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A. D'Alessandro
Telecom Italia
M.Paul
Deutsche Telekom
S. Ueno
NTT Communications
Y.Koike
NTT

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Temporal and hitless path segment monitoring
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Abstract

The MPLS transport profile (MPLS-TP) is being standardized to enable carrier-grade packet transport and complement converged packet network deployments. Among the most attractive features of MPLS-TP are OAM functions, which enable network operators or service providers to provide various maintenance characteristics, such as fault location, survivability, performance monitoring, and preliminary or in-service measurements.

One of the most important mechanisms which is common for transport network operation is fault location. A segment monitoring function of a transport path is effective in terms of extension of the maintenance work and indispensable particularly when the OAM function is effective only between end points. However, the current approach defined for MPLS-TP for the segment monitoring (SPME) has some fatal drawbacks. This document elaborates on the problem statement for the Sub-path Maintenance Elements (SPMEs) which provides monitoring of a portion of a set of transport paths (LSPs or MS-PWs). Based on the problems, this document specifies new requirements to consider a new improved mechanism of hitless transport path segment monitoring.

This document is a product of a joint Internet Engineering Task Force (IETF) / International Telecommunications Union Telecommunications Standardization Sector (ITU-T) effort to include an MPLS Transport Profile within the IETF MPLS and PWE3 architectures to support the capabilities and functionalities of a packet transport network.

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1. Introduction

A packet transport network will enable carriers or service providers to use network resources efficiently, reduce operational complexity and provide carrier-grade network operation. Appropriate maintenance functions, supporting fault location, survivability, performance monitoring and preliminary or in-service measurements, are essential to ensure quality and reliability of a network. They are essential in transport networks and have evolved along with TDM, ATM, SDH and OTN.

Unlike in SDH or OTN networks, where OAM is an inherent part of every frame and frames are also transmitted in idle mode, it is not per se possible to constantly monitor the status of individual connections in packet networks. Packet-based OAM functions are flexible and selectively configurable according to operators' needs.

According to the MPLS-TP OAM requirements [1], mechanisms MUST be available for alerting a service provider of a fault or defect affecting the service(s) provided. In addition, to ensure that faults or degradations can be localized, operators need a method to analyze or investigate the problem. From the fault localization perspective, end-to-end monitoring is insufficient. Using end-to-end OAM monitoring, when one problem occurs in an MPLS-TP network, the operator can detect the fault, but is not able to localize it.

Thus, a specific segment monitoring function for detailed analysis, by focusing on and selecting a specific portion of a transport path, is indispensable to promptly and accurately localize the fault.

For MPLS-TP, a path segment monitoring function has been defined to perform this task. However, as noted in the MPLS-TP OAM Framework[5], the current method for segment monitoring function of a transport path has implications that hinder the usage in an operator network.

This document elaborates on the problem statement for the path segment monitoring function and proposes to consider a new improved method of the segment monitoring, following up the work done in [5]. Moreover, this document explains detailed requirements on the new temporal and hitless segment monitoring function which are not covered in [5].

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 RFC-2119 [1].

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

PST Path Segment Tunnel

TCM Tandem connection monitoring

SDH Synchronous Digital Hierarchy

SPME Sub-path Maintenance Element

2.2. Definitions

None

3. Network objectives for monitoring

There are two indispensable network objectives for MPLS-TP networks as described in section 3.8 of [5].

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

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

It is common in transport networks that network objective (1) is mandatory and that regarding network objective (2) the monitoring shall not change the forwarding behavior.

4. Problem statement

To monitor, protect, or manage portions of transport paths, such as LSPs in MPLS-TP networks, the Sub-Path Maintenance Element (SPME) is defined in [2]. The SPME is defined between the edges of the portion of the transport path that needs to be monitored, protected, or managed. This SPME is created by stacking the shim header (MPLS header)[3] and is defined as the segment where the header is stacked. OAM messages can be initiated at the edge of the SPME and 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 per-node model.

This method has the following general issues, which are fatal in terms of cost and operation.

(P-1) Increasing the overhead by the stacking of shim header(s)

(P-2) Increasing the address management complexity, as new MEPs and MIPs need to be configured for the SPME in the old MEG

Problem (P-1) leads to decreased efficiency as bandwidth is wasted only for maintenance purposes. As the size of monitored segments increases, the size of the label stack grows. Moreover, if the operator wants to monitor the portion of a transport path without service disruption, one or more SPMEs have to be set in advance until the end of life of a transport path, which is not temporal or on-demand. Consuming additional bandwidth permanently for only the monitoring purpose should be avoided to maximize the available bandwidth.

Problem (P-2) is related to an identifier-management issue. The identification of each layer in case of LSP label stacking is required in terms of strict sub-layer management for the segment monitoring in a MPLS-TP network. When SPME/TCM is applied for on-demand OAM functions in MPLS-TP networks in a similar manner to OTN or Ethernet transport networks, a possible rule of differentiating those SPME/TCMs operationally will be necessary at least within an administrative domain. This enforces operators to create an additional permanent layer identification policy only for temporal path segment monitoring. Moreover, from the perspective of operation, increasing the managed addresses and the managed layer is not desirable in terms of simplified operation featured by current transport networks. Reducing the managed identifiers and managed layers should be the fundamental direction in designing the architecture.

The most familiar example for SPME in transport networks is Tandem Connection Monitoring (TCM), which can for example be used for a carrier's carrier solution, as shown in Fig. 17 of the framework document[2]. However, in this case, the SPMEs have to be pre-configured. If this solution is applied to specific segment monitoring within one operator domain, all the necessary specific segments have to be pre-configured. This setting increases the managed objects as well as the necessary bandwidth, shown as Problem (P-1) and (P-2). Moreover, as a result of these pre-configurations, they impose operators to pre-design the structure of sub-path maintenance elements, which is not preferable in terms of operators' increased burden. These concerns are summarized in section 3.8 of [5].

Furthermore, in reality, all the possible patterns of path segment cannot be set in SPME, because overlapping of path segments is limited to nesting relationship. As a result, possible SPME patterns of portions of an original transport path are limited due to the characteristic of SPME shown in Figure.1, even if SPMEs are pre-configured. This restriction is inconvenient when operators have to fix issues in an on-demand manner. To avoid these issues, the temporal and on-demand setting of the SPME(s) is needed and more efficient for monitoring in MPLS-TP transport network operation.

However, using currently defined methods, the temporal setting of SPMEs also causes the following problems due to label stacking, which are fatal in terms of intrinsic monitoring and service disruption.

(P'-1) Changing the condition of the original transport path by changing the length of all the MPLS frames and changing label value(s)

(P'-2) Disrupting client traffic over a transport path, if the SPME is temporally configured.

Problem (P'-1) is a fatal problem in terms of intrinsic monitoring. As shown in network objective (2), the monitoring function needs to monitor the status without changing any conditions of the targeted monitored segment or the transport path. If the conditions of the transport path change, the measured value or observed data will also change. This can make the monitoring meaningless because the result of the monitoring would no longer reflect the reality of the connection where the original fault or degradation occurred.

Another aspect is that changing the settings of the original shim header should not be allowed because those changes correspond to creating a new portion of the original transport path, which differs from the original data plane conditions.

Figure 1 shows an example of SPME setting. In the figure, X means the one label expected on the tail-end node D of the original transport path. "210" and "220" are label allocated for SPME. The label values of the original path are modified as well as the values of stacked label. As shown in Fig.1, SPME changes the length of all the MPLS frames and changes label value(s). This is no longer the monitoring of the original transport path but the monitoring of a different path. Particularly, performance monitoring measurement (Delay measurement and loss measurement) are sensitive to those changes.

(Before SPME settings)

```
 ---     ---     ---     ---     ---
|   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |
 ---     ---     ---     ---     ---
 A---100--B--110--C--120--D--130--E  <= transport path
```

```
 MEP                                MEP

(After SPME settings)
 ---     ---     ---     ---     ---
|   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |
 ---     ---     ---     ---     ---
 A---100--B-------X-------D--130--E
 MEP     \                  /    MEP <= transport path
          --210--C--220--            <= SPME
         MEP'          MEP'
```

Figure 1 : An Example of a SPME setting

Problem (P'-2) was not fully discussed, although the make-before-break procedure in the survivability document [4] seemingly supports the hitless configuration for monitoring according to the framework document [2]. The reality is the hitless configuration of SPME is impossible without affecting the conditions of the targeted transport path, because the make-before-break procedure is premised on the change of the inner label value. This means changing one of the settings in MPLS shim header.

Moreover, this might not be effective under the static model without a control plane because the make-before-break is a restoration application based on the control plane. The removal of SPME whose segment is monitored could have the same impact (disruption of client traffic) as the creation of an SPME on the same LSP.

Note: (P'-2) will be removed when non-disruptive make-before-break (in both with and without Control Plane environment) is specified in

other MPLS-TP documents. However, (P'-2) could be replaced with the following issue. Non-disruptive make-before-break, in other words, taking an action similar to switching just for monitoring is not an ideal operation in transport networks.

The other potential risks are also envisaged. Setting up a temporal 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 could not be found when setting up SPME.

This might include hardware problems during label look-up, mis-configuration 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 inversion of this situation is also possible, .e.g., incorrect or unexpected treatment of SPME labels can result in false detection of a fault where none of the problem originally existed.

The utility of SPMEs is basically limited to inter-carrier or inter-domain segment monitoring where they are typically pre-configured or pre-instantiated. SPME instantiates a hierarchical transport path (introducing MPLS label stacking) through which OAM packets can be sent. SPME construct monitoring function is particularly important mainly for protecting bundles of transport paths and carriers' carrier solutions. SPME is expected to be mainly used for protection purpose within one administrative domain.

To summarize, the problem statement is that the current sub-path maintenance based on a hierarchical LSP (SPME) is problematic for pre-configuration in terms of increasing bandwidth by label stacking and managing objects by layer stacking and address management. A on-demand/temporal configuration of SPME is one of the possible approaches for minimizing the impact of these issues. However, the current method is unfavorable because the temporal configuration for monitoring can change the condition of the original monitored transport path(and disrupt the in-service customer traffic). From the perspective of monitoring in transport network operation, a solution avoiding those issues or minimizing their impact is required. Another monitoring mechanism is therefore required that supports temporal and hitless path segment monitoring. Hereafter it is called on-demand hitless path segment monitoring (HPSM).

Note: The above sentence "and disrupt the in-service customer traffic" might need to be modified depending on the result of future discussion about (P'-2).

5. OAM functions using segment monitoring

OAM functions in which on-demand HPSM is required are basically limited to on-demand monitoring which are defined in OAM framework document [5], because those segment monitoring functions are used to locate the fault/degraded point or to diagnose the status for detailed analyses, especially when a problem occurred. In other words, the characteristic of "on-demand" is generally temporal for maintenance operation. Conversely, this could be a good reason that operations should not be based on pre-configuration and pre-design.

Packet loss and packet delay measurements are OAM functions in which hitless and temporal segment monitoring are strongly required because these functions are supported only between end points of a transport path. If a fault or defect occurs, there is no way to locate the defect or degradation point without using the segment monitoring function. If an operator cannot locate or narrow the cause of the fault, it is quite difficult to take prompt action to solve the problem. Therefore, on-demand HPSM for packet loss and packet delay measurements are indispensable for transport network operation.

Regarding other on-demand monitoring functions path segment monitoring is desirable, but not as urgent as for packet loss and packet delay measurements.

Regarding out-of-service on-demand monitoring functions, such as diagnostic tests, there seems no need for HPSM. However, specific segment monitoring should be applied to the OAM function of diagnostic test, because SPME doesn't meet network objective (2) in section 3. See section 6.3.

Note:

The solution for temporal and hitless segment monitoring should not be limited to label stacking mechanisms based on pre-configuration, such as PST/TCM(label stacking), which can cause the issues (P-1) and (P-2) described in Section 4.

The solution for HPSM has to cover both per-node model and per-interface model which are specified in [5].

6. Further consideration of requirements for enhanced segment monitoring

6.1. Necessity of on-demand single-level monitoring

The new segment monitoring function is supposed to be applied mainly for diagnostic purpose on-demand. We can differentiate this monitoring from the proactive segment monitoring as on-demand multi-level monitoring. The most serious problem at the moment is that there is no way to localize the degradation point on a path without changing the conditions of the original path. Therefore, as a first step, single layer segment monitoring not affecting the monitored path is required for a new on-demand and hitless segment monitoring function.

A combination of multi-level and simultaneous monitoring is the most powerful tool for accurately diagnosing the performance of a transport path. However, considering the substantial benefits to operators, a strict monitoring function which is required in such as a test environment of a laboratory does not seem to be necessary in the field. To summarize, on-demand and in-service (hitless) single-level segment monitoring is required, on-demand and in-service multi-level segment monitoring is desirable. Figure 2 shows an example of a multi-level on-demand segment monitoring.

```
 ---     ---     ---     ---     ---
|   |   |   |   |   |   |   |   |   |
| A |   | B |   | C |   | D |   | E |
 ---     ---     ---     ---     ---
 MEP                             MEP <= ME of a transport path
   +-----------------------------+   <= End-to-end monitoring
         *-------------------*       <= segment monitoring level1
           *-------------*           <= segment monitoring level2
                 *-*                 <= segment monitoring level3
```

Figure 2 : An Example of a multi-level on-demand segment monitoring

6.2. Necessity of on-demand monitoring independent from end-to-end proactive monitoring

As multi-level simultaneous monitoring only for on-demand new path segment monitoring was already discussed in section6.1, next we consider the necessity of simultaneous monitoring of end-to-end current proactive monitoring and new on-demand path segment monitoring. Normally, the on-demand path segment monitoring is configured in a segment of a maintenance entity of a transport path. In this environment, on-demand single-level monitoring should be done without disrupting pro-active monitoring of the targeted end-to-end transport path.

If operators have to disable the pro-active monitoring during the on-demand hitless path segment monitoring, the network operation system might miss any performance degradation of user traffic. This kind of inconvenience should be avoided in the network operations.

Accordingly, the on-demand single lavel path segment monitoring is required without changing or interfering the proactive monitoring of the original end-to-end transport path.

```
 ---     ---     ---     ---     ---
|   |   |   |   |   |   |   |   |   |
| A |   | B |   | C |   | D |   | E |
 ---     ---     ---     ---     ---
 MEP                             MEP <= ME of a transport path
   +-----------------------------+   <= Proactive E2E monitoring
         *-------------------*       <= On-demand segment monitoring
```

Figure 3 : Independency between proactive end-to-end monitoring and on-demand segment monitoring

6.3. Necessity of arbitrary segment monitoring

The main objective of on-demand segment monitoring is to diagnose the fault points. One possible diagnostic procedure is to fix one end point of a segment at the MEP of a transport path and change progressively the length of the segment in order. This example is shown in Fig. 4. This approach is considered as a common and realistic diagnostic procedure. In this case, one end point of a segment can be anchored at MEP at any time.

Other scenarios are also considered, one shown in Fig. 5. In this case, the operators want to diagnose a transport path from a transit node that is located at the middle, because the end nodes(A and E) are located at customer sites and consist of cost effective small box in which a subset of OAM functions are supported. In this case, if one end point and an originator of the diagnostic packet are limited to the position of MEP, on-demand segment monitoring will be ineffective because all the segments cannot be diagnosed (For example, segment monitoring 3 in Fig.5 is not available and it is not possible to localize the fault point).

```
    ---     ---     ---     ---     ---
   |   |   |   |   |   |   |   |   |   |
   | A |   | B |   | C |   | D |   | E |
    ---     ---     ---     ---     ---
    MEP                             MEP <= ME of a transport path
      +-----------------------------+   <= Proactive E2E monitoring
      *-----*                        <= 1st On-demand segment monitoring
      *-------*                      <= 2nd On-demand segment monitoring
      *------------*                 <= 3rd On-demand segment monitoring
           |
           |
      *----------------------*       <= 6th On-demand segment monitoring
      *-----------------------------*<= 7th On-demand segment monitoring
```

Figure 4 : One possible procedure to localize a fault point by sequential on-demand segment monitoring

Accordingly, on-demand monitoring of arbitrary segments is mandatory in the case in Fig. 5. As a result, on-demand HSPM should be set in an arbitrary segment of a transport path and diagnostic packets should be inserted from at least any of intermediate maintenance points of the original ME.

```
            ---     ---     ---
    ---    |   |   |   |   |   |    ---
   | A |   | B |   | C |   | D |   | E |
    ---     ---     ---     ---     ---
    MEP                             MEP <= ME of a transport path
      +-----------------------------+   <= Proactive E2E monitoring
      *-----*                        <= On-demand segment monitoring 1
            *-----------------------*<= On-demand segment monitoring 2
            *---------*              <= On-demand segment monitoring 3
```

Figure 5 : Example where on-demand monitoring has to be configured in arbitrary segments

6.4. Fault during HPSM in case of protection

Node or link failures may occur during the HPSM is activated. In that case, the hitless path segment monitoring function should be suspended immediately and must not continue the monitoring on a new protected or restored path when a protection or restoration for the fault path is available. Therefore a solution of HPSM should avoid such a situation that a target node of the hitless segment monitoring is changed to unintended node when failures occur on the segment.

Fig.6 and Fig.7 exemplify one of the examples that should be avoided. However, this example is just for clarification of the problem that should be avoided. It does not intend to restrict any solution for meeting the requirements of HPSM. Protection scenario A is shown in figure 6. In this scenario, a working LSP and a protection LSP are separately set, in other words as independent LSPs. HPSM is set between A and E. Therefore, considering the case that a fault happens between B and C, the HPSM doesn't continue in a protected path. As a result, there is no issue.

```
A - B -- C -- D - E - F
     \       /
      G - H

Where:

- working LSP: A-B-C-D-E-F
- protection LSP: A-B-G-H-D-E-F
- HPSM: A-E
---------------
```

Figure 6 : Protection scenario A having no issue when a fault happens on HPSM

On the other hand, figure 7 shows a scenario where only a portion of a transport path has different label assignments (sub-paths). In this case, when a fault condition is identified on working sub-path B-C-D, the sub-path is switched to protection sub-path B-G-H-D. As a result, the target node of HPSM changes from E to D due to the difference of hop counts between a route of working path(ABCDE: 4 hops) and that of protection path(ABGHDE: 5 hops), because the forwarding and processing of HPSM OAM packets depend only on TTL value of MPLS label header. In this case, some additional mechanisms to notify the fault on working path to the source of HPSM may be necessary to suspend the monitoring.

```
     A - B -- C -- D - E - F
           \       /
            G - H

   - e2e LSP: A-B...D-E-F
   - working sub-path: B-C-D
   - protection sub-path: B-G-H-D
   - HPSM: A-E
   ---------------
```

Figure 7 : Protection scenario B having an issue when a fault happens on HPSM

6.5. Consideration of maintenance point for HPSM

An intermediate maintenance point supporting the HPSM has to be able to generate and inject OAM packets. Although maintenance points for the HPSM do not necessarily have to coincide with MIPs or MEPs in terms of the architecture definition, the same identifier for MIPs or MEPs could be applied to maintenance points of the HPSM.

7. Summary

An enhanced monitoring mechanism is required to support temporal and hitless segment monitoring which meets the two network objectives mentioned in Section 3 of this document that are described also in section 3.8 of [5].
The enhancements should minimize the issues described in Section 4, i.e., P-1, P-2, P'-1(and P'-2), to meet those two network objectives.

The solution for the temporal and hitless segment monitoring has to cover both per-node model and per-interface model which are specified in [5]. In addition, the following requirements should be considered for an enhanced temporal and hitless path segment monitoring function:

- "On-demand and in-service" single level segment should be done without changing or interfering any condition of pro-active monitoring of an original ME of a transport path.

- On-demand and in-service segment monitoring should be able to be set in an arbitrary segment of a transport path.

The temporal and hitless segment monitoring solutions is applicable to and needs to support several on-demand OAM functions, as follows: Mandatory: Packet Loss Measurement and Packet Delay Measurement

Optional: Connectivity Verification, Diagnostic Tests (Throughput test), and Route Tracing.

8. Security Considerations

This document does not by itself raise any particular security considerations.

9. IANA Considerations

There are no IANA actions required by this draft.

10. References

10.1. Normative References

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10.2. Informative References

None

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This document was prepared using 2-Word-v2.0.template.dot.

Authors' Addresses

Alessandro D'Alessandro
Telecom Italia
Email: alessandro.dalessandro@telecomitalia.it

Manuel Paul
Deutsche Telekom
Email: Manuel.Paul@telekom.de

Satoshi Ueno
NTT Communications
Email: satoshi.ueno@ntt.com

Yoshinori Koike
NTT
Email: koike.yoshinori@lab.ntt.co.jp