OSPF, IS-IS, RSVP, CR-LDP extensions to support inter-area traffic engineering using MPLS TE

1. Abstract

In this draft, we propose the extensions required to the routing protocols, signaling protocols, and the MIB to support the idea of inter-area LSPs. A companion document [INTER_AREA_REQ] provides the architectural requirements for such a concept. This document also provides the signaling extensions to support the crankback as defined in the architecture document [INTER_AREA-REQ].

2. Notation and Conventions used in this document

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABR</td>
<td>Area Border Router</td>
</tr>
<tr>
<td>ASBR</td>
<td>Autonomous System Border Router</td>
</tr>
<tr>
<td>CR-LDP</td>
<td>Constraint Based Routing LDP</td>
</tr>
<tr>
<td>CSPF</td>
<td>Constraint-based Shortest Path First</td>
</tr>
<tr>
<td>ER</td>
<td>Explicit Route</td>
</tr>
<tr>
<td>ERO</td>
<td>Explicit Route Object</td>
</tr>
<tr>
<td>IACO</td>
<td>Inter Area Criteria Object</td>
</tr>
<tr>
<td>IACCUO</td>
<td>Inter Area Criteria Used Object</td>
</tr>
<tr>
<td>IGP</td>
<td>Interior Gateway Protocol</td>
</tr>
<tr>
<td>ISIS</td>
<td>Intermediate System to Intermediate System</td>
</tr>
<tr>
<td>ISP</td>
<td>Internet Service Provider</td>
</tr>
<tr>
<td>LDP</td>
<td>Label Distribution Protocol</td>
</tr>
<tr>
<td>LER</td>
<td>Label Edge Router</td>
</tr>
<tr>
<td>LSA</td>
<td>Link State Attribute</td>
</tr>
<tr>
<td>LSR</td>
<td>Label Switch Router</td>
</tr>
<tr>
<td>LSP</td>
<td>Label Switched Path</td>
</tr>
<tr>
<td>MIB</td>
<td>Management Information Base</td>
</tr>
<tr>
<td>MPLS</td>
<td>Multi Protocol Label Switching</td>
</tr>
<tr>
<td>OSPF</td>
<td>Open Shortest Path First</td>
</tr>
<tr>
<td>PDU</td>
<td>Protocol Data Unit</td>
</tr>
<tr>
<td>PLRO</td>
<td>Primary LSP Route Object</td>
</tr>
<tr>
<td>PRO</td>
<td>Path Route Object</td>
</tr>
</tbody>
</table>
3. Introduction

Current work in the MPLS traffic engineering group (such as [TE_FRAMEWORK], [QOS_CONST]) focuses only on the intra-area LSP setup issues. In this work we propose an architecture to extend the traffic engineering capability across IGP areas and recommend relevant modifications to the routing protocols, the signaling protocols and the MIBs.

The ISP’s networks are divided into Autonomous Systems (ASs), where each AS is divided into Interior Gateway Protocol (IGP) areas to allow the hiding and aggregating of routing information. Although this concept of hierarchical routing by an IGP makes sense from the routing perspective, it is a bottleneck for traffic engineering - as it hides the path taken by a packet to destinations in the other routing areas. Hence, from the Traffic Engineering (TE) perspective, requirements such as path selection and crankback need different architectural additions to the existing IGPs and signaling protocols for inter-area Label Switched Path (LSP) setup.

Traffic engineering practice currently involves the setup and use of LSPs as dedicated bandwidth pipes between two end points. LSPs can be setup across several routers, either through the use of manually specified routes, or routes that are computed. The routes can be computed offline through the use of a dedicated tool, or through the use of online constraint based routing using an IGP [IGP_REQ, RSVP_EXT].

The offline tool will be centralized, and has the advantage of being able to consider the traffic pattern history over a large period of time, and hence will be efficient in optimizing the resources over time, not just the particular instant when the request is received. The offline traffic engineering tool, if also used for LSP setup in addition to routing, may be able to optimize the resources across LSPs. This would include mechanisms to tear down LSP segments and reroute them when better resources become available or new requests arrive.

The online constraint based routing model [IGP_REQ] requires (1) a constraint based routing process implemented on certain Label Switched Routers (LSRs) that serve as Label Edge Routers (LERs) to the LSPs, and (2) a set of mechanisms to flood out and maintain the TE characteristics of the topology.

From [TOOL_VS_RP] discussion, it is clear that traffic engineering can be implemented with the help of tools and routing protocol extensions, as initiated by [IGP_REQ]. Although there has been some work in the area of realizing some of the issues such as TE crankback [CRANKBACK] and DiffServ realizations [QOS_CONST], [QOS_TE_EXT], no work has been performed that directly related to the inter-area extensions and a framework for such in the TE working group.

In our solution, we propose to send across IGP areas, the summary routes containing criteria-based route attributes, which will be used at the Autonomous System Border Routers (ASBRs) in their TE path computation. Since an off-line TE tool cannot compute the complete explicit path from ASBR to ASBR unless it knows the complete routing table of the AS, we expect to have loose path specification, which can be translated into explicit path in-steps at the intermediate Area.
Border Routers (ABRs). The solutions we are providing in this draft are applicable to the destination networks inside the AS or outside the AS. For the sake of simplicity we consider the customer networks inside an autonomous system.

The companion document [INTER_AREA_REQ] presents the architectural requirements for such a solution. In this document, the extensions to provide such a solution of criteria-based inter-area routing are separated into routing protocol extensions, signaling protocol extensions and configuration extensions. In section 4, we present the OSPF and IS-IS extensions. The signaling extensions for RSVP and CR-LDP are presented in section 5. The configuration extensions for such architectural changes are presented in section 6. Security considerations, references and acknowledgements follow in sections 7, 8, and 9 respectively.

4. Routing protocol extensions

4.1 Intra-area requirements

OSPF or ISIS implementation SHOULD support the [INTRA_TE], [ISIS_INTRA_TE] extensions to advertise and distribute the TE information of the interfaces of the area. In addition, [QOS_TE_EXT] may be supported to flood the bandwidth per class type of each interface.

[INTRA_TE], [ISIS_INTRA_TE] defines the following TE attributes:

- Traffic engineering metric
- Maximum bandwidth
- Maximum reservable bandwidth
- Unreserved bandwidth
- Resource class/color

[QOS_TE_EXT] defines the unreserved bandwidth for different class types.

Not all of the TE attributes specified in [INTRA_TE], [ISIS_INTRA_TE] and [QOS_TE_EXT] need to be supported - in fact a subset may be chosen that reflects the traffic engineering condition of the network and does not impose a burden on the storage and flooding of the TE information.

Specific to OSPF:

When a request for the setup of a constraint based LSP within the area is received, a CSPF computation will be performed on the TE resources of the area (as specified by the intra-area TE-LSAs) to determine the best path that satisfies the constraints. The constraints on the LSP can be one or more of the TE attributes flooded by OSPF in the intra-area TE LSA.

Specific to ISIS:

When a request for the setup of a constraint based LSP within the area is received, a CSPF computation will be performed on the TE resources of the area (as specified by the intra-area TE-LSAs) to determine the best path that satisfies the constraints of the LSP. The constraints on the LSP can be one or more of the TE attributes flooded by ISIS in the L1 extended IS reachability TE sub-TLVs.

4.2 Inter-area requirements

The route computation process uses the inter-area TE summary information.

- to determine if a path to the inter-area destination that satisfies the constraints does exist, and
- to determine the ABR to reach the next area.
TE attribute summarization is similar to the route summarization that is already a part of OSPF or ISIS. The TE attributes can be summarized through the use of a dijkstra based algorithm as described in section. The value of the TE summary attribute to a destination advertised by an ABR represents the TE resources of the best path available from the ABR to that destination based on that TE attribute alone.

A separate route calculation is necessary to determine the summary value for each TE attribute that needs to be summarized. Since these route calculations are based on the intra-area TE attribute values, the set of TE attributes to be summarized should be a subset of the set of TE attributes supported inside the areas.

In the general case of TE attribute summarization, any number of TE attributes such as bandwidth, delay to a destination can be summarized. However, since a large number of TE attributes to be summarized will result in an increase in processing required, the number of TE attributes to be summarized should be kept small.

Specific to OSPF:

The summarized TE attributes will be distributed inside the areas by the use of a new link state message (called TE summary LSA) as defined in [INTER_TE_OSPF]. The definitions for the various TE attributes in the TE summary LSA are also described in [INTER_TE_OSPF]. In addition to those TE attributes, the following three TLVs are proposed to be added in the TE summary LSA.

Specific to ISIS:

The summarized TE attributes will be distributed inside the areas by extending the IP reachability TLV in the L1 and L2 link state PDU to include TE sub-TLVs as described below.

4.3 Requirements for OSPF

4.3.1 Unreserved Bandwidth for CT1 to CT3

The unreserved bandwidth for class-types 1, 2 and 3 [QOS_CONST] to the destination are each individually described in a TLV. The units is bytes/second and the representation is IEEE floating point. The TLV types are 7, 8, and 9, respectively and the length is 32 octets each.

4.4. Requirements for ISIS

4.4.1 Traffic Engineering Extensions to the IP Reachability TLV

This draft extends the IP Reachability TLV in the L1 and L2 link state PDUs to allow the representation of TE information in the form of TE sub-TLVs. Each TE sub-TLV in the IP Reachability TLV carries the type and value of a traffic engineering attribute to the remote destination.

An L2 link state PDU containing the IP reachability TLV with the TE extensions will be originated by an L1/L2 router and flooded throughout the L2 domain. This PDU will contain IP reachability TLV with the TE sub-TLVs for each reachable address in the connected areas. The value for each TE attribute will have been computed through the use of a dijkstra based algorithm as detailed in the next section. (This is the 'up' part of the redistribution as detailed in [ISIS_TE]).

An L1 link state PDU containing the IP reachability TLV with the TE extensions will be originated by an L1/L2 router and flooded throughout its connected areas. This PDU will contain IP reachability TLV with the TE sub-TLVs for each reachable address in a remote area. (This is the 'down' part of the redistribution as detailed in [ISIS_TE]).

4.4.2 Format of the IP reachability TLV with TE Sub-TLVs
The extended IP reachability TLV as described in [ISIS_TE] with TYPE = 135 is further extended with the addition of the TE sub-TLVs describing the traffic engineering attributes to the destination network.

Hence the IP reachability TLV has a structure as described in [ISIS_TE], followed by zero or more TE sub-TLVs, each of which is of the form:

<table>
<thead>
<tr>
<th>No. of Octets</th>
</tr>
</thead>
</table>
| +---------------------------+  
| | CODE | 1 |
| +---------------------------+  
| | LENGTH | 1 |
| +---------------------------+  
| | VALUE | LENGTH |

4.4.3 The Traffic Engineering Sub-TLVs

The following traffic engineering attributes are defined:

<table>
<thead>
<tr>
<th>Sub-TLV type</th>
<th>Length (octets)</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
<td>Resource Class/Color</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>Maximum Bandwidth</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>Reservable Bandwidth</td>
</tr>
<tr>
<td>11</td>
<td>32</td>
<td>Unreserved Bandwidth</td>
</tr>
<tr>
<td>18</td>
<td>3</td>
<td>TE Default Metric</td>
</tr>
<tr>
<td>TBD</td>
<td>4</td>
<td>Delay</td>
</tr>
<tr>
<td>TBD</td>
<td>32</td>
<td>Unreserved Bandwidth for CT1</td>
</tr>
<tr>
<td>TBD</td>
<td>32</td>
<td>Unreserved Bandwidth for CT2</td>
</tr>
<tr>
<td>TBD</td>
<td>32</td>
<td>Unreserved Bandwidth for CT3</td>
</tr>
</tbody>
</table>

Most of these traffic engineering attributes have sizes and types the same as in [ISIS_TE]. Note that new traffic engineering attributes and sub-TLVs to represent them may be defined in the future. The TE attributes are described below.

4.4.3.1 Resource Class/Color

The resource class or color of the destination network is a combination of the colors for the various paths to the network. The sub-TLV type of the resource class/color attribute is 3, and the length is 4 octets.

4.4.3.2 Maximum Bandwidth

The maximum bandwidth to the destination is described in bytes/second as an IEEE floating point number. The sub-TLV type is 9, and the length is 4 octets.

4.4.3.3 Reservable Bandwidth

The reservable bandwidth to the destination is described in bytes/second as an IEEE floating point number. The sub-TLV type is 10, and the length is 4 octets.

4.4.3.4 Unreserved Bandwidth

The unreserved bandwidth to the destination is described in bytes/second as an IEEE floating point number. The sub-TLV type is 11, and the length is 4 octets.

4.4.3.5 Traffic Engineering Metric

The traffic engineering metric represents the traffic engineering cost of reaching the destination network from the advertising L2 router. The sub-TLV type is 18, and the length of this attribute is 3 octets.
4.4.3.6 Delay

The delay attribute is the delay cost to reach the destination network in milliseconds, represented as an unsigned (4-byte) long integer. The TLV-type is TBD, and the length is 4 octets.

4.4.3.7 Unreserved Bandwidth for CT1 to CT3

The unreserved bandwidth for class-types 1, 2 and 3 [QOS_CONST] to the destination are each individually described in a sub-TLV. The units is bytes/second and the representation is IEEE floating point. The sub-TLV types are TBD, and the length is 4 octets.

4.5 Summarization of Traffic Engineering Attributes

The traffic engineering metric is an additive metric similar to the OSPF/ISIS metrics, but need not be the same. The traffic engineering and metric advertised by the router for the given summary destination will have been computed in a manner similar to the dijkstra computation for the OSPF/ISIS metric.

The delay is an additive metric. The value of the delay attribute for a summary destination will have been determined through a dijkstra computation based on the delay.

The maximum bandwidth to the summary destination is the largest of all path-capacities, each associated with a possible path to the destination. The path-capacity is the smallest link capacity of all the links in the path. Hence, the maximum bandwidth is the maximum amount of traffic that can be sent to that destination, when there is no other traffic on the links.

The unreserved bandwidth to the summary destination is the largest of all path-unreserved bandwidths, each associated with a possible path to the destination. The path-unreserved bandwidth is the smallest unreserved bandwidth of all the links in the path. Hence, the unreserved bandwidth is the maximum amount of traffic that can currently be sent to that destination, the other traffic on the links being steady. The unreserved bandwidth for Class-Types 1, 2, and 3 [QOS_CONST] will be computed similarly.

The value of the color attribute to the summary destination is some combination of the path-colors, each associated with a possible path to the destination. The path-color is a combination of the colors of the links in the path. This combination can be a "logical and" of the colors, or a concatenation.

5. Signaling Extensions

The signaling protocol requirements for the setup of the inter-area LSP are (as mentioned in [INTE_AREA_REQ]):

1. Signaling SHOULD be extended to carry the criteria based elements, such as: Primary criteria (Attribute 1, ..., Attribute N); Secondary criteria (Attribute 1, ..., Attribute N).
2. Signaling SHOULD trigger IGP computation for the explicit route in an area at the transit ABRs. If the path, which satisfies the primary criteria, is not available then it should trigger for the IGP computation of the path for the secondary criteria.
3. It MAY inform the initiating node about the change the criteria for the path set up in the intermediate path. This deliberate notification can also be derived when the actual setup is completed.
4. The intermediate ABRs SHOULD know the difference between the primary and the backup LSPs. This enables the signaling component to distinguish between the paths taken by the primary LSP during the computation of the backup LSP.
5. The same mechanisms used for the primary LSP setup SHOULD be used for the backup LSP setup also.
6. Crankback in an area SHOULD always be performed from the starting ABR of that LSP section. If the path is not available send the
information one area back and try to perform the computation.

5.1 RSVP extensions

In this section we describe extensions to RSVP for the support of Inter-Area LSP setup as described in [INTER_AREA_REQ]. These extensions are in addition to the extensions to RSVP as defined in [RSVP_EXT] and includes attributes from [QOS_TE_EXT] [TE_FRAMEWORK] as sub-objects.

Three new objects are introduced as follows:

- **<INTER AREA CRITERIA>** object (from now on is also abbreviated as IACO) introduced to carry the primary and the secondary criteria in the PATH message.
- **<INTER AREA CRITERIA USED>** object (from now on is also abbreviated as IACUO) is introduced in the RESV message to capture the route taken by the primary or the secondary PATH message.
- **<PRIMARY LSP ROUTE>** object (from now on abbreviated as PLRO) to carry the path followed by the primary LSP in the PATH message.

In the following sections we also demonstrate different uses of ERO (EXPLICIT ROUTE OBJECT) and RRO (RECORD ROUTE OBJECT) from the [RSVP_EXT] draft. Note that constraint-related objects such as <CLASSTYPE> as mentioned in [QOS_TE_EXT] can be sub-objects in the IACO. The following table illustrates the objects discussed that are relevant for this draft.

<table>
<thead>
<tr>
<th>Object type</th>
<th>Message</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;INTER AREA CRITERIA&gt;</td>
<td>Path</td>
<td>Mandatory</td>
</tr>
<tr>
<td>&lt;INTER AREA CRITERIA USED&gt;</td>
<td>Resv</td>
<td>Mandatory</td>
</tr>
<tr>
<td>&lt;PRIAMRY LSP ROUTE&gt;</td>
<td>Path</td>
<td>Mandatory</td>
</tr>
<tr>
<td>&lt;DIFFSERV&gt;&lt;CLASSTYPE&gt;</td>
<td>Path</td>
<td>Optional</td>
</tr>
<tr>
<td>&lt;TE CONSTRAINTS&gt;</td>
<td>Path</td>
<td>Optional</td>
</tr>
<tr>
<td>&lt;EXPLICIT ROUTE&gt;</td>
<td>Path</td>
<td>Optional</td>
</tr>
<tr>
<td>&lt;RECORD ROUTE&gt;</td>
<td>Path, Resv</td>
<td>Optional but recommended</td>
</tr>
</tbody>
</table>

5.1.1 PATH and RESV message format changes

The format of the Path message is changed as follows:

```plaintext
<Path Message> ::=<Common Header> [<INTEGRITY>] <SESSION> <RSVP_HOP> <TIME_VALUES> [<EXPLICIT_ROUTE>] <LABEL_REQUEST> [<SESSION_ATTRIBUTE>] [<INTER AREA CRITERIA>] (For Primary Criteria) [<DIFFSERV>][<CLASSTYPE>] [<TE CONSTRAINTS>] [<INTER AREA CRITERIA>] (For Secondary Criteria) [<DIFFSERV>][<CLASSTYPE>] [<TE CONSTRAINTS>] [<PRIMARY LSP ROUTE>] [<POLICY_DATA> ... ] [sender descriptor] <sender descriptor> ::=  <SENDER_TEMPLATE> [<SENDER_TSPEC>] [<ADSPEC>] [<RECORD_ROUTE>]```

The format of the Resv message is changed as follows:

```plaintext
<Resv Message> ::=<Common Header> [ <INTEGRITY> ] <SESSION> <RSVP_HOP>```
5.1.2 Handling of the new objects

The following are the message formats for the new objects that are introduced in this document.

**INTER AREA CRITERIA Object (IACO):**

<table>
<thead>
<tr>
<th>Length (12 bits)</th>
<th>C-Number = TBD</th>
<th>C-Type = 0 for Primary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(8 bits)</td>
<td>(8 bits) 1 for Secondary</td>
</tr>
</tbody>
</table>

**Attribute 1 Â» For example <DIFFSERV> <CLASSTYPE> and/or <TE CONSTRAINTS>**

\[\ldots\]

Till Attribute N

**C-Number:**
To be defined by IANA

**C-Type:**

<table>
<thead>
<tr>
<th>0</th>
<th>for the Primary Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>for the Secondary Criteria</td>
</tr>
</tbody>
</table>

**Attribute:**
Constraints from the traffic engineering related drafts.

**INTER AREA CRITERIA USED Object (IACUO):**

<table>
<thead>
<tr>
<th>Length</th>
<th>C-Number = TBD</th>
<th>C-Type = 0 for Primary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(8 bits)</td>
<td>(8 bits) 1 for Secondary</td>
</tr>
</tbody>
</table>

**C-Number:**
To be defined by IANA

**C-Type:**

<table>
<thead>
<tr>
<th>0</th>
<th>for the Primary Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>for the Secondary Criteria</td>
</tr>
<tr>
<td>2</td>
<td>for none</td>
</tr>
</tbody>
</table>

**PRIMARY LSP ROUTE Object (PLO):**

<table>
<thead>
<tr>
<th>Length = N*4 or 16</th>
<th>C-Number = TBD</th>
<th>C-Type = 0 for IPV4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(8 bits)</td>
<td>(8 bits) 1 for IPV6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 for unavailable</td>
</tr>
</tbody>
</table>

**IP Address 1 (V4 or V6)**

\[\ldots\]

**IP Address N (V4 or V6)**

**C-Number:**
To be defined by IANA

**C-Type:**

<table>
<thead>
<tr>
<th>0</th>
<th>for the IPV4 address</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>for the IPV6 address</td>
</tr>
<tr>
<td>2</td>
<td>for the unavailability of the objects.</td>
</tr>
</tbody>
</table>
The IACO can be used very effectively in conjunction with the ERO and RRO objects. It is possible that the ERO and RRO options are enabled to specify a preferred path and to know the path taken by the LSP respectively.

The following list of cases will illustrate the handling of the IACO, IACUO, and PLRO objects in conjunction with the ERO and RRO objects.

Case 1: IACO + ERO with strict route option: Here we can have two situations in one case the primary fails and the other in which both the primary and the secondary fail. The following explain the operation:

i. Primary fails: Since the path is strict route a PATHErr message will be sent to crankback to the nearest ABR in the path with error code for "Primary Criteria Failed". The ABR should attempt to setup the LSP with secondary criteria.

ii. Primary and secondary fails: When both the primary and the secondary fails the source of the LSP setup is informed with the help of a PATHErr message with the error code "Primary and Secondary Criteria Failed".

Case 2: IACO + ERO with loose source route option: Here also we have the same situation as above except for the choice of different path when either the primary or the secondary fails. Also when both the primary and the secondary fail we have to go only one previous ABR hop to recomputed the path till the source is reached.

Case 3: IACUO with and without RRO: In the case of no RRO in the RESV message the LSP initiating node (Ingress LER) will not know the path taken by the primary LSP and hence backup LSP may have overlapping LSP sections with the primary. Where as when the RRO object is used, above problem can be avoided, with the use of PLRO.

Case 4: With and without PLRO: When PLRO is present we can avoid overlapping segments between the primary and the backup LSPs.

5.1.3 Error conditions

The following are the error conditions

1 Primary Criteria Failed (with the ABRs traversed)
2 Secondary Criteria Failed (with the ABRs traversed)
3 Primary and Secondary Criteria Failed (with the ABRs traversed)
4 Unknown Criteria
5 Unknown Object

5.2 CR-LDP extensions

In this section we describe extensions to CR-LDP for the support of Inter-Area LSP setup as described in [INTER_AREA_REQ]. These extensions are in addition to the extensions to CR-LDP as defined in [CR_LDP] and includes the attributes from [QOS_TE_EXT], [TE_FRAMEWORK] as sub-objects.

Three new objects are introduced as follows:

- <INTER AREA CRITERIA TLV> (from now on is also abbreviated as IACO) introduced to carry the primary and the secondary criteria in the Label Request message.
- <INTER AREA CRITERIA USED TLV> (from now on is also abbreviated as IACUO) is introduced in the Label Mapping message to capture the route taken by the primary or the secondary Label Request message.
- <PRIMARY LSP ROUTE TLV> (from now on abbreviated as PLRO) to carry the path followed by the primary LSP in the Label Request message.

Note that constraint-related TLVs such as <CLASSTYPE> as mentioned in [QOS_TE_EXT] can be sub-TLVs in the IACO. The following table illustrates the objects discussed that are relevant for this draft.

<table>
<thead>
<tr>
<th>Object type</th>
<th>Message</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;INTER AREA CRITERIA TLV&gt;</td>
<td>Label Request</td>
<td>Mandatory</td>
</tr>
</tbody>
</table>
5.2.1 Label Request and Label Mapping messages Encoding

The encoding for the CR-LDP Label Request message is extended as follows, to optionally include the Inter Area Criteria TLV (which contains the Primary and Secondary Criteria TLVs) and Primary LSP Route TLV:

```
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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
0 |   Label Request (0x0401)   |      Message Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Message ID                                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     FEC TLV                                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                ER-LSP TLV   (CR-LDP Optional)                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          PATH VECTOR TLV    (Optional but Recommended)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  INTER AREA CRITERIA TLV (Optional)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    PRIAMRY LSP ROUTE TLV (Optional)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Other CR-LDP TLVs                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The encoding for the CR-LDP Label Mapping Message is extended as follows, to optionally include the Inter Area Criteria Used TLV:

```
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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
0 |   Label Mapping (0x0400)   |      Message Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Message ID                                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     FEC TLV                                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Label TLV                                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Label Request Message ID TLV                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     LSPID TLV            (CR-LDP, optional)   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Traffic TLV         (CR-LDP, optional)   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         INTER AREA CRITERIA USED         (Optional)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Other CR-LDP TLVs                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

5.2.2 Handling of the new objects

The following are the message formats for the new objects that are introduced in this document.

The INTER AREA CRITERIA TLV has the following format:

```
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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
0 |0 | IACO TLV |      Length                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| PRIMARY CRITERIA sub-TLV
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
This TLV has both the primary and the secondary criteria sub-TLVs. Notice that the U and F bits are set to 0 to abort the connection setup in case any LSP does not know how to use these mechanisms.

The PRIMARY/SECONDARY CRITERIA sub-TLV format:

```
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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|0|0|PRIMARY/SECONDARY CRITERIA |      Length                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     DiffServ TLV(Optional)                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Class Type TLV (Optional)               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Traffic Engineering TLV (Optional)                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Other TLVs                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The sub TLV carries either the Primary or the Secondary criteria. Each of these criteria has a list of constraints as exemplified in the above message format. Also note that the U and F flags are set to 0.

The INTER AREA CRITERIA USED TLV has the following format:

```
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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|0|0|        IACUO TLV          |      Length                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Reserved                                     |Used   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Inter Area Criteria Used TLV has a Criteria Used field ‘Used’, which will be set to:

- 0 for primary criteria,
- 1 for secondary criteria and
- 15 for none

PRIMARY LSP ROUTE TLV format:

```
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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|0|0|PRIMARY LSP ROUTE TLV      |      Length                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  IPV4/ IPV6 HOP 1                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Â Â Â Â                                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  IPV4/ IPV6 HOP N                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

This TLV contains the path taken by the Primary LSP. It can have IPV4 or IPV6 address hops taken by this path.

The IACO can be used very effectively in conjunction with the Explicit Route (ER) TLV and Path Vector (PV) TLV. It is possible that the ER TLV and PV TLV options are enabled to specify preferred path and to know the path taken by the LSP respectively.

The following list of cases we will illustrate the handling of the IACO, IACUO, and PLRO TLVs in conjunction with the ER TLV and PR TLV.
Case 1: IACO + ER TLV with strict route option: Here we can have two situations in one case the primary fails and the other in which both the primary and the secondary fail. The following explain the operation:

i. Primary fails: Since the path is strict route a LDP Notification message will be sent to crankback to the nearest ABR in the path with error code for "Primary Criteria Failed". The ABR should attempt to setup the LSP with secondary criteria.

ii. Primary and secondary fails: When both the primary and the secondary fails the source of the LSP setup is informed with the help of a LDP Notification message with the error code "Primary and Secondary Criteria Failed".

Case 2: IACO + ER TLV with loose source route option: Here also we have the same situation as above except for the choice of different path when either the primary or the secondary fails. Also when both the primary and the secondary fail we have to go only one previous ABR hop to recomputed the path till the source is reached.

Case 3: IACUO with and without PV TLV: In the case of no PV TLV in the LDP Mapping message the LSP initiating node (Ingress LER) will not know the path taken by the primary LSP and hence backup LSP may have overlapping LSP sections with the primary. Where as when the PV TLV is used, above problem can be avoided, with the use of PLRO.

Case 4: With and without PLRO: When PLRO is present we can avoid overlapping segments between the primary and the secondary LSPs.

5.2.3 Status codes for the inter-area LSP setup

In the procedures described above, certain errors must be reported. The following values are defined for the Status Code field:

<table>
<thead>
<tr>
<th>Status Code</th>
<th>E</th>
<th>Status Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Criteria Failed</td>
<td>0</td>
<td>TBD</td>
</tr>
<tr>
<td>Secondary Criteria Failed</td>
<td>0</td>
<td>TBD</td>
</tr>
<tr>
<td>Primary and Secondary Criteria Failed</td>
<td>0</td>
<td>TBD</td>
</tr>
<tr>
<td>Unknown Criteria</td>
<td>0</td>
<td>TBD</td>
</tr>
<tr>
<td>Unknown TLV</td>
<td>0</td>
<td>TBD</td>
</tr>
</tbody>
</table>

Note: The criteria failures should always inform the ABR path taken for the current reservation.

6. MIB requirements (TBD)

The configuration requirements for such architecture can be divided into:

- Routing configuration, such as criteria filtering, criteria-constraint mapping, route filtering for criteria summarization etc.
- LSP Setup configuration, such as primary criteria and backup criteria etc.
- Signaling configuration, such as the criteria change in the intermediate segment notification, crankback in-progress notification required etc.

These configuration information will be further elaborated in the later versions of this draft.

7. Security Considerations (TBD)

8. Acknowledgements

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9. References


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