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Enhanced path segment monitoring  
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## Abstract

The MPLS transport profile (MPLS-TP) has been standardized to enable carrier-grade packet transport and to complement converged packet network deployments. The most attractive features of MPLS-TP are the OAM functions. These functions enable maintenance tools that may be exploited by network operators and service providers for fault location, survivability, performance monitoring, in-service and out-of-service measurements.

One of the most important mechanisms that is common for transport network operation is fault localisation. 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 activated only between end points. However, the current approach defined for MPLS-TP of segment monitoring has some drawbacks. This document elaborates on the problem statement for the Sub-path Maintenance Elements (SPMEs) which provide monitoring of a segment of a set of transport paths (LSPs or MS-PWs). Based on the identified problems, this document provides considerations for the specification of new requirements to consider a new improved mechanism for hitless transport path segment monitoring to be named Enhanced Path Segment Monitoring (EPSM).

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Enhanced path segment monitoring

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[1.](#) Introduction

A packet transport network enables carriers and service providers to use network resources efficiently. It reduces operational complexity and provides carrier-grade network operation. Appropriate maintenance functions that support fault location, survivability, pro-active performance monitoring, pre-service and in-service measurements, are essential to ensure the quality of service and the reliability of a network. They are essential in transport networks and have evolved along with PDH, ATM, SDH and OTN.

Similar to legacy technologies, MPLS-TP also does not scale when an arbitrary number of OAM functions is enabled.

According to the MPLS-TP OAM requirements [RFC 5860](#) [[RFC5860](#)], mechanisms MUST be available for alerting a service provider of a fault or defect that affects 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 fact by using end-to-end OAM monitoring, an operator will not be able to localize a fault or service degradation accurately.

Thus, a dedicated segment monitoring function that can focus on a specific segment of a transport path and can provide a detailed analysis 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 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 for segment monitoring, following up the description in [RFC 6371](#) [[RFC6371](#)]. This document also provides additional detailed requirements for a new temporary and hitless segment monitoring function which is 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

ATM - Asynchronous Transfer Mode

EPSM - Enhanced 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

PDH - Plesiochronous Digital Hierarchy

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 segment monitoring

There are two network objectives for MPLS-TP segment monitoring 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.

## [4.](#) Problem Statement

The Sub-Path Maintenance Element (SPME) function is defined in [RFC 5921](#) [[RFC5921](#)]. It is used to monitor, protect, and/or manage segments of transport paths, such as LSPs in MPLS-TP networks. The SPME is defined between the edges of the segment of a transport path that needs to be monitored, protected, or managed. This SPME is created by stacking the shim header (MPLS header) according to [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 a per-node model.

This method has the following drawbacks that impact the operation costs:

(P-1) It lowers the bandwidth efficiency.

(P-2) It increases network management complexity, because a new sublayer and new MEPs and MIPs have to be configured for the SPME.

Problem (P-1) is caused by the shim headers stacking that increases the overhead.

Problem (P-2) is related to an identifier management issue. In the case of label stacking the identification of each sub-layer is required for segment monitoring in a MPLS-TP network. When SPME is applied for on-demand OAM functions in MPLS-TP networks in a similar manner as Tandem Connection Monitoring (TCM) in the Optical Transport Networks (OTN) and Ethernet transport networks, a rule for operationally differentiating those SPME/TCMs will be required; at least within an administrative domain. This forces operators to create an additional permanent layer identification policy that will only be used for temporary path segment monitoring. Additionally, from the perspective of operation, increasing the number of managed addresses and managed layers is not desirable in view of keeping the transport networks as simple as possible. Reducing the number of managed identifiers and managed sub-layers should be the fundamental objective in designing the architecture.

The analogy for SPME in legacy transport networks is TCM, which is on-demand and does not affect the transport path.

Also, using the currently defined methods, temporary setting of SPMEs causes the following problems due to additional label stacking:

(P-3) The original condition of the transport path is affected by changing the length of MPLS frames and changing the value of exposed label.

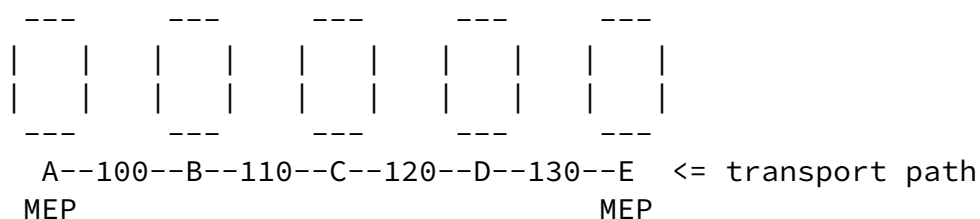
(P-4) The client traffic over a transport path is disrupted when the SPME is configured on-demand.

Problem (P-3) impacts network objective (2) in [Section 3](#). The monitoring function should monitor the status without changing any conditions of the targeted, to be monitored, segment or 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. And this differs from the original data plane conditions. When the conditions of the transport path change, the measured values or observed data will also change and

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.

Figure 1 shows an example of SPME settings. In the figure, "X" is the label value of the original transport 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 well as the values of the stacked labels. As shown in Figure 1, SPME changes both the length of MPLS frames and the label value(s). This means that it is no longer monitoring the original transport path but it is monitoring a different path. In particular, performance monitoring measurements (e.g. Delay Measurement and Packet Loss Measurement) are sensitive to these changes.

(Before SPME settings)



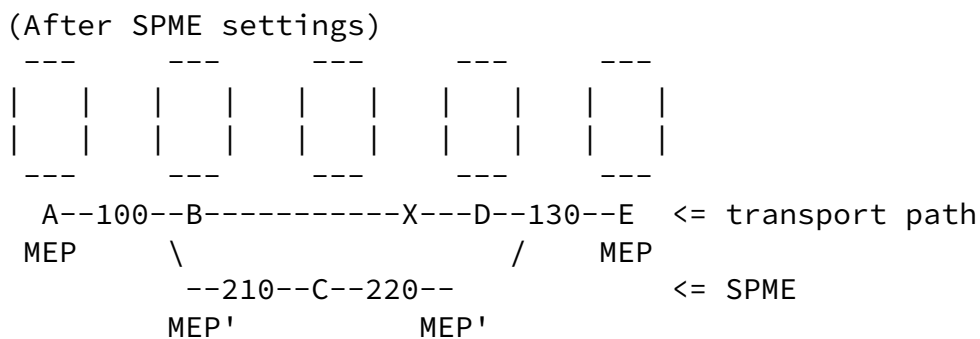


Figure 1: An Example of a SPME settings

Problem (P-4) can be avoided if the operator sets SPMEs in advance and maintains it until the end of life of a transport path, which is neither temporary nor on-demand. Furthermore SPMEs 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 SPME shown in Figure 1, even if SPMEs are pre-configured.

Although the make-before-break procedure in the survivability document [RFC 6372](#) [[RFC6372](#)] seemingly supports the hitless configuration for monitoring according to the framework document [RFC 5921](#) [[RFC5921](#)], the reality is that configuration of an SPME is impossible without violating network objective (2) in [Section 3](#). These concerns are described in [section 3.8 of RFC 6371](#) [[RFC6371](#)].

Additionally, the make-before-break approach might not be usable in the static model without a control plane. This is because the make-before-break is a restoration function based on a control plane. Consequently the management systems should support SPME creation and coordinated traffic switching from original transport path to the SPME.

Other potential risks are also envisaged. Setting up a temporary 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



within the monitored segment can not be identified 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 reverse of this situation is also possible, e.g., an incorrect or unexpected treatment of SPME labels can result in false detection of a fault where no problem existed originally.

The utilisation 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. The SPME monitoring function is mainly important for protecting bundles of transport paths and carriers' carrier solutions 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 the bandwidth by label stacking and increasing the number of managing objects by layer stacking and address management. An on-demand/temporary configuration of SPME is one of the possible approaches for minimizing the impact of these issues. However, the current procedure is unfavorable because the temporary configuration for monitoring can change the condition of the original monitored transport 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 on-demand Enhanced Path Segment Monitoring (EPSM), supporting temporary and hitless path segment monitoring is proposed.

## 5. OAM functions supported in segment monitoring

OAM functions that may usefully be exploited across on-demand EPSM are basically the on-demand performance monitoring functions which are defined in OAM framework document [RFC 6371](#) [[RFC6371](#)]. Segment performance monitoring is used to verify the performance and hence the status of transport path segments. The "on-demand" attribute is generally temporary for maintenance operation.

Packet Loss and Packet Delay measurement are OAM functions strongly required in hitless and temporary segment monitoring because these functions are normally only supported at the end points 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.

Regarding out-of-service on-demand performance management functions (e.g. Throughput measurement) there seems no need for EPSM. However, OAM functions specifically designed for segment monitoring should be developed to satisfy network objective (2) described in [Section 3](#).

Finally, the solution for EPSM has to cover both the per-node model and the per-interface model as specified in [RFC 6371](#) [[RFC6371](#)].

## [6](#). Requirements for enhanced segment monitoring

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

### [6.1](#). Non-intrusive segment monitoring

One of the major problems of legacy SPME highlighted in [section 4](#) is that it may not monitor the original transport path and it could disrupt service traffic when set-up on demand.

(M1) EPSM must not change the original condition of transport path (e.g. must not change the length of MPLS frames, the exposed label values, etc.)

(M2) EPSM must be provisioned on-demand without traffic disruption.

### [6.2](#). Single and multiple level monitoring

The new enhanced segment monitoring function is supposed to be applied mainly for on-demand diagnostic purposes. We can differentiate this monitoring from the existing proactive segment monitoring by referring to it as on-demand multi-level monitoring. Currently 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, 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 segment monitoring is the most powerful

tool for accurately diagnosing the performance of a transport path. However, in the field, a single level approach may be enough.

(M3) Single-level segment monitoring is required

(O1) Multi-level segment monitoring is desirable

Figure 2 shows an example of multi-level on-demand segment monitoring.

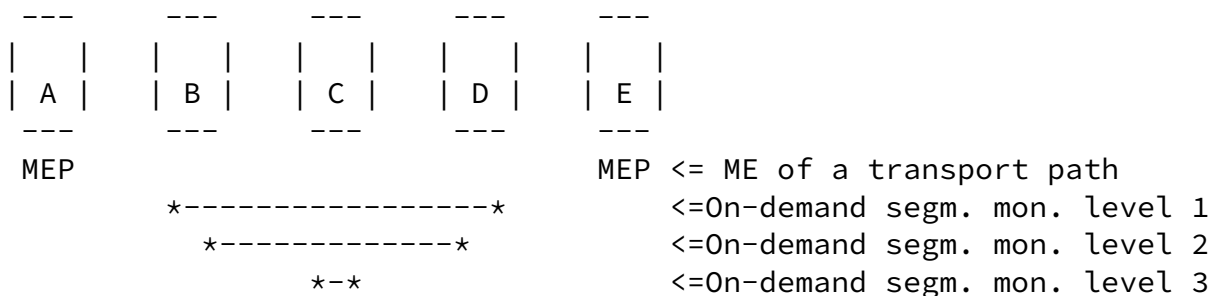


Figure 2: Example of multi-level on-demand segment monitoring

### 6.3. EPSM and end-to-end proactive monitoring independence

The need for simultaneously using existing end-to-end proactive monitoring and the enhanced on-demand path segment monitoring is considered. 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 pro-active monitoring of the targeted end-to-end transport path to avoid affecting user traffic performance monitoring.

Therefore:

(M4) EPSM shall be configured without changing or interfering with the already in place end-to-end pro-active monitoring of the transport path.

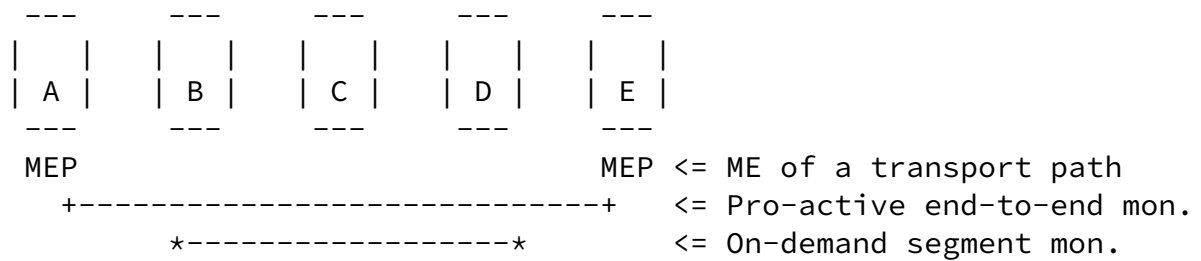
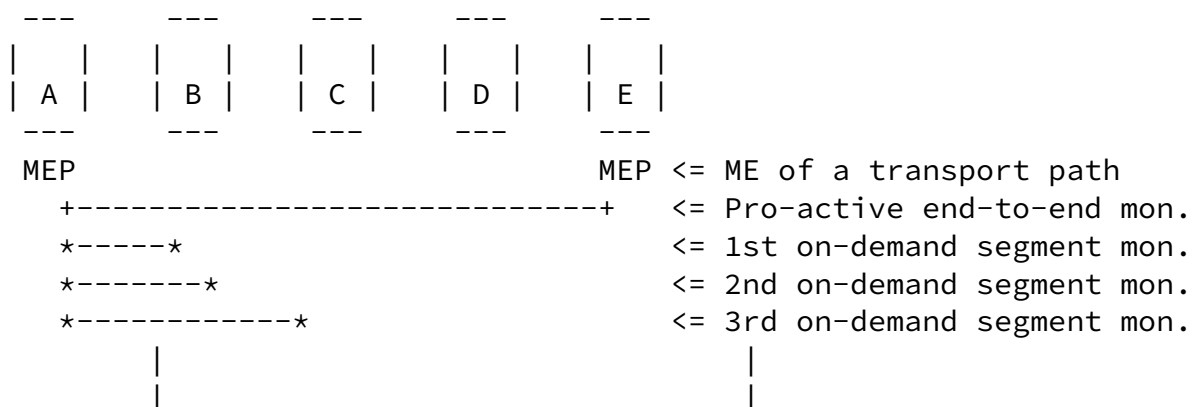


Figure 3: Independency between proactive end-to-end monitoring and on-demand segment monitoring

#### 6.4. Arbitrary segment monitoring

The main objective for enhanced on-demand segment monitoring is to diagnose the fault locations. A possible realistic diagnostic procedure is to fix one end point of a segment at the MEP of the transport path under observation and change progressively the length of the segments. This example is shown in Figure 4.



```

*-----*          <= 6th on-demand segment mon.
*-----*          <= 7th on-demand segment mon.

```

Figure 4: A procedure to localize a defect by consecutive on-demand segment monitoring

Another possible scenario is depicted in Figure 5. 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 cost effective 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 segment monitoring will be ineffective because not all the segments can be diagnosed (e.g. segment monitoring 3 in Figure 5 is not

available and it is not possible to determine the fault location exactly).

Therefore:

(M5) it shall be possible to provision EPSM on an arbitrary segment of a transport path and diagnostic packets should be inserted/terminated at any of intermediate maintenance points of the original ME.

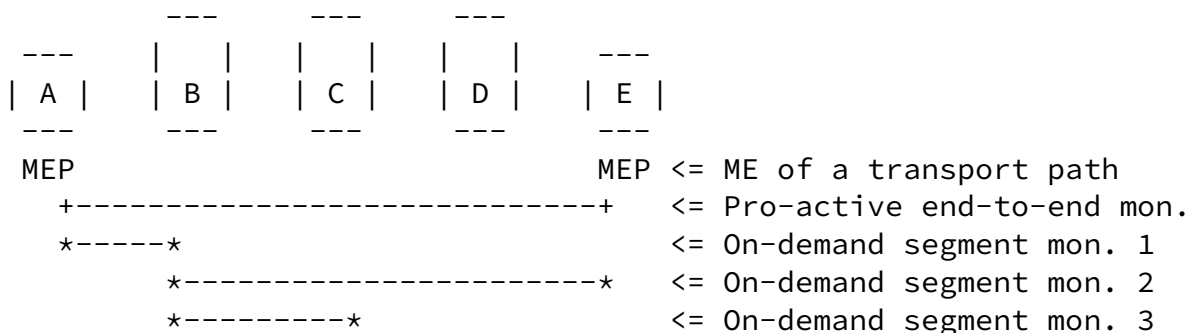


Figure 5: ESPM configured at arbitrary segments

### 6.5. Fault while EPSM is operational

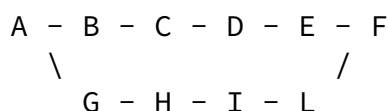
Node or link failures may occur while EPSM is active. In this case, if no resiliency mechanism is set-up on the subtended transport path, there is no particular requirement for the EPSM function. If the transport path is protected, the EPSM function should be terminated to avoid monitoring a new segment when a protection or restoration path is active.

Therefore:

(M6) the EPSM function should avoid monitoring an unintended segment when one or more failures occur

The following examples are provided for clarification only and they are not intended to restrict any solution for meeting the requirements of EPSM.

Protection scenario A is shown in figure 6. In this scenario a working LSP and a protection LSP are set-up. EPSM is activated between nodes A and E. When a fault occurs between nodes B and C, the operation of EPSM is not affected by the protection switch and continues on the active LSP path. As a result requirement (M6) is satisfied.



Where:

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

Figure 6: Protection scenario A

Protection scenario B is shown in figure 7. 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 EPSM 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). As a result requirement (M6) is not satisfied.

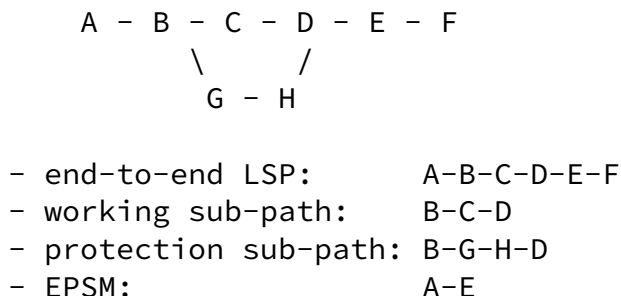


Figure 7: Protection scenario B

#### [6.6.](#) EPSM maintenance points

An intermediate maintenance point supporting the EPSM function has to be able to generate and inject OAM packets. However, maintenance points for the EPSM do not necessarily have to coincide with MIPs or MEPs defined in the architecture.

Therefore:

(M7) The same identifiers for MIPs and/or MEPs should be applied to EPSM maintenance points

#### [7.](#) Summary

An enhanced path segment monitoring (EPSM) mechanism is required to provide temporary and hitless segment monitoring. It shall meet the two network objectives described in [section 3.8 of RFC 6371](#) [RFC6371] and repeated in [Section 3](#) of this document.

The enhancements should minimize the problems described in [Section 4](#), i.e., (P-1), (P-2), (P-3) and (P-4).

The solution for the temporary and hitless segment monitoring has to

cover both the per-node model and the per-interface model specified in [RFC 6371](#) [[RFC6371](#)].

The temporary and hitless segment monitoring solutions shall support on-demand Packet Loss Measurement and Packet Delay Measurement functions and optionally other performance monitoring and fault management functions (e.g. Throughput measurement, Delay variation measurement, Diagnostic test, etc.).

## [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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