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Requirements for Hitless MPLS Path Segment Monitoring

Abstract

One of the most important Operations, Administration, and Maintenance (OAM) capabilities for transport-network operation is fault localization. An in-service, on-demand path segment monitoring function of a transport path is indispensable, particularly when the service monitoring function is activated only between endpoints. However, the current segment monitoring approach defined for MPLS (including the MPLS Transport Profile (MPLS-TP)) in RFC 6371 "Operations, Administration, and Maintenance Framework for MPLS-Based Transport Networks" has drawbacks. This document provides an analysis of the existing MPLS-TP OAM mechanisms for the path segment monitoring and provides requirements to guide the development of new OAM tools to support Hitless Path Segment Monitoring (HPSM).

Status of This Memo

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1. Introduction

According to the MPLS-TP OAM requirements [RFC5860], mechanisms MUST be available for alerting service providers of faults or defects that affect their services. In addition, to ensure that faults or service degradation can be localized, operators need a function to diagnose the detected problem. Using end-to-end monitoring for this purpose is insufficient in that an operator will not be able to localize a fault or service degradation accurately.

A segment monitoring function that can focus on a specific segment of a transport path and that can provide a detailed analysis is indispensable to promptly and accurately localize the fault. A function for monitoring path segments has been defined to perform this task for MPLS-TP. However, as noted in the MPLS-TP OAM Framework [RFC6371], the current method for segment monitoring of a transport path has implications that hinder the usage in an operator network.

After elaborating on the problem statement for the path segment monitoring function as it is currently defined, this document provides requirements for an on-demand path segment monitoring function without traffic disruption. Further works are required to evaluate how proposed requirements match with current MPLS architecture and to identify possible solutions.

2. Conventions Used in This Document

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.

2.1. Terminology

HPSM - Hitless Path Segment Monitoring

LSP - Label Switched Path

LSR - Label Switching Router

ME - Maintenance Entity

MEG - Maintenance Entity Group

MEP - Maintenance Entity Group End Point

MIP - Maintenance Entity Group Intermediate Point

OTN - Optical Transport Network

TCM - Tandem Connection Monitoring

SPME - Sub-Path Maintenance Element

3. Problem Statement

A Sub-Path Maintenance Element (SPME) function to monitor (and to protect and/or manage) MPLS-TP network segments is defined in [RFC5921]. The SPME is defined between the edges of the segment of a transport path that needs to be monitored, protected, or managed. SPME is created by stacking the shim header (MPLS header), according to [RFC3031]; it is defined as the segment where the header is stacked. OAM messages can be initiated at the edge of the SPME. They can be sent to the peer edge of the SPME or to a MIP along the SPME by setting the TTL value of the Label Stack Entry (LSE) and interface identifier value at the corresponding hierarchical LSP level in case of a per-node model.

According to Section 3.8 of [RFC6371], MPLS-TP segment monitoring should satisfy two network objectives:

(N1) The monitoring and maintenance of current transport paths has to be conducted in-service without traffic disruption.

(N2) Segment monitoring must not modify the forwarding of the segment portion of the transport path.

The SPME function that is defined in [RFC5921] has the following drawbacks:

(P1) It increases network management complexity, because a new sub-layer and new MEPs and MIPs have to be configured for the SPME.

(P2) Original conditions of the path change.

(P3) The client traffic over a transport path is disrupted if the SPME is configured on-demand.

Problem (P1) is related to the management of each additional sub-layer required for segment monitoring in an MPLS-TP network. When an SPME is applied to administer on-demand OAM functions in MPLS-TP networks, a rule for operationally differentiating those SPMEs will be required at least within an administrative domain. This forces operators to implement at least an additional layer into the management systems that will only be used for on-demand path segment monitoring. From the perspective of operation, increasing the number of managed layers and managed addresses/identifiers is not desirable in view of keeping the management systems as simple as possible. Moreover, using the currently defined methods, on-demand setting of SPMEs causes problems (P2) and (P3) due to additional label stacking.

Problem (P2) arises because the MPLS-exposed label value and MPLS frame length change. The monitoring function should monitor the status without changing any condition of the target segment or of the target transport path. Changing the settings of the original shim header should not be allowed, because this change corresponds to creating a new segment of the original transport path that differs from the original one. When the conditions of the path change, the measured values or observed data will also change. This may make the monitoring meaningless because the result of the measurement would no longer reflect the performance of the connection where the original fault or degradation occurred. As an example, setting up an on-demand SPME will result in the LSRs within the monitoring segment only looking at the added (stacked) labels and not at the labels of the original LSP. This means that problems stemming from incorrect (or unexpected) treatment of labels of the original LSP by the nodes within the monitored segment cannot be identified when setting up SPME. This might include hardware problems during label lookup, misconfiguration, etc. Therefore, operators have to pay extra attention to correctly setting and checking the label values of the original LSP in the configuration. Of course, the reverse of this situation is also possible; for example, an incorrect or unexpected treatment of SPME labels can result in false detection of a fault where no problem existed originally.

Figure 1 shows an example of SPME settings. In the figure, "X" is the label value of the original path expected at the tail end of node D. "210" and "220" are label values allocated for SPME. The label values of the original path are modified as are the values of the stacked labels. As shown in Figure 1, SPME changes both the length of MPLS frames and the label value(s). In particular, performance monitoring measurements (e.g., Delay Measurement and Packet Loss Measurement) are sensitive to these changes. As an example, increasing the packet length may impact packet loss due to MTU settings; modifying the label stack may introduce packet loss, or it may fix packet loss depending on the configuration status. Such changes influence packet delay, too, even if, from a practical point of view, it is likely that only a few services will experience a practical impact.

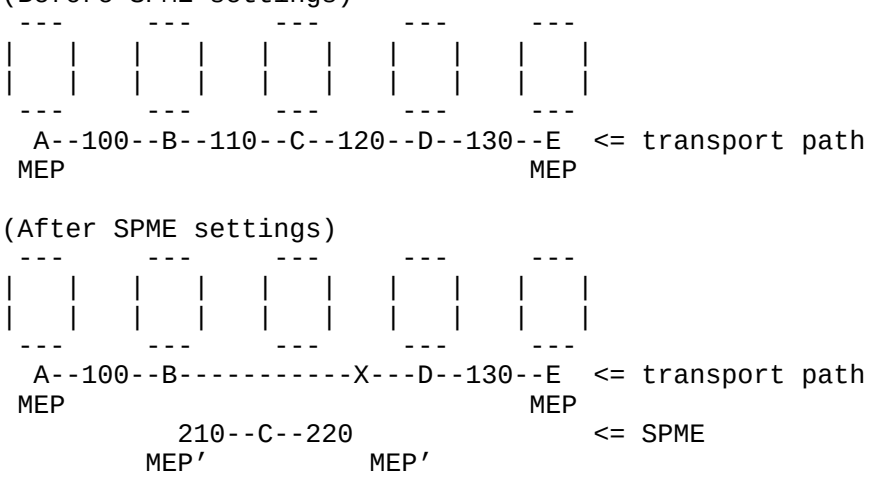


Figure 1: SPME Settings Example

Problem (P3) can be avoided if the operator sets SPMEs in advance and maintains them until the end of life of a transport path: but this does not support on-demand. Furthermore, SMPEs cannot be set arbitrarily because overlapping of path segments is limited to nesting relationships. As a result, possible SPME configurations of segments of an original transport path are limited due to the characteristic of the SPME shown in Figure 1, even if SPMEs are preconfigured.

Although the make-before-break procedure in the survivability document [RFC6372] supports configuration for monitoring according to the framework document [RFC5921], without traffic disruption the configuration of an SPME is not possible without violating the network objective (N2). These concerns are described in Section 3.8 of [RFC6371].

Additionally, the make-before-break approach typically relies on a control plane and requires additional functionalities for a management system to properly support SPME creation and traffic switching from the original transport path to the SPME.

As an example, the old and new transport resources (e.g., LSP tunnels) might compete with each other for resources that they have in common. Depending on availability of resources, this competition can cause admission control to prevent the new LSP tunnel from being established as this bandwidth accounting deviates from the traditional (non-control plane) management-system operation. While SPMEs can be applied in any network context (single-domain, multi-domain, single-carrier, multi-carrier, etc.), the main applications are in inter-carrier or inter-domain segment monitoring where they are typically preconfigured or pre-instantiated. SPME instantiates a hierarchical path (introducing MPLS-label stacking) through which OAM packets can be sent. The SPME monitoring function is also mainly important for protecting bundles of transport paths and the carriers' carrier solutions within an administrative domain.

The analogy for SPME in other transport technologies is Tandem Connection Monitoring (TCM). TCM is used in Optical Transport Networks (OTNs) and Ethernet transport networks. It supports on-demand but does not affect the path. For example, in OTNs, TCM allows the insertion and removal of performance monitoring overhead within the frame at intermediate points in the network. It is done such that their insertion and removal do not change the conditions of the path. Though, as the OAM overhead is part of the frame (designated overhead bytes), it is constrained to a predefined number of monitoring segments.

To summarize: the problem statement is that the current sub-path maintenance based on a hierarchical LSP (SPME) is problematic for preconfiguration in terms of increasing the number of managed objects by layer stacking and identifiers/addresses. An on-demand configuration of SPME is one of the possible approaches for minimizing the impact of these issues. However, the current procedure is unfavorable because the on-demand configuration for monitoring changes the condition of the original monitored path. To avoid or minimize the impact of the drawbacks discussed above, a more efficient approach is required for the operation of an MPLS-TP

transport network. A monitoring mechanism, named "Hitless Path Segment Monitoring" (HPSM), supporting on-demand path segment monitoring without traffic disruption is needed.

4. Requirements for HPSM

In the following sections, mandatory (M) and optional (O) requirements for the HPSM function are listed.

4.1. Backward Compatibility

HPSM would be an additional OAM tool that would not replace SPME. As such:

(M1) HPSM MUST be compatible with the usage of SPME.

(O1) HPSM SHOULD be applicable at the SPME layer too.

(M2) HPSM MUST support both the per-node and per-interface model as specified in [RFC6371].

4.2. Non-Intrusive Segment Monitoring

One of the major problems of legacy SPME highlighted in Section 3 is that it may not monitor the original path and it could disrupt service traffic when set up on demand.

(M3) HPSM MUST NOT change the original conditions of the transport path (e.g., the length of MPLS frames, the exposed label values, etc.).

(M4) HPSM MUST support on-demand provisioning without traffic disruption.

4.3. Monitoring Multiple Segments

Along a transport path, there may be the need to support monitoring multiple segments simultaneously.

(M5) HPSM MUST support configuration of multiple monitoring segments along a transport path.

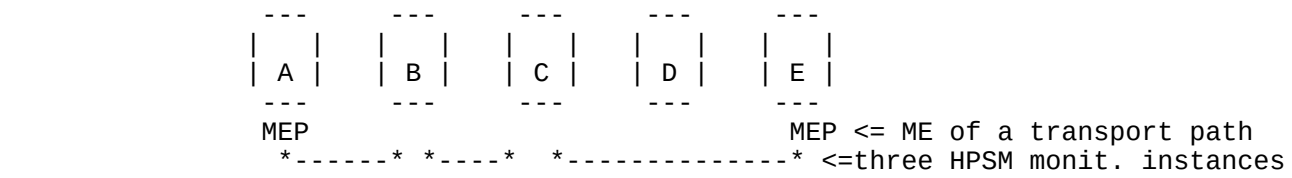


Figure 2: Multiple HPSM Instances Example

4.4. Monitoring Single and Multiple Levels

HPSM would apply mainly for on-demand diagnostic purposes. With the currently defined approach, the most serious problem is that there is no way to locate the degraded segment of a path without changing the conditions of the original path. Therefore, as a first step, a single-level, single-segment monitoring not affecting the monitored path is required for HPSM. Monitoring simultaneous segments on multiple levels is the most powerful tool for accurately diagnosing the performance of a transport path. However, in the field, a single-level, multiple-segment approach would be less complex for management and operations.

(M6) HPSM MUST support single-level segment monitoring.

(O2) HPSM MAY support multi-level segment monitoring.

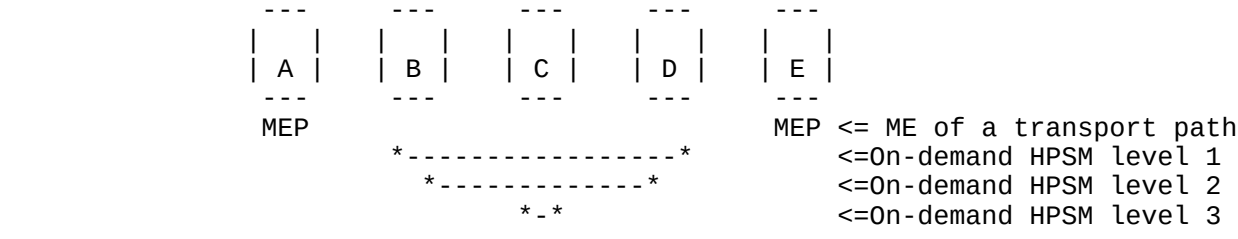


Figure 3: Multi-Level HPSM Example

4.5. HPSM and End-to-End Proactive Monitoring Independence

There is a need for simultaneously using existing end-to-end proactive monitoring and on-demand path segment monitoring. Normally, the on-demand path segment monitoring is configured on a segment of a maintenance entity of a transport path. In such an environment, on-demand single-level monitoring should be performed without disrupting the proactive monitoring of the targeted end-to-end transport path to avoid affecting monitoring of user traffic performance.

(M7) HPSM MUST support the capability of being operated concurrently to, and independently of, the OAM function on the end-to-end path.

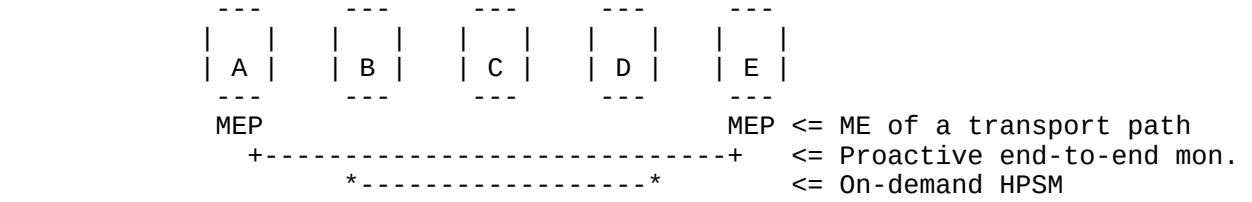


Figure 4: Independence between Proactive End-to-End Monitoring and On-Demand HPSM

4.6. Monitoring an Arbitrary Segment

The main objective for on-demand path segment monitoring is to diagnose the fault locations. A possible realistic diagnostic procedure is to fix one endpoint of a segment at the MEP of the transport path under observation and progressively change the length of the segments. It is, therefore, possible to monitor all the paths, step-by-step, with a granularity that depends on equipment implementations. For example, Figure 5 shows the case where the granularity is at the interface level (i.e., monitoring is at each input interface and output interface of each piece of equipment).

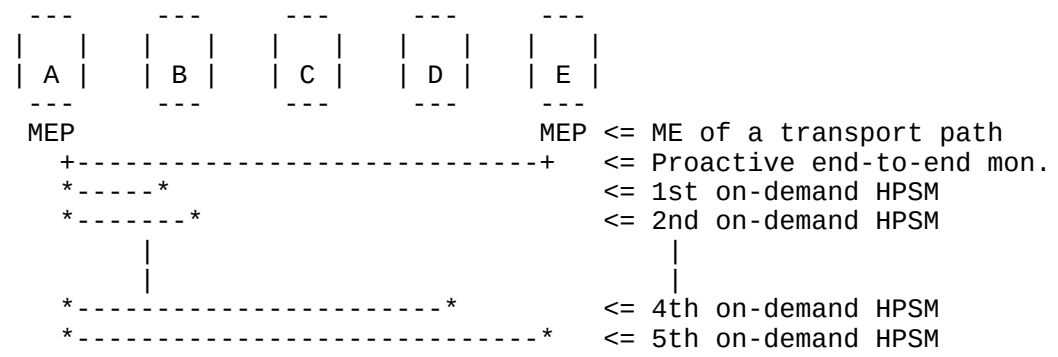


Figure 5: Localization of a Defect by Consecutive On-Demand Path Segment Monitoring Procedure

Another possible scenario is depicted in Figure 6. In this case, the operator wants to diagnose a transport path starting at a transit node because the end nodes (A and E) are located at customer sites and consist of small boxes supporting only a subset of OAM functions. In this case, where the source entities of the diagnostic packets are limited to the position of MEPs, on-demand path segment monitoring will be ineffective because not all the segments can be diagnosed (e.g., segment monitoring HPSM 3 in Figure 6 is not available, and it is not possible to determine the fault location exactly).

(M8) It SHALL be possible to provision HPSM on an arbitrary segment of a transport path.

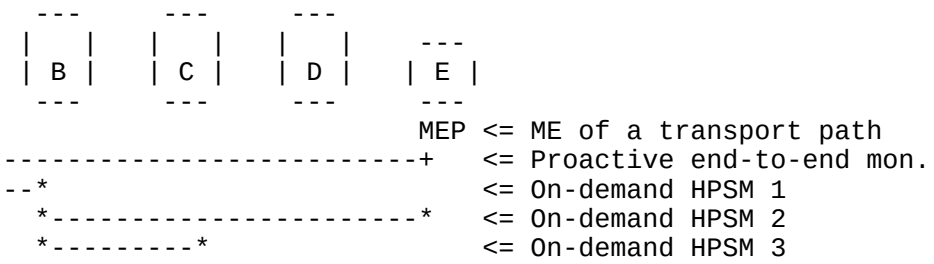
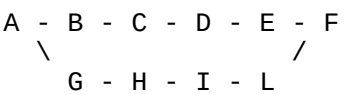


Figure 6: HPSM Configuration at Arbitrary Segments

4.7. Fault while HPSM Is Operational

Node or link failures may occur while HPSM is active. In this case, if no resiliency mechanism is set up on the subtended transport path, there is no particular requirement for HPSM. If the transport path is protected, the HPSM function may monitor unintended segments. The following examples are provided for clarification.

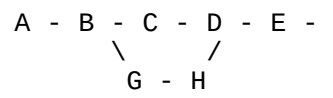
Protection scenario A is shown in Figure 7. In this scenario, a working LSP and a protection LSP are set up. HPSM is activated between nodes A and E. When a fault occurs between nodes B and C, the operation of HPSM is not affected by the protection switch and continues on the active LSP.



Where:
- end-to-end LSP: A-B-C-D-E-F
- working LSP: A-B-C-D-E-F
- protection LSP: A-G-H-I-L-F
- HPSM: A-E

Figure 7: Protection Scenario A

Protection scenario B is shown in Figure 8. The difference with scenario A is that only a portion of the transport path is protected. In this case, when a fault occurs between nodes B and C on the working sub-path B-C-D, traffic will be switched to protection sub-path B-G-H-D. Assuming that OAM packet termination depends only on the TTL value of the MPLS label header, the target node of the HPSM changes from E to D due to the difference of hop counts between the working path route (A-B-C-D-E: 4 hops) and protection path route (A-B-G-H-D-E: 5 hops). In this case, the operation of HPSM is affected.



- end-to-end LSP: A-B-C-D-E-F
- working sub-path: B-C-D
- protection sub-path: B-G-H-D
- HPSM: A-E

Figure 8: Protection Scenario B

(M9) The HPSM SHOULD avoid monitoring an unintended segment when one or more failures occur.

There are potentially different solutions to satisfy such a requirement. A possible solution may be to suspend HPSM monitoring until network restoration takes place. Another possible approach may be to compare the node/interface ID in the OAM packet with that at the node reached at TTL termination and, if this does not match, a

suspension of HPSM monitoring should be triggered. The above approaches are valid in any circumstance, both for protected and unprotected networks LSPs. These examples should not be taken to limit the design of a solution.

4.8. HPSM Manageability

From a managing perspective, increasing the number of managed layers and managed addresses/identifiers is not desirable in view of keeping the management systems as simple as possible.

(M10) HPSM SHOULD NOT be based on additional transport layers (e.g., hierarchical LSPs).

(M11) The same identifiers used for MIPs and/or MEPs SHOULD be applied to maintenance points for the HPSM when they are instantiated in the same place along a transport path.

Maintenance points for the HPSM may be different from the functional components of MIPs and MEPs as defined in the OAM framework document [RFC6371]. Investigating potential solutions for satisfying HPSM requirements may lead to identifying new functional components; these components need to be backward compatible with MPLS architecture. Solutions are outside the scope of this document.

4.9. Supported OAM Functions

A maintenance point supporting the HPSM function has to be able to generate and inject OAM packets. OAM functions that may be applicable for on-demand HPSM are basically the on-demand performance monitoring functions that are defined in the OAM framework document [RFC6371]. The "on-demand" attribute is typically temporary for maintenance operation.

(M12) HPSM MUST support Packet Loss and Packet Delay measurement.

These functions are normally only supported at the endpoints of a transport path. If a defect occurs, it might be quite hard to locate the defect or degradation point without using the segment monitoring function. If an operator cannot locate or narrow down the cause of the fault, it is quite difficult to take prompt actions to solve the problem.

Other on-demand monitoring functions (e.g., Delay Variation measurement) are desirable but not as necessary as the functions mentioned above.

(O3) HPSM MAY support Packet Delay variation, Throughput measurement, and other performance monitoring and fault management functions.

Support of out-of-service on-demand performance-management functions (e.g., Throughput measurement) is not required for HPSM.

5. Summary

A new HPSM mechanism is required to provide on-demand path segment monitoring without traffic disruption. It shall meet the two network objectives described in Section 3.8 of [RFC6371] and summarized in Section 3 of this document.

The mechanism should minimize the problems described in Section 3, i.e., (P1), (P2), and (P3).

The solution for the on-demand path segment monitoring without traffic disruption needs to cover both the per-node model and the per-interface model specified in [RFC6371].

The on-demand path segment monitoring without traffic disruption solution needs to support on-demand Packet Loss Measurement and Packet Delay Measurement functions and optionally other performance monitoring and fault management functions (e.g., Throughput measurement, Packet Delay variation measurement, Diagnostic test, etc.).

6. Security Considerations

Security is a significant requirement of the MPLS Transport Profile. This document provides a problem statement and requirements to guide the development of new OAM tools to support HPSM. Such new tools must follow the security considerations provided in OAM Requirements for MPLS-TP in [RFC5860].

7. IANA Considerations

This document does not require any IANA actions.

8. References

8.1. Normative References

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