Requirements for Inter-Area MPLS Traffic Engineering

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Abstract

This document lists a detailed set of functional requirements for the
support of inter-area MPLS Traffic Engineering (inter-area MPLS TE).
It is intended that solutions that specify procedures and protocol
extensions for inter-area MPLS TE satisfy these requirements.

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1. Introduction

   The set of MPLS Traffic Engineering components, defined in [RSVP-TE],
   [OSPF-TE], and [ISIS-TE], which supports the requirements defined in
   [TE-REQ], is used today by many network operators to achieve major
   Traffic Engineering objectives defined in [TE-OVW]. These objectives
   include:

      - Aggregated Traffic measurement
      - Optimization of network resources utilization
      - Support for services requiring end-to-end QoS guarantees
      - Fast recovery against link/node/Shared Risk Link Group (SRLG)
        failures

   Furthermore, the applicability of MPLS to traffic engineering in IP
   networks is discussed in [TE-APP].

   The set of MPLS Traffic Engineering mechanisms, to date, has been
   limited to use within a single Interior Gateway Protocol (IGP) area.

This document discusses the requirements for an inter-area MPLS
Traffic Engineering mechanism that may be used to achieve the same
set of objectives across multiple IGP areas.

Basically, it would be useful to extend MPLS TE capabilities across
IGP areas to support inter-area resources optimization, to provide
strict QoS guarantees between two edge routers located within
distinct areas, and to protect inter-area traffic against Area Border
Router (ABR) failures.

First, this document addresses current uses of MPLS Traffic
Engineering within a single IGP area. Then, it discusses a set of
functional requirements that a solution must or should satisfy in
order to support inter-area MPLS Traffic Engineering. Because the
scope of requirements will vary between operators, some requirements
will be mandatory (MUST), whereas others will be optional (SHOULD).
Finally, a set of evaluation criteria for any solution meeting these
requirements is given.

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 [RFC2119].

3. Terminology

LSR: Label Switching Router

LSP: Label Switched Path

TE LSP: Traffic Engineering Label Switched Path

Inter-area TE LSP: TE LSP whose head-end LSR and tail-end LSR do not
                    reside within the same IGP area or whose head-end
                    LSR and tail-end LSR are both in the same IGP area
                    although the TE-LSP transiting path is across
                    different IGP areas.

IGP area: OSPF area or IS-IS level.

ABR: Area Border Router, a router used to connect two
                    IGP areas (ABR in OSPF, or L1/L2 router in IS-IS).

CSPF: Constraint-based Shortest Path First.

SRLG: Shared Risk Link Group.

4. Current Intra-Area Uses of MPLS Traffic Engineering

   This section addresses architecture, capabilities, and uses of MPLS
   TE within a single IGP area. It first summarizes the current MPLS-TE
   architecture, then addresses various MPLS-TE capabilities, and
   finally lists various approaches to integrate MPLS TE into routing.
   This section is intended to help define the requirements for MPLS-TE
   extensions across multiple IGP areas.

4.1. Intra-Area MPLS Traffic Engineering Architecture

   The MPLS-TE control plane allows establishing explicitly routed MPLS
   LSPs whose paths follow a set of TE constraints. It is used to
   achieve major TE objectives such as resource usage optimization, QoS
   guarantee and fast failure recovery. It consists of three main
   components:

   - The routing component, responsible for the discovery of the TE
     topology. This is ensured thanks to extensions of link state IGP:
     [ISIS-TE], [OSPF-TE].
   - The path computation component, responsible for the placement of
     the LSP. It is performed on the head-end LSR thanks to a CSPF
     algorithm, which takes TE topology and LSP constraints as input.
   - The signaling component, responsible for the establishment of the
     LSP (explicit routing, label distribution, and resources
     reservation) along the computed path. This is ensured thanks to
     RSVP-TE [RSVP-TE].

4.2. Intra-Area MPLS Traffic Engineering Applications

4.2.1. Intra-Area Resource Optimization

   MPLS TE can be used within an area to redirect paths of aggregated
   flows away from over-utilized resources within a network. In a small
   scale, this may be done by explicitly configuring a path to be used
   between two routers. On a grander scale, a mesh of LSPs can be
   established between central points in a network. LSPs paths can be
   defined statically in configuration or arrived at by an algorithm
   that determines the shortest path given administrative constraints
   such as bandwidth. In this way, MPLS TE allows for greater control
   over how traffic demands are routed over a network topology and
   utilize a network's resources.

   Note also that TE LSPs allow measuring traffic matrix in a simple and
   scalable manner. The aggregated traffic rate between two LSRs is
   easily measured by accounting of traffic sent onto a TE LSP
   provisioned between the two LSRs in question.

4.2.2. Intra-Area QoS Guarantees

   The DiffServ IETF working group has defined a set of mechanisms
   described in [DIFF-ARCH], [DIFF-AF], and [DIFF-EF] or [MPLS-DIFF],
   that can be activated at the edge of or over a DiffServ domain to
   contribute to the enforcement of a QoS policy (or set of policies),
   which can be expressed in terms of maximum one-way transit delay,
   inter-packet delay variation, loss rate, etc. Many Operators have
   some or full deployment of DiffServ implementations in their networks
   today, either across the entire network or at least at its edge.

   In situations where strict QoS bounds are required, admission control
   inside the backbone of a network is in some cases required in
   addition to current DiffServ mechanisms. When the propagation delay
   can be bounded, the performance targets, such as maximum one-way
   transit delay, may be guaranteed by providing bandwidth guarantees
   along the DiffServ-enabled path.

   MPLS TE can be simply used with DiffServ: in that case, it only
   ensures aggregate QoS guarantees for the whole traffic. It can also
   be more intimately combined with DiffServ to perform per-class of
   service admission control and resource reservation. This requires
   extensions to MPLS TE called DiffServ-Aware TE, which are defined in
   [DSTE-PROTO]. DS-TE allows ensuring strict end-to-end QoS
   guarantees. For instance, an EF DS-TE LSP may be provisioned between
   voice gateways within the same area to ensure strict QoS to VoIP
   traffic.

   MPLS TE allows computing intra-area shortest paths, which satisfy
   various constraints, including bandwidth. For the sake of
   illustration, if the IGP metrics reflects the propagation delay, it
   allows finding a minimum propagation delay path, which satisfies
   various constraints, such as bandwidth.

4.2.3. Fast Recovery within an IGP Area

   As quality-sensitive applications are deployed, one of the key
   requirements is to provide fast recovery mechanisms, allowing traffic
   recovery to be guaranteed on the order of tens of msecs, in case of
   network element failure. Note that this cannot be achieved by
   relying only on classical IGP rerouting.

   Various recovery mechanisms can be used to protect traffic carried
   onto TE LSPs. They are defined in [MPLS-RECOV]. Protection
   mechanisms are based on the provisioning of backup LSPs that are used
   to recover traffic in case of failure of protected LSPs. Among those
   protection mechanisms, local protection (also called Fast Reroute) is
   intended to achieve sub-50ms recovery in case of link/node/SRLG

failure along the LSP path [FAST-REROUTE]. Fast Reroute is currently
used by many operators to protect sensitive traffic inside an IGP
area.

[FAST-REROUTE] defines two modes for backup LSPs. The first, called
one-to-one backup, consists of setting up one detour LSP per
protected LSP and per element to protect. The second, called
facility backup, consists of setting up one or several bypass LSPs to
protect a given facility (link or node). In case of failure, all
protected LSPs are nested into the bypass LSPs (benefiting from the
MPLS label stacking property).

4.3. Intra-Area MPLS TE and Routing

There are several possibilities for directing traffic into intra-area
TE LSPs:

1) Static routing to the LSP destination address or any other
   addresses.
2) IGP routes beyond the LSP destination, from an IGP SPF perspective
   (IGP shortcuts).
3) BGP routes announced by a BGP peer (or an MP-BGP peer) that is
   reachable through the TE LSP by means of a single static route to
   the corresponding BGP next-hop address (option 1) or by means of
   IGP shortcuts (option 2). This is often called BGP recursive
   routing.
4) The LSP can be advertised as a link into the IGP to become part of
   IGP database for all nodes, and thus can be taken into account
   during SPF for all nodes. Note that, even if similar in concept,
   this is different from the notion of Forwarding-Adjacency, as
   defined in [LSP-HIER]. Forwarding-Adjacency is when the LSP is
   advertised as a TE-link into the IGP-TE to become part of the TE
   database and taken into account in CSPF.

5. Problem Statement, Requirements, and Objectives of Inter-Area
    MPLS TE

5.1. Inter-Area Traffic Engineering Problem Statement

As described in Section 4, MPLS TE is deployed today by many
operators to optimize network bandwidth usage, to provide strict QoS
guarantees, and to ensure sub-50ms recovery in case of link/node/SRLG
failure.

However, MPLS-TE mechanisms are currently limited to a single IGP
area. The limitation comes more from the Routing and Path
computation components than from the signaling component. This is
basically because the hierarchy limits topology visibility of head-

   end LSRs to their IGP area, and consequently head-end LSRs can no
   longer run a CSPF algorithm to compute the shortest constrained path
   to the tail-end, as CSPF requires the whole topology to compute an
   end-to-end shortest constrained path.

   Several operators have multi-area networks, and many operators that
   are still using a single IGP area may have to migrate to a multi-area
   environment, as their network grows and single area scalability
   limits are approached.

   Thus, those operators may require inter-area traffic engineering to:

   - Perform inter-area resource optimization.
   - Provide inter-area QoS guarantees for traffic between edge nodes
     located in different areas.
   - Provide fast recovery across areas, to protect inter-area traffic
     in case of link or node failure, including ABR node failures.

   For instance, an operator running a multi-area IGP may have voice
   gateways located in different areas. Such VoIP transport requires
   inter-area QoS guarantees and inter-area fast protection.

   One possible approach for inter-area traffic engineering could
   consist of deploying MPLS TE on a per-area basis, but such an
   approach has several limitations:

   - Traffic aggregation at the ABR levels implies some constraints that
     do not lead to efficient traffic engineering. Actually, this per-
     area TE approach might lead to sub-optimal resource utilization, by
     optimizing resources independently in each area. What many
     operators want is to optimize their resources as a whole; in other
     words, as if there was only one area (flat network).
   - This does not allow computing an inter-area constrained shortest
     path and thus does not ensure end-to-end QoS guarantees across
     areas.
   - Inter-area traffic cannot be protected with local protection
     mechanisms such as [FAST-REROUTE] in case of ABR failure.

   Therefore, existing MPLS TE mechanisms have to be enhanced to support
   inter-area TE LSPs.

5.2. Overview of Requirements for Inter-Area MPLS TE

   For the reasons mentioned above, it is highly desired to extend the
   current set of MPLS-TE mechanisms across multiple IGP areas in order
   to support the intra-area applications described in Section 4 across
   areas.

The solution MUST allow setting up inter-area TE LSPs; i.e., LSPs
whose path crosses at least two IGP areas.

Inter-area MPLS-TE extensions are highly desired in order to provide:

- Inter-area resources optimization.
- Strict inter-area QoS guarantees.
- Fast recovery across areas, particularly to protect inter-area
  traffic against ABR failures.

It may be desired to compute inter-area shortest paths that satisfy
some bandwidth constraints or any other constraints, as is currently
possible within a single IGP area. For the sake of illustration, if
the IGP metrics reflects the propagation delay, it may be necessary
to be able to find the optimal (shortest) path satisfying some
constraints (e.g., bandwidth) across multiple IGP areas. Such a path
would be the inter-area path offering the minimal propagation delay.

Thus, the solution SHOULD provide the ability to compute inter-area
shortest paths satisfying a set of constraints (i.e., bandwidth).

5.3. Key Objectives for an Inter-Area MPLS-TE Solution

Any solution for inter-area MPLS TE should be designed with
preserving IGP hierarchy concept, and preserving routing and
signaling scalability as key objectives.

5.3.1. Preserving the IGP Hierarchy Concept

The absence of a full link-state topology database makes the
computation of an end-to-end optimal path by the head-end LSR not
possible without further signaling and routing extensions. There are
several reasons that network operators choose to break up their
network into different areas. These often include scalability and
containment of routing information. The latter can help isolate most
of a network from receiving and processing updates that are of no
consequence to its routing decisions. Containment of routing
information MUST not be compromised to allow inter-area traffic
engineering. Information propagation for path-selection MUST
continue to be localized. In other words, the solution MUST entirely
preserve the concept of IGP hierarchy.

5.3.2. Preserving Scalability

Achieving the requirements listed in this document MUST be performed
while preserving the IGP scalability, which is of the utmost
importance. The hierarchy preservation objective addressed in the
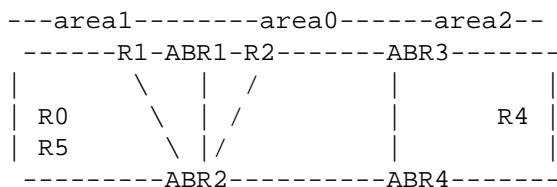above section is actually an element to preserve IGP scalability.

The solution also MUST not increase IGP load unreasonably, which
could compromise IGP scalability. In particular, a solution
satisfying those requirements MUST not require the IGP to carry some
unreasonable amount of extra information and MUST not unreasonably
increase the IGP flooding frequency.

Likewise, the solution MUST also preserve scalability of RSVP-TE
([RSVP-TE]).

Additionally, the base specification of MPLS TE is architecturally
structured and relatively devoid of excessive state propagation in
terms of routing or signaling. Its strength in extensibility can
also be seen as an Achilles heel, as there is no real limit to what
is possible with extensions. It is paramount to maintain
architectural vision and discretion when adapting it for use for
inter-area MPLS TE. Additional information carried within an area or
propagated outside of an area (via routing or signaling) should be
neither excessive, patchwork, nor non-relevant.

Particularly, as mentioned in Section 5.2, it may be desired for some
inter-area TE LSP carrying highly sensitive traffic to compute a
shortest inter-area path, satisfying a set of constraints such as
bandwidth. This may require an additional routing mechanism, as base
CSPF at head-end can no longer be used due to the lack of topology
and resource information. Such a routing mechanism MUST not
compromise the scalability of the overall system.

6. Application Scenario

```
    ---area1--------area0------area2--
     ------R1-ABR1-R2-------ABR3-------
    |        \  |  /        |          |
    | R0      \ | /         |      R4  |
    | R5       \|/          |          |
     --------ABR2----------ABR4-------
```

       - ABR1, ABR2: Area0-Area1 ABRs
       - ABR3, ABR4: Area0-Area2 ABRs

       - R0, R1, R5: LSRs in area 1
       - R2: an LSR in area 0
       - R4: an LSR in area 2

Although the terminology and examples provided in this document make
use of the OSPF terminology, this document equally applies to IS-IS.

   Typically, an inter-area TE LSP will be set up between R0 and R4,
   where both LSRs belong to different IGP areas. Note that the
   solution MUST support the capability to protect such an inter-area TE
   LSP from the failure on any Link/SRLG/Node within any area and the
   failure of any traversed ABR. For instance, if the TE LSP R0->R4
   goes through R1->ABR1->R2, then it can be protected against ABR1
   failure, thanks to a backup LSP (detour or bypass) that may follow
   the alternate path R1->ABR2->R2.

   For instance, R0 and R4 may be two voice gateways located in distinct
   areas. An inter-area DS-TE LSP with class-type EF is set up from R1
   to R4 to route VoIP traffic classified as EF. Per-class inter-area
   constraint-based routing allows the DS-TE LSP to be routed over a
   path that will ensure strict QoS guarantees for VoIP traffic.

   In another application, R0 and R4 may be two pseudo wire gateways
   residing in different areas. An inter-area LSP may be set up to
   carry pseudo wires.

   In some cases, it might also be possible to have an inter-area TE LSP
   from R0 to R5 transiting via the backbone area (or any other levels
   with IS-IS). There may be cases where there are no longer enough
   resources on any intra area path R0-to-R5, and where there is a
   feasible inter-area path through the backbone area.

7. Detailed Requirements for Inter-Area MPLS TE

7.1. Inter-Area MPLS TE Operations and Interoperability

   The inter-area MPLS TE solution MUST be consistent with requirements
   discussed in [TE-REQ], and the derived solution MUST interoperate
   seamlessly with current intra-area MPLS TE mechanisms and inherit its
   capability sets from [RSVP-TE].

   The proposed solution MUST allow provisioning at the head-end with
   end-to-end RSVP signaling (potentially with loose paths) traversing
   across the interconnected ABRs, without further provisioning required
   along the transit path.

7.2. Inter-Area TE-LSP Signaling

   The solution MUST allow for the signaling of inter-area TE LSPs,
   using RSVP-TE.

   In addition to the signaling of classical TE constraints (bandwidth,
   admin-groups), the proposed solution MUST allow the head-end LSR to
   specify a set of LSRs explicitly, including ABRs, by means of strict
   or loose hops for the inter-area TE LSP.

In addition, the proposed solution SHOULD also provide the ability to
specify and signal certain resources to be explicitly excluded in the
inter-area TE-LSP path establishment.

7.3. Path Optimality

In the context of this requirement document, an optimal path is
defined as the shortest path across multiple areas, taking into
account either the IGP or TE metric [METRIC]. In other words, such a
path is the path that would have been computed by making use of some
CSPF algorithm in the absence of multiple IGP areas.

As mentioned in Section 5.2, the solution SHOULD provide the
capability to compute an optimal path dynamically, satisfying a set
of specified constraints (defined in [TE-REQ]) across multiple IGP
areas. Note that this requirement document does not mandate that all
inter-area TE LSPs require the computation of an optimal (shortest)
inter-area path. Some inter-area TE-LSP paths may be computed via
some mechanisms that do not guarantee an optimal end-to-end path,
whereas some other inter-area TE-LSP paths carrying sensitive traffic
could be computed by making use of mechanisms allowing an optimal
end-to-end path to be computed dynamically. Note that regular
constraints such as bandwidth, affinities, IGP/TE metric
optimization, path diversity, etc., MUST be taken into account in the
computation of an optimal end-to-end path.

7.4. Inter-Area MPLS-TE Routing

As mentioned in Section 5.3, IGP hierarchy does not allow the head-
end LSR to compute an end-to-end optimal path. Additional mechanisms
are required to compute an optimal path. These mechanisms MUST not
alter the IGP hierarchy principles. Particularly, in order to
maintain containment of routing information and to preserve the
overall IGP scalability, the solution SHOULD avoid any dynamic-TE-
topology-related information from leaking across areas, even in a
summarized form.

Conversely, this does not preclude the leaking of non-topology-
related information that is not taken into account during path
selection, such as static TE Node information (TE router ids or TE
node capabilities).

7.5. Inter-Area MPLS-TE Path Computation

   Several methods may be used for path computation, including the
   following:

   - Per-area path computation based on ERO expansion on the head-end
     LSR and on ABRs, with two options for ABR selection:

        1) Static configuration of ABRs as loose hops at the head-end
           LSR.
        2) Dynamic ABR selection.

   - Inter-area end-to-end path computation, which may be based on (for
     instance) a recursive constraint-based searching thanks to
     collaboration between ABRs.

   Note that any path computation method may be used provided that it
   respect key objectives pointed out in Section 5.3.

   If a solution supports more than one method, it should allow the
   operator to select by configuration, and on a per-LSP basis, the
   desired option.

7.6. Inter-Area Crankback Routing

   Crankback routing, as defined in [CRANKBACK], may be used for inter-
   area TE LSPs. For paths computed thanks to ERO expansions with a
   dynamic selection of downstream ABRs, crankback routing can be used
   when there is no feasible path from a selected downstream ABR to the
   destination. The upstream ABR or head-end LSR selects another
   downstream ABR and performs ERO expansion.

   Note that this method does not allow computing an optimal path but
   just a feasible path. Note also that there can be 0(N^2) LSP setup
   failures before finding a feasible path, where N is the average
   number of ABR between two areas. This may have a non-negligible
   impact on the LSP setup delay.

   Crankback may also be used for inter-area LSP recovery. If a
   link/node/SRLG failure occurs in the backbone or tail-end area, the
   ABR upstream to the failure computes an alternate path and reroutes
   the LSP locally.

   An inter-area MPLS-TE solution MAY support [CRANKBACK]. A solution
   that does, MUST allow [CRANKBACK] to be activated/deactivated via
   signaling, on a per-LSP basis.

7.7. Support of Diversely-Routed Inter-Area TE LSPs

   There are several cases where the ability to compute diversely-routed
   TE-LSP paths may be desirable. For instance, in the case of LSP
   protection, primary and backup LSPs should be diversely routed.
   Another example is the requirement to set up multiple diversely-
   routed TE LSPs between a pair of LSRs residing in different IGP
   areas. For instance, when a single TE LSP satisfying the bandwidth
   constraint cannot be found between two end-points, a solution would
   consist of setting up multiple TE LSPs so that the sum of their
   bandwidth satisfy the bandwidth requirement. In this case, it may be
   desirable to have these TE LSPs diversely routed in order to minimize
   the impact of a failure, on the traffic between the two end-points.

   Thus, the solution MUST be able to establish diversely-routed inter-
   area TE LSPs when diverse paths exist. It MUST support all kinds of
   diversity (link, node, SRLG).

   The solution SHOULD allow computing an optimal placement of
   diversely-routed LSPs. There may be various criteria to determine an
   optimal placement. For instance, the placement of two diversely
   routed LSPs for load-balancing purposes may consist of minimizing
   their cumulative cost. The placement of two diversely-routed LSPs
   for protection purposes may consist of minimizing the cost of the
   primary LSP while bounding the cost or hop count of the backup LSP.

7.8. Intra/Inter-Area Path Selection Policy

   For inter-area TE LSPs whose head-end and tail-end LSRs reside in the
   same IGP area, there may be intra-area and inter-area feasible paths.
   If the shortest path is an inter-area path, an operator either may
   want to avoid, as far as possible, crossing area and thus may prefer
   selecting a sub-optimal intra-area path or, conversely, may prefer to
   use a shortest path, even if it crosses areas. Thus, the solution
   should allow IGP area crossing to be enabled/disabled, on a per-LSP
   basis, for TE LSPs whose head-end and tail-end reside in the same IGP
   area.

7.9. Reoptimization of Inter-Area TE LSP

   The solution MUST provide the ability to reoptimize in a minimally
   disruptive manner (make before break) an inter-area TE LSP, should a
   more optimal path appear in any traversed IGP area. The operator
   should be able to parameterize such a reoptimization according to a
   timer or event-driven basis. It should also be possible to trigger
   such a reoptimization manually.

The solution SHOULD provide the ability to reoptimize an inter-area
TE LSP locally within an area; i.e., while retaining the same set of
transit ABRs. The reoptimization process in that case MAY be
controlled by the head-end LSR of the inter-area LSP, or by an ABR.
The ABR should check for local optimality of the inter-area TE LSPs
established through it on a timer or event driven basis. The option
of a manual trigger to check for optimality should also be provided.

In some cases it is important to restrict the control of
reoptimization to the Head-End LSR only. Thus, the solution MUST
allow for activating/deactivating ABR control of reoptimization, via
signaling on a per LSP-basis.

The solution SHOULD also provide the ability to perform an end-to-end
reoptimization, potentially resulting in a change on the set of
transit ABRs. Such reoptimization can only be controlled by the
Head-End LSR.

In the case of head-end control of reoptimization, the solution
SHOULD provide the ability for the inter-area head-end LSR to be
informed of the existence of a more optimal path in a downstream area
and keep a strict control over the reoptimization process. Thus, the
inter-area head-end LSR, once informed of a more optimal path in some
downstream IGP areas, could decide to perform a make-before-break
reoptimization gracefully (or not to), according to the inter-area
TE-LSP characteristics.

7.10. Inter-Area LSP Recovery

7.10.1. Rerouting of Inter-Area TE LSPs

The solution MUST support rerouting of an inter-area TE LSP in case
of SRLG/link/node failure or preemption. Such rerouting may be
controlled by the Head-End LSR or by an ABR (see Section 7.6, on
crankback).

7.10.2. Fast Recovery of Inter-Area TE LSP

The solution MUST provide the ability to benefit from fast recovery,
making use of the local protection techniques specified in
[FAST-REROUTE] both in the case of an intra-area network element
failure (link/SRLG/node) and in that of an ABR node failure. Note
that different protection techniques SHOULD be usable in different
parts of the network to protect an inter-area TE LSP. This is of the
utmost importance, particularly in the case of an ABR node failure,
as this node typically carries a great deal of inter-area traffic.
Moreover, the solution SHOULD allow computing and setting up a backup
tunnel following an optimal path that offers bandwidth guarantees

during failure, along with other potential constraints (such as
bounded propagation delay increase along the backup path).

The solution SHOULD allow ABRs to be protected, while providing the
same level of performances (recovery delay, bandwidth consumption) as
provided today within an area.

Note that some signaling approaches may have an impact on FRR
performances (recovery delay, bandwidth consumption). Typically,
when some intra-area LSPs (LSP-Segment, FA-LSPs) are used to support
the inter-area TE LSP, the protection of ABR using [FAST-REROUTE] may
lead to higher bandwidth consumption and higher recovery delays. The
use of [FAST-REROUTE] to protect ABRs, although ensuring the same
level of performances, currently requires a single end-to-end RSVP
session (contiguous LSP) to be used, without any intra-area LSP.
Thus, the solution MUST provide the ability, via signalling on a
per-LSP basis, to allow or preclude the use of intra-area LSPs to
support the inter-area LSPs.

7.11. DS-TE support

The proposed inter-area MPLS TE solution SHOULD also satisfy core
requirements documented in [DSTE-REQ] and interoperate seamlessly
with current intra-area MPLS DS-TE mechanism [DSTE-PROTO].

7.12. Hierarchical LSP Support

In the case of a large inter-area MPLS deployment, potentially
involving a large number of LSRs, it may be desirable/necessary to
introduce some level of hierarchy in order to reduce the number of
states on LSRs (such a solution implies other challenges). Thus, the
proposed solution SHOULD allow inter-area TE-LSP aggregation (also
referred to as LSP nesting) so that individual TE LSPs can be carried
onto one or more aggregating LSPs. One such mechanism, for example,
is described in [LSP-HIER].

7.13. Hard/Soft Preemption

As defined in [MPLS-PREEMPT], two preemption models are applicable to
MPLS: Soft and Hard Preemption.

An inter-area MPLS-TE solution SHOULD support the two models.

In the case of hard preemption, the preempted inter-area TE LSP
should be rerouted, following requirements defined in Section 7.10.1.

   In the case of soft preemption, the preempted inter-area TE LSP
   should be re-optimized, following requirements defined in Section
   7.9.

7.14. Auto-Discovery of TE Meshes

   A TE mesh is a set of LSRs that are fully interconnected by a full
   mesh of TE LSPs. Because the number of LSRs participating in some TE
   mesh might be quite large, it might be desirable to provide some
   discovery mechanisms allowing an LSR to discover automatically the
   LSRs members of the TE mesh(es) that it belongs to. The discovery
   mechanism SHOULD be applicable across multiple IGP areas, and SHOULD
   not impact the IGP scalability, provided that IGP extensions are used
   for such a discovery mechanism.

7.15. Inter-Area MPLS TE Fault Management Requirements

   The proposed solution SHOULD be able to interoperate with fault
   detection mechanisms of intra-area MPLS TE.

   The solution SHOULD support [LSP-PING] and [MPLS-TTL].

   The solution SHOULD also support fault detection on backup LSPs, in
   case [FAST-REROUTE] is deployed.

7.16. Inter-Area MPLS TE and Routing

   In the case of intra-area MPLS TE, there are currently several
   possibilities for routing traffic into an intra-area TE LSP. They
   are listed in Section 4.2.

   In the case of inter-area MPLS TE, the solution MUST support static
   routing into the LSP, and also BGP recursive routing with a static
   route to the BGP next-hop address.

   ABRs propagate IP reachability information (summary LSA in OSPF and
   IP reachability TLV in ISIS), that MAY be used by the head-end LSR to
   route traffic to a destination beyond the TE-LSP tail-head LSR (e.g.,
   to an ASBR).

   The use of IGP shortcuts MUST be precluded when TE-LSP head-end and
   tail-end LSRs do not reside in the same IGP area. It MAY be used
   when they reside in the same area.

   The advertisement of an inter-area TE LSP as a link into the IGP, in
   order to attract traffic to an LSP source, MUST be precluded when
   TE-LSP head-end and tail-end LSRs do not reside in the same IGP area.
   It MAY be used when they reside in the same area.

8. Evaluation criteria

8.1. Performances

   The solution will be evaluated with respect to the following
   criteria:

   (1) Optimality of the computed inter-area TE-LSP primary and backup
       paths, in terms of path cost.
   (2) Capability to share bandwidth among inter-area backup LSPs
       protecting independent facilities.
   (3) Inter-area TE-LSP setup time (in msec).
   (4) RSVP-TE and IGP scalability (state impact, number of messages,
       message size).

8.2. Complexity and Risks

   The proposed solution SHOULD not introduce complexity to the current
   operating network to such a degree that it would affect the stability
   and diminish the benefits of deploying such a solution over SP
   networks.

8.3. Backward Compatibility

   In order to allow for a smooth migration or co-existence, the
   deployment of inter-area MPLS TE SHOULD not affect existing MPLS TE
   mechanisms. In particular, the solution SHOULD allow the setup of an
   inter-area TE LSP among transit LSRs that do not support inter-area
   extensions, provided that these LSRs do not participate in the
   inter-area TE procedure. For illustration purposes, the solution MAY
   require inter-area extensions only on end-point LSRs, on ABRs, and,
   potentially, on Points of Local Repair (PLR) protecting an ABR.

9. Security Considerations

   This document does not introduce new security issues beyond those
   inherent in MPLS TE [RSVP-TE] and an inter-area MPLS-TE solution may
   use the same mechanisms proposed for that technology. It is,
   however, specifically important that manipulation of administratively
   configurable parameters be executed in a secure manner by authorized
   entities.

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