IS-IS Traffic Engineering (TE) Metric Extensions

Abstract

   In certain networks, such as, but not limited to, financial
   information networks (e.g., stock market data providers), network-
   performance criteria (e.g., latency) are becoming as critical to
   data-path selection as other metrics.

   This document describes extensions to IS-IS Traffic Engineering
   Extensions (RFC 5305) such that network-performance information can
   be distributed and collected in a scalable fashion. The information
   distributed using IS-IS TE Metric Extensions can then be used to make
   path-selection decisions based on network performance.

   Note that this document only covers the mechanisms with which
   network-performance information is distributed. The mechanisms for
   measuring network performance or acting on that information, once
   distributed, are outside the scope of this document.

Status of This Memo

   This is an Internet Standards Track document.

   This document is a product of the Internet Engineering Task Force
   (IETF). It represents the consensus of the IETF community. It has
   received public review and has been approved for publication by the
   Internet Engineering Steering Group (IESG). Further information on
   Internet Standards is available in Section 2 of RFC 5741.

   Information about the current status of this document, any errata,
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1. Introduction

   In certain networks, such as, but not limited to, financial
   information networks (e.g., stock market data providers), network-
   performance information (e.g., latency) is becoming as critical to
   data-path selection as other metrics.

   In these networks, extremely large amounts of money rest on the
   ability to access market data in "real time" and to predictably make
   trades faster than the competition. Because of this, using metrics
   such as hop count or cost as routing metrics is becoming only
   tangentially important. Rather, it would be beneficial to be able to
   make path-selection decisions based on performance data (such as
   latency) in a cost-effective and scalable way.

   This document describes extensions (hereafter called "IS-IS TE Metric
   Extensions") to the IS-IS Extended Reachability TLV defined in
   [RFC5305], that can be used to distribute network-performance
   information (such as link delay, delay variation, packet loss,
   residual bandwidth, and available bandwidth).

   The data distributed by the IS-IS TE Metric Extensions proposed in
   this document is meant to be used as part of the operation of the
   routing protocol (e.g., by replacing cost with latency or considering
   bandwidth as well as cost), to enhance Constrained-SPF (CSPF), or for
   other uses such as supplementing the data used by an ALTO server
   [RFC7285]. With respect to CSPF, the data distributed by IS-IS TE
   Metric Extensions can be used to set up, fail over, and fail back
   data paths using protocols such as RSVP-TE [RFC3209].

   Note that the mechanisms described in this document only disseminate
   performance information. The methods for initially gathering that
   performance information, such as described in [RFC6375], or acting on
   it once it is distributed are outside the scope of this document.
   Example mechanisms to measure latency, delay variation, and loss in
   an MPLS network are given in [RFC6374]. While this document does not
   specify how the performance information should be obtained, the
   measurement of delay SHOULD NOT vary significantly based upon the
   offered traffic load. Thus, queuing delays SHOULD NOT be included in
   the delay measurement. For links such as Forwarding Adjacencies,
   care must be taken that measurement of the associated delay avoids
   significant queuing delay; that could be accomplished in a variety of
   ways, including either by measuring with a traffic class that
   experiences minimal queuing or by summing the measured link delays of
   the components of the link's path.

1.1. Conventions Used in This Document

   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].

   In this document, these words will appear with that interpretation
   only when in ALL CAPS. Lowercase uses of these words are not to be
   interpreted as carrying the significance described in RFC 2119.

2. TE Metric Extensions to IS-IS

   This document registers new IS-IS TE sub-TLVs that can be announced
   in the "Sub-TLVs for TLVs 22, 23, 141, 222, and 223" registry in
   order to distribute network-performance information. The extensions
   in this document build on the ones provided in IS-IS TE [RFC5305] and
   GMPLS [RFC4203].

   IS-IS Extended Reachability TLV 22 (defined in [RFC5305]), Inter-AS
   Reachability Information TLV 141 (defined in [RFC5316]), and MT-ISIS
   TLV 222 (defined in [RFC5120]) have nested sub-TLVs that permit the
   TLVs to be readily extended. This document registers several sub-
   TLVs:

   Type   Description
   ----
    33   Unidirectional Link Delay

    34   Min/Max Unidirectional Link Delay

    35   Unidirectional Delay Variation

    36   Unidirectional Link Loss

    37   Unidirectional Residual Bandwidth

    38   Unidirectional Available Bandwidth

    39   Unidirectional Utilized Bandwidth

   As can be seen in the list above, the sub-TLVs described in this
   document carry different types of network-performance information.
   The new sub-TLVs include a bit called the Anomalous (or "A") bit.
   When the A bit is clear (or when the sub-TLV does not include an A
   bit), the sub-TLV describes steady-state link performance. This
   information could conceivably be used to construct a steady-state
   performance topology for initial tunnel-path computation, or to
   verify alternative failover paths.

When network performance violates configurable link-local thresholds,
a sub-TLV with the A bit set is advertised. These sub-TLVs could be
used by the receiving node to determine whether to fail traffic to a
backup path or whether to calculate an entirely new path. From an
MPLS perspective, the intent of the A bit is to permit label switched
path ingress nodes to determine whether the link referenced in the
sub-TLV affects any of the label switched paths for which it is
ingress. If they are affected, then they can determine whether those
label switched paths still meet end-to-end performance objectives.
If not, then the node could conceivably move affected traffic to a
pre-established protection label switched path or establish a new
label switched path and place the traffic in it.

If link performance then improves beyond a configurable minimum value
(reuse threshold), that sub-TLV can be re-advertised with the A bit
cleared. In this case, a receiving node can conceivably do whatever
re-optimization (or failback) it wishes to do (including nothing).

Note that when a sub-TLV does not include the A bit, that sub-TLV
cannot be used for failover purposes. The A bit was intentionally
omitted from some sub-TLVs to help mitigate oscillations. See
Section 5 for more information.

Consistent with existing IS-IS TE specification [RFC5305], the
bandwidth advertisements defined in this document MUST be encoded as
IEEE floating-point values. The delay and delay-variation
advertisements defined in this document MUST be encoded as integer
values. Delay values MUST be quantified in units of microseconds,
packet loss MUST be quantified as a percentage of packets sent, and
bandwidth MUST be sent as bytes per second. All values (except
residual bandwidth) MUST be calculated as rolling averages where the
averaging period MUST be a configurable period of time. See
Section 5 for more information.

3. Interface and Neighbor Addresses

   The use of IS-IS TE Metric Extensions sub-TLVs is not confined to the
   TE context. In other words, IS-IS TE Metric Extensions sub-TLVs
   defined in this document can also be used for computing paths in the
   absence of a TE subsystem.

   However, as for the TE case, Interface Address and Neighbor Address
   sub-TLVs (IPv4 or IPv6) MUST be present. The encoding is defined in
   [RFC5305] for IPv4 and in [RFC6119] for IPv6.

4. Sub-TLV Details

4.1. Unidirectional Link Delay Sub-TLV

   This sub-TLV advertises the average link delay between two directly
   connected IS-IS neighbors. The delay advertised by this sub-TLV MUST
   be the delay from the local neighbor to the remote one (i.e., the
   forward-path 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      |    Length     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |A|  RESERVED   |                    Delay                      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

                              Figure 1

   where:

   Type: 33

   Length: 4

   A bit: The A bit represents the Anomalous (A) bit. The A bit is set
   when the measured value of this parameter exceeds its configured
   maximum threshold. The A bit is cleared when the measured value
   falls below its configured reuse threshold. If the A bit is clear,
   the sub-TLV represents steady-state link performance.

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

   Delay: This 24-bit field carries the average link delay over a
   configurable interval in microseconds, encoded as an integer value.
   When set to the maximum value 16,777,215 (16.777215 sec), then the
   delay is at least that value and may be larger.

4.2. Min/Max Unidirectional Link Delay Sub-TLV

   This sub-TLV advertises the minimum and maximum delay values between
   two directly connected IS-IS neighbors. The delay advertised by this
   sub-TLV MUST be the delay from the local neighbor to the remote one
   (i.e., the forward-path latency). The format of this sub-TLV is
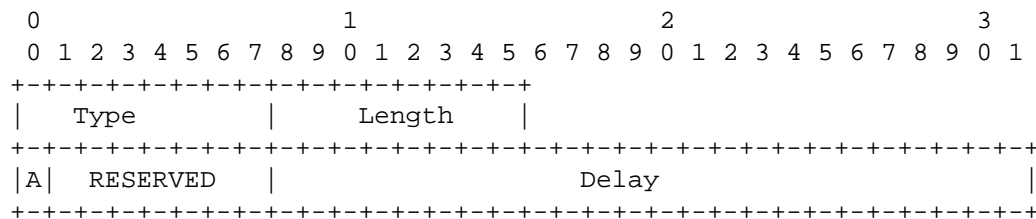   shown in the following diagram:

```
    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       |    Length     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |A|  RESERVED   |                   Min Delay                   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |    RESERVED   |                   Max Delay                   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

                            Figure 2

   where:

   Type: 34

   Length: 8

   A bit: This field represents the Anomalous (A) bit. The A bit is set
   when one or more measured values exceed a configured maximum
   threshold. The A bit is cleared when the measured value falls below
   its configured reuse threshold. If the A bit is clear, the sub-TLV
   represents steady-state link performance.

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

   Min Delay: This 24-bit field carries the minimum measured link delay
   value (in microseconds) over a configurable interval, encoded as an
   integer value.

   Max Delay: This 24-bit field carries the maximum measured link delay
   value (in microseconds) over a configurable interval, encoded as an
   integer value.

   Implementations MAY also permit the configuration of an offset value
   (in microseconds) to be added to the measured delay value, to
   facilitate the communication of operator-specific delay constraints.

   It is possible for the Min and Max delay to be the same value.

When the delay value (Min or Max) is set to the maximum value
16,777,215 (16.777215 sec), then the delay is at least that value and
may be larger.

4.3. Unidirectional Delay Variation Sub-TLV

   This sub-TLV advertises the average link delay variation between two
   directly connected IS-IS neighbors. The delay variation advertised
   by this sub-TLV MUST be the delay from the local neighbor to the
   remote one (i.e., the forward-path latency). The format of this sub-
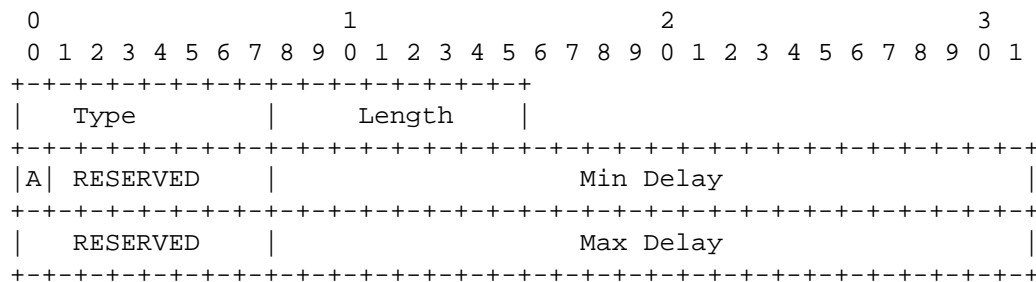   TLV is shown in the following diagram:

```
 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       |    Length     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   RESERVED    |             Delay Variation                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

                              Figure 3

   where

   Type: 35

   Length: 4

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

   Delay Variation: This 24-bit field carries the average link delay
   variation over a configurable interval in microseconds, encoded as an
   integer value. When set to 0, it has not been measured. When set to
   the maximum value 16,777,215 (16.777215 sec), then the delay is at
   least that value and may be larger.

4.4. Unidirectional Link Loss Sub-TLV

   This sub-TLV advertises the loss (as a packet percentage) between two
   directly connected IS-IS neighbors. The link loss advertised by this
   sub-TLV MUST be the packet loss from the local neighbor to the remote
   one (i.e., the forward-path loss). The format of this sub-TLV is
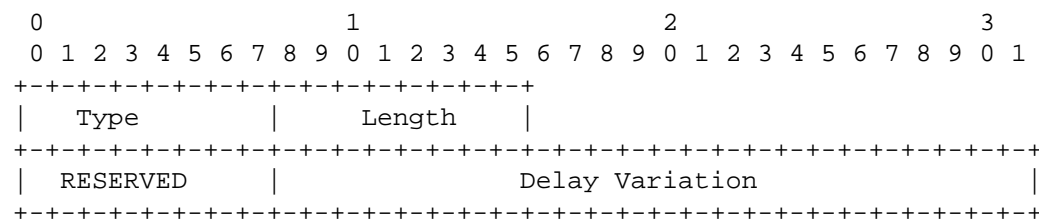   shown in the following diagram:

```
    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         |     Length      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |A|   RESERVED    |                 Link Loss                   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

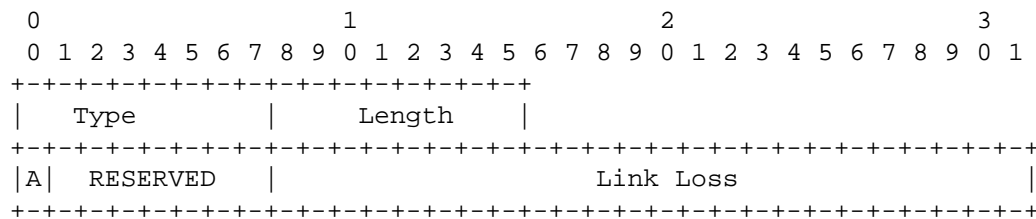   Figure 4
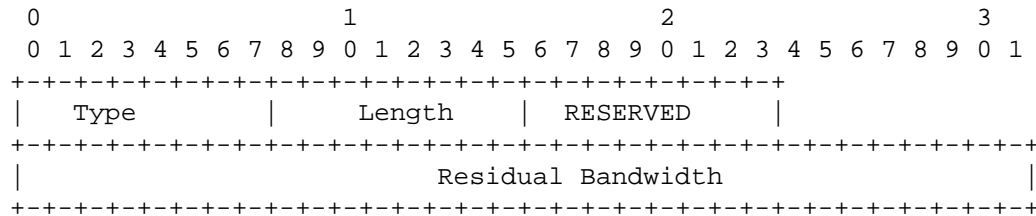
   where:

   Type: 36

   Length: 4

   A bit: The A bit represents the Anomalous (A) bit. The A bit is set
   when the measured value of this parameter exceeds its configured
   maximum threshold. The A bit is cleared when the measured value
   falls below its configured reuse threshold. If the A bit is clear,
   the sub-TLV represents steady-state link performance.

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

   Link Loss: This 24-bit field carries link packet loss as a percentage
   of the total traffic sent over a configurable interval. The basic
   unit is 0.000003%, where $(2^{24} - 2)$ is 50.331642%. This value is the
   highest packet-loss percentage that can be expressed (the assumption
   being that precision is more important on high-speed links than the
   ability to advertise loss rates greater than this, and that high-
   speed links with over 50% loss are unusable). Therefore, measured
   values that are larger than the field maximum SHOULD be encoded as
   the maximum value.

4.5. Unidirectional Residual Bandwidth Sub-TLV

   This sub-TLV advertises the residual bandwidth between two directly
   connected IS-IS neighbors. The residual bandwidth advertised by this
   sub-TLV MUST be the residual bandwidth from the system originating
   the Link State Advertisement (LSA) to its neighbor.

```
    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      |     Length    |    RESERVED      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                     Residual Bandwidth                        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   where:

   Type: 37

   Length: 4

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

   Residual Bandwidth: This field carries the residual bandwidth on a
   link, forwarding adjacency [RFC4206], or bundled link in IEEE
   floating-point format with units of bytes per second. For a link or
   forwarding adjacency, residual bandwidth is defined to be the Maximum
   Bandwidth [RFC5305] minus the bandwidth currently allocated to RSVP-
   TE label switched paths. For a bundled link, residual bandwidth is
   defined to be the sum of the component link residual bandwidths.

   The calculation of residual bandwidth is different than that of
   unreserved bandwidth [RFC5305]. Residual bandwidth subtracts tunnel
   reservations from maximum bandwidth (i.e., the link capacity)
   [RFC5305] and provides an aggregated remainder across priorities.
   Unreserved bandwidth, on the other hand, is subtracted from the
   maximum reservable bandwidth (the bandwidth that can theoretically be
   reserved) and provides per-priority remainders. Residual bandwidth
   and unreserved bandwidth [RFC5305] can be used concurrently and each
   has a separate use case (e.g., the former can be used for
   applications like Weighted ECMP while the latter can be used for call
   admission control).

4.6. Unidirectional Available Bandwidth Sub-TLV

   This sub-TLV advertises the available bandwidth between two directly
   connected IS-IS neighbors. The available bandwidth advertised by
   this sub-TLV MUST be the available bandwidth from the system
   originating this sub-TLV. 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      |     Length    |    RESERVED      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Available Bandwidth                         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

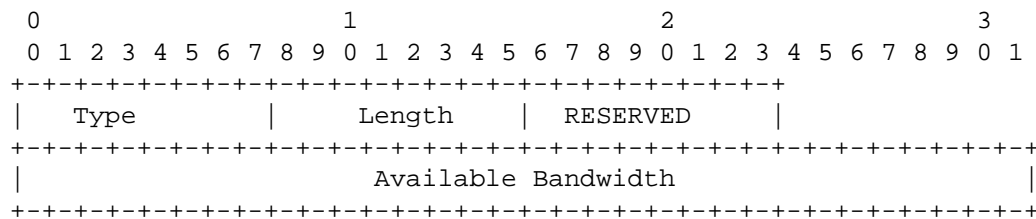   Figure 5

   where:

   Type: 38

   Length: 4

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

   Available Bandwidth: This field carries the available bandwidth on a
   link, forwarding adjacency, or bundled link in IEEE floating-point
   format with units of bytes per second. For a link or forwarding
   adjacency, available bandwidth is defined to be residual bandwidth
   (see Section 4.5) minus the measured bandwidth used for the actual
   forwarding of non-RSVP-TE label switched path packets. For a bundled
   link, available bandwidth is defined to be the sum of the component
   link available bandwidths minus the measured bandwidth used for the
   actual forwarding of non-RSVP-TE label switched path packets. For a
   bundled link, available bandwidth is defined to be the sum of the
   component link available bandwidths.

4.7. Unidirectional Utilized Bandwidth Sub-TLV

   This sub-TLV advertises the bandwidth utilization between two
   directly connected IS-IS neighbors. The bandwidth utilization
   advertised by this sub-TLV MUST be the bandwidth from the system
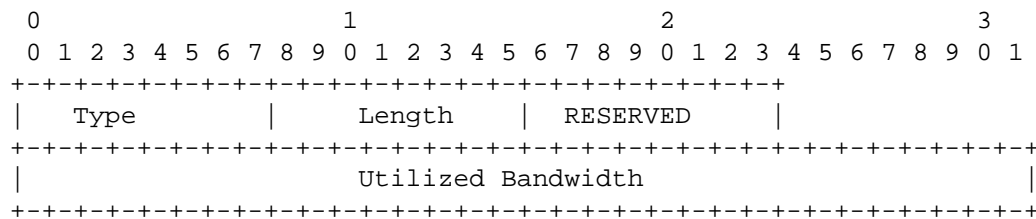   originating this sub-TLV. The format of this sub-TLV is shown in the
   following diagram:

```
 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       |    Length     |   RESERVED     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Utilized Bandwidth                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

                              Figure 6

   where:

   Type: 39

   Length: 4

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

   Utilized Bandwidth: This field carries the bandwidth utilization on a
   link, forwarding adjacency, or bundled link in IEEE floating-point
   format with units of bytes per second. For a link or forwarding
   adjacency, bandwidth utilization represents the actual utilization of
   the link (i.e., as measured by the advertising node). For a bundled
   link, bandwidth utilization is defined to be the sum of the component
   link bandwidth utilizations.

5. Announcement Thresholds and Filters

   The values advertised in all sub-TLVs (except min/max delay and
   residual bandwidth) MUST represent an average over a period or be
   obtained by a filter that is reasonably representative of an average.
   For example, a rolling average is one such filter.

   Min and max delay MUST each be derived in one of the following ways:
   by taking the lowest and/or highest measured value over a measurement
   interval or by making use of a filter or other technique to obtain a
   reasonable representation of a min and max value representative of
   the interval, with compensation for outliers.

The measurement interval, any filter coefficients, and any
advertisement intervals MUST be configurable per sub-TLV.

In addition to the measurement intervals governing re-advertisement,
implementations SHOULD provide configurable accelerated advertisement
thresholds per sub-TLV, such that:

1. If the measured parameter falls outside a configured upper bound
    for all but the minimum delay metric (or lower bound for minimum
    delay metric only) and the advertised sub-TLV is not already
    outside that bound or,

2. If the difference between the last advertised value and current
    measured value exceeds a configured threshold then,

3. The advertisement is made immediately.

4. For sub-TLVs that include an A bit, an additional threshold
    SHOULD be included corresponding to the threshold for which the
    performance is considered anomalous (and sub-TLVs with the A bit
    are sent). The A bit is cleared when the sub-TLV's performance
    has been below (or re-crosses) this threshold for an
    advertisement interval(s) to permit fail back.

To prevent oscillations, only the high threshold or the low threshold
(but not both) may be used to trigger any given sub-TLV that supports
both.

Additionally, once outside the bounds of the threshold, any
re-advertisement of a measurement within the bounds would remain
governed solely by the measurement interval for that sub-TLV.

6. Announcement Suppression

When link-performance values change by small amounts that fall under
thresholds that would cause the announcement of a sub-TLV,
implementations SHOULD suppress sub-TLV re-advertisement and/or
lengthen the period within which they are refreshed.

Only the accelerated advertisement threshold mechanism described in
Section 5 may shorten the re-advertisement interval. All suppression
and re-advertisement interval backoff timer features SHOULD be
configurable.

7. Network Stability and Announcement Periodicity

   Sections 5 and 6 provide configurable mechanisms to bound the number
   of re-advertisements. Instability might occur in very large networks
   if measurement intervals are set low enough to overwhelm the
   processing of flooded information at some of the routers in the
   topology. Therefore, care should be taken in setting these values.

   Additionally, the default measurement interval for all sub-TLVs
   SHOULD be 30 seconds.

   Announcements MUST also be able to be throttled using configurable
   inter-update throttle timers. The minimum announcement periodicity
   is 1 announcement per second. The default value SHOULD be set to 120
   seconds.

   Implementations SHOULD NOT permit the inter-update timer to be lower
   than the measurement interval.

   Furthermore, it is RECOMMENDED that any underlying performance-
   measurement mechanisms not include any significant buffer delay, any
   significant buffer-induced delay variation, or any significant loss
   due to buffer overflow or due to active queue management.

8. Enabling and Disabling Sub-TLVs

   Implementations MUST make it possible to individually enable or
   disable each sub-TLV based on configuration.

9. Static Metric Override

   Implementations SHOULD permit static configuration and/or manual
   override of dynamic measurements for each sub-TLV in order to
   simplify migration and to mitigate scenarios where dynamic
   measurements are not possible.

10. Compatibility

   As per [RFC5305], unrecognized sub-TLVs should be silently ignored.

11. Security Considerations

   The sub-TLVs introduced in this document allow an operator to
   advertise state information of links (bandwidth, delay) that could be
   sensitive and that an operator may not want to disclose.

   Section 7 describes a mechanism to ensure network stability when the
   new sub-TLVs defined in this document are advertised. Implementation
   SHOULD follow the described guidelines to mitigate the instability
   risk.

   [RFC5304] describes an authentication method for IS-IS Link State
   PDUs that allows cryptographic authentication of IS-IS Link State
   PDUs.

   It is anticipated that in most deployments, the IS-IS protocol is
   used within an infrastructure entirely under control of the same
   operator. However, it is worth considering that the effect of
   sending IS-IS Traffic Engineering sub-TLVs over insecure links could
   result in a man-in-the-middle attacker delaying real-time data to a
   given site or destination, which could negatively affect the value of
   the data for that site or destination. The use of Link State PDU
   cryptographic authentication allows mitigation the risk of man-in-
   the-middle attack.

12. IANA Considerations

   IANA maintains the registry for the sub-TLVs. IANA has registered
   the following sub-TLVs in the "Sub-TLVs for TLVs 22, 23, 141, 222,
   and 223" registry:

   Type   Description
   ----
    33   Unidirectional Link Delay

    34   Min/Max Unidirectional Link Delay

    35   Unidirectional Delay Variation

    36   Unidirectional Link Loss

    37   Unidirectional Residual Bandwidth

    38   Unidirectional Available Bandwidth

    39   Unidirectional Utilized Bandwidth

13. References

13.1. Normative References

   [RFC2119]   Bradner, S., "Key words for use in RFCs to Indicate
               Requirement Levels", BCP 14, RFC 2119,
               DOI 10.17487/RFC2119, March 1997,
               <http://www.rfc-editor.org/info/rfc2119>.

   [RFC4206]   Kompella, K. and Y. Rekhter, "Label Switched Paths (LSP)
               Hierarchy with Generalized Multi-Protocol Label Switching
               (GMPLS) Traffic Engineering (TE)", RFC 4206,
               DOI 10.17487/RFC4206, October 2005,
               <http://www.rfc-editor.org/info/rfc4206>.

   [RFC5120]   Przygienda, T., Shen, N., and N. Sheth, "M-ISIS: Multi
               Topology (MT) Routing in Intermediate System to
               Intermediate Systems (IS-ISs)", RFC 5120,
               DOI 10.17487/RFC5120, February 2008,
               <http://www.rfc-editor.org/info/rfc5120>.

   [RFC5304]   Li, T. and R. Atkinson, "IS-IS Cryptographic
               Authentication", RFC 5304, DOI 10.17487/RFC5304, October
               2008, <http://www.rfc-editor.org/info/rfc5304>.

   [RFC5305]   Li, T. and H. Smit, "IS-IS Extensions for Traffic
               Engineering", RFC 5305, DOI 10.17487/RFC5305, October
               2008, <http://www.rfc-editor.org/info/rfc5305>.

   [RFC5316]   Chen, M., Zhang, R., and X. Duan, "ISIS Extensions in
               Support of Inter-Autonomous System (AS) MPLS and GMPLS
               Traffic Engineering", RFC 5316, DOI 10.17487/RFC5316,
               December 2008, <http://www.rfc-editor.org/info/rfc5316>.

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