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OSPF Extensions to Support Maximally Redundant Trees
draft-ietf-ospf-mrt-00

Abstract

   This document specifies extensions to OSPF to support the distributed
   computation of Maximally Redundant Trees (MRT). Some example uses of
   the MRTs include IP/LDP Fast-Reroute and global protection or live-
   live for multicast traffic. The extensions indicate what MRT
   profile(s) each router supports. Different MRT profiles can be
   defined to support different uses and to allow transitioning of
   capabilities. An extension is introduced to flood MRT-Ineligible
   links, due to administrative policy.

   The need for a mechanism to allow routers to advertise a worst-case
   FIB compute/install time is well understood for controlling
   convergence. This specification introduces the Controlled
   Convergence TLV to be carried in the Router Information LSA.

Status of This Memo

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1. Introduction

This document describes the OSPF extensions necessary to support the
architecture that defines how IP/LDP Fast-Reroute can use MRTs
[I-D.ietf-rtgwg-mrt-frr-architecture]. At least one common
standardized algorithm (such as the lowpoint algorithm explained and
fully documented in [I-D.ietf-rtgwg-mrt-frr-algorithm]) is required

so that the routers supporting MRT computation consistently compute
the same MRTs. MRT can also be used to protect multicast traffic via
either global protection or local
protection.[I-D.atlas-rtgwg-mrt-mc-arch]

IP/LDP Fast-Reroute using MRTs can provide 100% coverage for link and
node failures in an arbitrary network topology where the failure
doesn't split the network. It can also be deployed incrementally
inside an OSPF area; an MRT Island is formed of connected supporting
routers and the MRTs are computed inside that island.

In the default MRT profile, a supporting router both computes the
MRTs and creates the necessary transit forwarding state necessary to
provide the two additional forwarding topologies, known as MRT-Blue
and MRT-Red.

2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
"SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
document are to be interpreted as described in [RFC2119]

3. Terminology

For ease of reading, some of the terminology defined in
[I-D.ietf-rtgwg-mrt-frr-architecture] is repeated here.

network graph: A graph that reflects the network topology where all
   links connect exactly two nodes and broadcast links have been
   transformed into the standard pseudo-node representation.

Redundant Trees (RT):   A pair of trees where the path from any node
   X to the root R along the first tree is node-disjoint with the
   path from the same node X to the root along the second tree.
   These can be computed in 2-connected graphs.

Maximally Redundant Trees (MRT):   A pair of trees where the path
   from any node X to the root R along the first tree and the path
   from the same node X to the root along the second tree share the
   minimum number of nodes and the minimum number of links. Each
   such shared node is a cut-vertex. Any shared links are cut-links.
   Any RT is an MRT but many MRTs are not RTs.

MRT Island: From the computing router, the set of routers that
   support a particular MRT profile and are connected via MRT-
   eligible links.

GADAG: Generalized Almost Directed Acyclic Graph - a graph that is
   the combination of the ADAGs of all blocks. Transforming a
   network graph into a GADAG is part of the MRT algorithm.

MRT-Red: MRT-Red is used to describe one of the two MRTs; it is
   used to described the associated forwarding topology and MT-ID.
   Specifically, MRT-Red is the decreasing MRT where links in the
   GADAG are taken in the direction from a higher topologically
   ordered node to a lower one.

MRT-Blue: MRT-Blue is used to describe one of the two MRTs; it is
   used to described the associated forwarding topology and MT-ID.
   Specifically, MRT-Blue is the increasing MRT where links in the
   GADAG are taken in the direction from a lower topologically
   ordered node to a higher one.

4. Overview of OSPF Extensions for MRT

There are two separate aspects that need to be advertised in OSPF.
Both derive from the need for all routers supporting an MRT profile
to compute the same pair of MRTs to each destination. By executing
the same algorithm on the same network graph, distributed routers
will compute the same MRTs. Convergence considerations are discussed
in [I-D.ietf-rtgwg-mrt-frr-architecture].

The first aspect that must be advertised is which MRT profile(s) are
supported and the associated GADAG Root Selection Priority. The
second aspect that must be advertised is any links that are not
eligible, due to administrative policy, to be part of the MRTs. This
must be advertised consistently across the area so that all routers
in the MRT Island use the same network graph.

4.1. Supporting MRT Profiles

An MRT Profile defines the exact MRT Algorithm, the MRT-Red LDP MT-
ID, the MRT-Blue LDP MT-ID, and the forwarding mechanisms supported
for the transit MRT-Red and MRT-Blue forwarding topologies. Finally,
the MRT Profile defines exact behavioral rules such as:

o how reconvergence is handled,

o inter-area forwarding behavior,

A router that advertises support for an MRT Profile MUST provide the
specified forwarding mechanism for its MRT-Red and MRT-Blue
forwarding topologies. A router that advertises support for an MRT
Profile MUST implement an algorithm that produces the same set of
MRT-Red and MRT-Blue next-hops for its MRT-Red and MRT-Blue

topologies as is provided by the algorithm specified in the MRT
Profile.

A router MAY indicate support for multiple MRT Profiles. A router
computes its local MRT Island for each separate MRT Profile that the
router supports. Supporting multiple MRT Profiles also provides a
mechanism for transitioning from one profile to another. Different
uses of MRT forwarding topologies may behave better on different MRT
profiles.

The default MRT Profile is defined in
[I-D.ietf-rtgwg-mrt-frr-architecture]. Its behavior is intended to
support IP/LDP unicast and multicast fast-reroute.

4.2. GADAG Root Selection

One aspect of the MRT algorithms is that the selection of the GADAG
root can affect the alternates and the traffic through that GADAG
root. Therefore, it is important to provide an operator with control
over which router will play the role of GADAG root. A measure of the
centrality of a node may help determine how good a choice a
particular node is.

The GADAG Root Selection Policy (defined as part of an MRT profile)
may make use of the GADAG Root Selection Priority value advertised in
the MRT Profile TLV of the Router Information LSA. For example, the
GADAG Root Selection Policy for the default MRT profile is the
following: Among the routers in the MRT Island and with the highest
priority advertised, an implementation MUST pick the router with the
highest Router ID to be the GADAG root.

4.3. Triggering an MRT Computation

When an MRT Computation is triggered, it is triggered for a given MRT
Profile in a given area. First, the associated MRT Island is
determined. Then, the GADAG Root is selected. Finally, the actual
MRT algorithm is run to compute the transit MRT-Red and MRT-Blue
topologies. Additionally, the router MAY choose to compute MRT-FRR
alternates or make other use of the MRT computation results.

Prefixes can be attached and detached and have their associated MRT-
Red and MRT-Blue next-hops computed without requiring a new MRT
computation.

5. MRT Capability Advertisement

A router that supports MRT indicates this by setting a newly defined
M bit in the Router LSA. If the router provides no other information
via a separate MRT Profile TLV, then the router supports the default
MRT Profile with a GADAG Root Selection Priority of 128.

In addition, a router can advertise a newly-defined MRT Profile TLV
within the scope of the OSPF router information LSA [RFC4970]. This
TLV also includes the GADAG Root Selection Priority.

5.1. Advertising MRT Capability in OSPFv2

A new M-bit is defined in the Router-LSA (defined in [RFC2328] and
updated in [RFC4915]), as pictured below.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              LS age           |     Options   |      1        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Link State ID                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Advertising Router                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      LS sequence number                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         LS checksum           |              length           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|*|*|M|N|W|V|E|B|       0       |            # links            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Link ID                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Link Data                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |    # MT-ID    |            metric            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     MT-ID     |       0       |         MT-ID  metric       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            ...                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     MT-ID     |       0       |         MT-ID  metric       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Link ID                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Link Data                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            ...                               |
```
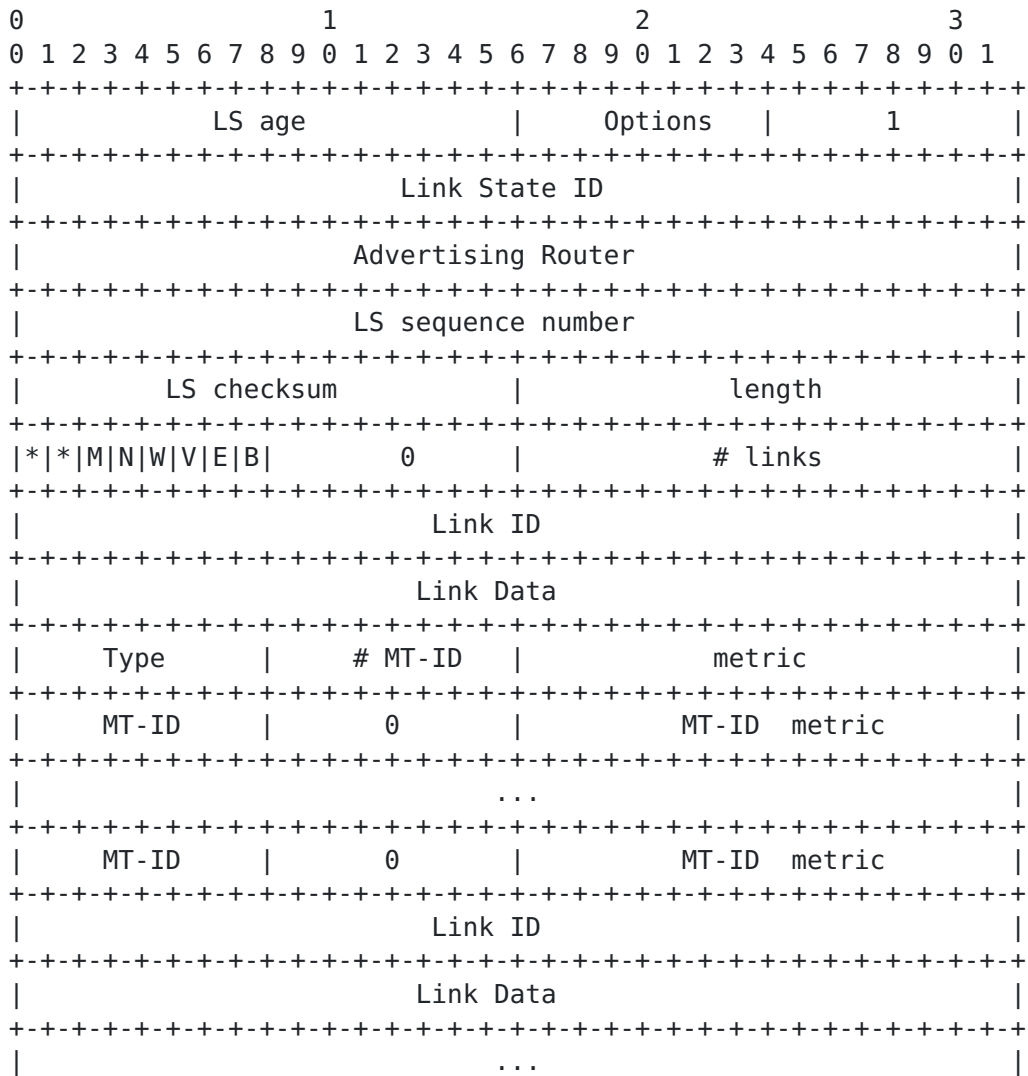
                    M-bit in OSPFv2 Router LSA

   M bit: When set, the router supports MRT. If no separate MRT
      Profile TLV is advertised in the associated Router Information
      LSA, then the router supports the default MRT Profile and has a
      GADAG Root Selection Priority of 128.

5.2. Advertising MRT Capability in OSPFv3

   Similarly, the M-bit is defined in the OSPFv3 Router LSA as shown
   below. Since there can be multiple router LSAs, the M-bit needs to
   be set on all of them.

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |             LS Age             |0|0|1|          1           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                       Link State ID                         |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Advertising Router                      |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                    LS Sequence Number                       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |      LS Checksum               |             Length         |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    | 0|M|Nt|x|V|E|B|           Options                           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    Type       |      0        |          Metric             |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                       Interface ID                          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                   Neighbor Interface ID                     |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                    Neighbor Router ID                       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                         ...                                 |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    Type       |      0        |          Metric             |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                       Interface ID                          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                   Neighbor Interface ID                     |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                    Neighbor Router ID                       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                         ...                                 |
```
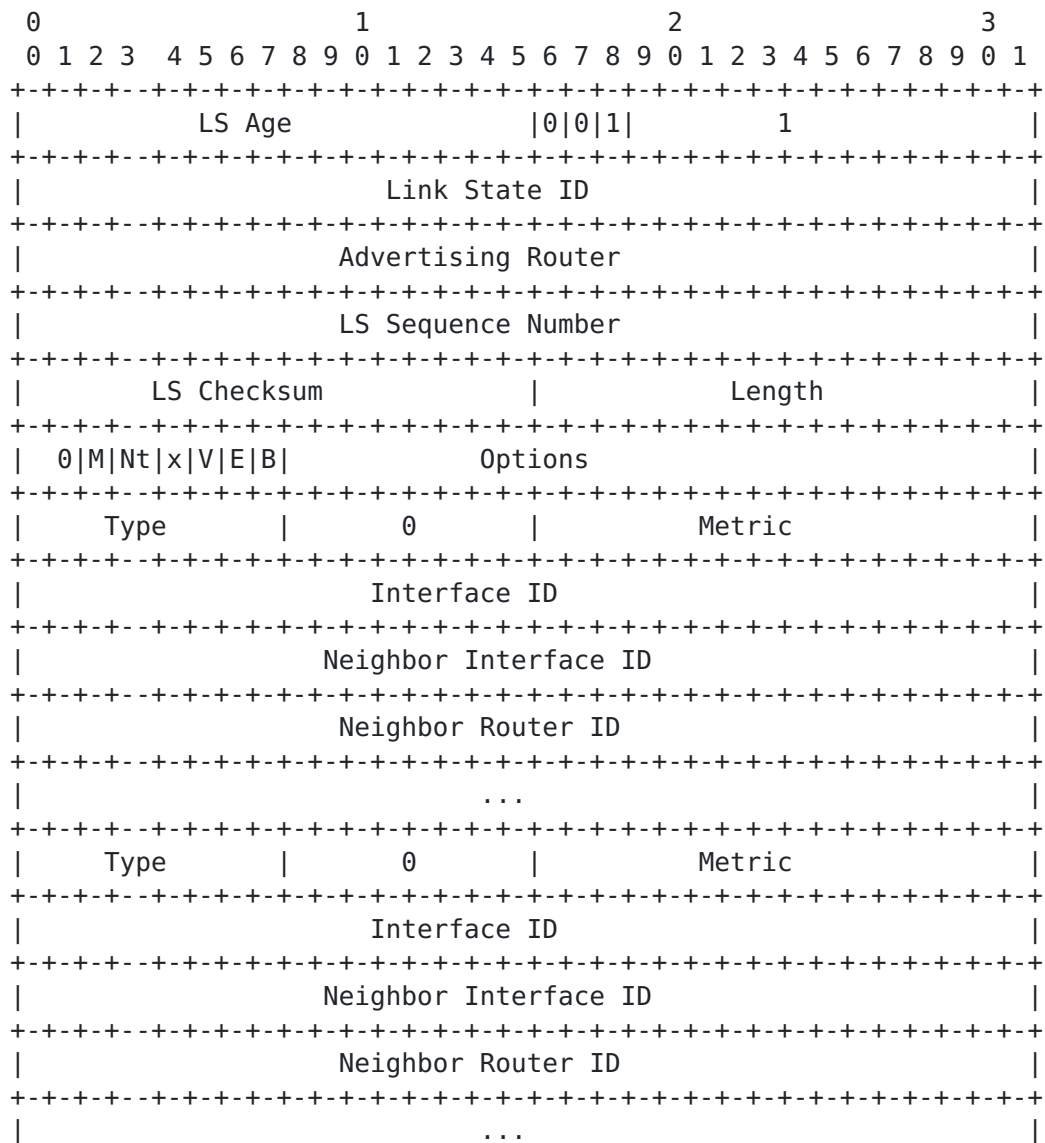
                    M-bit in OSPFv3 Router LSA

   M bit: When set, the router supports MRT. If no separate MRT
      Profile TLV is advertised in the associated Router Information
      LSA, then the router supports the default MRT Profile and has a
      GADAG Root Selection Priority of 128.

5.3. MRT Profile TLV in Router Information LSA

   A router may advertise an MRT Profile TLV to indicate support for
   multiple MRT Profiles, for a non-default MRT Profile, and/or to
   indicate a non-default GADAG Root Selection Priority. The MRT
   Profile TLV is advertised within the OSPF router information LSA

which is defined for both OSPFv2 and OSPFv3 in [RFC4970]. The RI LSA
MUST have area scope.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Type             |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Profile ID(1) |GADAG Priority |           Reserved            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         .............                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Profile ID(n) |GADAG Priority |           Reserved            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

      TYPE: TBA-MRT-OSPF-1 (To Be Allocated by IANA)
      LENGTH: 4 * (number of Profiles)
      Profile ID : 1 byte
      GADAG Priority: 1 byte

              MRT Profile TLV in Router Information LSA

   Each Profile ID listed indicates support for a given MRT Profile, as
   defined in [I-D.ietf-rtgwg-mrt-frr-architecture]. A Profile ID value
   of 0 corresponds to the default MRT profile.

   The GADAG Priority is the GADAG Root Selection Priority associated
   with the advertising router in the MRT Island for the associated MRT
   Profile, as indicated by the Profile ID. If multiple MRT Profiles
   are supported, then the length of this TLV varies. The ordering of
   the profiles inside the TLV is not significant. Multiple appearances
   of this TLV is not an error.

   Lack of support for the default MRT profile is indicated by the
   presence of an MRT Profile TLV with a non-zero Profile ID value, and
   the absence of an MRT Profile TLV with a zero Profile ID value.

6. Advertising MRT-ineligible links for MRT

   Due to adminstrative policy, some otherwise eligible links in the
   network topology may need to be excluded from the network graph upon
   which the MRT algorithm is run. Since the same network graph must be
   used across the area, it is critical for OSPF to flood which links to
   exclude from the MRT calculation. This is done by introducing a new
   MRT-Ineligible Link sub-TLV. For OSPFv2, this sub-TLV is carried in

the Extended Link TLV defined in
[I-D.ietf-ospf-segment-routing-extensions]. For OSPFv3, this sub-TLV
is carried in the Router-Link TLV defined in
[I-D.ietf-ospf-ospfv3-lsa-extend].

If a link is marked by administrative policy as MRT-Ineligible, then
a router MUST flood the OSPFv2 Extended Link TLV (or OSPFv3 Router-
Link TLV) for that link, including the MRT-Ineligible Link sub-TLV.
The OSPVv2 Extended Link TLV and OSPFv3 Router-Link TLV have area
wide scope.

6.1. MRT-Ineligible Link sub-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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Type             |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

TYPE:   TBA-MRT-OSPF-2 in OSPFv2 Extended Link TLV
        TBA-MRT-OSPF-3 in OSPFv3 Router-Link TLV
        (To Be Allocated by IANA)
LENGTH: 0


                 MRT-Ineligible Link sub-TLV
```

This zero-length sub-TLV can appear in the OSPFv2 Extended Link TLV
or the OSPFv3 Router-Link TLV. Its presence indicates that the
associated link MUST NOT be used in the MRT calculation for all
profiles.

7. Worst-Case Network Convergence Time

As part of converging the network after a single failure,
Section 12.2 of [I-D.ietf-rtgwg-mrt-frr-architecture] describes the
need to wait for a configured or advertised period for all routers to
be using their new SPTs. Similarly, any work on avoiding micro-
forwarding loops during convergence[RFC5715] requires determining the
maximum among all routers in the area of the worst-case route
computation and FIB installation time. More details on the specific
reasoning and need for flooding it are given in
[I-D.atlas-bryant-shand-lf-timers].

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Type              |              Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Reserved            |    FIB compute/install time    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

        TYPE: TBA-MRT-OSPF-4 (To Be Allocated by IANA)
        LENGTH: 4
        FIB compute/install time: This is the worst-case time the router
            may take to compute and install all OSPF routes in the area
            after a change to a stable network. The value is
            in milliseconds.

           Controlled Convergence TLV in Router Information LSA

   The Controlled Convergence TLV is carried in the Router Information
   LSA and flooded with area-wide scope. The FIB compute/install time
   value sent by a router SHOULD be an estimate taking into account
   network scale or real-time measurements, or both. Advertisements
   SHOULD be dampened to avoid frequent communication of small changes
   in the FIB compute/install time.

   A router receiving the Controlled Convergence sub-TLV SHOULD estimate
   the network convergence time as the maximum of the FIB compute/
   install times advertised by the routers in an area, including itself.
   In order to account for routers that do not advertise the Controlled
   Convergence sub-TLV, a router MAY use a locally configured minimum
   network convergence time as a lower bound on the computed network
   convergence time. A router MAY use a locally configured maximum
   network convergence time as an upper bound on the computed network
   convergence time.

8. Backwards Compatibility

   The MRT capability bit, the MRT Profile, the MRT-Ineligible Link, and
   the OSPFv3 MRT-Ineligible Link TLVs are defined in this document.
   They should not introduce any interoperability issues. Routers that
   do not support the MRT capability bit in the router LSA SHOULD
   silently ignore it. Routers that do not support the new MRT-related
   TLVs SHOULD silently ignore them.

8.1. Handling MRT Capability Changes

   When a router changes from supporting MRT to not supporting MRT, it
   is possible that Router Information LSAs with MRT-related TLVs remain
   in the neighbors' database briefly. Such MRT-related TLVs SHOULD be
   ignored when the associated Router LSA from that router does not have
   the MRT capability set in its Router LSA.

   When a router changes from not supporting MRT to supporting MRT, it
   will flood its Router LSA(s) with the M-bit set and may send an
   updated Router Information LSA. If a Router LSA is received with the
   M-bit newly set, an MRT computation SHOULD be scheduled but MAY be
   delayed up to 60 seconds to allow reception of updated related Router
   Information LSAs. In general, when changes in MRT-related
   information is received, an MRT computation SHOULD be triggered.

   The rationale behind using the M bit in router LSA is to handle the
   MRT capability changes gracefully in case of version upgrade/
   downgrade. The M bit in router LSA ensures the latest "MRT
   capability" information is available for computation when there is a
   downgrade to the version that doesn't support MRT and RI LSA.

9. Implementation Status

   [RFC Editor: please remove this section prior to publication.]

   Please see [I-D.ietf-rtgwg-mrt-frr-architecture] for details on
   implementation status.

10. Security Considerations

   This OSPF extension is not believed to introduce new security
   concerns. It relies upon the security architecture already provided
   for Router LSAs and Router Information LSAs.

11. IANA Considerations

   IANA is requested to allocate values for the following OSPF Router
   Information TLV Types [RFC4970]: MRT Profile TLV (TBA-MRT-OSPF-1),
   and Controlled Convergence TLV (TBA-MRT-OSPF-4).

   IANA is requested to allocate a value from the OSPF Extended Link LSA
   sub-TLV registry [I-D.ietf-ospf-segment-routing-extensions] for the
   MRT-Ineligible Link sub-TLV (TBA-MRT-OSPF-2).

   IANA is requested to allocate a value from the OSPFv3 Extended-LSA
   sub-TLV registry [I-D.ietf-ospf-ospfv3-lsa-extend] for the MRT-
   Ineligible Link sub-TLV (TBA-MRT-OSPF-3).

12. References

12.1. Normative References

[I-D.ietf-ospf-ospfv3-lsa-extend]
          Lindem, A., Mirtorabi, S., Roy, A., and F. Baker, "OSPFv3
          LSA Extendibility", draft-ietf-ospf-ospfv3-lsa-extend-05
          (work in progress), November 2014.

[I-D.ietf-ospf-segment-routing-extensions]
          Psenak, P., Previdi, S., Filsfils, C., Gredler, H.,
          Shakir, R., Henderickx, W., and J. Tantsura, "OSPF
          Extensions for Segment Routing", draft-ietf-ospf-segment-
          routing-extensions-03 (work in progress), December 2014.

[I-D.ietf-rtgwg-mrt-frr-algorithm]
          Enyedi, G., Csaszar, A., Atlas, A., Bowers, C., and A.
          Gopalan, "Algorithms for computing Maximally Redundant
          Trees for IP/LDP Fast-Reroute", draft-rtgwg-mrt-frr-
          algorithm-01 (work in progress), July 2014.

[I-D.ietf-rtgwg-mrt-frr-architecture]
          Atlas, A., Kebler, R., Bowers, C., Enyedi, G., Csaszar,
          A., Tantsura, J., Konstantynowicz, M., and R. White, "An
          Architecture for IP/LDP Fast-Reroute Using Maximally
          Redundant Trees", draft-rtgwg-mrt-frr-architecture-04
          (work in progress), July 2014.

[RFC2328] Moy, J., "OSPF Version 2", STD 54, RFC 2328, April 1998.

[RFC4970] Lindem, A., Shen, N., Vasseur, JP., Aggarwal, R., and S.
          Shaffer, "Extensions to OSPF for Advertising Optional
          Router Capabilities", RFC 4970, July 2007.

[RFC5340] Coltun, R., Ferguson, D., Moy, J., and A. Lindem, "OSPF
          for IPv6", RFC 5340, July 2008.

12.2. Informative References

[I-D.atlas-bryant-shand-lf-timers]
          K, A. and S. Bryant, "Synchronisation of Loop Free Timer
          Values", draft-atlas-bryant-shand-lf-timers-04 (work in
          progress), February 2008.

[I-D.atlas-rtgwg-mrt-mc-arch]
          Atlas, A., Kebler, R., Wijnands, I., Csaszar, A., and G.
          Envedi, "An Architecture for Multicast Protection Using
          Maximally Redundant Trees", draft-atlas-rtgwg-mrt-mc-
          arch-02 (work in progress), July 2013.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate
          Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC3137] Retana, A., Nguyen, L., White, R., Zinin, A., and D.
          McPherson, "OSPF Stub Router Advertisement", RFC 3137,
          June 2001.

[RFC4915] Psenak, P., Mirtorabi, S., Roy, A., Nguyen, L., and P.
          Pillay-Esnault, "Multi-Topology (MT) Routing in OSPF", RFC
          4915, June 2007.

[RFC5715] Shand, M. and S. Bryant, "A Framework for Loop-Free
          Convergence", RFC 5715, January 2010.

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