                    OSPF Multiple Area Links

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1.0 Abstract

This memo describes an option to the OSPF Version 2 specification
which allows multiple areas to share the same link. This option adds
no additional link state flooding over shared links other than the
normal link state database exchange and update originating from the
link's configured primary area. The option applies to standard areas,
stub areas, and NSSAreas. It eliminates the excess Area 0 link state
baggage that accompanies the use of virtual links as currently
practiced when configuring similar transits for standard OSPF areas.
Routers with this option configured are backward compatible with
routers running the standard OSPF Version 2 compliant implementation
as defined in RFC 2328, and can be restricted to a subset of the OSPF
routing domain. This option is applied only on OSPF border routers.

Implementation of OSPF multiple area links requires a modification to
the OSPF interface data structure which allows each interface of a
border router to be connected to multiple areas. One area is always
configured as the interface's primary area. Any additional areas
which are configured for an interface are called the interface's
secondary areas. Two adjacent border routers with mutually shared
secondary areas may transit a secondary area's intra-area traffic
over the adjacency. A typical application is a stub area or NSSArea
which is dual homed to the Area 0 backbone and loosely joined by an
internal slow speed link. If there exists a high speed Area 0 link
between two of the stub area's border routers, this option allows the

stub area's intra-area traffic to route across this high speed area 0 link. The current specification forces traffic to prefer the intra-area path over the slow speed link.

Another not so common application makes Area 0 the secondary area over a local high speed LAN link with the primary area a local stub or NSSArea. Here Area 0 is not primary due to topological limitations which restrict its applicability. E.g. the local LAN link could be a campus backbone with dozens of routers on it, all part of the same NSSArea.
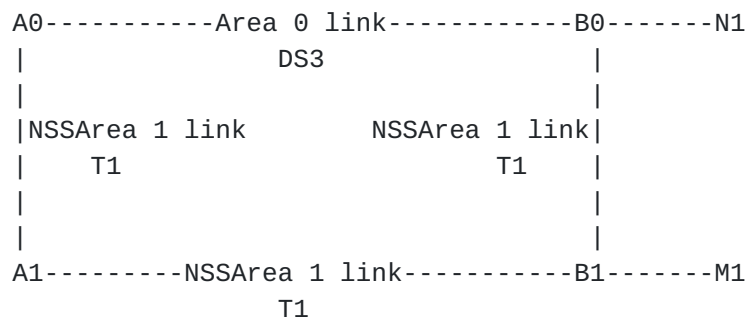
Please send comments to ospf@discuss.microsoft.com.

2.0 Overview

2.1 Requirement for OSPF Multiple Area Links

   Large corporate networks in todays modern Internet invest tremendous
   human and equipment resources, coupled with sizable budget, into
   their backbone infrastructure. Their regional networks are normally
   not so fortunate, and must multi-home to the backbone in order to
   take advantage of the backbone's high speed and high reliability
   network links. Performance over a T1 link can pale by comparison to
   performance over a DS3 or OC3 backbone link. Indeed, even a high
   speed 100 megabit LAN link can carry an order of magnitude more
   traffic than a standard 10 megabit link. Large corporate networks
   have sizable backbone routing tables and routinely use stub areas and
   NSSAreas. Under the current OSPF specification intra-area routes are
   always preferred over inter-area routes even when the traffic is
   sourced from and destined to the same non-backbone OSPF area.

   Consider the following typical OSPF example:

```
        A0-----------Area 0 link------------B0-------N1
        |                  DS3                     |
        |                                          |
        |NSSArea 1 link        NSSArea 1 link|
        |     T1                           T1    |
        |                                          |
        |                                          |
        A1---------NSSArea 1 link-----------B1-------M1
                        T1
```

   where A0 and B0 are border routers attached to NSSArea 1. A1 and B1
   are internal routers in NSSArea 1. N1 and M1 are standard ethernet
   networks in NSSArea 1 directly attached to B0 and B1 respectively.
   Assume all T1 links have an OSPF cost of 28 in both directions, N1
   and M1 are attached with interface costs 2. The DS3 link has an OSPF
   cost of 1. All costs are symmetric. Under the current OSPF
   specification the preferred path between A0 and M1 is

              A0<->A1<->B1<->M1

   with OSPF cost 58, even though there exists a more preferred path
   through B0 namely

              A0<->B0<->B1<->M1

   with OSPF cost 31. Indeed the DS3 link between A0 and B0 has the
   potential of making the performance between A0 and B1 approach that
   of a single T1.

Consider also the NSSArea 1 OSPF preferred path between A1 and N1,

                   A1<->B1<->B0<->N1,

with cost 58. Again there exists a more preferred path through the
link between A0 and B0, namely

                   A1<->A0<->B0<->N1

with cost 31. This link also has the potential of performing at
single hop T1 speeds. Under the current OSPF specification NSSArea
1's router A1 does not even see this path to N1 since it has no
knowledge of Area 0's topology. A0, on the other hand, would at
lease see the summary LSA of N1, but still cannot take advantage of
it due to OSPF intra-area path preference.

What is needed is a tool which makes the Area 0 link between A0 and
B0 visible in NSSArea 1. Virtual links are not an option since
virtual links don't work over NSSAreas. If the link between A0 and B0
were part of NSSArea 1, path preference would be optimal as the DS3
path would be intra-area for NSSArea 1. This cannot be the non-
backbone equivalent of an Area 0 virtual link. Excessive use of such
a feature would negate the purpose of the Area 0 backbone.

2.2 Proposed Solution

OSPF multiple area links provide the capability of allowing multiple
areas to use the same link/path between two border routers for
intra-area traffic. Traffic may originate from inside each of the
configured areas, as every router in the configured areas sees the
link/path as part of its link state topology. Only areas which are
dual homed to Area 0 may take advantage of this option, since any
router with multiple directly attached areas must be in Area 0 and it
takes at least two such border routers to create a multiple area
link.

The current OSPF specification only allows one area per interface.
Thus, should an Area L dual-home to two Area 0 border routers which
are adjacent over another Area K's router<->router link or router<-
>network link, the adjacent link over Area K is not seen inside Area
L, even though the two border routers exist physically adjacent
within Area L. This coupled with intra-area route preference prevents
Area L from utilizing Area K's adjacent link.

The softening of this restriction is facilitated by the addition of a
new parameter to the interface data structure called SecondaryAreas.
The SecondaryAreas interface parameter is a self-defining structure
containing a list of Area Ids for additional areas in which the

interface also belongs, along with their associated OSPF costs. The
areas listed in this parameter are called the interface's secondary
areas, as opposed to the interface's configured Area ID, hereafter
called the primary area. For each secondary area listed in the
SecondaryAreas parameter there is a list of neighboring Router Ids
which have formed adjacencies for the secondary area across the
interface's directly attached network or router link. These
adjacencies are called secondary adjacencies. Secondary adjacencies
are formed during the primary area's link state data base exchange
and update as defined in Sections 3.2 and 3.3.

A type 9 Opaque LSA is used to exchange/update the interface's
secondary areas with adjacent Opaque capable border routers. Until an
opaque type is assigned for this option, it will be simply referred
to as an mlink type 9 opaque LSA. A type 9 opaque LSA is used because
the flooding scope of the mlink type 9 opaque LSA needs to be
restricted to those routers directly attached to a common network or
router link. Each router will list its configured secondary addresses
as defined by the interface's SecondaryAreas parameter in its mlink
type 9 opaque LSA. The mlink type 9 opaque LSA is propagated during
the primary area's link state data base exchange and update with its
fully adjacent neighbors. If a router A receives an mlink type 9
opaque LSA from an adjacent router B during primary area K's link
state data base exchange, then router A and B form a secondary
adjacency in area L if and only if

     1) Area L is listed in the interface's SecondaryArea parameter.

     2) Area L is listed in router B's received mlink type 9 opaque
        LSA.

     3) Router A contains a type 1 (router) LSA from router B in Area
        L's link state data base.

If routers A and B form a secondary adjacency then the router ID of
router B is added to Area L's list of secondary adjacencies for the
interface.

Secondary adjacencies are either point-to-point or point-to-
multipoint. Any intervening transit networks always belong to the
interface's primary area. There is no network LSA for a secondary
adjacency's intervening transit network in the secondary area. Hence
all secondary adjacencies for Area L must be advertised in router A's
type 1 (router) LSA with unnumbered point-to-point type.

During the Dykstra SPF calculation the LSAs for secondary adjacencies
look like unnumbered point-to-point links, except on border routers
where they originate. A Border router never includes in a secondary

area's SPF tree any network across which one of its secondary
adjacencies span. This ensures synchronization of the SPF tree
amongst the secondary area's routers. However border routers do use
the IP addresses stored in neighboring border router LSAs for
determining link paths across a multi-access secondary adjacency.

There is no secondary link state data base exchange or update over
secondary adjacencies. Instead, these adjacencies rely on the
secondary area's base topology (minus the secondary links) for
flooding link state information regarding an area's secondary
adjacencies. The reasons for not attempting a secondary link state
data base exchange/update are two fold. First, the goal of this
document is to establish a transit for multiple areas over a single
link without imposing the additional traffic load caused by passing
the secondary area's link state database over that link. Second the
added complexity of synchronizing multiple secondary area link state
databases over the link is unnecessary when the primary area is the
Area 0 backbone. Should the secondary area partition, traffic between
the two parts of the partitioned secondary area would still use the
secondary adjacent link via OSPF inter-area routing.

It is true that routing between the different parts of a secondary
area partitioned by a defunct secondary adjacency over an Area 0 link
would be based on the inter-area route computation results from
processing summary links. Summary-range aggregation may over simplify
routing between the different parts of a partitioned area. However
this is no different that what exists under the current OSPF base
standards. Furthermore, the proper partitioning of a secondary area's
assigned address space not only allows the summary-range aggregates
to effect proper routing during topological failures, but it also
promotes more cost effective and efficient routing even when
secondary areas are whole.

Consider now the example mentioned in Section 2.3 and assume Area 1
is configured as a secondary area over the Area 0 link between A0 and
B0. The NSSArea 1 intra-area shortest path first tree computed by the
Dykstra calculation now includes the DS3 link between A0 and B0 with
a cost of 1. Given that all four routers possess link state
advertisements for the link between A0 and B0 in NSSArea 1, the path
between A0 and M1 is now

                A0<->B0<->B1<->M1

and the path between A1 and N1 is

                A1<->A0<->B0<->N1

Furthermore, should the link between A1 and B1 fail terminating the

NSSArea 1's secondary adjacency between A0 and B0, the path between
A0 and M1 would still be

                    A0<->B0<->B1<->M1,

as the summary LSA for M1 originating from B0 forms an inter-area
path to M1.

3.0 Implementation Details

3.1 SecondaryAreas Interface parameter

A new parameter called SecondaryAreas is added to the OSPF interface
data structure. Implementations must support the manual configuration
of this parameter. The SecondaryAreas interface parameter lists the
set of Areas which can form secondary adjacencies over the interface,
complete with their secondary area interface costs. By default a
secondary area's interface cost is set to the value of the
interface's primary area cost. Only those Areas listed in the
SecondaryAreas interface parameter are candidate areas for the
interface's secondary adjacencies. If the SecondaryAreas interface
parameter has a null list, then no secondary areas are configured for
this interface and no secondary adjacencies can be formed over the
interface.

For each secondary area listed in the SecondaryAreas interface
parameter, there is a list of Router Ids which have formed secondary
adjacencies to the router over the interface. These Routers Ids
should also be listed in the interface's list of neighboring routers.
If the list of Router Ids is null, then the interface has no
secondary adjacencies for this secondary area. This list is
populated as defined in Section 3.3 below.

3.2 Advertising Secondary Areas

All routers which support secondary areas must also be opaque
capable. If the interface is of broadcast type, then all candidate
designated routers must be opaque capable, even if they have no
secondary areas configured for the interface which connects to the
broadcast transit network. Otherwise type 9 opaque LSAs, which are
used by this option, will not propagate to all potential routers
capable of forming secondary adjacencies over the broadcast transit
network. Note that candidate designated routers do not have to
support OSPF multiple area links, but they do have to be opaque
capable in order to flood the type 9 opaque LSA to their adjacent
neighbors who may or may not support OSPF multiple area links.

Any router which has an interface with a non-empty SecondaryAreas

interface parameter must advertise a type 9 opaque LSA with opaque
type mlink to the interface's fully adjacent neighbors. The mlink
type 9 opaque LSA contains the Area Ids listed in the interface's
SecondaryAreas parameter as Opaque Information. See Appendix B for
details. If an interface's SecondaryAreas parameter is null, then the
mlink type 9 opaque LSA should not be advertised.

By default, the mlink opaque type sets it opaque ID to the last 24
bits of the interface's IP address, if it has one. In the case of
unnumbered point-to-point connections, the mlink opaque ID is set to
the last 24 bits of the interface's MIB-II [MIB] ifIndex value. All
implementations should also support the manual configuration of an
interface's mlink opaque ID in the rare instance this default schema
results in duplication.

3.3 Forming Secondary Adjacencies

Two border routers A and B in area L may form a secondary adjacency
across an interface, whose primary area is K, under the following
conditions:

  (a) Routers A and B are fully adjacent across the interface's
       primary area K or they share a common area K full adjacency
       with the interface's designated router.

  (b) Routers A and B see router LSAs (type-1) for each other in
       Area L's link state data base.

  (c) Routers A and B have exchanged/updated mlink type 9 opaque
       LSAs across the interface both of which contain Area L as a
       candidate secondary area.

When all three conditions are met, a secondary adjacency is formed
between routers A and B across the interface's primary area. There is
no particular ordering of events. Either (a), (b), or (c) can trigger
the event which forms the secondary adjacency, provided the other two
conditions have already been met.

3.4 Advertising Secondary Adjacencies

Border routers advertise their secondary adjacencies in their router
LSAs as unnumbered point-to-point links even though they may be
numbered point-to-point links, point-to-multipoint links, or transit
network links in their associated interface's primary area. This
allows their interconnecting networks to retain a single area
identity, thus avoiding the inevitable problems which would occur
with duplicate summary links advertisements and aggregation. It also
makes configuration and deployment seamless.

As unnumbered point-to-point links, all secondary adjacencies have link type 1. The building of the router LSA is described in [OSPF] Section 12.4.1. For the purpose of building the router LSA, an interface belongs to both its primary area and its secondary areas. With this in mind, no change is required to [OSPF] Section 12.4.1.

Even though secondary adjacencies are considered unnumbered point-to-point links, for the purpose of defining Link Data in the type 1 (router) LSA (see Appendix A) we allow them to use the interface's IP address. For secondary adjacencies [OSPF] Section 12.4.1.1 is reduced to simply

> If a neighboring router has formed a secondary adjacency then add a Type 1 link (point-to-point). The Link ID should be set to the Router ID of the neighboring router. If the interface is numbered, the Link Data should specify the IP interface address. For unnumbered point-to-point networks, the Link Data field should specify the interface's MIB-II [MIB] ifIndex value. The cost should be set to the secondary area's cost of the point-to-point interface as defined in the interface's SecondaryAreas parameter.

By not adding the type 3 links noted in [OSPF] Section 12.4.1. secondary adjacencies retain the look and feel of an unnumbered point-to-point links to the remaining routers in the secondary area, even though they may configure their link data with the interface's IP address.

3.5 Secondary Area Link State Data Base Exchange and Update

There is no link state data base exchange or update across a secondary adjacency. Only the interface's primary area synchronizes its link state data base with the interface's neighboring routers. Instead, secondary areas rely on their base topology (i.e. the topology without the secondary links), for complete flooding and synchronization of the link state data base throughout the secondary area. If the primary area is the area 0 backbone this is not a problem, since the routing table entries generated by the secondary areas summary links will forward packets when a secondary area's base topology partitions in such a way that its secondary adjacencies are dropped.

If the primary area is non-zero, then a simple IP over IP tunnel may be configured for the secondary across the physical link. This tunnel will perform link state data base synchronization for the secondary area across the interface. The IP tunnel is not part of this specification, but clearly it is advantageous to any OSPF multiple area links implementation if tunneling of IP over IP is supported. Note that if the tunnel is suitably configured with a high OSPF cost,

it would never be used for forwarding packets other than those
required for link state data base exchange and update. Moreover the
tunnel will always exist as long as the secondary adjacency's
physical link is active.

[3.6](#) The Shortest Path First Calculation

Since secondary links appear in the link state data base of an area
as unnumbered point-to-point links there is no change required in the
Shortest Path First (SPF) calculation, except on those border routers
where they are configured. Border routers do not include in a
secondary area's SPF tree any network which one of its secondary
adjacencies transit. This ensures synchronization of the SPF tree
amongst the secondary area's routers. However border routers do use
the IP addresses stored in their secondary neighbors' type-1 (router)
LSAs for determining the destination next hop across a secondary
adjacency when the associated interface connects the destination
router via a point-to-multipoint link or transit network link. In
this case the outgoing interface is derived directly from the
destination router's next hop IP address.

[3.7](#) Flushing Secondary Adjacencies

The dropping and flushing of secondary adjacencies from the link
state database of a secondary area is triggered by any of the
following events:

   The secondary area is manually purged from the interface's
   SecondaryAreas parameter.

   An adjacent router looses its primary area adjacency. Note that
   over a multi-access network termination happens when a neighboring
   router ceases to be listed in the Designated Router's list of
   neighbors.

   The secondary area is no longer listed in the adjacent router's
   mlink type 9 opaque LSA.

   The adjacent router's mlink type 9 opaque LSA is flushed from the
   primary area or exceeds MAXAge.

   The adjacent router's type 1 (router) LSA is flushed from the
   secondary area or exceeds MAXAge. In other words, the secondary
   area has partitioned with the two formerly adjacent routers now in
   separate parts.

When any of these events occur the interface's SecondaryAreas
parameter is updated to purge the adjacency. A new router LSA is

built for the secondary area and flooded out those interfaces for
which the secondary area is primary. The SPF calculation is done to
reflect the new link state topology.

4.0 Acknowledgments

This document was produced by the OSPF Working Group, chaired by John
Moy.

In addition, the comments of the following individuals are also
acknowledged:

    Derek Yeung   Cisco Systems
    Rob Colton   Fore Systems

5.0 References

[MIB]   McCloghrie, K., and M. Rose, "Management Information Base for
         network management of TCP/IP-based internets: MIB-II", STD
         17, RFC 1213, Hughes LAN Systems, Performance Systems
         International, March 1991.

[OPAQ]   Coltun, Rob, "The OSPF Opaque LSA Option", FORE Systems,
         August 1998.

[OSPF]   Moy, J., "OSPF Version 2", RFC 2328, Ascend Communications,
         Inc., April 1998.

[1583]   Moy, J., "OSPF Version 2", RFC 1583, Proteon, Inc., March
         1994.

6.0 Security Considerations

Security issues are not discussed in this memo.

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Appendix A. **Router-LSAs**

   Router-LSAs are Type 1 LSAs. Each router in an area originates a router-LSA.
   The router-LSA describes the state and cost of the router's links (i.e.,
   interfaces) to the area. All of the router's links, including secondary
   links, to an area must be described in a single router-LSA. For details
   concerning the construction of router-LSAs, see this document's Section 3.6
   and [OSPF] Section 12.4.1.

```
    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            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     0     |V|E|B|      0       |            # links            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                            Link ID                            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                           Link Data                           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     Type      |     # TOS     |             metric            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                              ...                              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      TOS      |       0       |           TOS  metric         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                            Link ID                            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                           Link Data                           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                              ...                              |
```

   In router-LSAs, the Link State ID field is set to the router's OSPF
   Router ID. Router-LSAs are flooded throughout a single area only.

      bit V
          When set, the router is an endpoint of one or more fully
          adjacent virtual links having the described area as Transit
          area (V is for virtual link endpoint).

bit E
     When set, the router is an AS boundary router (E is for
     external).

bit B
     When set, the router is an area border router (B is for
     border).

bit W
     When set, the router is a wild-card multicast receiver (W is
     for for wild).

bit Nt
     When set, the router is a NSSA border router which translates
     type-7 LSAs into type-5 LSAs (Nt is for NSSA translation).

links
     The number of router links described in this LSA. This must be
     the total collection of router links (i.e., interfaces) to the
     area.

The following fields are used to describe each router link (i.e.,
interface). Each router link is typed (see the below Type field). The
Type field indicates the kind of link being described. It may be a
link to a transit network, to another router or to a stub network.
The values of all the other fields describing a router link depend on
the link's Type. For example, each link has an associated 32-bit Link
Data field. For links to stub networks this field specifies the
network's IP address mask. For other link types the Link Data field
specifies the router interface's IP address.

   Type
     A quick description of the router link for one of the
     following. Note that host routes are classified as links to
     stub networks with network mask of 0xffffffff.

Type	Description
1	Point-to-point connection to another router
2	Connection to a transit network
3	Connection to a stub network
4	Virtual link

   Link ID
     Identifies the object that this router link connects to. Value

depends on the link's Type. When connecting to an object that
also originates an LSA (i.e., another router or a transit
network) the Link ID is equal to the neighboring LSA's Link
State ID. Secondary links area are always type 1 point-to-
point regardless of the type of their associated primary area.
This provides the key for looking up the neighboring LSA in
the link state database during the routing table calculation.
See [OSPF] Section 12.2 for more details.

>   Type   Link ID
>   _____
>   1   Neighboring router's Router ID
>   2   IP address of Designated Router
>   3   IP network/subnet number
>   4   Neighboring router's Router ID

Link Data
    Value again depends on the link's Type field. For connections
    to stub networks, Link Data specifies the network's IP address
    mask. For unnumbered point-to-point connections, it specifies
    the interface's MIB-II [MIB] ifIndex value. For the other link
    types it specifies the router interface's IP address. This
    latter piece of information is needed during the routing table
    build process, when calculating the IP address of the next
    hop. Although secondary links are considered unnumbered
    point-to-point links, they do evaluate Link Data as if they
    were numbered whenever their interface has an IP address
    associated with its primary area. See Section 3.6 of this
    document and [OSPF] Section 16.1.1 for more details.

TOS
    The number of different TOS metrics given for this link, not
    counting the required link metric (referred to as the TOS 0
    metric in [1583]). For example, if no additional TOS metrics
    are given, this field is set to 0. Secondary Areas may use
    TOS.

metric
    The cost of using this router link.

Additional TOS-specific information may also be included, for
backward compatibility with previous versions of the OSPF
specification ([1583]). Within each link, and for each desired TOS,
TOS TOS-specific link information may be encoded as follows:

    TOS
        IP Type of Service that this metric refers to. The encoding of

TOS in OSPF LSAs is described in [1583] Section 12.3.

TOS metric
     TOS-specific metric information.

Appendix B. mlink Opaque LSA

   The mlink Opaque LSA is used directly by OSPF to distribute list of
   candidate secondary areas among neighboring routers. The flooding
   scope of the mlink type 9 Opaque LSA is link-local, which means mlink
   LSAs are never forwarded beyond the local (sub)network.

   Section 3.3 of this document describes the purpose of the mlink
   Opaque LSA in more detail.

```
    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    |  Link State   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Opaque Type   |               Opaque ID                       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      Advertising Router                       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      LS Sequence Number                       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        LS checksum            |             Length            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                     Secondary Area ID 1                       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                              .                                |
   |                              .                                |
   |                              .                                |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                     Secondary Area ID n                       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   Syntax Of The Opaque LSA's Link-State ID

      The link-state ID of the mlink Opaque LSA is divided into an
      Opaque Type field (the first 8 bits), which has value mlink, and
      the Opaque ID (the remaining 24 bits). The mlink Opaque ID is set
      to the last 24 bits of the interface's primary area IP address, if
      it has one. In the case of unnumbered point-to-point connections,
      the mlink opaque ID is set to the last 24 bits of the interface's
      MIB-II [MIB] ifIndex value. All implementations should also
      support the manual configuration of an interface's mlink opaque ID
      in the rare instance this default schema results in duplication.

Appendix C. **Interface Data Structure**

Chapter 9 in the OSPF specification documents the interface data
structure and the data items which are included in it. Section 3.1 of
this document defines a new configuration parameter called
SecondaryAreas which is to be included in support of OSPF multiple
area links. Sections 3.2 and 3.4 describe the application of the
parameter.

In addition, for each secondary area listed in an interface's
SecondaryAreas parameter, the interface data structure must maintain
a list of Router IDs which have formed secondary adjacencies for this
secondary area.