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Zafar Ali  
George Swallow  
Clarence Filsfils  
Matt Hartley  
Ori Gerstel  
Gabriele Maria Galimberti  
Cisco Systems  
Kenji Kumaki  
KDDI Corporation  
Ruediger Kunze  
Deutsche Telekom AG  
Julien Meuric  
France Telecom Orange  
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Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Path  
Diversity using Exclude Routes

[draft-ietf-ccamp-lsp-diversity-01.txt](#)

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Internet Draft

[draft-ietf-ccamp-lsp-diversity-01.txt](#)

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#### Abstract

[RFC 4874](#) specifies methods by which route exclusions may be communicated during RSVP-TE signaling in networks where precise explicit paths are not computed by the LSP source node. This document specifies signaling for additional route exclusions based on Paths currently existing or expected to exist within the network.

#### 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](#)].

#### Table of Contents

<a href="#">1.</a>	Introduction .....	<a href="#">3</a>
<a href="#">2.</a>	RSVP-TE signaling extensions .....	<a href="#">5</a>
<a href="#">2.1.</a>	Terminology .....	<a href="#">5</a>
<a href="#">2.2.</a>	Path XRO Subobjects .....	<a href="#">5</a>
<a href="#">2.2.1.</a>	IPv4 Point-to-Point Path subobject .....	<a href="#">5</a>
<a href="#">2.2.2.</a>	IPv6 Point-to-Point Path subobject .....	<a href="#">9</a>
<a href="#">2.3.</a>	Processing rules for the Path XRO subobjects .....	<a href="#">10</a>
<a href="#">2.4.</a>	Path EXRS Subobject .....	<a href="#">13</a>
<a href="#">2.4.1.</a>	Processing Rules for the EXRS with Path subobject .....	<a href="#">14</a>
<a href="#">3.</a>	Security Considerations .....	<a href="#">14</a>
<a href="#">4.</a>	IANA Considerations .....	<a href="#">14</a>
<a href="#">4.1.</a>	New XRO subobject types .....	<a href="#">14</a>
<a href="#">4.2.</a>	New EXRS subobject types .....	<a href="#">15</a>

Internet Draft [draft-ietf-ccamp-lsp-diversity-01.txt](#)

[5. Acknowledgements .....](#)[15](#)  
[6. References .....](#)[15](#)  
    [6.1. Normative References .....](#)[15](#)  
    [6.2. Informative References .....](#)[16](#)

[1. Introduction](#)

Path diversity is a well-known requirement from Service Providers. Such diversity is required to ensure Label-Switched Path (LSPs) may be established without sharing resources, thus greatly reducing the probability of simultaneous connection failures.

When route computation for paths that need to be diverse is performed at the LSP's source node, this requirement can be met by a local decision at that node. However, there are scenarios when route computations are performed by remote nodes, there is a need for relevant diversity requirements to be communicated to those nodes. These include (but are not limited to):

- . LSPs with loose hops in the Explicit Route Object (ERO), e.g. inter-domain LSPs.
- . Generalized Multi-Protocol Label Switching (GMPLS) User-Network Interface (UNI) where route computation may be performed by the (server layer) core node [[RFC4208](#)];

[RFC4874] introduced a means of specifying nodes and resources to be excluded from a route, using the eXclude Route Object (XRO) and Explicit Exclusion Route Subobject (EXRS).

[RFC4874] facilitates the calculation of diverse routes for LSPs based on known properties of those paths including addresses of links and nodes traversed, and Shared Risk Link Groups (SRLGs) of traversed links. This requires that these properties of the path(s) from which diversity is required be known to the source node which initiates signaling. However, there are circumstances under which this may not be possible or desirable, including (but not limited to):

- . Exclusion of a path which does not originate, terminate or traverse the source node signaling the diverse LSP, in which

case the addresses and SRLGs of the path from which diversity is required are unknown to the source node.

- . Exclusion of a path which, while known at the source node of the diverse LSP, has incomplete or unavailable route information, e.g. due to confidentiality of the path

Internet Draft [draft-ietf-ccamp-lsp-diversity-01.txt](#)

attributes. In other words, the scenario in which the reference path is hosted by the source / requesting node but the properties required to construct an XRO object are not known to source / requesting node. Inter-domain and GMPLS overlay networks may present such restrictions.

- . If the source node knows the route of the reference path from which diversity is required, it can use this information to construct an XRO and send it in the path message during the signaling of a diverse LSP. However, if the route of the excluded path changes (e.g. due to re-optimization or failure in the network), the source node would need to change the diverse path to ensure that it remains diverse from the excluded path. It is preferable to have this decision made by the node that performed the path-calculation for the diverse path. For example, in the case of GMPLS-UNI, it is better to have such responsibility at the server layer as opposed to at the client layer so that the diversity requirements are transparent to the client layer. Furthermore, in all networking scenarios, if the node performing the route computation/ expansion is aware of the diversity requirements of the two paths, it may consider joint re-optimization of the diverse paths.

This document addresses such scenarios and defines procedures that may be used to exclude the route taken by a particular LSP, or the routes taken by all LSPs belonging to a single tunnel. Note that this diversity requirement is different from the diversity requirements of path protection where both the reference and diverse LSPs belong to the same tunnel. The diversity requirements considered in this document do not require that the paths in question belonging to the same tunnel or share the same source or destination node.

The means by which the node calculating or expanding the route of the signaled LSP discovers the route of the path(s) from which

the signaled LSP requires diversity are beyond the scope of this document.

This document addresses only the exclusion of point-to-point paths; point-to-multipoint paths will be addressed in a future version.

If mutually diverse routes are desired for two LSPs belonging to different tunnels, it is recommended that they be signaled with XRO LSP subobjects referencing each other. The processing rules specified in this document cover this case.

Internet Draft [draft-ietf-ccamp-lsp-diversity-01.txt](#)

## 2. RSVP-TE signaling extensions

This section describes the signaling extensions required to address the aforementioned requirements. Specifically, this document defines a new LSP subobject to be signaled in the EXCLUDE\_ROUTE object (XRO) and/ or Explicit Exclusion Route Subobject (EXRS) defined in [[RFC4874](#)]. Inclusion of the LSP subobject in any other RSVP object is not defined.

### 2.1. Terminology

In this document, the following terminology is adopted:

Excluded path: the path from which diversity is required.

Diverse LSP: the LSP being signaled with XRO/ EXRS containing the path subobject referencing the excluded path(s).

Processing node: the node performing a path-calculation involving an exclusion specified in an XRO or EXRS.

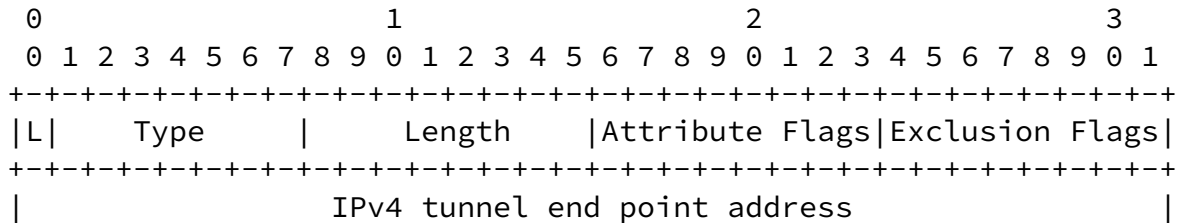
Destination node: in the context of an XRO, this is the destination of the LSP being signaled. In the context of an EXRS, the destination node is the last explicit node to which the loose hop is expanded.

Penultimate node: in the context of an XRO, this is the penultimate hop of the LSP being signaled. In the context of an EXRS, the penultimate node is the penultimate node of the loose hop undergoing expansion.

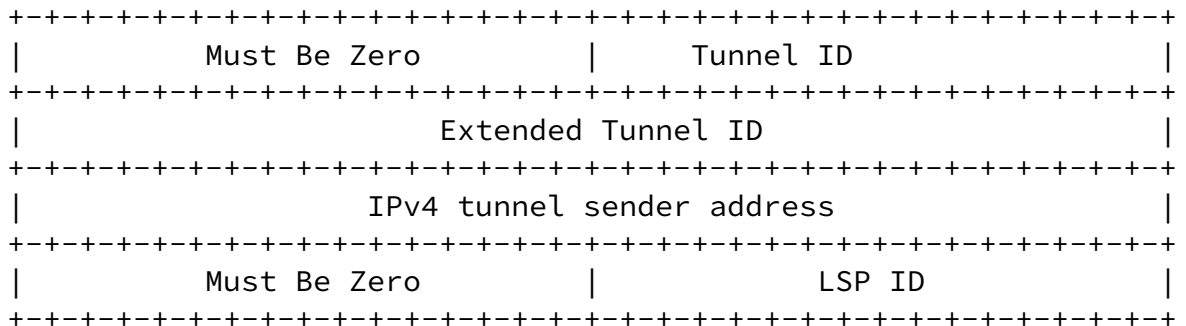
## 2.2. Path XRO Subobjects

New IPv4 and IPv6 Point-to-Point (P2P) Path XRO subobjects are defined by this document as follows.

### 2.2.1. IPv4 Point-to-Point Path subobject



Internet Draft [draft-ietf-ccamp-lsp-diversity-01.txt](#)



L

The L-flag is used as for the other XRO subobjects defined in [RFC4874].

0 indicates that the attribute specified MUST be excluded.

1 indicates that the attribute specified SHOULD be avoided.

Type

IPv4 Point-to-Point Path subobject  
(to be assigned by IANA; suggested value: 36).

Length

The length contains the total length of the subobject in bytes, including the type and length fields. The length is always 24.

### Attribute Flags

The Attribute Flags are used to communicate desirable attributes of the LSP being signaled. The following flags are defined. None, all or multiple attribute flags MAY be set within the same subobject.

0x01 = LSP ID to be ignored

This flag is used to indicate tunnel level exclusion. Specifically, this flag is used to indicate that the lsp-id field of the subobject is to be ignored and the

Internet Draft [draft-ietf-ccamp-lsp-diversity-01.txt](#)

exclusion applies to any LSP matching the rest of the supplied FEC.

0x02 = Destination node exception

This flag is used to indicate that the destination node of the LSP being signaled MAY be shared with the excluded path even when this violates the exclusion flags.

0x04 = Processing node exception

This flag is used to indicate that the processing node MAY be shared with the excluded path even when this violates the exclusion flags.

0x08 = Penultimate node exception

This flag is used to indicate that the penultimate node of the LSP being signaled MAY be shared with the excluded path even when this violates the exclusion flags.

### Exclusion Flags

The Exclusion-Flags are used to communicate desirable types of exclusion. The following flags are defined.

0x01 = SRLG exclusion

This flag is used to indicate that the route of the LSP being signaled is requested to be SRLG diverse from the excluded path specified by the LSP subobject.

0x02 = Node exclusion

This flag is used to indicate that the route of the LSP being signaled is requested to be node diverse from the excluded path specified by the LSP subobject.

(Note: the meaning of this flag may be modified by the value of the Attribute-flags.)

0x04 = Link exclusion

This flag is used to indicate that the route of the LSP being signaled is requested to be link diverse from the path specified by the LSP subobject.

The remaining fields are as defined in [[RFC3209](#)].



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Internet Draft [draft-ietf-ccamp-lsp-diversity-01.txt](#)

### 2.2.2. IPv6 Point-to-Point Path subobject

```

      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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|L|  Type  |  Length  |Attribute Flags|Exclusion Flags|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     IPv6 tunnel end point address |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     IPv6 tunnel end point address (cont.) |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     IPv6 tunnel end point address (cont.) |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     IPv6 tunnel end point address (cont.) |

```

Must Be Zero	Tunnel ID
Extended Tunnel ID	
Extended Tunnel ID (cont.)	
Extended Tunnel ID (cont.)	
Extended Tunnel ID (cont.)	
IPv4 tunnel sender address	
IPv4 tunnel sender address (cont.)	
IPv4 tunnel sender address (cont.)	
IPv4 tunnel sender address (cont.)	
Must Be Zero	LSP ID

L

The L-flag is used as for the other XRO subobjects defined in [[RFC4874](#)].

0 indicates that the attribute specified MUST be excluded.

1 indicates that the attribute specified SHOULD be avoided.

Type

IPv6 Point-to-Point Path subobject  
(to be assigned by IANA; suggested value: 37).

Length

The length contains the total length of the subobject in bytes, including the type and length fields. The length is

always 48.

The Attribute Flags and Exclusion Flags are as defined for the IPv4 Point-to-Point LSP XRO subobject.

The remaining fields are as defined in [[RFC3209](#)].

### [2.3](#). Processing rules for the Path XRO subobjects

XRO processing as described in [[RFC4874](#)] is unchanged.

If the processing node is the destination for the LSP being signaled, it SHOULD NOT process a Path XRO subobject.

If the L-flag is not set, the processing node follows the following procedure:

- The processing node MUST ensure that any route calculated for the signaled LSP respects the requested exclusion flags with respect to the excluded path referenced by the subobject, including local resources.
- If the processing node fails to find a route that meets the requested constraint, the processing node MUST return a PathErr with the error code "Routing Problem" (24) and error sub-code "Route blocked by Exclude Route" (67).
- If the excluded path referenced in the LSP subobject is unknown to the processing node, the processing node SHOULD ignore the LSP subobject in the XRO and SHOULD proceed with the

signaling request. After sending the Resv for the signaled LSP, the processing node SHOULD return a PathErr with the error code "Notify Error" (25) and error sub-code "Route of XRO path unknown" (value to be assigned by IANA, suggested value: 13) for the signaled LSP.

If the L-flag is set, the processing node follows the following procedure:

- The processing node SHOULD respect the requested exclusion flags with respect to the excluded path as far as possible.

- If the processing node fails to find a route that meets the requested constraint, it SHOULD proceed with signaling using a suitable route that meets the constraint as far as possible. After sending the Resv for the signaled LSP, it SHOULD return a PathErr message with error code "Notify Error" (25) and error sub-code "Failed to respect Exclude Route" (value: to be assigned by IANA, suggest value: 14) to the source node.
- If the excluded path referenced in the LSP subobject is unknown to the processing node, the processing node SHOULD ignore the LSP subobject in the XRO and SHOULD proceed with the signaling request. After sending the Resv for signaled LSP, the processing node SHOULD return a PathErr message with the error code "Notify Error" (25) and error sub-code "Route of XRO path unknown" for the signaled LSP.

If, subsequent to the initial signaling of a diverse LSP:

- an excluded path referenced in the diverse LSP's XRO subobject becomes known to the processing node (e.g. when the excluded path is signaled), or
- A change in the excluded path becomes known to the processing node,

the processing node SHOULD re-evaluate the exclusion and diversity constraints requested by the diverse LSP to determine whether they are still satisfied.

- If the requested exclusion constraints for the diverse LSP are no longer satisfied and an alternative route for the diverse LSP that can satisfy those constraints exists, the processing node SHOULD send a PathErr message for the diverse LSP with the error code "Notify Error" (25) and error sub-code "Preferable path exists" (6). A source node receiving a PathErr

message with this error code and sub-code combination MAY try to reoptimize the diverse tunnel to the new compliant path.

- If the requested exclusion constraints for the diverse LSP are no longer satisfied and no alternative path for the diverse LSP that can satisfy those constraints exists, then:

- o If the L-flag was not set in the original exclusion, the processing node MUST send a PathErr message for the diverse LSP with the error code "Routing Problem" (24) and error sub-code "Route blocked by Exclude Route" (67). The PSR flag SHOULD NOT be set.
- o If the L-flag was set in the original exclusion, the processing node SHOULD send a PathErr message for the diverse LSP with the error code error code "Notify Error" (25) and error sub-code "Failed to respect Exclude Route" (value: to be assigned by IANA, suggest value: 14).

The following rules apply whether or not the L-flag is set:

- An XRO object MAY contain multiple path subobjects.
- As specified in [[RFC4874](#)], a node receiving a Path message carrying an XRO MAY reject the message if the XRO is too large or complicated for the local implementation or the rules of local policy. In this case, the node MUST send a PathErr message with the error code "Routing Error" (24) and error sub-code "XRO Too Complex" (68). A source node receiving this error code/sub-code combination MAY reduce the complexity of the XRO or route around the node that rejected the XRO.
- A source node receiving a PathErr message with the error code "Notify Error" (25) and error sub-codes "Route of XRO path unknown" or "Failed to respect Exclude Route" MAY take no action.
- The attribute-flags affect the processing of the XRO subobject as follows:
  - o When the "LSP ID to be ignored" flag is set, the processing node MUST calculate a route based on exclusions from the routes of all known LSPs matching the tunnel-id, source, destination and extended tunnel-id specified in the subobject. When this flag is not set, the lsp-id is not ignored and the exclusion applies only to the specified LSP (i.e., LSP level exclusion).

- o When the "destination node exception" flag is not set, the

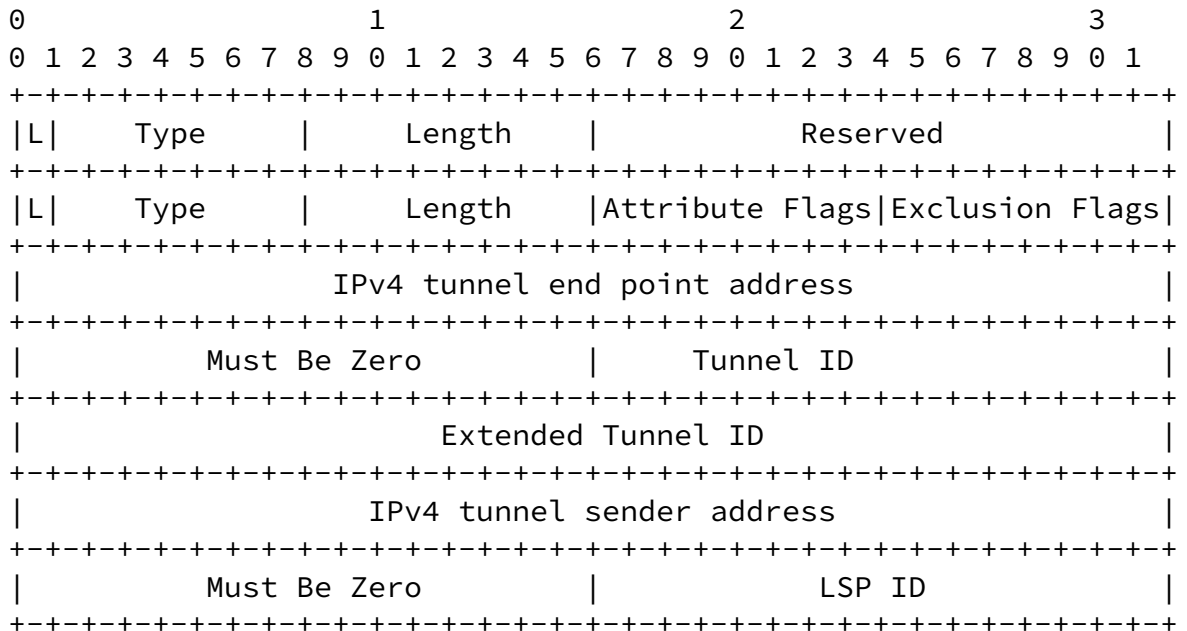
exclusion flags SHOULD also be respected for the destination node.

- o When the "processing node exception" flag is not set, the exclusion flags SHOULD also be respected for the processing node.
- o When the "penultimate node exception" flag is not set, the exclusion flags SHOULD also be respected for the penultimate node.

#### 2.4. Path EXRS Subobject

[RFC4874] defines the EXRS ERO subobject. An EXRS is used to identify abstract nodes or resources that must not or should not be used on the path between two inclusive abstract nodes or resources in the explicit route. An EXRS contains one or more subobjects of its own, called EXRS subobjects [RFC4874].

An EXRS MAY include an IPv4 Point-to-Point (P2P) Path subobject as specified in [section 2.2.1](#). In this case, the EXRS format would be as follows:



The meaning of respective fields in EXRS header is as defined in [RFC4874]. The meaning of respective fields in IPv4 P2P Path

subobject is as defined earlier in this document. This is with the exceptions that:

- The processing node exception applies to the node processing the ERO.
- If the L bit in the ERO header is not set (ERO.L = 0), the IPv4 P2P Path subobject is processed against the path(s) for which the processing node is a source, destination or transit node.
- The penultimate node exception applies to the penultimate node of the loose hop. This flag is only processed if the ERO.L bit is set, i.e. in the loose ERO hop case.
- The destination node exception applies to the last explicit node to which the loose hop is expanded. This flag is only processed if ERO.L bit is set, i.e., in the loose ERO hop case.

#### [2.4.1](#). Processing Rules for the EXRS with Path subobject

The processing rules for the EXRS object are unchanged from [[RFC4874](#)]. When the EXRS contains one or more Path subobject(s), the processing rules specified in [Section 2.3](#) apply to the node processing the ERO with the EXRS subobject.

The EXRS scope is limited to the loose hop in which the EXRS appears. If loose-hop expansion results in the creation of another loose-hop in the outgoing ERO, the processing node MAY include the EXRS in the newly-created loose hop for further processing by downstream nodes.

### [3](#). Security Considerations

This document does not introduce any additional security issues above those identified in [[RFC5920](#)], [[RFC2205](#)], [[RFC3209](#)], [[RFC3473](#)] and [[RFC4874](#)].

### [4](#). IANA Considerations

#### [4.1](#). New XRO subobject types

IANA registry: RSVP PARAMETERS

Subsection: Class Names, Class Numbers, and Class Types

Internet Draft [draft-ietf-ccamp-lsp-diversity-01.txt](#)

This document introduces two new subobjects for the EXCLUDE\_ROUTE object [[RFC4874](#)], C-Type 1.

Subobject Type

Subobject Description

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To be assigned by IANA (suggested value: 36)	IPv4 P2P Path subobject
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To be assigned by IANA (suggested value: 37)	IPv6 P2P Path subobject
---	-------------------------

#### [4.2.](#) New EXRS subobject types

The IPv4 and IPv6 P2P Path subobjects are also defined as new EXRS subobjects.

#### [4.3.](#) New RSVP error sub-codes

IANA registry: RSVP PARAMETERS

Subsection: Error Codes and Globally-Defined Error Value Sub-Codes

For Error Code "Notify Error" (25) (see [[RFC3209](#)]) the following sub-codes are defined.

Sub-code -----	Value -----
Route of XRO path unknown	To be assigned by IANA. Suggested Value: 13.
Failed to respect Exclude Route	To be assigned by IANA. Suggested Value: 14.

#### [5.](#) Acknowledgements

The authors would like to thank Luyuan Fang and Walid Wakim for their review comments.

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Internet Draft [draft-ietf-ccamp-lsp-diversity-01.txt](#)

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- [RFC5920] Fang, L., Ed., "Security Framework for MPLS and GMPLS Networks", [RFC 5920](#), July 2010.

## Authors' Addresses

Zafar Ali  
Cisco Systems.  
Email: [zali@cisco.com](mailto:zali@cisco.com)

George Swallow  
Cisco Systems

swallow@cisco.com

Clarence Filsfils  
Cisco Systems, Inc.  
cfilsfil@cisco.com

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[draft-ietf-ccamp-lsp-diversity-01.txt](#)

Matt Hartley  
Cisco Systems  
Email: mhartley@cisco.com

Ori Gerstel  
Cisco Systems  
ogerstel@cisco.com

Gabriele Maria Galimberti  
Cisco Systems  
ggalimbe@cisco.com

Kenji Kumaki  
KDDI Corporation  
Email: ke-kumaki@kddi.com

Rudiger Kunze  
Deutsche Telekom AG  
Ruediger.Kunze@telekom.de

Julien Meuric  
France Telecom Orange  
Email: julien.meuric@orange.com

