                 Temporal and hitless path segment monitoring
                 draft-ietf-mpls-tp-temporal-hitless-psm-06.txt

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.

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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 RFC 5860 [RFC5860],
   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
   RFC 6371 [RFC6371], 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 RFC
   6371 [RFC6371]. Moreover, this document explains detailed
   requirements on the new temporal and hitless segment monitoring
   function which are not covered in RFC 6371 [RFC6371].

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 [RFC2119].

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 RFC 6371 [RFC6371].

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 [RFC 5921](#) [[RFC5921](#)]. 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) [RFC 3031](#) [[RFC3031](#)] 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 RFC 5921 [RFC5921]. 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 RFC 6371 [RFC6371].

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'
```
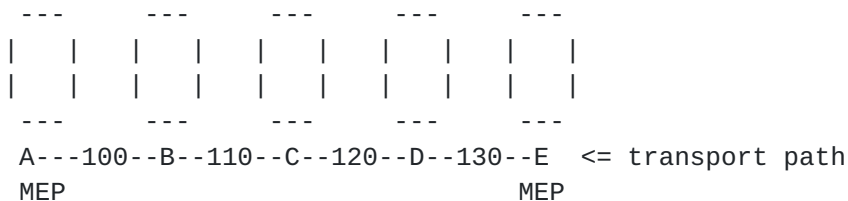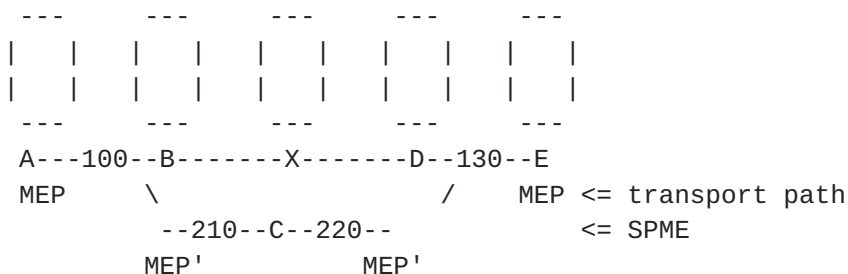
                  Figure 1: An Example of a SPME setting

Problem (P'-2) was not fully discussed, although the make-before-
break procedure in the survivability document RFC 6371 [RFC6372]
seemingly supports the hitless configuration for monitoring according
to the framework document RFS 5921 [RFC5921]. 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 RFC 6371 [RFC6371], 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 RFC 6371 [RFC6371].

6. **Further consideration of requirements for enhanced segmentmonitoring**

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 level path segment monitoring is
required without changing or interfering the proactive monitoring of
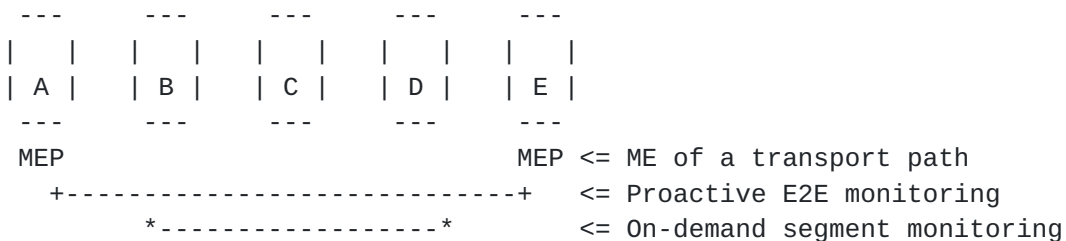the original end-to-end transport path.

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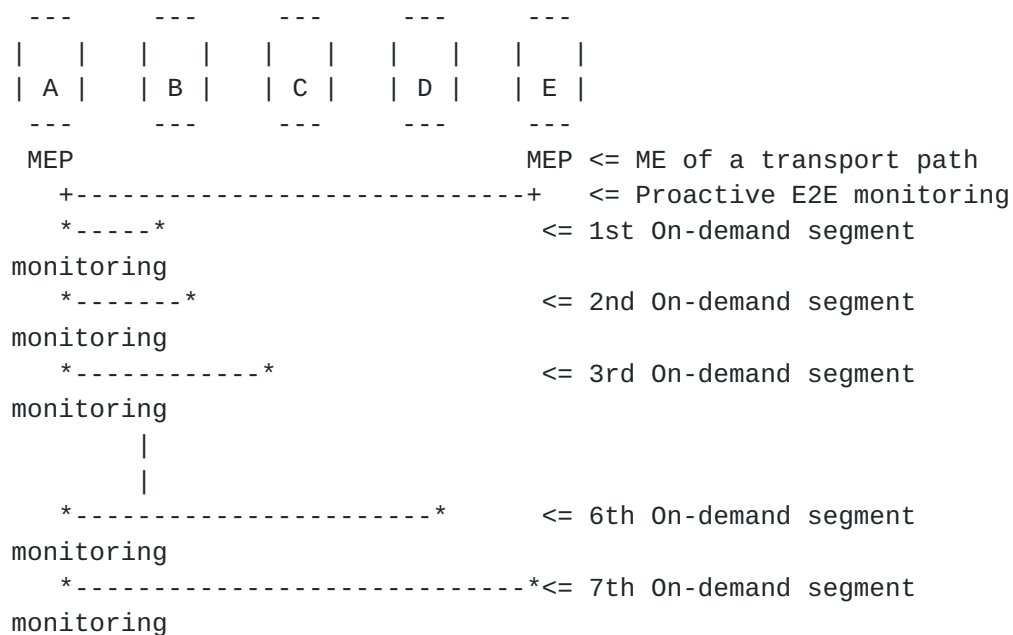
      Figure 4: One possible procedure to localize a fault point by
                 sequential on-demand segment monitoring

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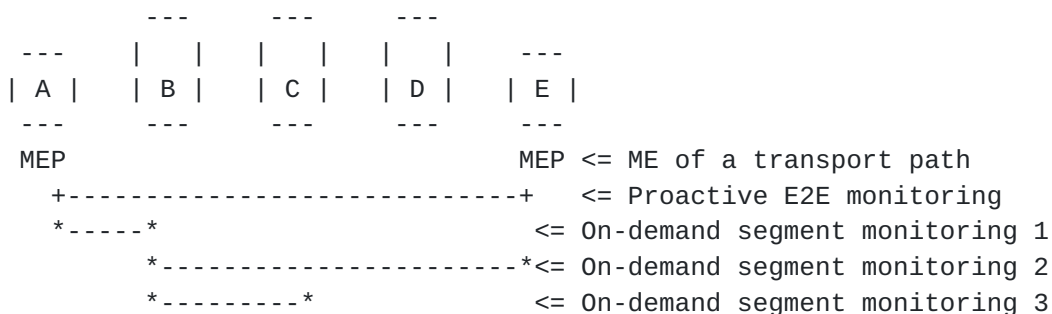
      Figure 5: Example where on-demand monitoring has to be configured in
                           arbitrary segments

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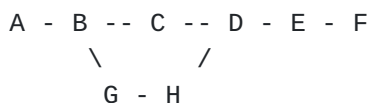
      A - B -- C -- D - E - F
           \   /
            G - H

      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 HPSMs

   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
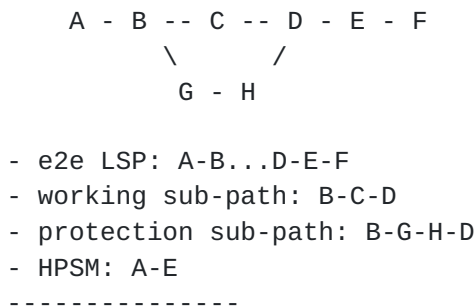   necessary to suspend the monitoring.

```
        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 RFC 6371 [RFC6371].

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 RFC 6371 [RFC6371]. In addition, the following requirements
should be considered for an enhanced temporal and hitless path
segment monitoring function:

o "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.

o 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

The security considerations defined for RFC 6378 apply to this
document as well. As this is simply a re-use of RFC 6378, there are
no new security considerations.

9. IANA Considerations

There are no requests for IANA actions in this document.

Note to the RFC Editor - this section can be removed before
publication.

10. Acknowledgements

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Authors' Addresses

   Alessandro D'Alessandro
   Telecom Italia

   Email: alessandro.dalessandro@telecomitalia.it

   Loa Andersson
   Huawei Technologies

   Email: loa@mail01.huawei.com

   Manuel Paul
   Deutsche Telekom

   Email: Manuel.Paul@telekom.de

   Satoshi Ueno
   NTT

   Email: satoshi.ueno@ntt.com

   Kaoru Arai
   NTT

   Email: arai.kaoru@lab.ntt.co.jp

   Yoshinori Koike
   NTT

   Email: koike.yoshinori@lab.ntt.co.jp