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Path Computation Element Communication Protocol (PCEP) Extensions to Enable IFIT

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Abstract

This document defines PCEP extensions to distribute In-situ Flow Information Telemetry (IFIT) information. So that IFIT behavior can be enabled automatically when the path is instantiated. In-situ Flow Information Telemetry (IFIT) refers to network OAM data plane on-path telemetry techniques, in particular the most popular are In-situ OAM (IOAM) and Alternate Marking. The IFIT attributes here described can be generalized for all path types but the application to Segment Routing (SR) is considered in this document. The SR policy is a set of candidate SR paths consisting of one or more segment lists and necessary path attributes. It enables instantiation of an ordered list of segments with a specific intent for traffic steering.

Requirements Language

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].

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1. Introduction

In-situ Flow Information Telemetry (IFIT) refers to network OAM data plane on-path telemetry techniques, including In-situ OAM (IOAM) [I-D.ietf-ippm-ioam-data] and Alternate Marking [RFC8321]. It can provide flow information on the entire forwarding path on a per-packet basis in real time.

An automatic network requires the Service Level Agreement (SLA) monitoring on the deployed service. So that the system can quickly detect the SLA violation or the performance degradation, hence to change the service deployment.

This document defines extensions to PCEP to distribute paths carrying IFIT information. So that IFIT behavior can be enabled automatically when the path is instantiated.

RFC 5440 [RFC5440] describes the Path Computation Element Protocol (PCEP) as a communication mechanism between a Path Computation Client (PCC) and a Path Computation Element (PCE), or between a PCE and a PCE.

RFC 8231 [RFC8231] specifies extensions to PCEP to enable stateful control and it describes two modes of operation: passive stateful PCE and active stateful PCE. Further, RFC 8281 [RFC8281] describes the setup, maintenance, and teardown of PCE-initiated LSPs for the stateful PCE model, while RFC 8733 [RFC8733] is focused on the active stateful PCE, where the LSPs are controlled by the PCE.

When a PCE is used to initiate paths using PCEP, it is important that the head end of the path also understands the IFIT behavior that is intended for the path. When PCEP is in use for path initiation it makes sense for that same protocol to be used to also carry the IFIT attributes that describe the IOAM or Alternate Marking procedure that needs to be applied to the data that flow those paths.

The PCEP extension defined in this document allows to signal the IFIT capabilities. In this way IFIT methods are automatically activated and running. The flexibility and dynamicity of the IFIT applications are given by the use of additional functions on the controller and on the network nodes, but this is out of scope here.

The Use Case of Segment Routing (SR) is discussed considering that IFIT methods are becoming mature for Segment Routing over the MPLS data plane (SR-MPLS) and Segment Routing over IPv6 data plane (SRv6). In this way SR policy native IFIT can facilitate the closed loop control and enable the automation of SR service.

Segment Routing (SR) policy [I-D.ietf-spring-segment-routing-policy] is a set of candidate SR paths consisting of one or more segment lists and necessary path attributes. It enables instantiation of an ordered list of segments with a specific intent for traffic steering.

It is to be noted the companion document [I-D.qin-idr-sr-policy-ifit] that proposes the BGP extension to enable IFIT methods for SR policy.

2. PCEP Extensions for IFIT Attributes

This document is to add IFIT attribute TLVs as PCEP Extensions. The following sections will describe the requirement and usage of different IFIT modes, and define the corresponding TLV encoding in PCEP.

The IFIT attributes here described can be generalized and included as TLVs carried inside the LSPA (LSP Attributes) object in order to be applied for all path types, as long as they support the relevant data plane telemetry method. IFIT TLVs are o ptional and can be taken into account by the PCE during path computation. In general, the LSPA object is carried within a PCInitiate message or a PCRpt message.

In this document it is considered the case of SR Policy since IOAM and Alternate Marking are more mature especially for Segment Routing (SR) and for IPv6.

2.1. IFIT for SR Policies

RFC 8664 [RFC8664] and [I-D.ietf-pce-segment-routing-ipv6] specify extensions to the Path Computation Element Communication Protocol (PCEP) that allow a stateful PCE to compute and initiate Traffic-Engineering (TE) paths, as well as a Path Computation Client (PCC) to request a path subject to certain constraints and optimization criteria in SR networks both for SR-MPLS and SRv6.

IFIT attibutes, here defined as TLVs for the LSPA object, complement both RFC 8664 [RFC8664], [I-D.ietf-pce-segment-routing-ipv6] and [I-D.ietf-pce-segment-routing-policy-cp].

3. IFIT capability advertisement TLV

During the PCEP initialization phase, PCEP speakers (PCE or PCC) SHOULD advertise their support of IFIT methods (e.g. IOAM and Alternate Marking).

A PCEP speaker includes the IFIT TLVs in the OPEN object to advertise its support for PCEP IFIT extensions.

RFC 8664 [RFC8664] and and [I-D.ietf-pce-segment-routing-ipv6] define a new Path Setup Type (PST) for SR and also define the SR-PCE-CAPABILITY sub-TLV. This document defined a new IFIT-CAPABILITY TLV, that is an optional TLV for use in the OPEN Object for IFIT attributes via PCEP capability advertisement.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Type                |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                              Flag                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fig. 1 IFIT-CAPABILITY TLV Format

Where:

Type: to be assigned by IANA.

Length: The Length field defines the length of the value portion in bytes as per RFC 5440 [RFC5440].

Flag: No flags are defined for this TLV in this document. Unassigned bits are considered reserved. They MUST be set to 0 on transmission and MUST be ignored on receipt.

Advertisement of the IFIT-CAPABILITY TLV implies support of IFIT methods (IOAM and/or Alternate Marking) as well as the objects, TLVs, and procedures defined in this document. It is worth mentioning that IOAM and Alternate Marking can be activated one at a time or can coexist; so it is possible to have only IOAM or only Alternate Marking enabled but they are recognized in general as IFIT capability.

4. IFIT Attributes TLV

The IFIT TLV provides the configurable knobs of the IFIT feature, and it can be included as an optional TLV in the LSPA object (as described in RFC 5440 [RFC5440]).

For a PCE-initiated LSP RFC 8281 [RFC8281], this TLV is included in the LSPA object with the PCInitiate message. For the PCC-initiated delegated LSPs, this TLV is carried in the Path Computation State Report (PCRpt) message in the LSPA object. This TLV is also carried in the LSPA object with the Path Computation Update Request (PCUpd) message to direct the PCC (LSP head-end) to make updates to IFIT attributes.

The TLV is encoded in all PCEP messages for the LSP if IFIT feature is enabled. The absence of the TLV indicates the PCEP speaker wishes to disable the feature. This TLV includes multiple IFIT-ATTRIBUTES sub-TLVs. The IFIT-ATTRIBUTES sub-TLVs are included if there is a change since the last information sent in the PCEP message. The default values for missing sub-TLVs apply for the first PCEP message for the LSP.

The format of the IFIT-ATTRIBUTES TLV is shown in the following figure:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Type              |           Length              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
//                              sub-TLVs                       //
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fig. 2 IFIT-ATTRIBUTES TLV Format

Where:

Type: to be assigned by IANA.

Length: The Length field defines the length of the value portion in bytes as per RFC 5440 [RFC5440].

Value: This comprises one or more sub-TLVs.

The following sub-TLVs are defined in this document:

Type	Len	Name
1	8	IOAM Pre-allocated Trace Option
2	8	IOAM Incremental Trace Option
3	12	IOAM Directly Export Option
4	4	IOAM Edge-to-Edge Option
5	4	Enhanced Alternate Marking

Fig. 3 Sub-TLV Types of the IFIT-ATTRIBUTES TLV

4.1. IOAM Sub-TLVs

In-situ Operations, Administration, and Maintenance (IOAM) [I-D.ietf-ippm-ioam-data] records operational and telemetry information in the packet while the packet traverses a path between two points in the network. In terms of the classification given in RFC 7799 [RFC7799] IOAM could be categorized as Hybrid Type 1. IOAM mechanisms can be leveraged where active OAM do not apply or do not offer the desired results.

For the SR use case, when SR policy enables IOAM, the IOAM header will be inserted into every packet of the traffic that is steered into the SR paths. Since this document aims to define the control plane, it is to be noted that a relevant document for the data plane is [I-D.ietf-ippm-ioam-ipv6-options] for Segment Routing over IPv6 data plane (SRv6).

4.1.1. IOAM Pre-allocated Trace Option Sub-TLV

The IOAM tracing data is expected to be collected at every node that a packet traverses to ensure visibility into the entire path a packet takes within an IOAM domain. The preallocated tracing option will create pre-allocated space for each node to populate its information.

The format of IOAM pre-allocated trace option Sub-TLV is defined as follows:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-------------------------------+-------------------------------+
|          Type=1               |           Length              |
+---------------------------------------------------------------+
|       Namespace ID            |           Rsvd1               |
+-------------------------------+-----------------------+-------+
|         IOAM Trace Type                       | Flags  | Rsvd2 |
+-----------------------------------------------+--------+-------+
```

Fig. 4 IOAM Pre-allocated Trace Option Sub-TLV

Where:

Type: 1 (to be assigned by IANA).

Length: the total length of the value field not including Type and Length fields.

Namespace ID: A 16-bit identifier of an IOAM-Namespace. The definition is the same as described in section 4.4 of [I-D.ietf-ippm-ioam-data].

IOAM Trace Type: A 24-bit identifier which specifies which data types are used in the node data list. The definition is the same as described in section 4.4 of [I-D.ietf-ippm-ioam-data].

Flags: A 4-bit field. The definition is the same as described in [I-D.ietf-ippm-ioam-flags] and section 4.4 of [I-D.ietf-ippm-ioam-data].

Rsvd1: A 16-bit field reserved for further usage. It MUST be zero.

Rsvd2: A 4-bit field reserved for further usage. It MUST be zero.

4.1.2. IOAM Incremental Trace Option Sub-TLV

The incremental tracing option contains a variable node data fields where each node allocates and pushes its node data immediately following the option header.

The format of IOAM incremental trace option Sub-TLV is defined as follows:

```
     0                   1                   2                   3
     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
    +-------------------------------+-------------------------------+
    |           Type=2              |             Length            |
    +---------------------------------------------------------------+
    |        Namespace ID           |             Rsvd1             |
    +-------------------------------+-----------------------+-------+
    |          IOAM Trace Type                      | Flags | Rsvd2 |
    +-----------------------------------------------+-------+-------+
```

Fig. 5 IOAM Incremental Trace Option Sub-TLV

Where:

Type: 2 (to be assigned by IANA).

Length: the total length of the value field not including Type and Length fields.

All the other fields definition is the same as the pre-allocated trace option Sub-TLV in the previous section.

4.1.3. IOAM Directly Export Option Sub-TLV

IOAM directly export option is used as a trigger for IOAM data to be directly exported to a collector without being pushed into in-flight data packets.

The format of IOAM directly export option Sub-TLV is defined as follows:

```
     0                   1                   2                   3
     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
    +-------------------------------+-------------------------------+
    |            Type=3             |         Length                |
    +---------------------------------------------------------------+
    |         Namespace ID          |             Flags             |
    +-------------------------------+---------------+---------------+
    |               IOAM Trace Type                 |      Rsvd     |
    +-----------------------------------------------+---------------+
    |                         Flow ID                               |
    +---------------------------------------------------------------+
```

Fig. 6 IOAM Directly Export Option Sub-TLV

Where:

Type: 3 (to be assigned by IANA).

Length: the total length of the value field not including Type and Length fields.

Namespace ID: A 16-bit identifier of an IOAM-Namespace. The definition is the same as described in section 4.4 of [I-D.ietf-ippm-ioam-data].

IOAM Trace Type: A 24-bit identifier which specifies which data types are used in the node data list. The definition is the same as described in section 4.4 of [I-D.ietf-ippm-ioam-data].

Flags: A 16-bit field. The definition is the same as described in section 3.2 of [I-D.ietf-ippm-ioam-direct-export].

Flow ID: A 32-bit flow identifier. The definition is the same as described in section 3.2 of [I-D.ietf-ippm-ioam-direct-export].

Rsvd: A 4-bit field reserved for further usage. It MUST be zero.

4.1.4. IOAM Edge-to-Edge Option Sub-TLV

The IOAM edge to edge option is to carry data that is added by the IOAM encapsulating node and interpreted by IOAM decapsulating node.

The format of IOAM edge-to-edge option Sub-TLV is defined as follows:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-------------------------------+-------------------------------+
|          Type=4               |           Length              |
+---------------------------------------------------------------+
|        Namespace ID           |         IOAM E2E Type         |
+-------------------------------+-------------------------------+
```

Fig. 7 IOAM Edge-to-Edge Option Sub-TLV

Where:

Type: 4 (to be assigned by IANA).

Length: the total length of the value field not including Type and Length fields.

Namespace ID: A 16-bit identifier of an IOAM-Namespace. The definition is the same as described in section 4.6 of [I-D.ietf-ippm-ioam-data].

IOAM E2E Type: A 16-bit identifier which specifies which data types are used in the E2E option data. The definition is the same as described in section 4.6 of [I-D.ietf-ippm-ioam-data].

4.2. Enhanced Alternate Marking Sub-TLV

The Alternate Marking [RFC8321]technique is an hybrid performance measurement method, per RFC 7799 [RFC7799] classification of measurement methods. Because this method is based on marking consecutive batches of packets. It can be used to measure packet loss, latency, and jitter on live traffic.

For the SR use case, since this document aims to define the control plane, it is to be noted that a relevant document for the data plane is [I-D.ietf-6man-ipv6-alt-mark] for Segment Routing over IPv6 data plane (SRv6).

The format of Enhanced Alternate Marking (EAM) Sub-TLV is defined as follows:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-------------------------------+-------------------------------+
|             Type=5            |             Length            |
+-------------------------------+-------+---------------+-------+
|            FlowMonID                  |     Period    | Rsvd  |
+---------------------------------------+---------------+-------+
```

Fig. 8 Enhanced Alternate Marking Sub-TLV

Where:

Type: 5 (to be assigned by IANA).

Length: the total length of the value field not including Type and Length fields.

FlowMonID: A 20-bit identifier to uniquely identify a monitored flow within the measurement domain. The definition is the same as described in section 5.3 of [I-D.ietf-6man-ipv6-alt-mark]. It is to be noted that PCE also needs to maintain the uniqueness of FlowMonID as described in [I-D.ietf-6man-ipv6-alt-mark].

Period: Time interval between two alternate marking period. The unit is second.

Rsvd: A 4-bit field reserved for further usage. It MUST be zero.

5. Example of operation

5.1. PCE Initiated SR Policy with single or multiple candidate-paths

A PCC or PCE sets the IFIT-CAPABILITY TLV in the Open message during the PCEP initialization phase to indicate that it supports the IFIT procedures.

1. For single candidate-path, PCE sends PCInitiate message, containing the SRPAG Association object ([I-D.ietf-pce-segment-routing-policy-cp]) and IFIT-ATTRIBUTES via LSPA TLVs. For multiple candidate-paths, PCE sends a separate PCInitiate message for every candidate path that it wants to create, or it sends multiple LSP objects within a single PCInitiate message. The SRPAG Association object ([I-D.ietf-pce-segment-routing-policy-cp]) is sent for every LSP in the PCInitiate message and the IFIT-ATTRIBUTES are sent as LSPA TLVs.

2. For single candidate-path, PCC uses the color, endpoint and preference from the SRPAG object to create a new candidate path. If no SR policy exists to hold the candidate path, then a new SR policy is created to hold the new candidate-path considering the IFIT LSPA TLVs too. For multiple candidate-paths, PCC creates multiple candidate paths under the same SR policy, identified by Color and Endpoint and also IFIT-ATTRIBUTES.

3. For both single candidate-path and multiple candidate-paths, PCC sends a PCRpt message back to the PCE to report the newly created Candidate Path. The PCRpt message contains the SRPAG Association object and IFIT-ATTRIBUTES information.

```
+-+-+                            +-+-+
|PCC|                            |PCE|
+-+-+                            +-+-+
  |                                |
  |<--PCInitiate-------------------|
  |                                |
  |---PCRpt----------------------->|
  |                                |
```

The procedure of enabling/disabling IFIT is simple, indeed the PCE can update the IFIT-ATTRIBUTES of the LSP by sending subsequent Path Computation Update Request (PCUpd) messages.

```
+-+-+                             +-+-+
|PCC|                             |PCE|
+-+-+                             +-+-+
  |                                 |
  |<--PCUpd-------------------------|
  |                                 |
  |---PCRpt------------------------>|
  |                                 |
```

6. IANA Considerations

This document defines the new IFIT-CAPABILITY TLV and IFIT-ATTRIBUTES TLV. IANA is requested to make the assignment from the "PCEP TLV Type Indicators" subregistry of the "Path Computation Element Protocol (PCEP) Numbers" registry as follows:

Value	Description	Reference
TBD1	IFIT-CAPABILITY	This document
TBD2	IFIT-ATTRIBUTES	This document

This document also specifies the IFIT-ATTRIBUTES sub-TLVs. IANA is requested to create an "IFIT-ATTRIBUTES Sub-TLV Types" subregistry within the "Path Computation Element Protocol (PCEP) Numbers" registry.

This document defines the following types:

Type	Description	Reference
0	Reserved	This document
1	IOAM Pre-allocated Trace Option	This document
2	IOAM Incremental Trace Option	This document
3	IOAM Directly Export Option	This document
4	IOAM Edge-to-Edge Option	This document
5	Enhanced Alternate Marking	This document
6-65535	Unassigned/Experimental Use	This document

7. Security Considerations

This document defines the new IFIT-CAPABILITY TLV and IFIT Attributes TLVs, which do not add any substantial new security concerns beyond those already discussed in RFC 8231 [RFC8231] and RFC 8281 [RFC8281] for stateful PCE operations.

8. Acknowledgements

The authors would like to thank Dhruv Doody for the precious inputs and suggestions.

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Appendix A.

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