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Label Switched Path (LSP) Data Path Delay Metrics in Generalized MPLS and MPLS Traffic Engineering (MPLS-TE) Networks

Abstract

When setting up a Label Switched Path (LSP) in Generalized MPLS (GMPLS) and MPLS Traffic Engineering (MPLS-TE) networks, the completion of the signaling process does not necessarily mean that the cross-connection along the LSP has been programmed accordingly and in a timely manner. Meanwhile, the completion of the signaling process may be used by LSP users or applications that control their use as an indication that the data path has become usable. The existence of the inconsistency between the signaling messages and cross-connection programming, and the possible failure of cross-connection programming, if not properly treated, will result in data loss or even application failure. Characterization of this performance can thus help designers to improve the way in which LSPs are used and to make applications or tools that depend on and use LSPs more robust. This document defines a series of performance metrics to evaluate the connectivity of the data path in the signaling process.

Status of This Memo

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1. Introduction

Label Switched Paths (LSPs) are established, controlled, and allocated for use by management tools or directly by the components that use them. In this document, we call such management tools and the components that use LSPs "applications". Such applications may be Network Management Systems (NMSs); hardware or software components that forward data onto virtual links; programs or tools that use dedicated links; or any other user of an LSP.

Ideally, the completion of the signaling process means that the signaled LSP is ready to carry traffic. However, in actual implementations, vendors may choose to program the cross-connection in a pipelined manner, so that the overall LSP provisioning delay can be reduced. In such situations, the data path may not be ready for use instantly after the signaling process completes. Implementation deficiency may also cause inconsistency between the signaling process and data path provisioning. For example, if the data plane fails to program the cross-connection accordingly but does not manage to report this to the control plane, the signaling process may complete successfully while the corresponding data path will never become functional at all.

On the other hand, the completion of the signaling process may be used in many cases as an indication of data path connectivity. For example, when invoking through the User-Network Interface (UNI) [RFC4208], a client device or an application may use the reception of the correct Resv message as an indication that the data path is fully functional and start to transmit traffic. This will result in data loss or even application failure.

Although RSVP(-TE) specifications have suggested that the cross-connections are programmed before signaling messages are propagated upstream, it is still worthwhile to verify the conformance of an implementation and measure the delay, when necessary.

This document defines a series of performance metrics to evaluate the connectivity of the data path during the signaling process. The metrics defined in this document complement the control plane metrics defined in [RFC5814]. These metrics can be used to verify the conformance of implementations against related specifications, as elaborated in [RFC6383]. They also can be used to build more robust applications.

2. 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 [RFC2119].

3. Overview of Performance Metrics

In this memo, we define five performance metrics to characterize the performance of data path provisioning with GMPLS/MPLS-TE signaling. These metrics complement the metrics defined in [RFC5814], in the sense that the completion of the signaling process for an LSP and the programming of cross-connections along the LSP may not be consistent. The performance metrics in [RFC5814] characterize the performance of LSP provisioning from the pure signaling point of view, while the metric in this document takes into account the validity of the data path.

The five metrics are:

- Resv Received, Forward Data (RRFD) - the delay between the point when the Resv message is received by the ingress node and the forward data path becomes ready for use.

- Resv Sent, Reverse Data (RSRD) - the delay between the point when the Resv message is sent by the egress node and the reverse data path becomes ready for use.

- PATH Received, Forward Data (PRFD) - the delay between the point when the PATH message is received by the egress node and the forward data path becomes ready for use.

- PATH Sent, Forward Data (PSFD) - the delay between the point when the PATH message is sent by the ingress node and the forward data path becomes ready for use.

- PATH Sent, Reverse Data (PSRD) - the delay between the point when the PATH message is sent by the ingress node and the reverse data path becomes ready for use.

As in [RFC5814], we continue to use the structures and notions introduced and discussed in the IP Performance Metrics (IPPM) Framework documents [RFC2330] [RFC2679] [RFC2681]. The reader is assumed to be familiar with the notions in those documents. The reader is also assumed to be familiar with the definitions in [RFC5814].

4. Terms Used in This Document

- Forward data path - the data path from the ingress node to the egress node. Instances of a forward data path include the data path of a unidirectional LSP and a data path from the ingress node to the egress node in a bidirectional LSP.

- Reverse data path - the data path from the egress node to the ingress node in a bidirectional LSP.

- Data path delay - the time needed to complete the data path configuration, in relation to the signaling process. Five types of data path delay are defined in this document, namely RRFD, RSRD, PRFD, PSFD, and PSRD. Data path delay as used in this document must be distinguished from the transmission delay along the data path, i.e., the time needed to transmit traffic from one side of the data path to the other.

- Error-free signal - data-plane-specific indication of connectivity of the data path. For example, for interfaces capable of packet switching, the reception of the first error-free packet from one side of the LSP to the other may be used as the error-free signal. For Synchronous Digital Hierarchy/Synchronous Optical Network (SDH/SONET) cross-connects, the disappearance of alarm can be used as the error-free signal. Throughout this document, we will use "error-free signal" as a general term. An implementation must choose a proper data path signal that is specific to the data path technology being tested.

- Ingress/egress node - in this memo, an ingress/egress node means a measurement endpoint with both control plane and data plane features. Typically, the control plane part on an ingress/egress node interacts with the control plane of the network under test. The data plane part of an ingress/egress node will generate data path signals and send the signal to the data plane of the network under test, or receive data path signals from the network under test.

5. A Singleton Definition for RRFD

This part defines a metric for forward data path delay when an LSP is set up.

As described in [RFC6383], the completion of the RSVP-TE signaling process does not necessarily mean that the cross-connections along the LSP being set up are in place and ready to carry traffic. This metric defines the time difference between the reception of a Resv message by the ingress node and the completion of the cross-connection programming along the forward data path.

5.1. Motivation

RRFD is useful for the following reasons:

- o For the reasons described in [RFC6383], the data path may not be ready for use instantly after the completion of the RSVP-TE signaling process. The delay itself is part of the implementation performance.

- o The completion of the signaling process may be used by application designers as an indication of data path connectivity. The existence of this delay and the potential failure of cross-connection programming, if not properly treated, will result in data loss or application failure. The typical value of this delay can thus help designers to improve the application model.

5.2. Metric Name

RRFD = Resv Received, Forward Data path

5.3. Metric Parameters

- o ID0, the ingress Label Switching Router (LSR) ID

- o ID1, the egress LSR ID

- o T, a time when the setup is attempted

5.4. Metric Units

The value of RRFD is either a real number of milliseconds or undefined.

5.5. Definition

For a real number dT,

RRFD from ingress node ID0 to egress node ID1 at T is dT

means that

- o ingress node ID0 sends a PATH message to egress node ID1,
- o the last bit of the corresponding Resv message is received by ingress node ID0 at T, and
- o an error-free signal is received by egress node ID1 by using a data-plane-specific test pattern at T+dT.

5.6. Discussion

The following issues are likely to come up in practice:

- o The accuracy of RRFD depends on the clock resolution of both the ingress node and egress node. Clock synchronization between the ingress node and egress node is required.
- o The accuracy of RRFD is also dependent on how the error-free signal is received and may differ significantly when the underlying data plane technology is different. For instance, for an LSP between a pair of Ethernet interfaces, the ingress node may use a rate-based method to verify the connectivity of the data path and use the reception of the first error-free frame as the error-free signal. In this case, the interval between two successive frames has a significant impact on accuracy. It is RECOMMENDED that the ingress node use small intervals, under the condition that the injected traffic does not exceed the capacity of the forward data path. The value of such intervals MUST be reported.
- o The accuracy of RRFD is also dependent on the time needed to propagate the error-free signal from the ingress node to the egress node. A typical value for propagating the error-free signal from the ingress node to the egress node under the same measurement setup MAY be reported. The methodology to obtain such values is outside the scope of this document.
- o The accuracy of this metric is also dependent on the physical-layer serialization/deserialization of the test signal for certain data path technologies. For instance, for an LSP between a pair

of low-speed Ethernet interfaces, the time needed to serialize/ deserialize a large frame may not be negligible. In this case, it is RECOMMENDED that the ingress node use small frames. The average length of the frame MAY be reported.

- It is possible that under some implementations, a node may program the cross-connection before it sends a PATH message further downstream, and the data path may be ready for use before a Resv message reaches the ingress node. In such cases, RRFD can be a negative value. It is RECOMMENDED that a PRFD measurement be carried out to further characterize the forward data path delay when a negative RRFD value is observed.

- If an error-free signal is received by the egress node before a PATH message is sent on the ingress node, an error MUST be reported and the measurement SHOULD terminate.

- If the corresponding Resv message is received but no error-free signal is received by the egress node within a reasonable period of time, i.e., a threshold, RRFD MUST be treated as undefined. The value of the threshold MUST be reported.

- If the LSP setup fails, this metric value MUST NOT be counted.

5.7. Methodologies

Generally, the methodology would proceed as follows:

- Make sure that the network has enough resources to set up the requested LSP.

- Start the data path measurement and/or monitoring procedures on the ingress node and egress node. If an error-free signal is received by the egress node before a PATH message is sent, report an error and terminate the measurement.

- At the ingress node, form the PATH message according to the LSP requirements and send the message towards the egress node.

- Upon receiving the last bit of the corresponding Resv message, take the timestamp (T1) on the ingress node as soon as possible.

- When an error-free signal is observed on the egress node, take the timestamp (T2) as soon as possible. An estimate of RRFD (T2 - T1) can be computed.

- o If the corresponding Resv message arrives but no error-free signal is received within a reasonable period of time by the ingress node, RRFD is deemed to be undefined.

- o If the LSP setup fails, RRFD is not counted.

6. A Singleton Definition for RSRD

This part defines a metric for reverse data path delay when an LSP is set up.

As described in [RFC6383], the completion of the RSVP-TE signaling process does not necessarily mean that the cross-connections along the LSP being set up are in place and ready to carry traffic. This metric defines the time difference between the completion of the signaling process and the completion of the cross-connection programming along the reverse data path. This metric MAY be used together with RRFD to characterize the data path delay of a bidirectional LSP.

6.1. Motivation

RSRD is useful for the following reasons:

- o For the reasons described in [RFC6383], the data path may not be ready for use instantly after the completion of the RSVP-TE signaling process. The delay itself is part of the implementation performance.

- o The completion of the signaling process may be used by application designers as an indication of data path connectivity. The existence of this delay and the possible failure of cross-connection programming, if not properly treated, will result in data loss or application failure. The typical value of this delay can thus help designers to improve the application model.

6.2. Metric Name

RSRD = Resv Sent, Reverse Data path

6.3. Metric Parameters

- o ID0, the ingress LSR ID

- o ID1, the egress LSR ID

- o T, a time when the setup is attempted

6.4. Metric Units

The value of RSRD is either a real number of milliseconds or undefined.

6.5. Definition

For a real number dT,

RSRD from ingress node ID0 to egress node ID1 at T is dT

means that

- ingress node ID0 sends a PATH message to egress node ID1,
- the last bit of the corresponding Resv message is sent by egress node ID1 at T, and
- an error-free signal is received by the ingress node ID0 using a data-plane-specific test pattern at T+dT.

6.6. Discussion

The following issues are likely to come up in practice:

- The accuracy of RSRD depends on the clock resolution of both the ingress node and egress node. Clock synchronization between the ingress node and egress node is required.
- The accuracy of RSRD is also dependent on how the error-free signal is received and may differ significantly when the underlying data plane technology is different. For instance, for an LSP between a pair of Ethernet interfaces, the egress node (sometimes the tester) may use a rate-based method to verify the connectivity of the data path and use the reception of the first error-free frame as the error-free signal. In this case, the interval between two successive frames has a significant impact on accuracy. It is RECOMMENDED in this case that the egress node use small intervals, under the condition that the injected traffic does not exceed the capacity of the reverse data path. The value of the interval MUST be reported.
- The accuracy of RSRD is also dependent on the time needed to propagate the error-free signal from the egress node to the ingress node. A typical value for propagating the error-free signal from the egress node to the ingress node under the same measurement setup MAY be reported. The methodology to obtain such values is outside the scope of this document.

- o The accuracy of this metric is also dependent on the physical-layer serialization/deserialization of the test signal for certain data path technologies. For instance, for an LSP between a pair of low-speed Ethernet interfaces, the time needed to serialize/deserialize a large frame may not be negligible. In this case, it is RECOMMENDED that the egress node use small frames. The average length of the frame MAY be reported.

- o If the corresponding Resv message is sent but no error-free signal is received by the ingress node within a reasonable period of time, i.e., a threshold, RSRD MUST be treated as undefined. The value of the threshold MUST be reported.

- o If an error-free signal is received before a PATH message is sent on the ingress node, an error MUST be reported and the measurement SHOULD terminate.

- o If the LSP setup fails, this metric value MUST NOT be counted.

6.7. Methodologies

Generally, the methodology would proceed as follows:

- o Make sure that the network has enough resources to set up the requested LSP.

- o Start the data path measurement and/or monitoring procedures on the ingress node and egress node. If an error-free signal is received by the ingress node before a PATH message is sent, report an error and terminate the measurement.

- o At the ingress node, form the PATH message according to the LSP requirements and send the message towards the egress node.

- o Upon sending the last bit of the corresponding Resv message, take the timestamp (T1) on the egress node as soon as possible.

- o When an error-free signal is observed on the ingress node, take the timestamp (T2) as soon as possible. An estimate of RSRD (T2 - T1) can be computed.

- o If the LSP setup fails, RSRD is not counted.

- o If no error-free signal is received within a reasonable period of time by the ingress node, RSRD is deemed to be undefined.

7. A Singleton Definition for PRFD

This part defines a metric for forward data path delay when an LSP is set up.

In an RSVP-TE implementation, when setting up an LSP, each node may choose to program the cross-connection before it sends a PATH message further downstream. In this case, the forward data path may become ready for use before the signaling process completes, i.e., before the Resv message reaches the ingress node. This metric can be used to identify such an implementation practice and give useful information to application designers.

7.1. Motivation

PRFD is useful for the following reasons:

- o PRFD can be used to identify an RSVP-TE implementation practice in which cross-connections are programmed before a PATH message is sent downstream.
- o The value of PRFD may also help application designers to fine-tune their application model.

7.2. Metric Name

PRFD = PATH Received, Forward Data path

7.3. Metric Parameters

- o ID0, the ingress LSR ID
- o ID1, the egress LSR ID
- o T, a time when the setup is attempted

7.4. Metric Units

The value of PRFD is either a real number of milliseconds or undefined.

7.5. Definition

For a real number dT,

PRFD from ingress node ID0 to egress node ID1 at T is dT

means that

- o ingress node ID0 sends a PATH message to egress node ID1,
- o the last bit of the PATH message is received by egress node ID1 at T, and
- o an error-free signal is received by the egress node ID1 using a data-plane-specific test pattern at T+dT.

7.6. Discussion

The following issues are likely to come up in practice:

- o The accuracy of PRFD depends on the clock resolution of the egress node. Clock synchronization between the ingress node and egress node is not required.
- o The accuracy of PRFD is also dependent on how the error-free signal is received and may differ significantly when the underlying data plane technology is different. For instance, for an LSP between a pair of Ethernet interfaces, the egress node (sometimes the tester) may use a rate-based method to verify the connectivity of the data path and use the reception of the first error-free frame as the error-free signal. In this case, the interval between two successive frames has a significant impact on accuracy. It is RECOMMENDED in this case that the ingress node use small intervals, under the condition that the injected traffic does not exceed the capacity of the forward data path. The value of the interval MUST be reported.
- o The accuracy of PRFD is also dependent on the time needed to propagate the error-free signal from the ingress node to the egress node. A typical value for propagating the error-free signal from the ingress node to the egress node under the same measurement setup MAY be reported. The methodology to obtain such values is outside the scope of this document.
- o The accuracy of this metric is also dependent on the physical-layer serialization/deserialization of the test signal for certain data path technologies. For instance, for an LSP between a pair

of low-speed Ethernet interfaces, the time needed to serialize/deserialize a large frame may not be negligible. In this case, it is RECOMMENDED that the ingress node use small frames. The average length of the frame MAY be reported.

- o If an error-free signal is received before a PATH message is sent, an error MUST be reported and the measurement SHOULD terminate.
- o If the LSP setup fails, this metric value MUST NOT be counted.
- o This metric SHOULD be used together with RRFD. It is RECOMMENDED that a PRFD measurement be carried out after a negative RRFD value has already been observed.

7.7. Methodologies

Generally, the methodology would proceed as follows:

- o Make sure that the network has enough resources to set up the requested LSP.
- o Start the data path measurement and/or monitoring procedures on the ingress node and egress node. If an error-free signal is received by the egress node before a PATH message is sent, report an error and terminate the measurement.
- o At the ingress node, form the PATH message according to the LSP requirements and send the message towards the egress node.
- o Upon receiving the last bit of the PATH message, take the timestamp (T1) on the egress node as soon as possible.
- o When an error-free signal is observed on the egress node, take the timestamp (T2) as soon as possible. An estimate of PRFD (T2 - T1) can be computed.
- o If the LSP setup fails, PRFD is not counted.
- o If no error-free signal is received within a reasonable period of time by the egress node, PRFD is deemed to be undefined.

8. A Singleton Definition for PSFD

This part defines a metric for forward data path delay when an LSP is set up.

As described in [RFC6383], the completion of the RSVP-TE signaling process does not necessarily mean that the cross-connections along the LSP being set up are in place and ready to carry traffic. This metric defines the time difference between the point when the PATH message is sent by the ingress node and the completion of the cross-connection programming along the LSP forward data path.

8.1. Motivation

PSFD is useful for the following reasons:

- For the reasons described in [RFC6383], the data path setup delay may not be consistent with the control plane LSP setup delay. The data path setup delay metric is more precise for LSP setup performance measurement.

- The completion of the signaling process may be used by application designers as an indication of data path connectivity. The difference between the control plane setup delay and data path delay, and the potential failure of cross-connection programming, if not properly treated, will result in data loss or application failure. This metric can thus help designers to improve the application model.

8.2. Metric Name

PSFD = PATH Sent, Forward Data path

8.3. Metric Parameters

- ID0, the ingress LSR ID

- ID1, the egress LSR ID

- T, a time when the setup is attempted

8.4. Metric Units

The value of PSFD is either a real number of milliseconds or undefined.

8.5. Definition

For a real number dT,

PSFD from ingress node ID0 to egress node ID1 at T is dT

means that

- o ingress node ID0 sends the first bit of a PATH message to egress node ID1 at T, and
- o an error-free signal is received by the egress node ID1 using a data-plane-specific test pattern at T+dT.

8.6. Discussion

The following issues are likely to come up in practice:

- o The accuracy of PSFD depends on the clock resolution of both the ingress node and egress node. Clock synchronization between the ingress node and egress node is required.
- o The accuracy of PSFD is also dependent on how the error-free signal is received and may differ significantly when the underlying data plane technology is different. For instance, for an LSP between a pair of Ethernet interfaces, the ingress node may use a rate-based method to verify the connectivity of the data path and use the reception of the first error-free frame as the error-free signal. In this case, the interval between two successive frames has a significant impact on accuracy. It is RECOMMENDED that the ingress node use small intervals, under the condition that the injected traffic does not exceed the capacity of the forward data path. The value of the interval MUST be reported.
- o The accuracy of PSFD is also dependent on the time needed to propagate the error-free signal from the ingress node to the egress node. A typical value for propagating the error-free signal from the ingress node to the egress node under the same measurement setup MAY be reported. The methodology to obtain such values is outside the scope of this document.
- o The accuracy of this metric is also dependent on the physical-layer serialization/deserialization of the test signal for certain data path technologies. For instance, for an LSP between a pair

of low-speed Ethernet interfaces, the time needed to serialize/deserialize a large frame may not be negligible. In this case, it is RECOMMENDED that the ingress node use small frames. The average length of the frame MAY be reported.

- If an error-free signal is received before a PATH message is sent, an error MUST be reported and the measurement SHOULD terminate.

- If the LSP setup fails, this metric value MUST NOT be counted.

- If the PATH message is sent by the ingress node but no error-free signal is received by the egress node within a reasonable period of time, i.e., a threshold, PSFD MUST be treated as undefined. The value of the threshold MUST be reported.

8.7. Methodologies

Generally, the methodology would proceed as follows:

- Make sure that the network has enough resources to set up the requested LSP.

- Start the data path measurement and/or monitoring procedures on the ingress node and egress node. If an error-free signal is received by the egress node before a PATH message is sent, report an error and terminate the measurement.

- At the ingress node, form the PATH message according to the LSP requirements and send the message towards the egress node. A timestamp (T1) may be stored locally in the ingress node when the PATH message packet is sent towards the egress node.

- When an error-free signal is observed on the egress node, take the timestamp (T2) as soon as possible. An estimate of PSFD (T2 - T1) can be computed.

- If the LSP setup fails, PSFD is not counted.

- If no error-free signal is received within a reasonable period of time by the egress node, PSFD is deemed to be undefined.

9. A Singleton Definition for PSRD

This part defines a metric for reverse data path delay when an LSP is set up.

This metric defines the time difference between the point when the ingress node sends the PATH message and the completion of the cross-connection programming along the LSP reverse data path. This metric MAY be used together with PSFD to characterize the data path delay of a bidirectional LSP.

9.1. Motivation

PSRD is useful for the following reasons:

- o For the reasons described in [RFC6383], the data path setup delay may not be consistent with the control plane LSP setup delay. The data path setup delay metric is more precise for LSP setup performance measurement.
- o The completion of the signaling process may be used by application designers as an indication of data path connectivity. The difference between the control plane setup delay and data path delay, and the potential failure of cross-connection programming, if not properly treated, will result in data loss or application failure. This metric can thus help designers to improve the application model.

9.2. Metric Name

PSRD = PATH Sent, Reverse Data path

9.3. Metric Parameters

- o ID0, the ingress LSR ID
- o ID1, the egress LSR ID
- o T, a time when the setup is attempted

9.4. Metric Units

The value of PSRD is either a real number of milliseconds or undefined.

9.5. Definition

For a real number dT,

PSRD from ingress node ID0 to egress node ID1 at T is dT

means that

- o ingress node ID0 sends the first bit of a PATH message to egress node ID1 at T, and
- o an error-free signal is received through the reverse data path by the ingress node ID0 using a data-plane-specific test pattern at T+dT.

9.6. Discussion

The following issues are likely to come up in practice:

- o The accuracy of PSRD depends on the clock resolution of the ingress node. Clock synchronization between the ingress node and egress node is not required.
- o The accuracy of PSRD is also dependent on how the error-free signal is received and may differ significantly when the underlying data plane technology is different. For instance, for an LSP between a pair of Ethernet interfaces, the egress node may use a rate-based method to verify the connectivity of the data path and use the reception of the first error-free frame as the error-free signal. In this case, the interval between two successive frames has a significant impact on accuracy. It is RECOMMENDED that the egress node use small intervals, under the condition that the injected traffic does not exceed the capacity of the forward data path. The value of the interval MUST be reported.
- o The accuracy of PSRD is also dependent on the time needed to propagate the error-free signal from the egress node to the ingress node. A typical value for propagating the error-free signal from the egress node to the ingress node under the same measurement setup MAY be reported. The methodology to obtain such values is outside the scope of this document.
- o The accuracy of this metric is also dependent on the physical-layer serialization/deserialization of the test signal for certain data path technologies. For instance, for an LSP between a pair

of low-speed Ethernet interfaces, the time needed to serialize/deserialize a large frame may not be negligible. In this case, it is RECOMMENDED that the egress node use small frames. The average length of the frame MAY be reported.

- o If an error-free signal is received before a PATH message is sent, an error MUST be reported and the measurement SHOULD terminate.
- o If the LSP setup fails, this metric value MUST NOT be counted.
- o If the PATH message is sent by the ingress node but no error-free signal is received by the ingress node within a reasonable period of time, i.e., a threshold, PSRD MUST be treated as undefined. The value of the threshold MUST be reported.

9.7. Methodologies

Generally, the methodology would proceed as follows:

- o Make sure that the network has enough resources to set up the requested LSP.
- o Start the data path measurement and/or monitoring procedures on the ingress node and egress node. If an error-free signal is received by the egress node before a PATH message is sent, report an error and terminate the measurement.
- o At the ingress node, form the PATH message according to the LSP requirements and send the message towards the egress node. A timestamp (T1) may be stored locally in the ingress node when the PATH message packet is sent towards the egress node.
- o When an error-free signal is observed on the ingress node, take the timestamp (T2) as soon as possible. An estimate of PSRD (T2 - T1) can be computed.
- o If the LSP setup fails, PSRD is not counted.
- o If no error-free signal is received within a reasonable period of time by the ingress node, PSRD is deemed to be undefined.

10. A Definition for Samples of Data Path Delay

In Sections 5, 6, 7, 8, and 9, we defined the singleton metrics of data path delay. Now, we define how to get one particular sample of such a delay. Sampling is done to select a particular portion of singleton values of the given parameters. As in [RFC2330], we use Poisson sampling as an example.

10.1. Metric Name

Type <X> data path delay sample, where X is either RRFD, RSRD, PRFD, PSFD, or PSRD.

10.2. Metric Parameters

- o ID0, the ingress LSR ID
- o ID1, the egress LSR ID
- o T0, a time
- o Tf, a time
- o Lambda, a rate in reciprocal milliseconds
- o Th, the LSP holding time
- o Td, the maximum waiting time for successful LSP setup
- o Ts, the maximum waiting time for an error-free signal

10.3. Metric Units

A sequence of pairs; the elements of each pair are:

- o T, a time when setup is attempted
- o dT, either a real number of milliseconds or undefined

10.4. Definition

Given T0, Tf, and Lambda, compute a pseudo-random Poisson process beginning at or before T0, with average arrival rate Lambda, and ending at or after Tf. Those time values greater than or equal to T0 and less than or equal to Tf are then selected. At each of the times in this process, we obtain the value of a data path delay sample of type <X> at this time. The value of the sample is the sequence made up of the resulting <time, type <X> data path delay> pairs. If there are no such pairs, the sequence is of length zero and the sample is said to be empty.

10.5. Discussion

The following issues are likely to come up in practice:

- The parameters Lambda, Th, and Td should be carefully chosen, as explained in the discussions for LSP setup delay (see [RFC5814]).

- The parameter Ts should be carefully chosen and MUST be reported along with the LSP forward/reverse data path delay sample.

10.6. Methodologies

Generally, the methodology would proceed as follows:

- Select specific times, using the specified Poisson arrival process.

- Set up the LSP and obtain the value of type <X> data path delay.

- Release the LSP after Th, and wait for the next Poisson arrival process.

10.7. Typical Testing Cases

10.7.1. With No LSP in the Network

10.7.1.1. Motivation

Data path delay with no LSP in the network is important because this reflects the inherent delay of a device implementation. The minimum value provides an indication of the delay that will likely be experienced when an LSP data path is configured under light traffic load.

10.7.1.2. Methodologies

Make sure that there is no LSP in the network, and proceed with the methodologies described in Section 10.6.

10.7.2. With a Number of LSPs in the Network

10.7.2.1. Motivation

Data path delay with a number of LSPs in the network is important because it reflects the performance of an operational network with considerable load. This delay may vary significantly as the number of existing LSPs varies. It can be used as a scalability metric of a device implementation.

10.7.2.2. Methodologies

- o Set up the required number of LSPs.
- o Wait until the network reaches a stable state.
- o Then proceed with the methodologies described in Section 10.6.

11. Some Statistics Definitions for Metrics to Report

Given the samples of the performance metric, we now offer several statistics of these samples to report. From these statistics, we can draw some useful conclusions regarding a GMPLS network. The value of these metrics is either a real number of milliseconds or undefined. In the following discussion, we only consider the finite values.

11.1. The Minimum of the Metric

The minimum of the metric is the minimum of all the dT values in the sample. In computing this, undefined values SHOULD be treated as infinitely large. Note that this means that the minimum could thus be undefined if all the dT values are undefined. In addition, the metric minimum SHOULD be set to undefined if the sample is empty.

11.2. The Median of the Metric

The median of the metric is the median of the dT values in the given sample. In computing the median, the undefined values MUST NOT be included. The median SHOULD be set to undefined if all the dT values are undefined, or if the sample is empty. When the number of defined values in the given sample is small, the metric median may not be typical and SHOULD be used carefully.

11.3. The Percentile of the Metric

The "empirical distribution function" (EDF) of a set of scalar measurements is a function F(x), which, for any x, gives the fractional proportion of the total measurements that were <= x.

Given a percentage X, the Xth percentile of the metric means the smallest value of x for which F(x) >= X. In computing the percentile, undefined values MUST NOT be included.

See [RFC2330] for further details.

11.4. Failure Probability

Given the samples of the performance metric, we now offer two statistics of failure events of these samples to report: Failure Count and Failure Ratio. The two statistics can be applied to both the forward data path and reverse data path. For example, when a sample of RRFD has been obtained, the forward data path failure statistics can be obtained, while a sample of RSRD can be used to calculate the reverse data path failure statistics. Detailed definitions of Failure Count and Failure Ratio are given below.

11.4.1. Failure Count

Failure Count is defined as the number of the undefined value of the corresponding performance metric in a sample. The value of Failure Count is an integer.

11.4.2. Failure Ratio

Failure Ratio is the percentage of the number of failure events to the total number of requests in a sample. Here, a failure event means that the signaling completes with no error, while no error-free signal is observed. The calculation for Failure Ratio is defined as follows:

Failure Ratio = Number of undefined value/(Number of valid metric values + Number of undefined value) * 100%.

12. Security Considerations

In the control plane, since the measurement endpoints must be conformant to signaling specifications and behave as normal signaling endpoints, it will not incur security issues other than normal LSP provisioning. However, the measurement parameters must be carefully selected so that the measurements inject trivial amounts of additional traffic into the networks they measure. If they inject "too much" traffic, they can skew the results of the measurement and in extreme cases cause congestion and denial of service.

In the data plane, the measurement endpoint MUST use a signal that is consistent with what is specified in the control plane. For example, in a packet switched case, the traffic injected into the data plane

MUST NOT exceed the specified rate in the corresponding LSP setup request. In a wavelength switched case, the measurement endpoint MUST use the specified or negotiated lambda with appropriate power.

The security considerations pertaining to the original RSVP protocol [RFC2205] and its TE extensions [RFC3209] also remain relevant.

13. References

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Appendix A. Acknowledgements

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