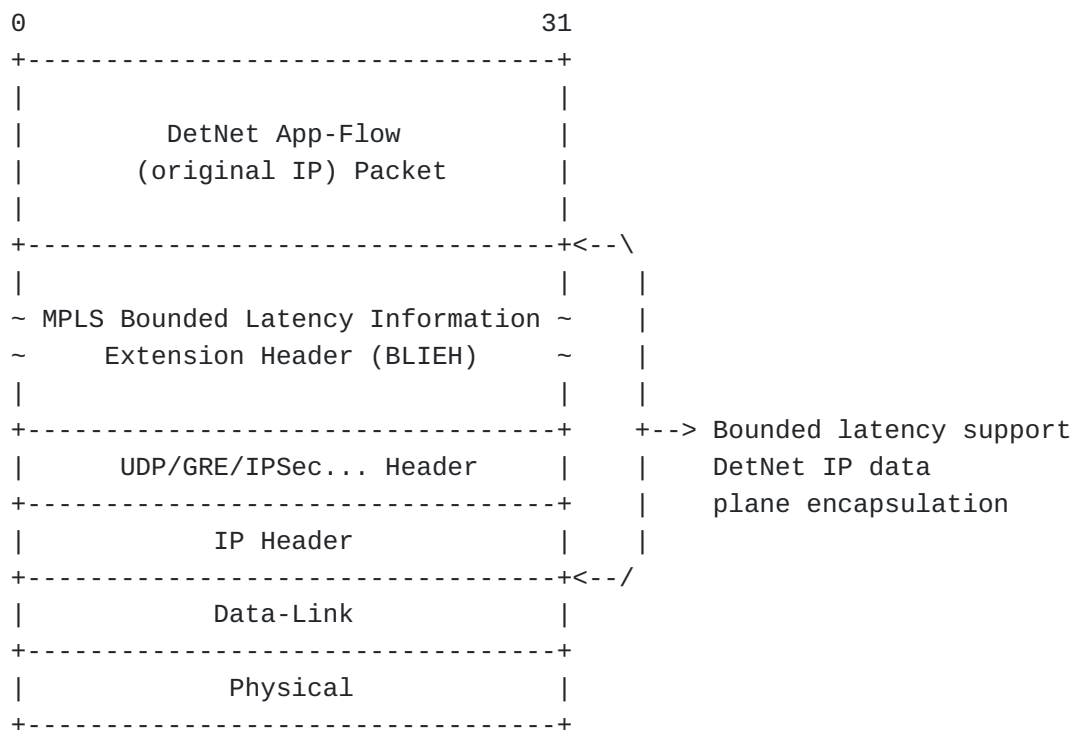


Figure 8: IPv6 extension option of bounded latency

## 6. IANA Considerations

### 6.1. New Destination Options and Hop-by-Hop Options

IANA is requested to allocate a value of "Destination Options and Hop-by-Hop Options" under "Internet Protocol Version 6 (IPv6) Parameters" registry. The suggested value is:

Hex	act	chg	rest	Description	Reference
TBD	00	1	TBD	BLI Option	This I-D

Bounded Latency Information Option

### 6.2. New Type of MPLS Extension Header

IANA is requested to allocate a 8-bit indicator for the Next Header to the Bounded Latency Extension Header.

### 6.3. New Subregistry of Bounded Latency Information Type

IANA is requested to define a new subregistry of "Bounded Latency Information Type" for the "Bounded Latency Information Option" under "Internet Protocol Version 6 (IPv6) Parameters" registry.

This new subregistry will include the following registries:

Suggested Value	Meaning	Reference
TBD	Reserved	This I-D
TBD	Time resource ID	This I-D
TBD	Priority	This I-D
TBD	End-to-end delay budget	This I-D
TBD	Local delay budget	This I-D
TBD	End-to-end deadline	This I-D
TBD	Local deadline	This I-D
TBD	End-to-end delay variation budget	This I-D
TBD	Local delay variation budget	This I-D

Bounded Latency Information Type

## 7. Security Considerations

TBD

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## Appendix A. BLI Examples

The following examples are provided to give instructions on how Bounded Latency Information is used when network node implements different algorithms to guarantee the bounded latency transmission.

### A.1. Cycle Based Algorithms

When network node implements cycle based algorithms for example [I-D.yizhou-detnet-ipv6-options-for-cqf-variant], cycles are the local resources used to guarantee the bounded latency transmission. Cycle ID is expected to be carried in data plane. Thus, the data field of BLI is suggested as follows:

```
+-----+-----+-----+-----+
| BLI Type (=1) | Format(=1) | Flag | Reserved |
+-----+-----+-----+-----+
|                               |
|                               |
|                               |
|                               |
|                               |
|                               |
|                               |
|                               |
|                               |
|                               |
+-----+-----+-----+-----+
```

Figure A.1: Data Field of BLI Used With Cycle Based Algorithms

## A.2. Time Slot Based Algorithms

When network node implements time slot based algorithms, time slots are the local resources used to guarantee the bounded latency transmission. Time Slot ID is expected to be carried in data plane. Thus, the data field of BLI is suggested as follows:

BLI Type (=1)	Format(=1)	Flag		Reserved	
Time Slot ID					

Figure A.2: Data Field of BLI Used With Time Slot Based Algorithms

## A.3. Budget Based Algorithms

When network node implements the budget based algorithms to provide bounded latency transmission, end to end or per hop delay budget or delay variation budget information is the requirement proposed from the services and expected to be carried in data plane. The data fields of BLI used with delay budget based algorithms are suggested as follows:

BLI Type(=3/4)	Format(=1)	Flag		Reserved	
E2E/Local Delay Budget					

Figure A.3: Data Field of BLI Used With Delay Budget Based Algorithms

The data fields of BLI used with delay variation budget based algorithms are suggested as follows:

BLI Type(=7/8)	Format(=2)	Flag		Reserved	
E2E/Local Delay Variation Budget					

Figure A.4: Data Field of BLI Used With Delay Variation Budget Based Algorithms

## A.4. Deadline Based Algorithms

When network node implements deadline based algorithms like EDF, Deadline forwarding [[I-D.peng-detnet-deadline-based-forwarding](#)] to provide bounded latency transmission, end to end or per hop packet

deadline is the requirement proposed from the services and expected to be carried in data plane. The data fields of BLI used with deadline based algorithms are suggested as follows:

BLI Type(=5/6)	Format(=5)	Flag	Reserved
E2E/Local Deadline			

Figure A.5: Data Field of BLI Used With Deadline Based Algorithms

### A.5. Priority Based Algorithms

When network node implements priority based algorithms, priority is the requirement proposed from the services. Priority ID is expected to be carried in data plane. The data field of BLI is suggested as follows:

BLI Type (=2)	Format(=3)	Flag	Reserved
Priority ID			

Figure A.6: Data Field of BLI Used With Priority Based Algorithms

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