OSPF for IPv6

Status of This Memo

Abstract

   This document describes the modifications to OSPF to support version
   6 of the Internet Protocol (IPv6). The fundamental mechanisms of
   OSPF (flooding, Designated Router (DR) election, area support, Short
   Path First (SPF) calculations, etc.) remain unchanged. However, some
   changes have been necessary, either due to changes in protocol
   semantics between IPv4 and IPv6, or simply to handle the increased
   address size of IPv6. These modifications will necessitate
   incrementing the protocol version from version 2 to version 3. OSPF
   for IPv6 is also referred to as OSPF version 3 (OSPFv3).

   Changes between OSPF for IPv4, OSPF Version 2, and OSPF for IPv6 as
   described herein include the following. Addressing semantics have
   been removed from OSPF packets and the basic Link State
   Advertisements (LSAs). New LSAs have been created to carry IPv6
   addresses and prefixes. OSPF now runs on a per-link basis rather
   than on a per-IP-subnet basis. Flooding scope for LSAs has been
   generalized. Authentication has been removed from the OSPF protocol
   and instead relies on IPv6's Authentication Header and Encapsulating
   Security Payload (ESP).

   Even with larger IPv6 addresses, most packets in OSPF for IPv6 are
   almost as compact as those in OSPF for IPv4. Most fields and packet-
   size limitations present in OSPF for IPv4 have been relaxed. In
   addition, option handling has been made more flexible.

   All of OSPF for IPv4's optional capabilities, including demand
   circuit support and Not-So-Stubby Areas (NSSAs), are also supported
   in OSPF for IPv6.

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1. Introduction

   This document describes the modifications to OSPF to support version
   6 of the Internet Protocol (IPv6). The fundamental mechanisms of
   OSPF (flooding, Designated Router (DR) election, area support,
   (Shortest Path First) SPF calculations, etc.) remain unchanged.
   However, some changes have been necessary, either due to changes in
   protocol semantics between IPv4 and IPv6, or simply to handle the
   increased address size of IPv6. These modifications will necessitate
   incrementing the protocol version from version 2 to version 3. OSPF
   for IPv6 is also referred to as OSPF version 3 (OSPFv3).

   This document is organized as follows. Section 2 describes the
   differences between OSPF for IPv4 (OSPF version 2) and OSPF for IPv6
   (OSPF version 3) in detail. Section 3 describes the difference
   between RFC 2740 and this document. Section 4 provides
   implementation details for the changes. Appendix A gives the OSPF
   for IPv6 packet and Link State Advertisement (LSA) formats. Appendix
   B lists the OSPF architectural constants. Appendix C describes
   configuration parameters.

1.1. Requirements Notation

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

1.2. Terminology

   This document attempts to use terms from both the OSPF for IPv4
   specification ([OSPFV2]) and the IPv6 protocol specifications
   ([IPV6]). This has produced a mixed result. Most of the terms used
   both by OSPF and IPv6 have roughly the same meaning (e.g.,

interfaces). However, there are a few conflicts. IPv6 uses "link"
similarly to IPv4 OSPF's "subnet" or "network". In this case, we
have chosen to use IPv6's "link" terminology. "Link" replaces OSPF's
"subnet" and "network" in most places in this document, although
OSPF's network-LSA remains unchanged (and possibly unfortunately, a
new link-LSA has also been created).

The names of some of the OSPF LSAs have also changed. See
Section 2.8 for details.

In the context of this document, an OSPF instance is a separate
protocol instance complete with its own protocol data structures
(e.g., areas, interfaces, neighbors), link-state database, protocol
state machines, and protocol processing (e.g., SPF calculation).

2. Differences from OSPF for IPv4

Most of the algorithms from OSPF for IPv4 [OSPFV2] have been
preserved in OSPF for IPv6. However, some changes have been
necessary, either due to changes in protocol semantics between IPv4
and IPv6, or simply to handle the increased address size of IPv6.

The following subsections describe the differences between this
document and [OSPFV2].

2.1. Protocol Processing Per-Link, Not Per-Subnet

IPv6 uses the term "link" to indicate "a communication facility or
medium over which nodes can communicate at the link layer" ([IPV6]).
"Interfaces" connect to links. Multiple IPv6 subnets can be assigned
to a single link, and two nodes can talk directly over a single link,
even if they do not share a common IPv6 subnet (IPv6 prefix).

For this reason, OSPF for IPv6 runs per-link instead of the IPv4
behavior of per-IP-subnet. The terms "network" and "subnet" used in
the IPv4 OSPF specification ([OSPFV2]) should generally be replaced
by link. Likewise, an OSPF interface now connects to a link instead
of an IP subnet.

This change affects the receiving of OSPF protocol packets, the
contents of Hello packets, and the contents of network-LSAs.

2.2. Removal of Addressing Semantics

In OSPF for IPv6, addressing semantics have been removed from the
OSPF protocol packets and the main LSA types, leaving a network-
protocol-independent core. In particular:

o IPv6 addresses are not present in OSPF packets, except in LSA
   payloads carried by the Link State Update packets. See
   Section 2.7 for details.

o Router-LSAs and network-LSAs no longer contain network addresses,
   but simply express topology information. See Section 2.8 for
   details.

o OSPF Router IDs, Area IDs, and LSA Link State IDs remain at the
   IPv4 size of 32 bits. They can no longer be assigned as (IPv6)
   addresses.

o Neighboring routers are now always identified by Router ID.
   Previously, they had been identified by an IPv4 address on
   broadcast, NBMA (Non-Broadcast Multi-Access), and point-to-
   multipoint links.

2.3. Addition of Flooding Scope

Flooding scope for LSAs has been generalized and is now explicitly
coded in the LSA's LS type field. There are now three separate
flooding scopes for LSAs:

o Link-local scope. LSA is only flooded on the local link and no
   further. Used for the new link-LSA. See Section 4.4.3.8 for
   details.

o Area scope. LSA is only flooded throughout a single OSPF area.
   Used for router-LSAs, network-LSAs, inter-area-prefix-LSAs, inter-
   area-router-LSAs, and intra-area-prefix-LSAs.

o AS scope. LSA is flooded throughout the routing domain. Used for
   AS-external-LSAs. A router that originates AS scoped LSAs is
   considered an AS Boundary Router (ASBR) and will set its E-bit in
   router-LSAs for regular areas.

2.4. Explicit Support for Multiple Instances per Link

OSPF now supports the ability to run multiple OSPF protocol instances
on a single link. For example, this may be required on a NAP segment
shared between several providers. Providers may be supporting
separate OSPF routing domains that wish to remain separate even
though they have one or more physical network segments (i.e., links)
in common. In OSPF for IPv4, this was supported in a haphazard
fashion using the authentication fields in the OSPF for IPv4 header.

Another use for running multiple OSPF instances is if you want, for
one reason or another, to have a single link belong to two or more
OSPF areas.

Support for multiple protocol instances on a link is accomplished via
an "Instance ID" contained in the OSPF packet header and OSPF
interface data structures. Instance ID solely affects the reception
of OSPF packets and applies to normal OSPF interfaces and virtual
links.

2.5. Use of Link-Local Addresses

IPv6 link-local addresses are for use on a single link, for purposes
of neighbor discovery, auto-configuration, etc. IPv6 routers do not
forward IPv6 datagrams having link-local source addresses [IP6ADDR].
Link-local unicast addresses are assigned from the IPv6 address range
FE80/10.

OSPF for IPv6 assumes that each router has been assigned link-local
unicast addresses on each of the router's attached physical links
[IP6ADDR]. On all OSPF interfaces except virtual links, OSPF packets
are sent using the interface's associated link-local unicast address
as the source address. A router learns the link-local addresses of
all other routers attached to its links and uses these addresses as
next-hop information during packet forwarding.

On virtual links, a global scope IPv6 address MUST be used as the
source address for OSPF protocol packets.

Link-local addresses appear in OSPF link-LSAs (see Section 4.4.3.8).
However, link-local addresses are not allowed in other OSPF LSA
types. In particular, link-local addresses MUST NOT be advertised in
inter-area-prefix-LSAs (Section 4.4.3.4), AS-external-LSAs
(Section 4.4.3.6), NSSA-LSAs (Section 4.4.3.7), or intra-area-prefix-
LSAs (Section 4.4.3.9).

2.6. Authentication Changes

In OSPF for IPv6, authentication has been removed from the OSPF
protocol. The "AuType" and "Authentication" fields have been removed
from the OSPF packet header, and all authentication-related fields
have been removed from the OSPF area and interface data structures.

When running over IPv6, OSPF relies on the IP Authentication Header
(see [IPAUTH]) and the IP Encapsulating Security Payload (see
[IPESP]) as described in [OSPFV3-AUTH] to ensure integrity and
authentication/confidentiality of routing exchanges.

   Protection of OSPF packet exchanges against accidental data
   corruption is provided by the standard IPv6 Upper-Layer checksum (as
   described in Section 8.1 of [IPV6]), covering the entire OSPF packet
   and prepended IPv6 pseudo-header (see Appendix A.3.1).

2.7. Packet Format Changes

   OSPF for IPv6 runs directly over IPv6. Aside from this, all
   addressing semantics have been removed from the OSPF packet headers,
   making it essentially "network-protocol-independent". All addressing
   information is now contained in the various LSA types only.

   In detail, changes in OSPF packet format consist of the following:

   o The OSPF version number has been incremented from 2 to 3.

   o The Options field in Hello packets and Database Description
      packets has been expanded to 24 bits.

   o The Authentication and AuType fields have been removed from the
      OSPF packet header (see Section 2.6).

   o The Hello packet now contains no address information at all.
      Rather, it now includes an Interface ID that the originating
      router has assigned to uniquely identify (among its own
      interfaces) its interface to the link. This Interface ID will be
      used as the network-LSA's Link State ID if the router becomes the
      Designated Router on the link.

   o Two Options bits, the "R-bit" and the "V6-bit", have been added to
      the Options field for processing router-LSAs during the SPF
      calculation (see Appendix A.2). If the "R-bit" is clear, an OSPF
      speaker can participate in OSPF topology distribution without
      being used to forward transit traffic; this can be used in multi-
      homed hosts that want to participate in the routing protocol. The
      V6-bit specializes the R-bit; if the V6-bit is clear, an OSPF
      speaker can participate in OSPF topology distribution without
      being used to forward IPv6 datagrams. If the R-bit is set and the
      V6-bit is clear, IPv6 datagrams are not forwarded but datagrams
      belonging to another protocol family may be forwarded.

   o The OSPF packet header now includes an "Instance ID" that allows
      multiple OSPF protocol instances to be run on a single link (see
      Section 2.4).

2.8. LSA Format Changes

All addressing semantics have been removed from the LSA header,
router-LSAs, and network-LSAs. These two LSAs now describe the
routing domain's topology in a network-protocol-independent manner.
New LSAs have been added to distribute IPv6 address information and
data required for next-hop resolution. The names of some of IPv4's
LSAs have been changed to be more consistent with each other.

In detail, changes in LSA format consist of the following:

o The Options field has been removed from the LSA header, expanded
   to 24 bits, and moved into the body of router-LSAs, network-LSAs,
   inter-area-router-LSAs, and link-LSAs. See Appendix A.2 for
   details.

o The LSA Type field has been expanded (into the former Options
   space) to 16 bits, with the upper three bits encoding flooding
   scope and the handling of unknown LSA types (see Section 2.9).

o Addresses in LSAs are now expressed as [prefix, prefix length]
   instead of [address, mask] (see Appendix A.4.1). The default
   route is expressed as a prefix with length 0.

o Router-LSAs and network-LSAs now have no address information and
   are network protocol independent.

o Router interface information MAY be spread across multiple router-
   LSAs. Receivers MUST concatenate all the router-LSAs originated
   by a given router when running the SPF calculation.

o A new LSA called the link-LSA has been introduced. Link-LSAs have
   link-local flooding scope; they are never flooded beyond the link
   with which they are associated. Link-LSAs have three purposes: 1)
   they provide the router's link-local address to all other routers
   attached to the link, 2) they inform other routers attached to the
   link of a list of IPv6 prefixes to associate with the link, and 3)
   they allow the router to advertise a collection of Options bits to
   associate with the network-LSA that will be originated for the
   link. See Section 4.4.3.8 for details.

o In IPv4, the router-LSA carries a router's IPv4 interface
   addresses, the IPv4 equivalent of link-local addresses. These are
   only used when calculating next hops during the OSPF routing
   calculation (see Section 16.1.1 of [OSPFV2]), so they do not need
   to be flooded past the local link. Hence, using link-LSAs to
   distribute these addresses is more efficient. Note that link-
   local addresses cannot be learned through the reception of Hellos

in all cases. On NBMA links, next-hop routers do not necessarily
exchange Hellos. Rather, these routers learn of each other's
existence by way of the Designated Router (DR).

o The Options field in the network LSA is set to the logical OR of
   the Options that each router on the link advertises in its link-
   LSA.

o Type-3 summary-LSAs have been renamed "inter-area-prefix-LSAs".
   Type-4 summary LSAs have been renamed "inter-area-router-LSAs".

o The Link State ID in inter-area-prefix-LSAs, inter-area-router-
   LSAs, NSSA-LSAs, and AS-external-LSAs has lost its addressing
   semantics and now serves solely to identify individual pieces of
   the Link State Database. All addresses or Router IDs that were
   formerly expressed by the Link State ID are now carried in the LSA
   bodies.

o Network-LSAs and link-LSAs are the only LSAs whose Link State ID
   carries additional meaning. For these LSAs, the Link State ID is
   always the Interface ID of the originating router on the link
   being described. For this reason, network-LSAs and link-LSAs are
   now the only LSAs whose size cannot be limited: a network-LSA MUST
   list all routers connected to the link and a link-LSA MUST list
   all of a router's addresses on the link.

o A new LSA called the intra-area-prefix-LSA has been introduced.
   This LSA carries all IPv6 prefix information that in IPv4 is
   included in router-LSAs and network-LSAs. See Section 4.4.3.9 for
   details.

o Inclusion of a forwarding address or external route tag in AS-
   external-LSAs is now optional. In addition, AS-external-LSAs can
   now reference another LSA, for inclusion of additional route
   attributes that are outside the scope of the OSPF protocol. For
   example, this reference could be used to attach BGP path
   attributes to external routes.

2.9. Handling Unknown LSA Types

   Handling of unknown LSA types has been made more flexible so that,
   based on the LS type, unknown LSA types are either treated as having
   link-local flooding scope, or are stored and flooded as if they were
   understood. This behavior is explicitly coded in the LSA Handling
   bit of the link state header's LS type field (see the U-bit in
   Appendix A.4.2.1).

The IPv4 OSPF behavior of simply discarding unknown types is
unsupported due to the desire to mix router capabilities on a single
link. Discarding unknown types causes problems when the Designated
Router supports fewer options than the other routers on the link.

2.10. Stub/NSSA Area Support

In OSPF for IPv4, stub and NSSA areas were designed to minimize link-
state database and routing table sizes for the areas' internal
routers. This allows routers with minimal resources to participate
in even very large OSPF routing domains.

In OSPF for IPv6, the concept of stub and NSSA areas is retained. In
IPv6, of the mandatory LSA types, stub areas carry only router-LSAs,
network-LSAs, inter-area-prefix-LSAs, link-LSAs, and intra-area-
prefix-LSAs. NSSA areas are restricted to these types and, of
course, NSSA-LSAs. This is the IPv6 equivalent of the LSA types
carried in IPv4 stub areas: router-LSAs, network-LSAs, type 3
summary-LSAs and for NSSA areas: stub area types and NSSA-LSAs.

2.11. Identifying Neighbors by Router ID

In OSPF for IPv6, neighboring routers on a given link are always
identified by their OSPF Router ID. This contrasts with the IPv4
behavior where neighbors on point-to-point networks and virtual links
are identified by their Router IDs while neighbors on broadcast,
NBMA, and point-to-multipoint links are identified by their IPv4
interface addresses.

This change affects the reception of OSPF packets (see Section 8.2 of
[OSPFV2]), the lookup of neighbors (Section 10 of [OSPFV2]), and the
reception of Hello packets (Section 10.5 of [OSPFV2]).

The Router ID of 0.0.0.0 is reserved and SHOULD NOT be used.

3. Differences with RFC 2740

OSPFv3 implementations based on RFC 2740 will fully interoperate with
implementations based on this specification. There are, however,
some protocol additions and changes (all of which are backward
compatible).

3.1. Support for Multiple Interfaces on the Same Link

This protocol feature was only partially specified in the RFC 2740.
The level of specification was insufficient to implement the feature.
Section 4.9 specifies the additions and clarifications necessary for
implementation. They are fully compatible with RFC 2740.

3.2. Deprecation of MOSPF for IPv6

This protocol feature was only partially specified in RFC 2740. The
level of specification was insufficient to implement the feature.
There are no known implementations. Multicast Extensions to OSPF
(MOSPF) support and its attendant protocol fields have been
deprecated from OSPFv3. Refer to Section 4.4.3.2, Section 4.4.3.4,
Section 4.4.3.6, Section 4.4.3.7, Appendix A.2, Appendix A.4.2.1,
Appendix A.4.3, Appendix A.4.1.1, and Section 7.1.

3.3. NSSA Specification

This protocol feature was only partially specified in RFC 2740. The
level of specification was insufficient to implement the function.
This document includes an NSSA specification unique to OSPFv3. This
specification coupled with [NSSA] provide sufficient specification
for implementation. Refer to Section 4.8.5, Appendix A.4.3,
Appendix A.4.8, and [NSSA].

3.4. Stub Area Unknown LSA Flooding Restriction Deprecated

In RFC 2740 [OSPFV3], flooding of unknown LSA was restricted within
stub and NSSA areas. The text describing this restriction is
included below.

> However, unlike in IPv4, IPv6 allows LSAs with unrecognized
> LS types to be labeled "Store and flood the LSA, as if type
> understood" (see the U-bit in Appendix A.4.2.1). Uncontrolled
> introduction of such LSAs could cause a stub area's link-state
> database to grow larger than its component routers' capacities.

> To guard against this, the following rule regarding stub areas
> has been established: an LSA whose LS type is unrecognized can
> only be flooded into/throughout a stub area if both a) the LSA
> has area or link-local flooding scope and b) the LSA has U-bit
> set to 0. See Section 3.5 for details.

This restriction has been deprecated. OSPFv3 routers will flood link
and area scope LSAs whose LS type is unrecognized and whose U-bit is
set to 1 throughout stub and NSSA areas. There are no backward-
compatibility issues other than OSPFv3 routers still supporting the
restriction may not propagate newly defined LSA types.

3.5. Link LSA Suppression

The LinkLSASuppression interface configuration parameter has been
added. If LinkLSASuppression is configured for an interface and the
interface type is not broadcast or NBMA, origination of the link-LSA

      may be suppressed. The LinkLSASuppression interface configuration
      parameter is described in Appendix C.3. Section 4.8.2 and
      Section 4.4.3.8 were updated to reflect the parameter's usage.

3.6. LSA Options and Prefix Options Updates

      The LSA Options and Prefix Options fields have been updated to
      reflect recent protocol additions. Specifically, bits related to
      MOSPF have been deprecated, Options field bits common with OSPFv2
      have been reserved, and the DN-bit has been added to the prefix-
      options. Refer to Appendix A.2 and Appendix A.4.1.1.

3.7. IPv6 Site-Local Addresses

      All references to IPv6 site-local addresses have been removed.

4. Implementation Details

      When going from IPv4 to IPv6, the basic OSPF mechanisms remain
      unchanged from those documented in [OSPFV2]. These mechanisms are
      briefly outlined in Section 4 of [OSPFV2]. Both IPv6 and IPv4 have a
      link-state database composed of LSAs and synchronized between
      adjacent routers. Initial synchronization is performed through the
      Database Exchange process, which includes the exchange of Database
      Description, Link State Request, and Link State Update packets.
      Thereafter, database synchronization is maintained via flooding,
      utilizing Link State Update and Link State Acknowledgment packets.
      Both IPv6 and IPv4 use OSPF Hello packets to discover and maintain
      neighbor relationships, as well as to elect Designated Routers and
      Backup Designated Routers on broadcast and NBMA links. The decision
      as to which neighbor relationships become adjacencies, and the basic
      ideas behind inter-area routing, importing external information in
      AS-external-LSAs, and the various routing calculations are also the
      same.

      In particular, the following IPv4 OSPF functionality described in
      [OSPFV2] remains completely unchanged for IPv6:

      o Both IPv4 and IPv6 use OSPF packet types described in Section 4.3
         of [OSPFV2], namely: Hello, Database Description, Link State
         Request, Link State Update, and Link State Acknowledgment packets.
         While in some cases (e.g., Hello packets) their format has changed
         somewhat, the functions of the various packet types remain the
         same.

o The system requirements for an OSPF implementation remain
   unchanged, although OSPF for IPv6 requires an IPv6 protocol stack
   (from the network layer on down) since it runs directly over the
   IPv6 network layer.

o The discovery and maintenance of neighbor relationships, and the
   selection and establishment of adjacencies, remain the same. This
   includes election of the Designated Router and Backup Designated
   Router on broadcast and NBMA links. These mechanisms are
   described in Sections 7, 7.1, 7.2, 7.3, 7.4, and 7.5 of [OSPFV2].

o The link types (or equivalently, interface types) supported by
   OSPF remain unchanged, namely: point-to-point, broadcast, NBMA,
   point-to-multipoint, and virtual links.

o The interface state machine, including the list of OSPF interface
   states and events, and the Designated Router and Backup Designated
   Router election algorithm remain unchanged. These are described
   in Sections 9.1, 9.2, 9.3, and 9.4 of [OSPFV2].

o The neighbor state machine, including the list of OSPF neighbor
   states and events, remains unchanged. The neighbor state machine
   is described in Sections 10.1, 10.2, 10.3, and 10.4 of [OSPFV2].

o Aging of the link-state database, as well as flushing LSAs from
   the routing domain through the premature aging process, remains
   unchanged from the description in Sections 14 and 14.1 of
   [OSPFV2].

However, some OSPF protocol mechanisms have changed as previously
described in Section 2 herein. These changes are explained in detail
in the following subsections, making references to the appropriate
sections of [OSPFV2].

The following subsections provide a recipe for turning an IPv4 OSPF
implementation into an IPv6 OSPF implementation.

4.1. Protocol Data Structures

The major OSPF data structures are the same for both IPv4 and IPv6:
areas, interfaces, neighbors, the link-state database, and the
routing table. The top-level data structures for IPv6 remain those
listed in Section 5 of [OSPFV2], with the following modifications:

o All LSAs with known LS type and AS flooding scope appear in the
   top-level data structure, instead of belonging to a specific area
   or link. AS-external-LSAs are the only LSAs defined by this
   specification that have AS flooding scope. LSAs with unknown LS

type, U-bit set to 1 (flood even when unrecognized), and AS
flooding scope also appear in the top-level data structure.

4.1.1. The Area Data Structure

The IPv6 area data structure contains all elements defined for IPv4
areas in Section 6 of [OSPFV2]. In addition, all LSAs of known type
that have area flooding scope are contained in the IPv6 area data
structure. This always includes the following LSA types: router-
LSAs, network-LSAs, inter-area-prefix-LSAs, inter-area-router-LSAs,
and intra-area-prefix-LSAs. LSAs with unknown LS type, U-bit set to
1 (flood even when unrecognized), and area scope also appear in the
area data structure. NSSA-LSAs are also included in an NSSA area's
data structure.

4.1.2. The Interface Data Structure

In OSPF for IPv6, an interface connects a router to a link. The IPv6
interface structure modifies the IPv4 interface structure (as defined
in Section 9 of [OSPFV2]) as follows:

Interface ID
   Every interface is assigned an Interface ID, which uniquely
   identifies the interface with the router. For example, some
   implementations MAY be able to use the MIB-II IfIndex ([INTFMIB])
   as the Interface ID. The Interface ID appears in Hello packets
   sent out the interface, the link-local-LSA originated by the
   router for the attached link, and the router-LSA originated by the
   router-LSA for the associated area. It will also serve as the
   Link State ID for the network-LSA that the router will originate
   for the link if the router is elected Designated Router.
   The Interface ID for a virtual link is independent of the
   Interface ID of the outgoing interface it traverses in the transit
   area.

Instance ID
   Every interface is assigned an Instance ID. This should default
   to 0. It is only necessary to assign a value other than 0 on
   those links that will contain multiple separate communities of
   OSPF routers. For example, suppose that there are two communities
   of routers on a given ethernet segment that you wish to keep
   separate.
   The first community is assigned an Instance ID of 0 and all the
   routers in the first community will be assigned 0 as the Instance
   ID for interfaces connected to the ethernet segment. An Instance
   ID of 1 is assigned to the other routers' interfaces connected to
   the ethernet segment. The OSPF transmit and receive processing
   (see Section 4.2) will then keep the two communities separate.

List of LSAs with link-local scope
    All LSAs with link-local scope and that were originated/flooded on
    the link belong to the interface structure that connects to the
    link. This includes the collection of the link's link-LSAs.

IP interface address
    For IPv6, the IPv6 address appearing in the source of OSPF packets
    sent on the interface is almost always a link-local address. The
    one exception is for virtual links that MUST use one of the
    router's own global IPv6 addresses as IP interface address.

List of link prefixes
    A list of IPv6 prefixes can be configured for the attached link.
    These will be advertised by the router in link-LSAs, so that they
    can be advertised by the link's Designated Router in intra-area-
    prefix-LSAs.

In OSPF for IPv6, each router interface has a single metric
representing the cost of sending packets on the interface. In
addition, OSPF for IPv6 relies on the IP Authentication Header (see
[IPAUTH]) and the IP Encapsulating Security Payload (see [IPESP]) as
described in [OSPFV3-AUTH] to ensure integrity and authentication/
confidentiality of routing exchanges. For this reason, AuType and
Authentication key are not associated with IPv6 OSPF interfaces.

Interface states, events, and the interface state machine remain
unchanged from IPv4 as documented in Sections 9.1, 9.2, and 9.3 of
[OSPFV2] respectively. The Designated Router and Backup Designated
Router election algorithm also remains unchanged from the IPv4
election in Section 9.4 of [OSPFV2].

4.1.3. The Neighbor Data Structure

The neighbor structure performs the same function in both IPv6 and
IPv4. Namely, it collects all information required to form an
adjacency between two routers when such an adjacency becomes
necessary. Each neighbor structure is bound to a single OSPF
interface. The differences between the IPv6 neighbor structure and
the neighbor structure defined for IPv4 in Section 10 of [OSPFV2]
are:

Neighbor's Interface ID
    The Interface ID that the neighbor advertises in its Hello packets
    must be recorded in the neighbor structure. The router will
    include the neighbor's Interface ID in the router's router-LSA
    when either a) advertising a point-to-point or point-to-multipoint
    link to the neighbor or b) advertising a link to a network where
    the neighbor has become the Designated Router.

Neighbor IP address
    The neighbor's IPv6 address contained as the source address in
    OSPF for IPv6 packets. This will be an IPv6 link-local address
    for all link types except virtual links.

Neighbor's Designated Router
    The neighbor's choice of Designated Router is now encoded as a
    Router ID instead of as an IP address.

Neighbor's Backup Designated Router
    The neighbor's choice of Backup Designated Router is now encoded
    as a Router ID instead of as an IP address.

Neighbor states, events, and the neighbor state machine remain
unchanged from IPv4 as documented in Sections 10.1, 10.2, and 10.3 of
[OSPFV2] respectively. The decision as to which adjacencies to form
also remains unchanged from the IPv4 logic documented in Section 10.4
of [OSPFV2].

4.2. Protocol Packet Processing

OSPF for IPv6 runs directly over IPv6's network layer. As such, it
is encapsulated in one or more IPv6 headers with the Next Header
field of the immediately encapsulating IPv6 header set to the value
89.

As for OSPF for IPv4, OSPF for IPv6 OSPF routing protocol packets are
sent along adjacencies only (with the exception of Hello packets,
which are used to discover the adjacencies). OSPF packet types and
functions are the same in both IPv4 and IPv6, encoded by the Type
field of the standard OSPF packet header.

4.2.1. Sending Protocol Packets

When an IPv6 router sends an OSPF routing protocol packet, it fills
in the fields of the standard OSPF for IPv6 packet header (see
Appendix A.3.1) as follows:

Version #
    Set to 3, the version number of the protocol as documented in this
    specification.

Type
    The type of OSPF packet, such as Link State Update or Hello
    packet.

Packet length
   The length of the entire OSPF packet in bytes, including the
   standard OSPF packet header.

Router ID
   The identity of the router itself (who is originating the packet).

Area ID
   The OSPF area for the interface on which the packet is being sent.

Instance ID
   The OSPF Instance ID associated with the interface out of which
   the packet is being sent.

Checksum
   The standard IPv6 Upper-Layer checksum (as described in Section
   8.1 of [IPV6]) covering the entire OSPF packet and prepended IPv6
   pseudo-header (see Appendix A.3.1).

Selection of OSPF routing protocol packets' IPv6 source and
destination addresses is performed identically to the IPv4 logic in
Section 8.1 of [OSPFV2]. The IPv6 destination address is chosen from
among the addresses AllSPFRouters, AllDRouters, and the Neighbor IP
address associated with the other end of the adjacency (which in
IPv6, for all links except virtual links, is an IPv6 link-local
address).

The sending of Link State Request packets and Link State
Acknowledgment packets remains unchanged from the IPv4 procedures
documented in Sections 10.9 and 13.5 of [OSPFV2] respectively.
Sending Hello packets is documented in Section 4.2.1.1, and the
sending of Database Description packets in Section 4.2.1.2. The
sending of Link State Update packets is documented in Section 4.5.2.

4.2.1.1. Sending Hello Packets

   IPv6 changes the way OSPF Hello packets are sent in the following
   ways (compare to Section 9.5 of [OSPFV2]):

   o Before the Hello packet is sent on an interface, the interface's
      Interface ID MUST be copied into the Hello packet.

   o The Hello packet no longer contains an IP network mask since OSPF
      for IPv6 runs per-link instead of per-subnet.

   o The choice of Designated Router and Backup Designated Router is
      now indicated within Hellos by their Router IDs instead of by
      their IP interface addresses. Advertising the Designated Router

(or Backup Designated Router) as 0.0.0.0 indicates that the
Designated Router (or Backup Designated Router) has not yet been
chosen.

o   The Options field within Hello packets has moved around, getting
    larger in the process. More Options bits are now possible. Those
    that MUST be set correctly in Hello packets are as follows. The
    E-bit is set if and only if the interface attaches to a regular
    area, i.e., not a stub or NSSA area. Similarly, the N-bit is set
    if and only if the interface attaches to an NSSA area (see
    [NSSA]). Finally, the DC-bit is set if and only if the router
    wishes to suppress the sending of future Hellos over the interface
    (see [DEMAND]). Unrecognized bits in the Hello packet's Options
    field should be cleared.

Sending Hello packets on NBMA networks proceeds for IPv6 in exactly
the same way as for IPv4, as documented in Section 9.5.1 of [OSPFV2].

4.2.1.2. Sending Database Description Packets

The sending of Database Description packets differs from Section 10.8
of [OSPFV2] in the following ways:

o   The Options field within Database Description packets has moved
    around, getting larger in the process. More Options bits are now
    possible. Those that MUST be set correctly in Database
    Description packets are as follows. The DC-bit is set if and only
    if the router wishes to suppress the sending of Hellos over the
    interface (see [DEMAND]). Unrecognized bits in the Database
    Description packet's Options field should be cleared.

4.2.2. Receiving Protocol Packets

Whenever a router receives an OSPF protocol packet, it is marked with
the interface on which it was received. For routers that have
virtual links configured, it may not be immediately obvious with
which interface to associate the packet. For example, consider the
Router RT11 depicted in Figure 6 of [OSPFV2]. If RT11 receives an
OSPF protocol packet on its interface to Network N8, it may want to
associate the packet with the interface to Area 2, or with the
virtual link to Router RT10 (which is part of the backbone). In the
following, we assume that the packet is initially associated with the
non-virtual link.

In order for the packet to be passed to OSPF for processing, the
following tests must be performed on the encapsulating IPv6 headers:

o The packet's IP destination address MUST be one of the IPv6
   unicast addresses associated with the receiving interface (this
   includes link-local addresses), one of the IPv6 multicast
   addresses AllSPFRouters or AllDRouters, or an IPv6 global address
   (for virtual links).

o The Next Header field of the immediately encapsulating IPv6 header
   MUST specify the OSPF protocol (89).

o Any encapsulating IP Authentication Headers (see [IPAUTH]) and the
   IP Encapsulating Security Payloads (see [IPESP]) MUST be processed
   and/or verified to ensure integrity and authentication/
   confidentiality of OSPF routing exchanges. This is described in
   [OSPFV3-AUTH].

After processing the encapsulating IPv6 headers, the OSPF packet
header is processed. The fields specified in the header must match
those configured for the receiving OSPFv3 interface. If they do not,
the packet SHOULD be discarded:

o The version number field MUST specify protocol version 3.

o The IPv6 Upper-Layer checksum (as described in Section 8.1 of
   [IPV6]), covering the entire OSPF packet and prepended IPv6
   pseudo-header, must be verified (see Appendix A.3.1).

o The Area ID and Instance ID found in the OSPF header must be
   verified. If both of the following cases fail, the packet should
   be discarded. The Area ID and Instance ID specified in the header
   must either:

   1. Match one of the Area ID(s) and Interface Instance ID(s) for
       the receiving link. Unlike IPv4, the IPv6 source address is
       not restricted to lie within the same IPv6 subnet as the
       receiving link. IPv6 OSPF runs per-link instead of per-IP-
       subnet.

   2. Match the backbone area and other criteria for a configured
       virtual link. The receiving router must be an ABR (Area
       Border Router) and the Router ID specified in the packet (the
       source router) must be the other end of a configured virtual
       link. Additionally, the receiving link must have an OSPFv3
       interface that attaches to the virtual link's configured
       transit area and the Instance ID must match the virtual link's
       Instance ID. If all of these checks succeed, the packet is
       accepted and is associated with the virtual link (and the
       backbone area).

o Locally originated packets SHOULD NOT be processed by OSPF except
   for support of multiple interfaces attached to the same link as
   described in Section 4.9. Locally originated packets have a
   source address equal to one of the router's local addresses.

o Packets whose IPv6 destination is AllDRouters should only be
   accepted if the state of the receiving OSPFv3 interface is DR or
   Backup (see Section 9.1 [OSPFV2]).

After header processing, the packet is further processed according to
its OSPF packet type. OSPF packet types and functions are the same
for both IPv4 and IPv6.

If the packet type is Hello, it should then be further processed by
the Hello packet processing as described in Section 4.2.2.1. All
other packet types are sent/received only on adjacencies. This means
that the packet must have been sent by one of the router's active
neighbors. The neighbor is identified by the Router ID appearing in
the received packet's OSPF header. Packets not matching any active
neighbor are discarded.

The receive processing of Database Description packets, Link State
Request packets, and Link State Acknowledgment packets is almost
identical to the IPv4 procedures documented in Sections 10.6, 10.7,
and 13.7 of [OSPFV2] respectively with the exceptions noted below.

o LSAs with unknown LS types in Database Description packets that
   have an acceptable flooding scope are processed the same as LSAs
   with known LS types. In OSPFv2 [OSPFV2], these would result in
   the adjacency being brought down with a SequenceMismatch event.

The receiving of Hello packets is documented in Section 4.2.2.1 and
the receiving of Link State Update packets is documented in
Section 4.5.1.

4.2.2.1. Receiving Hello Packets

The receive processing of Hello packets differs from Section 10.5 of
[OSPFV2] in the following ways:

o On all link types (e.g., broadcast, NBMA, point-to-point, etc.),
   neighbors are identified solely by their OSPF Router ID. For all
   link types except virtual links, the Neighbor IP address is set to
   the IPv6 source address in the IPv6 header of the received OSPF
   Hello packet.

o There is no longer a Network Mask field in the Hello packet.

     o The neighbor's choice of Designated Router and Backup Designated
        Router is now encoded as an OSPF Router ID instead of an IP
        interface address.

4.3. The Routing table Structure

     The routing table used by OSPF for IPv4 is defined in Section 11 of
     [OSPFV2]. For IPv6, there are analogous routing table entries: there
     are routing table entries for IPv6 address prefixes and also for AS
     boundary routers. The latter routing table entries are only used to
     hold intermediate results during the routing table build process (see
     Section 4.8).

     Also, to hold the intermediate results during the shortest-path
     calculation for each area, there is a separate routing table for each
     area holding the following entries:

     o An entry for each router in the area. Routers are identified by
        their OSPF Router ID. These routing table entries hold the set of
        shortest paths through a given area to a given router, which in
        turn allows calculation of paths to the IPv6 prefixes advertised
        by that router in intra-area-prefix-LSAs. If the router is also
        an area border router, these entries are also used to calculate
        paths for inter-area address prefixes. If in addition the router
        is the other endpoint of a virtual link, the routing table entry
        describes the cost and viability of the virtual link.

     o An entry for each transit link in the area. Transit links have
        associated network-LSAs. Both the transit link and the network-
        LSA are identified by a combination of the Designated Router's
        Interface ID on the link and the Designated Router's OSPF Router
        ID. These routing table entries allow later calculation of paths
        to IP prefixes advertised for the transit link in intra-area-
        prefix-LSAs.

     The fields in the IPv4 OSPF routing table (see Section 11 of
     [OSPFV2]) remain valid for IPv6: optional capabilities (routers
     only), path type, cost, type 2 cost, link state origin, and for each
     of the equal cost paths to the destination, the next-hop and
     advertising routers.

     For IPv6, the link-state origin field in the routing table entry is
     the router-LSA or network-LSA that has directly or indirectly
     produced the routing table entry. For example, if the routing table
     entry describes a route to an IPv6 prefix, the link state origin is
     the router-LSA or network-LSA that is listed in the body of the
     intra-area-prefix-LSA that has produced the route (see
     Appendix A.4.10).

4.3.1. Routing Table Lookup

   Routing table lookup (i.e., determining the best matching routing
   table entry during IP forwarding) is the same for IPv6 as for IPv4.

4.4. Link State Advertisements

   For IPv6, the OSPF LSA header has changed slightly, with the LS type
   field expanding and the Options field being moved into the body of
   appropriate LSAs. Also, the formats of some LSAs have changed
   somewhat (namely, router-LSAs, network-LSAs, AS-external-LSAs, and
   NSSA-LSAs), while the names of other LSAs have been changed (type 3
   and 4 summary-LSAs are now inter-area-prefix-LSAs and inter-area-
   router-LSAs respectively) and additional LSAs have been added (link-
   LSAs and intra-area-prefix-LSAs). Type of Service (TOS) has been
   removed from the OSPFv2 specification [OSPFV2] and is not encoded
   within OSPF for IPv6's LSAs.

   These changes will be described in detail in the following
   subsections.

4.4.1. The LSA Header

   In both IPv4 and IPv6, all OSPF LSAs begin with a standard 20-byte
   LSA header. However, the contents of this 20-byte header have
   changed in IPv6. The LS age, Advertising Router, LS Sequence Number,
   LS checksum, and length fields within the LSA header remain
   unchanged, as documented in Sections 12.1.1, 12.1.5, 12.1.6, 12.1.7,
   and A.4.1 of [OSPFV2], respectively. However, the following fields
   have changed for IPv6:

   Options
      The Options field has been removed from the standard 20-byte LSA
      header and moved into the body of router-LSAs, network-LSAs,
      inter-area-router-LSAs, and link-LSAs. The size of the Options
      field has increased from 8 to 24 bits, and some of the bit
      definitions have changed (see Appendix A.2). Additionally, a
      separate PrefixOptions field, 8 bits in length, is attached to
      each prefix advertised within the body of an LSA.

   LS type
      The size of the LS type field has increased from 8 to 16 bits,
      with high-order bit encoding the handling of unknown types and the
      next two bits encoding flooding scope. See Appendix A.4.2.1 for
      the current coding of the LS type field.

Link State ID
    The Link State ID remains at 32 bits in length. However, except
    for network-LSAs and link-LSAs, the Link State ID has shed any
    addressing semantics. For example, an IPv6 router originating
    multiple AS-external-LSAs could start by assigning the first a
    Link State ID of 0.0.0.1, the second a Link State ID of 0.0.0.2,
    and so on. Instead of the IPv4 behavior of encoding the network
    number within the AS-external-LSA's Link State ID, the IPv6 Link
    State ID simply serves as a way to differentiate multiple LSAs
    originated by the same router.
    For network-LSAs, the Link State ID is set to the Designated
    Router's Interface ID on the link. When a router originates a
    link-LSA for a given link, its Link State ID is set equal to the
    router's Interface ID on the link.

4.4.2. The Link-State Database

In IPv6, as in IPv4, individual LSAs are identified by a combination
of their LS type, Link State ID, and Advertising Router fields.
Given two instances of an LSA, the most recent instance is determined
by examining the LSAs' LS sequence number, using LS checksum and LS
age as tiebreakers (see Section 13.1 of [OSPFV2]).

In IPv6, the link-state database is split across three separate data
structures. LSAs with AS flooding scope are contained within the
top-level OSPF data structure (see Section 4.1) as long as either
their LS type is known or their U-bit is 1 (flood even when
unrecognized); this includes the AS-external-LSAs. LSAs with area
flooding scope are contained within the appropriate area structure
(see Section 4.1.1) as long as either their LS type is known or their
U-bit is 1 (flood even when unrecognized); this includes router-LSAs,
network-LSAs, inter-area-prefix-LSAs, inter-area-router-LSAs, NSSA-
LSAs, and intra-area-prefix-LSAs. LSAs with an unknown LS type, the
U-bit set to 0, and/or link-local flooding scope are contained within
the appropriate interface structure (see Section 4.1.2); this
includes link-LSAs.

To look up or install an LSA in the database, you first examine the
LS type and the LSA's context (i.e., the area or link to which the
LSA belongs). This information allows you to find the correct
database of LSAs where you then search based on the LSA's type, Link
State ID, and Advertising Router.

4.4.3. Originating LSAs

   The process of reoriginating an LSA in IPv6 is the same as in IPv4:
   the LSA's LS sequence number is incremented, its LS age is set to 0,
   its LS checksum is calculated, and the LSA is added to the link state
   database and flooded on the appropriate interfaces.

   The list of events causing LSAs to be reoriginated for IPv4 is given
   in Section 12.4 of [OSPFV2]. The following events and/or actions are
   added for IPv6:

   o The state or interface ID of one of the router's interfaces
      changes. The router may need to (re)originate or flush its link-
      LSA and one or more router-LSAs and/or intra-area-prefix-LSAs. If
      the router is the Designated Router, the router may also need to
      (re)originate and/or flush the network-LSA corresponding to the
      interface.

   o The identity of a link's Designated Router changes. The router
      may need to (re)originate or flush the link's network-LSA and one
      or more router-LSAs and/or intra-area-prefix-LSAs.

   o A neighbor transitions to/from "Full" state. The router may need
      to (re)originate or flush the link's network-LSA and one or more
      router-LSAs and/or intra-area-prefix-LSAs.

   o The Interface ID of a neighbor changes. This may cause a new
      instance of a router-LSA to be originated for the associated area.

   o A new prefix is added to an attached link, or a prefix is deleted
      (both through configuration). This causes the router to
      reoriginate its link-LSA for the link or, if it is the only router
      attached to the link, causes the router to reoriginate an intra-
      area-prefix-LSA.

   o A new link-LSA is received, causing the link's collection of
      prefixes to change. If the router is the Designated Router for
      the link, it originates a new intra-area-prefix-LSA.

   o A new link-LSA is received, causing the logical OR of LSA options
      advertised by adjacent routers on the link to change. If the
      router is the Designated Router for the link, it originates a new
      network-LSA.

   Detailed construction of the seven required IPv6 LSA types is
   supplied by the following subsections. In order to display example
   LSAs, the network map in Figure 15 of [OSPFV2] has been reworked to
   show IPv6 addressing, resulting in Figure 1. The OSPF cost of each

interface is displayed in Figure 1. The assignment of IPv6 prefixes
to network links is shown in Table 1. A single area address range
has been configured for Area 1, so that outside of Area 1 all of its
prefixes are covered by a single route to 2001:0db8:c001::/48. The
OSPF interface IDs and the link-local addresses for the router
interfaces in Figure 1 are given in Table 2.

```
              ........................................
              .                            Area 1.   .
              .    +                                  .
              .    |                                  .
              .    | 3+---+1                          .
              .  N1|--|RT1|-----+                     .
              .    |  +---+      \                     .
              .    |              \                   .
              .    +               \  _____         .
              .    |                \/      \    1+---+
              .    +                 *   N3  *------|RT4|------
              .    |                /_____/    +---+
              .    +               /  |               .
              .    | 3+---+1      /   |               .
              .  N2|--|RT2|-----+    1|               .
              .    |  +---+          +---+            .
              .    |                 |RT3|---------------
              .    +                 +---+            .
              .    |                  |2               .
              .    +                  |                .
              .                +------------+         .
              .                      N4                .
              .                                        .
              ........................................
```
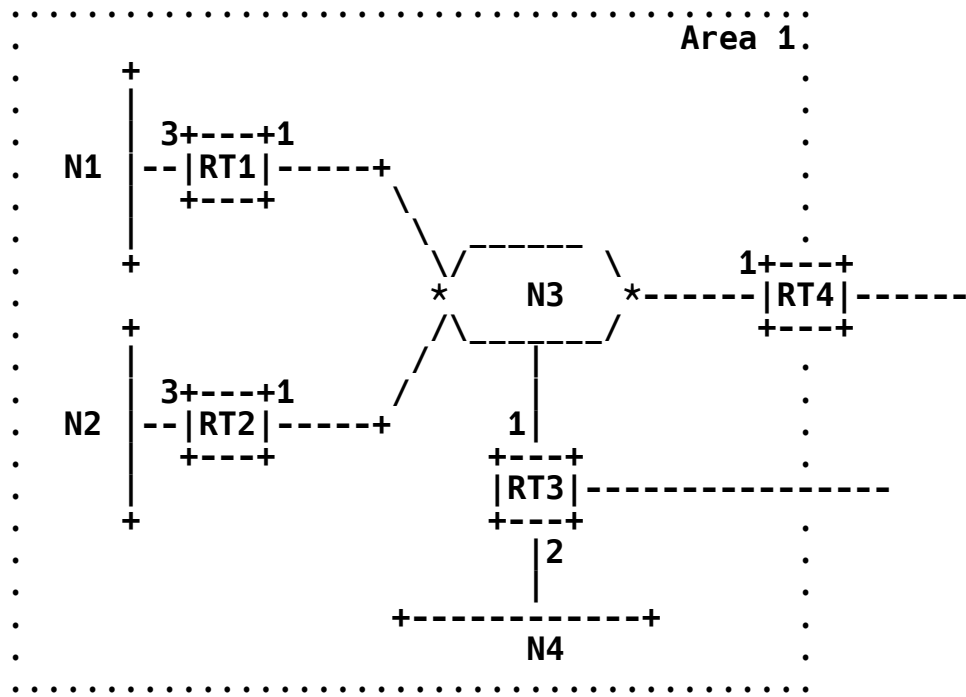
Figure 1: Area 1 with IP Addresses Shown

Network	IPv6 prefix
N1	2001:0db8:c001:0200::/56
N2	2001:0db8:c001:0300::/56
N3	2001:0db8:c001:0100::/56
N4	2001:0db8:c001:0400::/56

Table 1: IPv6 Link Prefixes for Sample Network

Router	Interface	Interface ID	link-local address
RT1	to N1	1	fe80:0001::RT1
	to N3	2	fe80:0002::RT1
RT2	to N2	1	fe80:0001::RT2
	to N3	2	fe80:0002::RT2
RT3	to N3	1	fe80:0001::RT3
	to N4	2	fe80:0002::RT3
RT4	to N3	1	fe80:0001::RT4

Table 2: OSPF Interface IDs and Link-Local Addresses

Figure 1

4.4.3.1. LSA Options

   The Options field in LSAs should be coded as follows. The V6-bit
   should be set unless the router will not participate in transit IPv6
   routing. The E-bit should be clear if and only if the attached area
   is an OSPF stub or OSPF NSSA area. The E-bit should always be set in
   AS scoped LSAs. The N-bit should be set if and only if the attached
   area is an OSPF NSSA area. The R-bit should be set unless the router
   will not participate in any transit routing. The DC-bit should be
   set if and only if the router can correctly process the DoNotAge bit
   when it appears in the LS age field of LSAs (see [DEMAND]). All
   unrecognized bits in the Options field should be cleared.

   The V6-bit and R-bit are only examined in Router-LSAs during the SPF
   computation. In other LSA types containing options, they are set for
   informational purposes only.

4.4.3.2. Router-LSAs

   The LS type of a router-LSA is set to the value 0x2001. Router-LSAs
   have area flooding scope. A router MAY originate one or more router-
   LSAs for a given area. Each router-LSA contains an integral number
   of interface descriptions. Taken together, the collection of router-
   LSAs originated by the router for an area describes the collected
   states of all the router's interfaces attached to the area. When
   multiple router-LSAs are used, they are distinguished by their Link
   State ID fields.

   To the left of the Options field, the router capability bits V, E,
   and B should be set according to Section 12.4.1 of [OSPFV2].

   Each of the router's interfaces to the area is then described by
   appending "link descriptions" to the router-LSA. Each link
   description is 16 bytes long, consisting of five fields: (link) Type,

Metric, Interface ID, Neighbor Interface ID, and Neighbor Router ID
(see Appendix A.4.3). Interfaces in the state "Down" or "Loopback"
are not described (although looped back interfaces can contribute
prefixes to intra-area-prefix-LSAs), nor are interfaces without any
full adjacencies described (except in the case of multiple Standby
Interfaces as described in Section 4.9). All other interfaces to the
area add zero, one, or more link descriptions. The number and
content of these depend on the interface type. Within each link
description, the Metric field is always set to the interface's output
cost, and the Interface ID field is set to the interface's OSPF
Interface ID.

Point-to-point interfaces
    If the neighboring router is fully adjacent, add a Type 1 link
    description (point-to-point). The Neighbor Interface ID field is
    set to the Interface ID advertised by the neighbor in its Hello
    packets, and the Neighbor Router ID field is set to the neighbor's
    Router ID.

Broadcast and NBMA interfaces
    If the router is fully adjacent to the link's Designated Router or
    if the router itself is the Designated Router and is fully
    adjacent to at least one other router, add a single Type 2 link
    description (transit network). The Neighbor Interface ID field is
    set to the Interface ID advertised by the Designated Router in its
    Hello packets, and the Neighbor Router ID field is set to the
    Designated Router's Router ID.

Virtual links
    If the neighboring router is fully adjacent, add a Type 4 link
    description (virtual). The Neighbor Interface ID field is set to
    the Interface ID advertised by the neighbor in its Hello packets,
    and the Neighbor Router ID field is set to the neighbor's Router
    ID. Note that the output cost of a virtual link is calculated
    during the routing table calculation (see Section 4.7).

Point-to-Multipoint interfaces
    For each fully adjacent neighbor associated with the interface,
    add a separate Type 1 link description (point-to-point) with the
    Neighbor Interface ID field set to the Interface ID advertised by
    the neighbor in its Hello packets and the Neighbor Router ID field
    set to the neighbor's Router ID.

As an example, consider the router-LSA that router RT3 would
originate for Area 1 in Figure 1. Only a single interface must be
described, namely, that which connects to the transit network N3. It
assumes that RT4 has been elected the Designated Router of Network
N3.

```
                    ; RT3's router-LSA for Area 1

              LS age = 0                          ;newly (re)originated
              LS type = 0x2001                    ;router-LSA
              Link State ID = 0                   ;first fragment
              Advertising Router = 192.0.2.3 ;RT3's Router ID
              bit E = 0                            ;not an AS boundary router
              bit B = 1                            ;area border router
              Options = (V6-bit|E-bit|R-bit)
                  Type = 2                          ;connects to N3
                  Metric = 1                        ;cost to N3
                  Interface ID = 1                  ;RT3's Interface ID on N3
                  Neighbor Interface ID = 1     ;RT4's Interface ID on N3
                  Neighbor Router ID = 192.0.2.4 ; RT4's Router ID

                        RT3's router-LSA for Area 1
```

   For example, if another router was added to Network N4, RT3 would
   have to advertise a second link description for its connection to
   (the now transit) network N4. This could be accomplished by
   reoriginating the above router-LSA, this time with two link
   descriptions. Or, a separate router-LSA could be originated with a
   separate Link State ID (e.g., using a Link State ID of 1) to describe
   the connection to N4.

   Host routes for stub networks no longer appear in the router-LSA.
   Rather, they are included in intra-area-prefix-LSAs.

4.4.3.3. Network-LSAs

   The LS type of a network-LSA is set to the value 0x2002. Network-
   LSAs have area flooding scope. A network-LSA is originated for every
   broadcast or NBMA link with an elected Designated Router that is
   fully adjacent with at least one other router on the link. The
   network-LSA is originated by the link's Designated Router and lists
   all routers on the link with which it is fully adjacent.

   The procedure for originating network-LSAs in IPv6 is the same as the
   IPv4 procedure documented in Section 12.4.2 of [OSPFV2], with the
   following exceptions:

   o An IPv6 network-LSA's Link State ID is set to the Interface ID of
      the Designated Router on the link.

   o IPv6 network-LSAs do not contain a Network Mask. All addressing
      information formerly contained in the IPv4 network-LSA has now
      been consigned to intra-Area-Prefix-LSAs originated by the link's
      Designated Router.

   o The Options field in the network-LSA is set to the logical OR of
      the Options fields contained within the link's associated link-
      LSAs corresponding to fully adjacent neighbors. In this way, the
      network link exhibits a capability when at least one fully
      adjacent neighbor on the link requests that the capability be
      advertised.

   As an example, assuming that Router RT4 has been elected the
   Designated Router of Network N3 in Figure 1, the following network-
   LSA is originated:

      ; Network-LSA for Network N3

      LS age = 0   ;newly (re)originated
      LS type = 0x2002   ;network-LSA
      Link State ID = 1   ;RT4's Interface ID on N3
      Advertising Router = 192.0.2.4 ;RT4's Router ID
      Options = (V6-bit|E-bit|R-bit)
              Attached Router = 192.0.2.4   ;Router ID
              Attached Router = 192.0.2.1   ;Router ID
              Attached Router = 192.0.2.2   ;Router ID
              Attached Router = 192.0.2.3   ;Router ID

                     Network-LSA for Network N3

4.4.3.4. Inter-Area-Prefix-LSAs

   The LS type of an inter-area-prefix-LSA is set to the value 0x2003.
   Inter-area-prefix-LSAs have area flooding scope. In IPv4, inter-
   area-prefix-LSAs were called type 3 summary-LSAs. Each inter-area-
   prefix-LSA describes a prefix external to the area, yet internal to
   the Autonomous System.

   The procedure for originating inter-area-prefix-LSAs in IPv6 is the
   same as the IPv4 procedure documented in Sections 12.4.3 and 12.4.3.1
   of [OSPFV2], with the following exceptions:

   o The Link State ID of an inter-area-prefix-LSA has lost all of its
      addressing semantics and simply serves to distinguish multiple
      inter-area-prefix-LSAs that are originated by the same router.

   o The prefix is described by the PrefixLength, PrefixOptions, and
      Address Prefix fields embedded within the LSA body. Network Mask
      is no longer specified.

   o The NU-bit in the PrefixOptions field should be clear.

   o Link-local addresses MUST never be advertised in inter-area-
      prefix-LSAs.

   As an example, the following shows the inter-area-prefix-LSA that
   Router RT4 originates into the OSPF backbone area, condensing all of
   Area 1's prefixes into the single prefix 2001:0db8:c001::/48. The
   cost is set to 4, which is the maximum cost of all of the individual
   component prefixes. The prefix is padded out to an even number of
   32-bit words, so that it consumes 64 bits of space instead of 48
   bits.

           ; Inter-area-prefix-LSA for Area 1 addresses
           ; originated by Router RT4 into the backbone

           LS age = 0   ;newly (re)originated
           LS type = 0x2003   ;inter-area-prefix-LSA
           Advertising Router = 192.0.2.4   ;RT4's ID
           Metric = 4   ;maximum to components
           PrefixLength = 48
           PrefixOptions = 0
           Address Prefix = 2001:0db8:c001 ;padded to 64-bits

        Inter-area-prefix-LSA for Area 1 addresses originated
      by Router
                              RT4 into the backbone

4.4.3.5. Inter-Area-Router-LSAs

   The LS type of an inter-area-router-LSA is set to the value 0x2004.
   Inter-area-router-LSAs have area flooding scope. In IPv4, inter-
   area-router-LSAs were called type 4 summary-LSAs. Each inter-area-
   router-LSA describes a path to a destination OSPF router (i.e., an AS
   Boundary Router (ASBR)) that is external to the area yet internal to
   the Autonomous System.

   The procedure for originating inter-area-router-LSAs in IPv6 is the
   same as the IPv4 procedure documented in Section 12.4.3 of [OSPFV2],
   with the following exceptions:

   o The Link State ID of an inter-area-router-LSA is no longer the
      destination router's OSPF Router ID and now simply serves to
      distinguish multiple inter-area-router-LSAs that are originated by
      the same router. The destination router's Router ID is now found
      in the body of the LSA.

   o The Options field in an inter-area-router-LSA should be set equal
      to the Options field contained in the destination router's own
      router-LSA. The Options field thus describes the capabilities
      supported by the destination router.

   As an example, consider the OSPF Autonomous System depicted in Figure
   6 of [OSPFV2]. Router RT4 would originate into Area 1 the following
   inter-area-router-LSA for destination router RT7.

        ; inter-area-router-LSA for AS boundary router RT7
        ; originated by Router RT4 into Area 1

        LS age = 0   ;newly (re)originated
        LS type = 0x2004   ;inter-area-router-LSA
        Advertising Router = 192.0.2.4 ;RT4's ID
        Options = (V6-bit|E-bit|R-bit) ;RT7's capabilities
        Metric = 14   ;cost to RT7
        Destination Router ID = Router RT7's ID

      Inter-area-router-LSA for AS boundary router RT7 originated by Router
                             RT4 into Area 1

4.4.3.6. AS-External-LSAs

   The LS type of an AS-external-LSA is set to the value 0x4005. AS-
   external-LSAs have AS flooding scope. Each AS-external-LSA describes
   a path to a prefix external to the Autonomous System.

   The procedure for originating AS-external-LSAs in IPv6 is the same as
   the IPv4 procedure documented in Section 12.4.4 of [OSPFV2], with the
   following exceptions:

   o The Link State ID of an AS-external-LSA has lost all of its
      addressing semantics and simply serves to distinguish multiple AS-
      external-LSAs that are originated by the same router.

   o The prefix is described by the PrefixLength, PrefixOptions, and
      Address Prefix fields embedded within the LSA body. Network Mask
      is no longer specified.

   o The NU-bit in the PrefixOptions field should be clear.

   o Link-local addresses can never be advertised in AS-external-LSAs.

   o The forwarding address is present in the AS-external-LSA if and
      only if the AS-external-LSA's bit F is set.

   o The external route tag is present in the AS-external-LSA if and
      only if the AS-external-LSA's bit T is set.

   o The capability for an AS-external-LSA to reference another LSA has
      been supported through the inclusion of the Referenced LS Type
      field and the optional Referenced Link State ID field (the latter
      present if and only if the Referenced LS Type is non-zero). This
      capability is for future use; the Referenced LS Type should be set
      to 0, and received non-zero values for this field should be
      ignored until its use is defined.

   As an example, consider the OSPF Autonomous System depicted in Figure
   6 of [OSPFV2]. Assume that RT7 has learned its route to N12 via BGP
   and that it wishes to advertise a Type 2 metric into the AS. Also
   assume that the IPv6 prefix for N12 is the value 2001:0db8:0a00::/40.
   RT7 would then originate the following AS-external-LSA for the
   external network N12. Note that within the AS-external-LSA, N12's
   prefix occupies 64 bits of space in order to maintain 32-bit
   alignment.

        ; AS-external-LSA for Network N12,
        ; originated by Router RT7

        LS age = 0   ;newly (re)originated
        LS type = 0x4005   ;AS-external-LSA
        Link State ID = 123   ;LSA type/scope unique identifier
        Advertising Router = Router RT7's ID
        bit E = 1   ;Type 2 metric
        bit F = 0   ;no forwarding address
        bit T = 1   ;external route tag included
        Metric = 2
        PrefixLength = 40
        PrefixOptions = 0
        Referenced LS Type = 0   ;no Referenced Link State ID
        Address Prefix = 2001:0db8:0a00 ;padded to 64-bits
        External Route Tag = as per BGP/OSPF interaction

         AS-external-LSA for Network N12, originated by Router RT7

4.4.3.7. NSSA-LSAs

   The LS type of an NSSA-LSA is set to the value 0x2007. NSSA-LSAs
   have area flooding scope. Each NSSA-LSA describes a path to a prefix
   external to the Autonomous System whose flooding scope is restricted
   to a single NSSA area.

   The procedure for originating NSSA-LSAs in IPv6 is the same as the
   IPv4 procedure documented in [NSSA], with the following exceptions:

o   The Link State ID of an NSSA-LSA has lost all of its addressing
    semantics and simply serves to distinguish multiple NSSA-LSAs that
    are originated by the same router in the same area.

o   The prefix is described by the PrefixLength, PrefixOptions, and
    Address Prefix fields embedded within the LSA body. Network Mask
    is no longer specified.

o   The NU-bit in the PrefixOptions field should be clear.

o   Link-local addresses can never be advertised in NSSA-LSAs.

o   The forwarding address is present in the NSSA-LSA if and only if
    the NSSA-LSA's bit F is set.

o   The external route tag is present in the NSSA-LSA if and only if
    the NSSA-LSA's bit T is set.

o   The capability for an NSSA-LSA to reference another LSA has been
    supported through the inclusion of the Referenced LS Type field
    and the optional Referenced Link State ID field (the latter
    present if and only if the Referenced LS Type is non-zero). This
    capability is for future use; the Referenced LS Type should be set
    to 0, and received non-zero values for this field should be
    ignored until its use is defined.

An example of an NSSA-LSA would only differ from an AS-external-LSA
in that the LS type would be 0x2007 rather than 0x4005.

4.4.3.8. Link-LSAs

The LS type of a link-LSA is set to the value 0x0008. Link-LSAs have
link-local flooding scope. A router originates a separate link-LSA
for each attached link that supports two or more (including the
originating router itself) routers. Link-LSAs SHOULD NOT be
originated for virtual links.

Link-LSAs have three purposes:

1. They provide the router's link-local address to all other routers
    attached to the link.

2. They inform other routers attached to the link of a list of IPv6
    prefixes to associate with the link.

3. They allow the router to advertise a collection of Options bits
    in the network-LSA originated by the Designated Router on a
    broadcast or NBMA link.

A link-LSA for a given Link L is built in the following fashion:

o The Link State ID is set to the router's Interface ID on Link L.

o The Router Priority of the router's interface to Link L is
   inserted into the link-LSA.

o The link-LSA's Options field is set to reflect the router's
   capabilities. On multi-access links, the Designated Router will
   logically OR the link-LSA Options fields for all fully adjacent
   neighbors in Link L's network-LSA.

o The router inserts its link-local address on Link L into the link-
   LSA. This information will be used when the other routers on Link
   L do their next-hop calculations (see Section 4.8.2).

o Each IPv6 address prefix that has been configured on Link L is
   added to the link-LSA by specifying values for the PrefixLength,
   PrefixOptions, and Address Prefix fields.

After building a link-LSA for a given link, the router installs the
link-LSA into the associated interface data structure and floods the
link-LSA on the link. All other routers on the link will receive the
link-LSA, but they will not flood the link-LSA on other links.

If LinkLSASuppression is configured for the interface and the
interface type is not broadcast or NBMA, origination of the link-LSA
may be suppressed. This implies that other routers on the link will
ascertain the router's next-hop address using a mechanism other than
the link-LSA (see Section 4.8.2). Refer to Appendix C.3 for a
description of the LinkLSASuppression interface configuration
parameter.

As an example, consider the link-LSA that RT3 will build for N3 in
Figure 1. Suppose that the prefix 2001:0db8:c001:0100::/56 has been
configured within RT3 for N3. This will result in the following
link-LSA that RT3 will flood only on N3. Note that not all routers
on N3 need be configured with the prefix; those not configured will
learn the prefix when receiving RT3's link-LSA.

```
; RT3's link-LSA for N3

LS age = 0                      ;newly (re)originated
LS type = 0x0008                ;link-LSA
Link State ID = 1               ;RT3's Interface ID on N3
Advertising Router = 192.0.2.3 ;RT3's Router ID
Rtr Priority = 1                ;RT3's N3 Router Priority
Options = (V6-bit|E-bit|R-bit)
Link-local Interface Address = fe80:0001::RT3
# prefixes = 1
PrefixLength = 56
PrefixOptions = 0
Address Prefix = 2001:0db8:c001:0100 ;pad to 64-bits
```

                        RT3's link-LSA for N3

4.4.3.9. Intra-Area-Prefix-LSAs

   The LS type of an intra-area-prefix-LSA is set to the value 0x2009.
   Intra-area-prefix-LSAs have area flooding scope. An intra-area-
   prefix-LSA has one of two functions. It either associates a list of
   IPv6 address prefixes with a transit network link by referencing a
   network-LSA, or associates a list of IPv6 address prefixes with a
   router by referencing a router-LSA. A stub link's prefixes are
   associated with its attached router.

   A router MAY originate multiple intra-area-prefix-LSAs for a given
   area. Each intra-area-prefix-LSA has a unique Link State ID and
   contains an integral number of prefix descriptions.

   A link's Designated Router originates one or more intra-area-prefix-
   LSAs to advertise the link's prefixes throughout the area. For a
   link L, L's Designated Router builds an intra-area-prefix-LSA in the
   following fashion:

   o In order to indicate that the prefixes are to be associated with
      the Link L, the fields Referenced LS Type, Referenced Link State
      ID, and Referenced Advertising Router are set to the corresponding
      fields in Link L's network-LSA (namely, LS type, Link State ID,
      and Advertising Router respectively). This means that the
      Referenced LS Type is set to 0x2002, the Referenced Link State ID
      is set to the Designated Router's Interface ID on Link L, and the
      Referenced Advertising Router is set to the Designated Router's
      Router ID.

   o Each link-LSA associated with Link L is examined (these are in the
      Designated Router's interface structure for Link L). If the link-
      LSA's Advertising Router is fully adjacent to the Designated

       Router and the Link State ID matches the neighbor's interface ID,
       the list of prefixes in the link-LSA is copied into the intra-
       area-prefix-LSA that is being built. Prefixes having the NU-bit
       and/or LA-bit set in their Options field SHOULD NOT be copied, nor
       should link-local addresses be copied. Each prefix is described
       by the PrefixLength, PrefixOptions, and Address Prefix fields.
       Multiple prefixes having the same PrefixLength and Address Prefix
       are considered to be duplicates. In this case, their
       PrefixOptions fields should be logically OR'ed together, and a
       single instance of the duplicate prefix should be included in the
       intra-area-prefix-LSA. The Metric field for all prefixes is set
       to 0.

   o   The "# prefixes" field is set to the number of prefixes that the
       router has copied into the LSA. If necessary, the list of
       prefixes can be spread across multiple intra-area-prefix-LSAs in
       order to keep the LSA size small.

   A router builds an intra-area-prefix-LSA to advertise prefixes for
   its attached stub links, looped-back interfaces, and hosts. A Router
   RTX would build its intra-area-prefix-LSA in the following fashion:

   o   In order to indicate that the prefixes are to be associated with
       the Router RTX itself, RTX sets the Referenced LS Type to 0x2001,
       the Referenced Link State ID to 0, and the Referenced Advertising
       Router to RTX's own Router ID.

   o   Router RTX examines its list of interfaces to the area. If the
       interface is in the state Down, its prefixes are not included. If
       the interface has been reported in RTX's router-LSA as a Type 2
       link description (link to transit network), prefixes that will be
       included in the intra-area-prefix-LSA for the link are skipped.
       However, any prefixes that would normally have the LA-bit set
       SHOULD be advertised independent of whether or not the interface
       is advertised as a transit link. If the interface type is point-
       to-multipoint or the interface is in the state Loopback, the
       global scope IPv6 addresses associated with the interface (if any)
       are copied into the intra-area-prefix-LSA with the PrefixOptions
       LA-bit set, the PrefixLength set to 128, and the metric set to 0.
       Otherwise, the list of global prefixes configured in RTX for the
       link are copied into the intra-area-prefix-LSA by specifying the
       PrefixLength, PrefixOptions, and Address Prefix fields. The
       Metric field for each of these prefixes is set to the interface's
       output cost.

   o   RTX adds the IPv6 prefixes for any directly attached hosts
       belonging to the area (see Appendix C.7) to the intra-area-prefix-
       LSA.

o If RTX has one or more virtual links configured through the area,
   it includes one of its global scope IPv6 interface addresses in
   the LSA (if it hasn't already), setting the LA-bit in the
   PrefixOptions field, the PrefixLength to 128, and the Metric to 0.
   This information will be used later in the routing calculation so
   that the two ends of the virtual link can discover each other's
   IPv6 addresses.

o The "# prefixes" field is set to the number of prefixes that the
   router has copied into the LSA. If necessary, the list of
   prefixes can be spread across multiple intra-area-prefix-LSAs in
   order to keep the LSA size small.

For example, the intra-area-prefix-LSA originated by RT4 for Network
N3 (assuming that RT4 is N3's Designated Router) and the intra-area-
prefix-LSA originated into Area 1 by Router RT3 for its own prefixes
are pictured below.

```
        ; RT4's Intra-area-prefix-LSA for network link N3

        LS age = 0                      ;newly (re)originated
        LS type = 0x2009                ;Intra-area-prefix-LSA
        Link State ID = 5               ;LSA type/scope unique identifier
        Advertising Router = 192.0.2.4 ;RT4's Router ID
        # prefixes = 1
        Referenced LS Type = 0x2002 ;network-LSA reference
        Referenced Link State ID = 1
        Referenced Advertising Router = 192.0.2.4
        PrefixLength = 56               ;N3's prefix
        PrefixOptions = 0
        Metric = 0
        Address Prefix = 2001:0db8:c001:0100 ;pad

        ; RT3's Intra-area-prefix-LSA for its own prefixes

        LS age = 0                      ;newly (re)originated
        LS type = 0x2009                ;Intra-area-prefix-LSA
        Link State ID = 177             ;LSA type/scope unique identifier
        Advertising Router = 192.0.2.3 ;RT3's Router ID
        # prefixes = 1
        Referenced LS Type = 0x2001 ;router-LSA reference
        Referenced Link State ID = 0
        Referenced Advertising Router = 192.0.2.3
        PrefixLength = 56               ;N4's prefix
        PrefixOptions = 0
        Metric = 2                      ;N4 interface cost
        Address Prefix = 2001:0db8:c001:0400 ;pad
```

                    Intra-area-prefix-LSA for Network Link N3

   When network conditions change, it may be necessary for a router to
   move prefixes from one intra-area-prefix-LSA to another. For
   example, if the router is the Designated Router for a link but the
   link has no other attached routers, the link's prefixes are
   advertised in an intra-area-prefix-LSA referring to the Designated
   Router's router-LSA. When additional routers appear on the link, a
   network-LSA is originated for the link and the link's prefixes are
   moved to an intra-area-prefix-LSA referring to the network-LSA.

   Note that in the intra-area-prefix-LSA, the Referenced Advertising
   Router is always equal to the router that is originating the intra-
   area-prefix-LSA (i.e., the LSA's Advertising Router). The reason the
   Referenced Advertising Router field appears is that, even though it
   is currently redundant, it may not be in the future. We may sometime
   want to use the same LSA format to advertise address prefixes for
   other protocol suites. In this case, the Designated Router may not

be running the other protocol suite, and so another of the link's
routers may need to originate the intra-area-prefix-LSA. In that
case, the Referenced Advertising Router and Advertising Router would
be different.

4.4.4. Future LSA Validation

It is expected that new LSAs will be defined that will not be
processed during the Shortest Path First (SPF) calculation as
described in Section 4.8, for example, OSPFv3 LSAs corresponding to
information advertised in OSPFv2 using opaque LSAs [OPAQUE]. In
general, the new information advertised in future LSAs should not be
used unless the OSPFv3 router originating the LSA is reachable.
However, depending on the application and the data advertised, this
reachability validation MAY be done less frequently than every SPF
calculation.

To facilitate inter-area reachability validation, any OSPFv3 router
originating AS scoped LSAs is considered an AS Boundary Router
(ASBR).

4.5. Flooding

Most of the flooding algorithm remains unchanged from the IPv4
flooding mechanisms described in Section 13 of [OSPFV2]. In
particular, the protocol processes for determining which LSA instance
is newer (Section 13.1 of [OSPFV2]), responding to updates of self-
originated LSAs (Section 13.4 of [OSPFV2]), sending Link State
Acknowledgment packets (Section 13.5 of [OSPFV2]), retransmitting
LSAs (Section 13.6 of [OSPFV2]), and receiving Link State
Acknowledgment packets (Section 13.7 of [OSPFV2]), are exactly the
same for IPv6 and IPv4.

However, the addition of flooding scope and unknown LSA type handling
(see Appendix A.4.2.1) has caused some changes in the OSPF flooding
algorithm: the reception of Link State Updates (Section 13 in
[OSPFV2]) and the sending of Link State Updates (Section 13.3 of
[OSPFV2]) must take into account the LSA's scope and U-bit setting.
Also, installation of LSAs into the OSPF database (Section 13.2 of
[OSPFV2]) causes different events in IPv6, due to the reorganization
of LSA types and the IPv6 LSA contents. These changes are described
in detail below.

4.5.1. Receiving Link State Update Packets

The encoding of flooding scope in the LS type and the need to process
unknown LS types cause modifications to the processing of received
Link State Update packets. As in IPv4, each LSA in a received Link

State Update packet is examined. In IPv4, eight steps are executed
for each LSA, as described in Section 13 of [OSPFV2]. For IPv6, all
the steps are the same, except that Steps 2 and 3 are modified as
follows:

>   (2)   Examine the LSA's LS type. Discard the LSA and get
>   the next one from the Link State Update packet if the
>   interface area has been configured as a stub or
>   NSSA area and the LS type indicates "AS flooding scope".
>
>   This generalizes the IPv4 behavior where AS-external-LSAs
>   and AS-scoped opaque LSAs [OPAQUE] are not flooded
>   throughout stub or NSSA areas.
>
>   (3)   Else if the flooding scope in the LSA's LS type is set to
>   "reserved", discard the LSA and get the next one from
>   the Link State Update packet.

Steps 5b (sending Link State Update packets) and 5d (installing LSAs
in the link-state database) in Section 13 of [OSPFV2] are also
somewhat different for IPv6, as described in Sections 4.5.2 and 4.5.3
below.

4.5.2. Sending Link State Update Packets

The sending of Link State Update packets is described in Section 13.3
of [OSPFV2]. For IPv4 and IPv6, the steps for sending a Link State
Update packet are the same (steps 1 through 5 of Section 13.3 in
[OSPFV2]). However, the list of eligible interfaces on which to
flood the LSA is different. For IPv6, the eligible interfaces are
selected based on the following factors:

o The LSA's flooding scope.

o For LSAs with area or link-local flooding scope, the particular
   area or interface with which the LSA is associated.

o Whether the LSA has a recognized LS type.

o The setting of the U-bit in the LS type. If the U-bit is set to
   0, unrecognized LS types are treated as having link-local scope.
   If set to 1, unrecognized LS types are stored and flooded as if
   they were recognized.

Choosing the set of eligible interfaces then breaks into the
following cases:

Case 1
    The LSA's LS type is recognized. In this case, the set of
    eligible interfaces is set depending on the flooding scope encoded
    in the LS type. If the flooding scope is "AS flooding scope", the
    eligible interfaces are all router interfaces excepting virtual
    links. In addition, AS-external-LSAs are not flooded on
    interfaces connecting to stub or NSSA areas. If the flooding
    scope is "area flooding scope", the eligible interfaces are those
    interfaces connecting to the LSA's associated area. If the
    flooding scope is "link-local flooding scope", then there is a
    single eligible interface, the one connecting to the LSA's
    associated link (which is also the interface on which the LSA was
    received in a Link State Update packet).

Case 2
    The LS type is unrecognized and the U-bit in the LS type is set to
    0 (treat the LSA as if it had link-local flooding scope). In this
    case, there is a single eligible interface, namely, the interface
    on which the LSA was received.

Case 3
    The LS type is unrecognized, and the U-bit in the LS type is set
    to 1 (store and flood the LSA as if the type is understood). In
    this case, select the eligible interfaces based on the encoded
    flooding scope the same as in Case 1 above.

A further decision must sometimes be made before adding an LSA to a
given neighbor's link-state retransmission list (Step 1d in Section
13.3 of [OSPFV2]). If the LS type is recognized by the router but
not by the neighbor (as can be determined by examining the Options
field that the neighbor advertised in its Database Description
packet) and the LSA's U-bit is set to 0, then the LSA should be added
to the neighbor's link-state retransmission list if and only if that
neighbor is the Designated Router or Backup Designated Router for the
attached link. The LS types described in detail by this document,
namely, router-LSAs (LS type 0x2001), network-LSAs (0x2002), inter-
area-prefix-LSAs (0x2003), inter-area-router-LSAs (0x2004), NSSA-LSAs
(0x2007), AS-external-LSAs (0x4005), link-LSAs (0x0008), and Intra-
Area-Prefix-LSAs (0x2009), are assumed to be understood by all
routers. However, all LS types MAY not be understood by all routers.
For example, a new LSA type with its U-bit set to 0 MAY only be
understood by a subset of routers. This new LS type should only be
flooded to an OSPF neighbor that understands the LS type or when the
neighbor is the Designated Router or Backup Designated Router for the
attached link.

The previous paragraph solves a problem for IPv4 OSPF extensions,
which require that the Designated Router support the extension in
order to have the new LSA types flooded across broadcast and NBMA
networks.

4.5.3. Installing LSAs in the Database

There are three separate places to store LSAs, depending on their
flooding scope. LSAs with AS flooding scope are stored in the global
OSPF data structure (see Section 4.1) as long as their LS type is
known or their U-bit is 1. LSAs with area flooding scope are stored
in the appropriate area data structure (see Section 4.1.1) as long as
their LS type is known or their U-bit is 1. LSAs with link-local
flooding scope, and those LSAs with unknown LS type and U-bit set to
0 (treat the LSA as if it had link-local flooding scope), are stored
in the appropriate interface data structure.

When storing the LSA into the link-state database, a check must be
made to see whether the LSA's contents have changed. Changes in
contents are indicated exactly as in Section 13.2 of [OSPFV2]. When
an LSA's contents have been changed, the following parts of the
routing table must be recalculated, based on the LSA's LS type:

Router-LSAs, Network-LSAs, Intra-Area-Prefix-LSAs, and Link-LSAs
    The entire routing table is recalculated, starting with the
    shortest-path calculation for each area (see Section 4.8).

Inter-Area-Prefix-LSAs and Inter-Area-Router-LSAs
    The best route to the destination described by the LSA must be
    recalculated (see Section 16.5 in [OSPFV2]). If this destination
    is an AS boundary router, it may also be necessary to re-examine
    all the AS-external-LSAs.

AS-external-LSAs and NSSA-LSAs
    The best route to the destination described by the AS-external-LSA
    or NSSA-LSA must be recalculated (see Section 16.6 in [OSPFV2] and
    Section 2.0 in [NSSA]).

As in IPv4, any old instance of the LSA must be removed from the
database when the new LSA is installed. This old instance must also
be removed from all neighbors' link-state retransmission lists.

4.6. Definition of Self-Originated LSAs

In IPv6, the definition of a self-originated LSA has been simplified
from the IPv4 definition appearing in Sections 13.4 and 14.1 of
[OSPFV2]. For IPv6, self-originated LSAs are those LSAs whose
Advertising Router is equal to the router's own Router ID.

4.7. Virtual Links

   OSPF virtual links for IPv4 are described in Section 15 of [OSPFV2].
   Virtual links are the same in IPv6, with the following exceptions:

   o LSAs having AS flooding scope are never flooded over virtual
      adjacencies, nor are LSAs with AS flooding scope summarized over
      virtual adjacencies during the database exchange process. This is
      a generalization of the IPv4 treatment of AS-external-LSAs.

   o The IPv6 interface address of a virtual link MUST be an IPv6
      address having global scope, instead of the link-local addresses
      used by other interface types. This address is used as the IPv6
      source for OSPF protocol packets sent over the virtual link.
      Hence, a link-LSA SHOULD NOT be originated for a virtual link
      since the virtual link has no link-local address or associated
      prefixes.

   o Likewise, the virtual neighbor's IPv6 address is an IPv6 address
      with global scope. To enable the discovery of a virtual
      neighbor's IPv6 address during the routing calculation, the
      neighbor advertises its virtual link's IPv6 interface address in
      an intra-area-prefix-LSA originated for the virtual link's transit
      area (see Section 4.4.3.9 and Section 4.8.1).

   o Like all other IPv6 OSPF interfaces, virtual links are assigned
      unique (within the router) Interface IDs. These are advertised in
      Hellos sent over the virtual link and in the router's router-LSAs.

4.8. Routing Table Calculation

   The IPv6 OSPF routing calculation proceeds along the same lines as
   the IPv4 OSPF routing calculation, following the five steps specified
   by Section 16 of [OSPFV2]. High-level differences between the IPv6
   and IPv4 calculations include:

   o Prefix information has been removed from router-LSAs and network-
      LSAs and is now advertised in intra-area-prefix-LSAs. Whenever
      [OSPFV2] specifies that stub networks within router-LSAs be
      examined, IPv6 will instead examine prefixes within intra-area-
      prefix-LSAs.

   o Type 3 and 4 summary-LSAs have been renamed inter-area-prefix-LSAs
      and inter-area-router-LSAs respectively.

   o Addressing information is no longer encoded in Link State IDs and
      is now only found within the body of LSAs.

   o In IPv6, a router can originate multiple router-LSAs,
      distinguished by Link State ID, within a single area. These
      router-LSAs MUST be treated as a single aggregate by the area's
      shortest-path calculation (see Section 4.8.1).

   For each area, the shortest-path tree calculation creates routing
   table entries for the area's routers and transit links (see
   Section 4.8.1). These entries are then used when processing intra-
   area-prefix-LSAs, inter-area-prefix-LSAs, and inter-area-router-LSAs,
   as described in Section 4.8.3.

   Events generated as a result of routing table changes (Section 16.7
   of [OSPFV2]) and the equal-cost multipath logic (Section 16.8 of
   [OSPFV2]) are identical for both IPv4 and IPv6.

4.8.1. Calculating the Shortest-Path Tree for an Area

   The IPv4 shortest-path calculation is contained in Section 16.1 of
   [OSPFV2]. The graph used by the shortest-path tree calculation is
   identical for both IPv4 and IPv6. The graph's vertices are routers
   and transit links, represented by router-LSAs and network-LSAs
   respectively. A router is identified by its OSPF Router ID, while a
   transit link is identified by its Designated Router's Interface ID
   and OSPF Router ID. Both routers and transit links have associated
   routing table entries within the area (see Section 4.3).

   Section 16.1 of [OSPFV2] splits up the shortest-path calculations
   into two stages. First, the Dijkstra calculation is performed, and
   then the stub links are added onto the tree as leaves. The IPv6
   calculation maintains this split.

   The Dijkstra calculation for IPv6 is identical to that specified for
   IPv4, with the following exceptions (referencing the steps from the
   Dijkstra calculation as described in Section 16.1 of [OSPFV2]):

   o The Vertex ID for a router is the OSPF Router ID. The Vertex ID
      for a transit network is a combination of the Interface ID and
      OSPF Router ID of the network's Designated Router.

   o In Step 2, when a router Vertex V has just been added to the
      shortest-path tree, there may be multiple LSAs associated with the
      router. All router-LSAs with the Advertising Router set to V's
      OSPF Router ID MUST be processed as an aggregate, treating them as
      fragments of a single large router-LSA. The Options field and the

      router type bits (bits Nt, V, E, and B) should always be taken
      from the router-LSA with the smallest Link State ID.

   o Step 2a is not needed in IPv6, as there are no longer stub network
      links in router-LSAs.

   o In Step 2b, if W is a router and the router-LSA V6-bit or R-bit is
      not set in the LSA options, the transit link W is ignored and V's
      next link is examined.

   o In Step 2b, if W is a router, there may again be multiple LSAs
      associated with the router. All router-LSAs with the Advertising
      Router set to W's OSPF Router ID MUST be processed as an
      aggregate, treating them as fragments of a single large router-
      LSA.

   o In Step 4, there are now per-area routing table entries for each
      of an area's routers rather than just the area border routers.
      These entries subsume all the functionality of IPv4's area border
      router routing table entries, including the maintenance of virtual
      links. When the router added to the area routing table in this
      step is the other end of a virtual link, the virtual neighbor's IP
      address is set as follows: The collection of intra-area-prefix-
      LSAs originated by the virtual neighbor is examined, with the
      virtual neighbor's IP address being set to the first prefix
      encountered with the LA-bit set.

   o Routing table entries for transit networks, which are no longer
      associated with IP networks, are also calculated in Step 4 and
      added to the per-area routing table.

   The next stage of the shortest-path calculation proceeds similarly to
   the two steps of the second stage of Section 16.1 in [OSPFV2].
   However, instead of examining the stub links within router-LSAs, the
   list of the area's intra-area-prefix-LSAs is examined. A prefix
   advertisement whose NU-bit is set SHOULD NOT be included in the
   routing calculation. The cost of any advertised prefix is the sum of
   the prefix's advertised metric plus the cost to the transit vertex
   (either router or transit network) identified by intra-area-prefix-
   LSA's Referenced LS Type, Referenced Link State ID, and Referenced
   Advertising Router fields. This latter cost is stored in the transit
   vertex's routing table entry for the area.

   This specification does not require that the above algorithm be used
   to calculate the intra-area shortest-path tree. However, if another
   algorithm or optimization is used, an identical shortest-path tree
   must be produced. It is also important that any alternate algorithm
   or optimization maintain the requirement that transit vertices must

be bidirectional for inclusion in the tree. Alternate algorithms and
optimizations are beyond the scope of this specification.

4.8.2. The Next-Hop Calculation

In IPv6, the calculation of the next-hop's IPv6 address (which will
be a link-local address) proceeds along the same lines as the IPv4
next-hop calculation (see Section 16.1.1 of [OSPFV2]). However,
there are some differences. When calculating the next-hop IPv6
address for a router (call it Router X) that shares a link with the
calculating router, the calculating router assigns the next-hop IPv6
address to be the link-local interface address contained in Router
X's link-LSA (see Appendix A.4.9) for the link. This procedure is
necessary for some link types, for example NBMA, where the two
routers need not be neighbors and might not be exchanging OSPF Hello
packets. For other link types, the next-hop address may be
determined via the IPv6 source address in the neighbor's Hello
packet.

Additionally, when calculating routes for the area's intra-area-
prefix-LSAs, the parent vertex can be either a router-LSA or network-
LSA. This is in contrast to the second stage of the OSPFv2 intra-
area SPF (Section 16.1 in [OSPFV2]) where the parent vertex is always
a router-LSA. In the case where the intra-area-prefix-LSA's
referenced LSA is a directly connected network-LSA, the prefixes are
also considered to be directly connected. In this case, the next hop
is solely the outgoing link and no IPv6 next-hop address is selected.

4.8.3. Calculating the Inter-Area Routes

Calculation of inter-area routes for IPv6 proceeds along the same
lines as the IPv4 calculation in Section 16.2 of [OSPFV2], with the
following modifications:

o The names of the Type 3 summary-LSAs and Type 4 summary-LSAs have
   been changed to inter-area-prefix-LSAs and inter-area-router-LSAs
   respectively.

o The Link State ID of the above LSA types no longer encodes the
   network or router described by the LSA. Instead, an address
   prefix is contained in the body of an inter-area-prefix-LSA and an
   advertised AS boundary router's OSPF Router ID is carried in the
   body of an inter-area-router-LSA.

o Prefixes having the NU-bit set in their PrefixOptions field should
   be ignored by the inter-area route calculation.

   When a single inter-area-prefix-LSA or inter-area-router-LSA has
   changed, the incremental calculations outlined in Section 16.5 of
   [OSPFV2] can be performed instead of recalculating the entire routing
   table.

4.8.4. Examining Transit Areas' Summary-LSAs

   Examination of transit areas' summary-LSAs in IPv6 proceeds along the
   same lines as the IPv4 calculation in Section 16.3 of [OSPFV2],
   modified in the same way as the IPv6 inter-area route calculation in
   Section 4.8.3.

4.8.5. Calculating AS External and NSSA Routes

   The IPv6 AS external route calculation proceeds along the same lines
   as the IPv4 calculation in Section 16.4 of [OSPFV2] and Section 2.5
   of [NSSA], with the following exceptions:

   o The Link State ID of the AS-external-LSA and NSSA-LSA types no
      longer encodes the network described by the LSA. Instead, an
      address prefix is contained in the body of the LSA.

   o The default route in AS-external-LSAs or NSSA-LSAs is advertised
      by a zero-length prefix.

   o Instead of comparing the AS-external-LSA's or NSSA-LSA's
      Forwarding Address field to 0.0.0.0 to see whether a forwarding
      address has been used, the bit F in the respective LSA is
      examined. A forwarding address is in use if and only if bit F is
      set.

   o Prefixes having the NU-bit set in their PrefixOptions field should
      be ignored by the inter-area route calculation.

   o AS Boundary Router (ASBR) and forwarding address selection will
      proceed the same as if RFC1583Compatibility is disabled.
      Furthermore, RFC1583Compatibility is not an OSPF for IPv6
      configuration parameter. Refer to Appendix C.1.

   When a single AS-external-LSA or NSSA-LSA has changed, the
   incremental calculations outlined in Section 16.6 of [OSPFV2] can be
   performed instead of recalculating the entire routing table.

4.9. Multiple Interfaces to a Single Link

   In OSPF for IPv6, a router may have multiple interfaces to a single
   link associated with the same OSPF instance and area. All interfaces

   will be used for the reception and transmission of data traffic while
   only a single interface sends and receives OSPF control traffic. In
   more detail:

   o Each of the multiple interfaces is assigned a different Interface
      ID. A router will automatically detect that multiple interfaces
      are attached to the same link when a Hello packet is received with
      one of the router's link-local addresses as the source address and
      an Interface ID other than the Interface ID of the receiving
      interface.

   o Each of the multiple interfaces MUST be configured with the same
      Interface Instance ID to be considered on the same link. If an
      interface has multiple Instance IDs, it will be grouped with other
      interfaces based on matching Instance IDs. Each Instance ID will
      be treated uniquely with respect to groupings of multiple
      interfaces on the same link. For example, if interface A is
      configured with Instance IDs 1 and 35, and interface B is
      configured with Instance ID 35, interface B may be the Active
      Interface for Instance ID 35 but interface A will be active for
      Instance ID 1.

   o The router will ignore OSPF packets other than Hello packets on
      all but one of the interfaces attached to the link. It will only
      send its OSPF control packets (including Hello packets) on a
      single interface. This interface is designated the Active
      Interface and other interfaces attached to the same link will be
      designated Standby Interfaces. The choice of the Active Interface
      is implementation dependent. For example, the interface with the
      highest Interface ID could be chosen. If the router is elected
      Designated Router, it will be the Active Interface's Interface ID
      that will be used as the network-LSA's Link State ID.

   o All of the interfaces to the link (Active and Standby) will appear
      in the router-LSA. In addition, a link-LSA will be generated for
      each of the interfaces. In this way, all interfaces will be
      included in OSPF's routing calculations.

   o Any link-local scope LSAs that are originated for a Standby
      Interface will be flooded over the Active Interface.
      If a Standby Interface goes down, then the link-local scope LSAs
      originated for the Standby Interfaces MUST be flushed on the
      Active Interface.

   o Prefixes on Standby Interfaces will be processed the same way as
      prefixes on the Active Interface. For example, if the router is
      the DR for the link, the Active Interface's prefixes are included

in an intra-area-prefix-LSA which is associated with the Active
Interface's network-LSA; prefixes from Standby Interfaces on the
link will also be included in that intra-area-prefix LSA.
Similarly, if the link is a stub link, then the prefixes for the
Active and Standby Interfaces will all be included in the same
intra-area-prefix-LSA that is associated with the router-LSA.

o If the Active Interface fails, a new Active Interface will have to
   take over. The new Active Interface SHOULD form all new neighbor
   adjacencies with routers on the link. This failure can be
   detected when the router's other interfaces to the Active
   Interface's link cease to hear the router's Hellos or through
   internal mechanisms, e.g., monitoring the Active Interface's
   status.

o If the network becomes partitioned with different local interfaces
   attaching to different network partitions, multiple interfaces
   will become Active Interfaces and function independently.

o During the SPF calculation when a network-LSA for a network that
   is directly connected to the root vertex is being examined, all of
   the multiple interfaces to the link of adjacent router-LSAs must
   be used in the next-hop calculation.
   This can be accomplished during the back link check (see Section
   16.1, Step 2 (B), in [OSPFV2]) by examining each link of the
   router-LSA and making a list of the links that point to the
   network-LSA. The Interface IDs for links in this list are then
   used to find the corresponding link-LSAs and the link-local
   addresses used as next hops when installing equal-cost paths in
   the routing table.

o The interface state machine is modified to add the state Standby.
   See Section 4.9.1 for a description of the Standby state.

4.9.1. Standby Interface State

In this state, the interface is one of multiple interfaces to a link
and this interface is designated Standby and is not sending or
receiving control packets. The interface will continue to receive
the Hello packets sent by the Active Interface. The interface will
maintain a timer, the Active Interface Timer, with the same interval
as the RouterDeadInterval. This timer will be reset whenever an OSPF
Hello packet is received from the Active Interface to the link.

Two new events are added to the list of events that cause interface
state changes: MultipleInterfacesToLink and ActiveInterfaceDead. The
descriptions of these events are as follows:

MultipleInterfacesToLink
     An interfaces on the router has received a Hello packet from
     another interface on the same router. One of the interfaces is
     designated as the Active Interface and the other interface is
     designated as a Standby Interface. The Standby Interface
     transitions to the Standby state.

ActiveInterfaceDead
     There has been an indication that a Standby Interface is no longer
     on a link with an Active Interface. The firing of the Active
     Interface Timer is one indication of this event, as it indicates
     that the Standby Interface has not received an OSPF Hello packet
     from the Active Interface for the RouterDeadInterval. Other
     indications may come from internal notifications, such as the
     Active Interface being disabled through a configuration change.
     Any indication internal to the router, such that the router knows
     the Active Interface is no longer active on the link, can trigger
     the ActiveInterfaceDead event for a Standby Interface.

   Interface state machine additions include:

       State(s): Waiting, DR Other, Backup, or DR

          Event: MultipleInterfacesToLink

      New state: Standby

         Action: All interface variables are reset and interface
                  timers disabled. Also, all neighbor connections
                  associated with the interface are destroyed. This
                  is done by generating the event KillNbr on all
                  associated neighbors. The Active Interface Timer is
                  started and the interface will listen for OSPF Hello
                  packets from the link's Active Interface.

       State(s): Standby

          Event: ActiveInterfaceDead

      New state: Down

         Action: The Active Interface Timer is first disabled. Then
                  the InterfaceUp event is invoked.

                   Standby Interface State Machine Additions

5. Security Considerations

   When running over IPv6, OSPFv3 relies on the IP Authentication Header
   (see [IPAUTH]) and the IP Encapsulating Security Payload (see
   [IPESP]) to ensure integrity and authentication/confidentiality of
   protocol packets. This is described in [OSPFV3-AUTH].

   Most OSPFv3 implementations will be running on systems that support
   multiple protocols with their own independent security assumptions
   and domains. When IPsec is used to protect OSPFv3 packets, it is
   important for the implementation to check the IPsec Security
   Association (SA) and local SA database to ensure the OSPF packet
   originated from a source that is trusted for OSPFv3. This is
   required to eliminate the possibility that the packet was
   authenticated using an SA defined for another protocol running on the
   same system.

   The mechanisms in [OSPFV3-AUTH] do not provide protection against
   compromised, malfunctioning, or misconfigured routers. Such routers
   can, either accidentally or deliberately, cause malfunctions
   affecting the whole routing domain. The reader is encouraged to
   consult [GENERIC-THREATS] for a more comprehensive description of
   threats to routing protocols.

6. Manageability Considerations

   The Management Information Base (MIB) for OSPFv3 is defined in
   [OSPFV3-MIB].

7. IANA Considerations

   Most OSPF for IPv6 IANA considerations are documented in [OSPF-IANA].
   IANA has updated the reference for RFC 2740 to this document.

   Additionally, this document introduces the following IANA
   requirements that were not present in [OSPFV3]:

   o Reserves the options with the values 0x000040 and 0x000080 for
      migrated OSPFv2 options in the OSPFv3 Options registry defined in
      [OSPF-IANA]. For information on the OSPFv3 Options field, refer
      to Appendix A.2.

   o Adds the prefix option P-bit with value 0x08 to the OSPFv3 Prefix
      Options registry defined in [OSPF-IANA]. For information on
      OSPFv3 Prefix Options, refer to Appendix A.4.1.1.

   o Adds the prefix option DN-bit with value 0x10 to the OSPFv3 Prefix
      Options registry defined in [OSPF-IANA]. For information on
      OSPFv3 Prefix Options, refer to Appendix A.4.1.1.

7.1. MOSPF for OSPFv3 Deprecation IANA Considerations

   With the deprecation of MOSPF for OSPFv3, the following code points
   are available for reassignment. Refer to [OSPF-IANA] for information
   on the respective registries. This document:

   o Deprecates the MC-bit with value 0x000004 in the OSPFv3 Options
      registry.

   o Deprecates Group-membership-LSA with value 6 in OSPFv3 LSA
      Function Code registry.

   o Deprecates MC-bit with value 0x04 in the OSPFv3 Prefix Options
      registry.

   The W-bit in the OSPFv3 Router Properties has also been deprecated.
   This requires a new registry for OSPFv3 router properties since it
   will diverge from the OSPFv2 Router Properties.

      Registry Name: OSPFv3 Router Properties Registry
      Reference: RFC 5340
      Registration Procedures: Standards Action

      Registry:
      Value   Description   Reference
      ------   -------------   ---------
      0x01   B-bit   RFC 5340
      0x02   E-bit   RFC 5340
      0x04   V-bit   RFC 5340
      0x08   Deprecated   RFC 5340
      0x10   Nt-bit   RFC 5340

                  OSPFv3 Router Properties Registry

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9. References

9.1. Normative References

   [DEMAND]   Moy, J., "Extending OSPF to Support Demand
                      Circuits", RFC 1793, April 1995.

   [DIFF-SERV]   Nichols, K., Blake, S., Baker, F., and D. Black,
                      "Definition of the Differentiated Services Field
                      (DS Field) in the IPv4 and IPv6 Headers",
                      RFC 2474, December 1998.

   [DN-BIT]   Rosen, E., Peter, P., and P. Pillay-Esnault,
                      "Using a Link State Advertisement (LSA) Options
                      Bit to Prevent Looping in BGP/MPLS IP Virtual
                      Private Networks (VPNs)", RFC 4576, June 2006.

   [INTFMIB]   McCloghrie, K. and F. Kastenholz, "The Interfaces
                      Group MIB", RFC 2863, June 2000.

   [IP6ADDR]   Hinden, R. and S. Deering, "IP Version 6
                      Addressing Architecture", RFC 4291, February 2006.

   [IPAUTH]   Kent, S., "IP Authentication Header", RFC 4302,
                      December 2005.

   [IPESP]   Kent, S., "IP Encapsulating Security Payload
                      (ESP)", RFC 4303, December 2005.

   [IPV4]   Postal, J., "Internet Protocol", STD 5, RFC 791,
                      September 1981.

   [IPV6]   Deering, S. and R. Hinden, "Internet Protocol,
                      Version 6 (IPv6) Specification", RFC 2460,
                      December 1998.

   [NSSA]   Murphy, P., "The OSPF Not-So-Stubby Area (NSSA)
                      Option", RFC 3101, January 2003.

   [OSPF-IANA]   Kompella, K. and B. Fenner, "IANA Considerations
                        for OSPF", BCP 130, RFC 4940, July 2007.

   [OSPFV2]   Moy, J., "OSPF Version 2", STD 54, RFC 2328,
                        April 1998.

   [OSPFV3-AUTH]   Gupta, M. and N. Melam, "Authentication/
                        Confidentiality for OSPFv3", RFC 4552, June 2006.

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

9.2. Informative References

   [GENERIC-THREATS]   Barbir, A., Murphy, S., and Y. Yang, "Generic
                        Threats to Routing Protocols", RFC 4593,
                        October 2006.

   [MOSPF]   Moy, J., "Multicast Extensions to OSPF", RFC 1584,
                        March 1994.

   [MTUDISC]   Mogul, J. and S. Deering, "Path MTU discovery",
                        RFC 1191, November 1990.

   [OPAQUE]   Coltun, R., "The OSPF Opaque LSA Option",
                        RFC 2370, July 1998.

   [OSPFV3]   Coltun, R., Ferguson, D., and J. Moy, "OSPF for
                        IPv6", RFC 2740, December 1999.

   [OSPFV3-MIB]   Joyal, D. and V. Manral, "Management Information
                        Base for OSPFv3", Work in Progress,
                        September 2007.

   [SERV-CLASS]   Babiarz, J., Chan, K., and F. Baker,
                        "Configuration Guidelines for DiffServ Service
                        Classes", RFC 4594, August 2006.

Appendix A. OSPF Data Formats

   This appendix describes the format of OSPF protocol packets and OSPF
   LSAs. The OSPF protocol runs directly over the IPv6 network layer.
   Before any data formats are described, the details of the OSPF
   encapsulation are explained.

   Next, the OSPF Options field is described. This field describes
   various capabilities that may or may not be supported by pieces of
   the OSPF routing domain. The OSPF Options field is contained in OSPF
   Hello packets, Database Description packets, and OSPF LSAs.

   OSPF packet formats are detailed in Section A.3.

   A description of OSPF LSAs appears in Section A.4. This section
   describes how IPv6 address prefixes are represented within LSAs,
   details the standard LSA header, and then provides formats for each
   of the specific LSA types.

A.1. Encapsulation of OSPF Packets

   OSPF runs directly over the IPv6's network layer. OSPF packets are
   therefore encapsulated solely by IPv6 and local data-link headers.

   OSPF does not define a way to fragment its protocol packets, and
   depends on IPv6 fragmentation when transmitting packets larger than
   the link MTU. If necessary, the length of OSPF packets can be up to
   65,535 bytes. The OSPF packet types that are likely to be large
   (Database Description, Link State Request, Link State Update, and
   Link State Acknowledgment packets) can usually be split into multiple
   protocol packets without loss of functionality. This is recommended;
   IPv6 fragmentation should be avoided whenever possible. Using this
   reasoning, an attempt should be made to limit the size of OSPF
   packets sent over virtual links to 1280 bytes unless Path MTU
   Discovery is being performed [MTUDISC].

   The other important features of OSPF's IPv6 encapsulation are:

   o Use of IPv6 multicast. Some OSPF messages are multicast when sent
      over broadcast networks. Two distinct IP multicast addresses are
      used. Packets sent to these multicast addresses should never be
      forwarded; they are meant to travel a single hop only. As such,
      the multicast addresses have been chosen with link-local scope and
      packets sent to these addresses should have their IPv6 Hop Limit
      set to 1. b

   AllSPFRouters
      This multicast address has been assigned the value FF02::5.
      All routers running OSPF should be prepared to receive packets
      sent to this address. Hello packets are always sent to this
      destination. Also, certain OSPF protocol packets are sent to
      this address during the flooding procedure.

   AllDRouters
      This multicast address has been assigned the value FF02::6.
      Both the Designated Router and Backup Designated Router must be
      prepared to receive packets destined to this address. Certain
      OSPF protocol packets are sent to this address during the
      flooding procedure.

   o OSPF is IP protocol 89. This number SHOULD be inserted in the
      Next Header field of the encapsulating IPv6 header.

   o The OSPFv2 specification (Appendix A.1 in [OSPFV2]) indicates that
      OSPF protocol packets are sent with IP precedence set to
      Internetwork Control (B'110') [IPV4]. If routers in the OSPF
      routing domain map their IPv6 Traffic Class octet to the
      Differentiated Services Code Point (DSCP) as specified in
      [DIFF-SERV], then OSPFv3 packets SHOULD be sent with their DSCP
      set to CS6 (B'110000'), as specified in [SERV-CLASS]. In networks
      supporting this mapping, OSPF packets will be given precedence
      over IPv6 data traffic.

A.2. The Options Field

   The 24-bit OSPF Options field is present in OSPF Hello packets,
   Database Description packets, and certain LSAs (router-LSAs, network-
   LSAs, inter-area-router-LSAs, and link-LSAs). The Options field
   enables OSPF routers to support (or not support) optional
   capabilities, and to communicate their capability level to other OSPF
   routers. Through this mechanism, routers of differing capabilities
   can be mixed within an OSPF routing domain.

   An option mismatch between routers can cause a variety of behaviors,
   depending on the particular option. Some option mismatches prevent
   neighbor relationships from forming (e.g., the E-bit below); these
   mismatches are discovered through the sending and receiving of Hello
   packets. Some option mismatches prevent particular LSA types from
   being flooded across adjacencies; these are discovered through the
   sending and receiving of Database Description packets. Some option
   mismatches prevent routers from being included in one or more of the
   various routing calculations because of their reduced functionality;
   these mismatches are discovered by examining LSAs.

Seven bits of the OSPF Options field have been assigned. Each bit is
described briefly below. Routers should reset (i.e., clear)
unrecognized bits in the Options field when sending Hello packets or
Database Description packets and when originating LSAs. Conversely,
routers encountering unrecognized Options bits in received Hello
packets, Database Description packets, or LSAs should ignore the
unrecognized bits and process the packet or LSA normally.

```
                          1                   2
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     | | | | | | | | | | | | | | | | | |*|*|DC|R|N|x| E|V6|
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

                         The Options field

                         The Options field

V6-bit
   If this bit is clear, the router/link should be excluded from IPv6
   routing calculations. See Section 4.8 for details.

E-bit
   This bit describes the way AS-external-LSAs are flooded, as
   described in Sections 3.6, 9.5, 10.8, and 12.1.2 of [OSPFV2].

x-Bit
   This bit was previously used by MOSPF (see [MOSPF]), which has
   been deprecated for OSPFv3. The bit should be set to 0 and
   ignored when received. It may be reassigned in the future.

N-bit
   This bit indicates whether or not the router is attached to an
   NSSA as specified in [NSSA].

R-bit
   This bit (the `Router' bit) indicates whether the originator is an
   active router. If the router bit is clear, then routes that
   transit the advertising node cannot be computed. Clearing the
   router bit would be appropriate for a multi-homed host that wants
   to participate in routing, but does not want to forward non-
   locally addressed packets.

DC-bit
   This bit describes the router's handling of demand circuits, as
   specified in [DEMAND].

     *-bit
        These bits are reserved for migration of OSPFv2 protocol
        extensions.

A.3. OSPF Packet Formats

    There are five distinct OSPF packet types. All OSPF packet types
    begin with a standard 16-byte header. This header is described
    first. Each packet type is then described in a succeeding section.
    In these sections, each packet's format is displayed and the packet's
    component fields are defined.

    All OSPF packet types (other than the OSPF Hello packets) deal with
    lists of LSAs. For example, Link State Update packets implement the
    flooding of LSAs throughout the OSPF routing domain. The format of
    LSAs is described in Section A.4.

    The receive processing of OSPF packets is detailed in Section 4.2.2.
    The sending of OSPF packets is explained in Section 4.2.1.

A.3.1. The OSPF Packet Header

    Every OSPF packet starts with a standard 16-byte header. Together
    with the encapsulating IPv6 headers, the OSPF header contains all the
    information necessary to determine whether the packet should be
    accepted for further processing. This determination is described in
    Section 4.2.2.

```
        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
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |   Version #   |     Type      |        Packet length          |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                         Router ID                             |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                          Area ID                              |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |          Checksum             |  Instance ID  |      0        |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
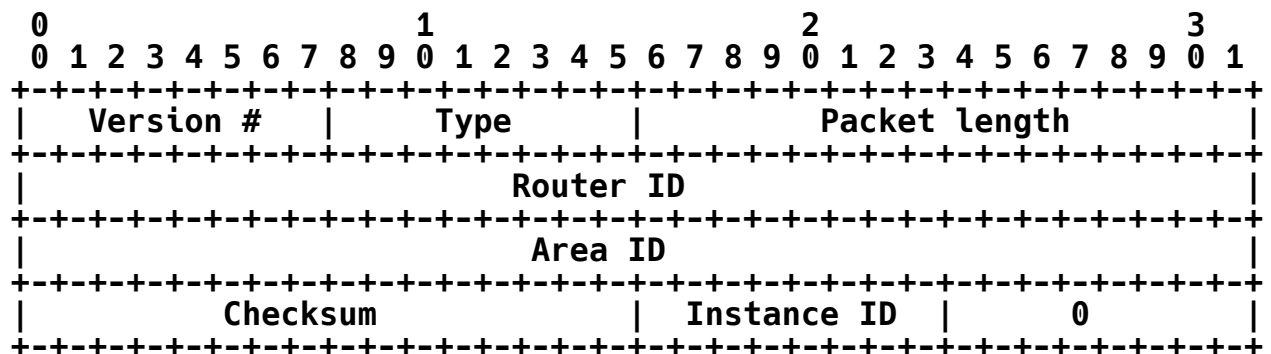
                    The OSPF Packet Header

    Version #
       The OSPF version number. This specification documents version 3
       of the OSPF protocol.

Type
    The OSPF packet types are as follows. See Appendix A.3.2 through
    Appendix A.3.6 for details.

            Type   Description
            ----
            1   Hello
            2   Database Description
            3   Link State Request
            4   Link State Update
            5   Link State Acknowledgment

Packet length
    The length of the OSPF protocol packet in bytes. This length
    includes the standard OSPF header.

Router ID
    The Router ID of the packet's source.

Area ID
    A 32-bit number identifying the area to which this packet belongs.
    All OSPF packets are associated with a single area. Most travel a
    single hop only. Packets traversing a virtual link are labeled
    with the backbone Area ID of 0.

Checksum
    OSPF uses the standard checksum calculation for IPv6 applications:
    The 16-bit one's complement of the one's complement sum of the
    entire contents of the packet, starting with the OSPF packet
    header, and prepending a "pseudo-header" of IPv6 header fields, as
    specified in Section 8.1 of [IPV6]. The "Upper-Layer Packet
    Length" in the pseudo-header is set to the value of the OSPF
    packet header's length field. The Next Header value used in the
    pseudo-header is 89. If the packet's length is not an integral
    number of 16-bit words, the packet is padded with a byte of zero
    before checksumming. Before computing the checksum, the checksum
    field in the OSPF packet header is set to 0.

Instance ID
    Enables multiple instances of OSPF to be run over a single link.
    Each protocol instance would be assigned a separate Instance ID;
    the Instance ID has link-local significance only. Received
    packets whose Instance ID is not equal to the receiving
    interface's Instance ID are discarded.

0

These fields are reserved. They SHOULD be set to 0 when sending
protocol packets and MUST be ignored when receiving protocol
packets.

A.3.2. The Hello Packet

Hello packets are OSPF packet type 1. These packets are sent
periodically on all interfaces (including virtual links) in order to
establish and maintain neighbor relationships. In addition, Hello
packets are multicast on those links having a multicast or broadcast
capability, enabling dynamic discovery of neighboring routers.

All routers connected to a common link must agree on certain
parameters (HelloInterval and RouterDeadInterval). These parameters
are included in Hello packets allowing differences to inhibit the
forming of neighbor relationships. The Hello packet also contains
fields used in Designated Router election (Designated Router ID and
Backup Designated Router ID), and fields used to detect bidirectional
communication (the Router IDs of all neighbors whose Hellos have been
recently received).

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |       3       |       1       |         Packet Length         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                         Router ID                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                          Area ID                              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |           Checksum            |  Instance ID  |       0       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                        Interface ID                           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Rtr Priority  |                    Options                    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        HelloInterval          |       RouterDeadInterval      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                     Designated Router ID                      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                  Backup Designated Router ID                  |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                         Neighbor ID                           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                              ...                              |
```
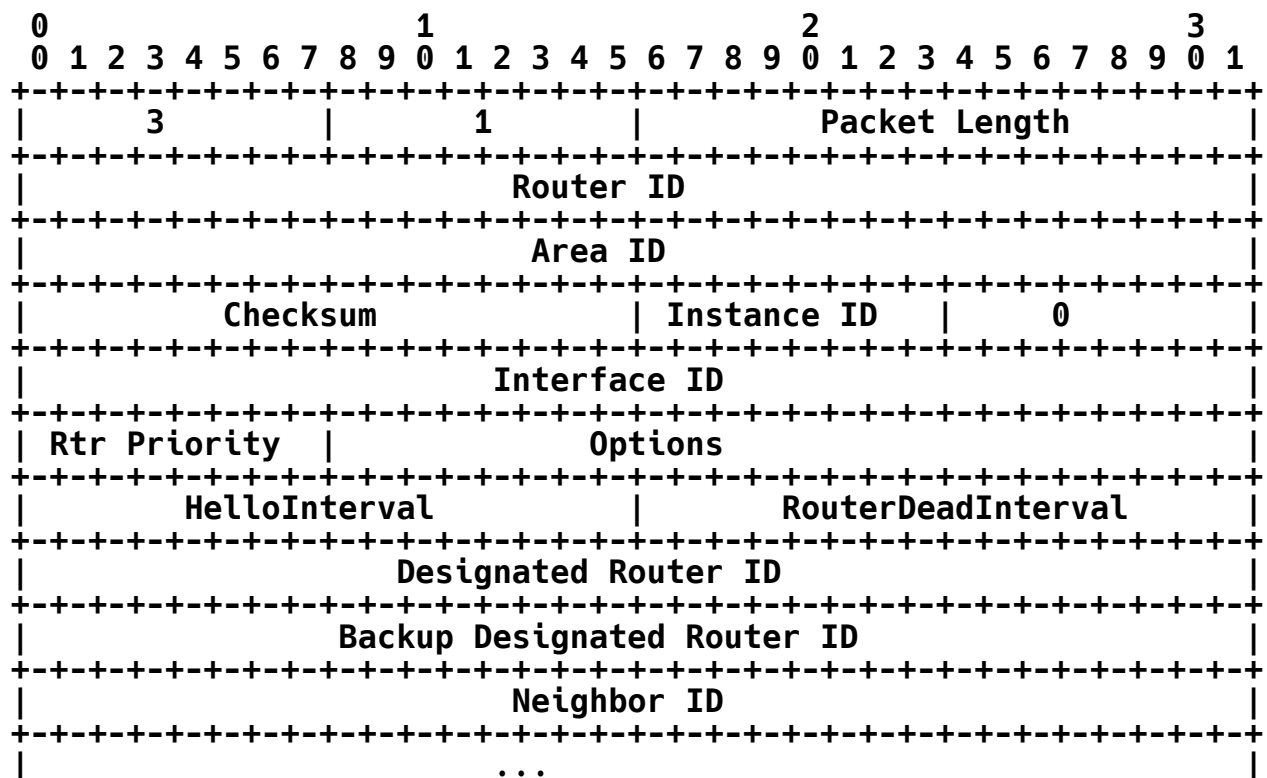
The OSPF Hello Packet

Interface ID
   32-bit number uniquely identifying this interface among the
   collection of this router's interfaces. For example, in some
   implementations it may be possible to use the MIB-II IfIndex
   ([INTFMIB]).

Rtr Priority
   This router's Router Priority. Used in (Backup) Designated Router
   election. If set to 0, the router will be ineligible to become
   (Backup) Designated Router.

Options
   The optional capabilities supported by the router, as documented
   in Section A.2.

HelloInterval
   The number of seconds between this router's Hello packets.

RouterDeadInterval
   The number of seconds before declaring a silent router down.

Designated Router ID
   The sending router's view of the identity of the Designated Router
   for this network. The Designated Router is identified by its
   Router ID. It is set to 0.0.0.0 if there is no Designated Router.

Backup Designated Router ID
   The sending router's view of the identity of the Backup Designated
   Router for this network. The Backup Designated Router is
   identified by its IP Router ID. It is set to 0.0.0.0 if there is
   no Backup Designated Router.

Neighbor ID
   The Router IDs of each router on the network with neighbor state
   1-Way or greater.

A.3.3. The Database Description Packet

   Database Description packets are OSPF packet type 2. These packets
   are exchanged when an adjacency is being initialized. They describe
   the contents of the link-state database. Multiple packets may be
   used to describe the database. For this purpose, a poll-response
   procedure is used. One of the routers is designated to be the master
   and the other is the slave. The master sends Database Description
   packets (polls) that are acknowledged by Database Description packets
   sent by the slave (responses). The responses are linked to the polls
   via the packets' DD sequence numbers.

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |       3       |       2       |         Packet Length         |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                           Router ID                           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                            Area ID                            |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |           Checksum            |  Instance ID  |       0       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |       0       |                   Options                     |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |        Interface MTU          |       0       |0|0|0|0|0|I|M|MS|
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                       DD sequence number                      |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                                                               |
    +-                                                             -+
    |                                                               |
    +-                        An LSA Header                        -+
    |                                                               |
    +-                                                             -+
    |                                                               |
    +-                                                             -+
    |                                                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                              ...                              |
```
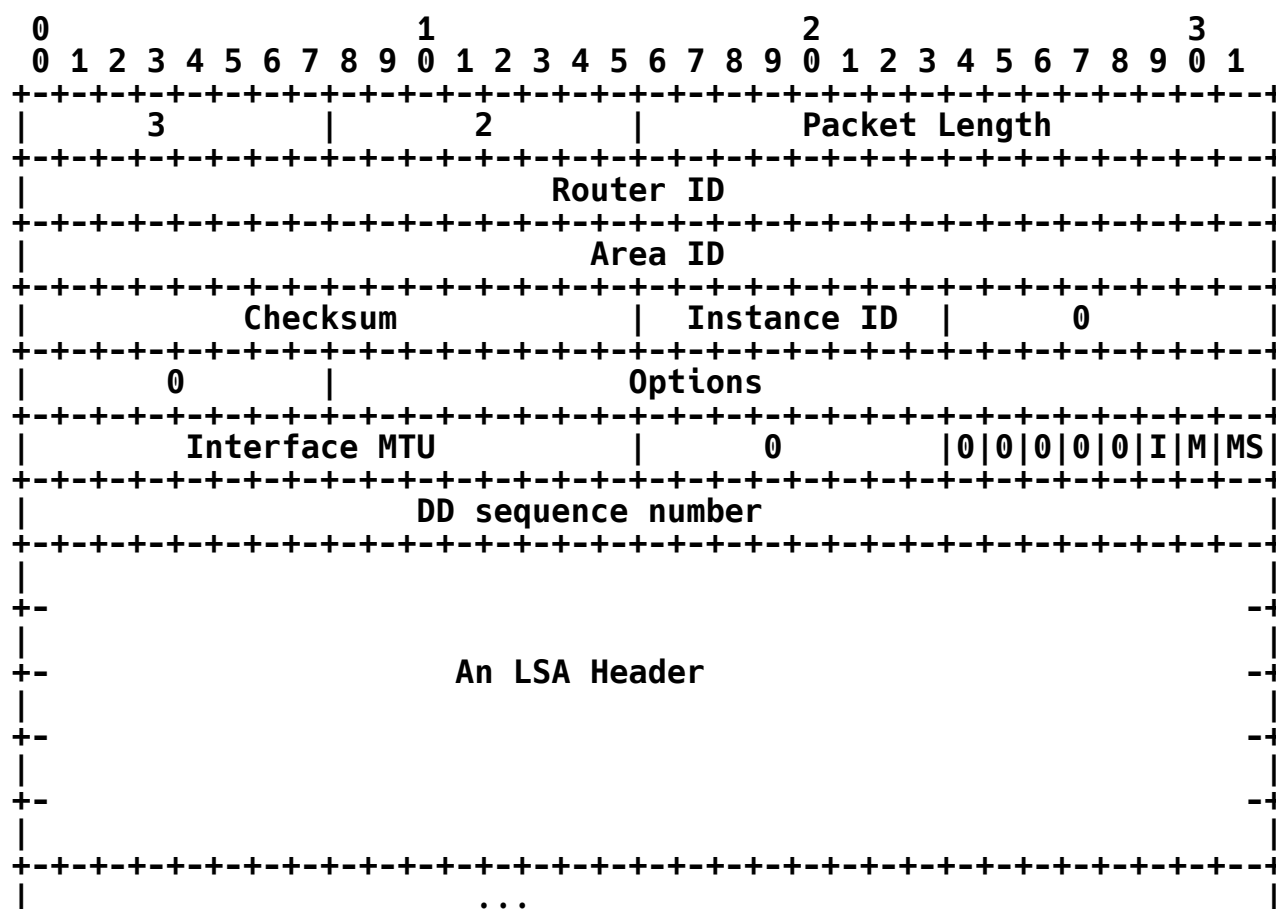
                The OSPF Database Description Packet

   The format of the Database Description packet is very similar to both
   the Link State Request packet and the Link State Acknowledgment
   packet. The main part of all three is a list of items, each item
   describing a piece of the link-state database. The sending of
   Database Description packets is documented in Section 10.8 of
   [OSPFV2]. The reception of Database Description packets is
   documented in Section 10.6 of [OSPFV2].

   Options
      The optional capabilities supported by the router, as documented
      in Section A.2.

   Interface MTU
      The size in bytes of the largest IPv6 datagram that can be sent
      out the associated interface without fragmentation. The MTUs of
      common Internet link types can be found in Table 7-1 of [MTUDISC].

Interface MTU should be set to 0 in Database Description packets
sent over virtual links.

I-bit
   The Init bit. When set to 1, this packet is the first in the
   sequence of Database Description packets.

M-bit
   The More bit. When set to 1, it indicates that more Database
   Description packets are to follow.

MS-bit
   The Master/Slave bit. When set to 1, it indicates that the router
   is the master during the Database Exchange process. Otherwise,
   the router is the slave.

DD sequence number
   Used to sequence the collection of Database Description packets.
   The initial value (indicated by the Init bit being set) should be
   unique. The DD sequence number then increments until the complete
   database for both the master and slave routers have been
   exchanged.

The rest of the packet consists of a (possibly partial) list of the
link-state database's pieces. Each LSA in the database is described
by its LSA header. The LSA header is documented in Appendix A.4.2.
It contains all the information required to uniquely identify both
the LSA and the LSA's current instance.

A.3.4. The Link State Request Packet

Link State Request packets are OSPF packet type 3. After exchanging
Database Description packets with a neighboring router, a router may
find that parts of its link-state database are out-of-date. The Link
State Request packet is used to request the pieces of the neighbor's
database that are more up-to-date. Multiple Link State Request
packets may need to be used.

A router that sends a Link State Request packet has in mind the
precise instance of the database pieces it is requesting. Each
instance is defined by its LS sequence number, LS checksum, and LS
age, although these fields are not specified in the Link State
Request packet itself. The router may receive even more recent LSA
instances in response.

The sending of Link State Request packets is documented in Section
10.9 of [OSPFV2]. The reception of Link State Request packets is
documented in Section 10.7 of [OSPFV2].

```
                       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
                      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                      |       3       |       3       |         Packet Length         |
                      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                      |                           Router ID                           |
                      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                      |                            Area ID                            |
                      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                      |           Checksum            |  Instance ID  |       0       |
                      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                      |              0               |            LS Type             |
                      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                      |                          Link State ID                        |
                      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                      |                       Advertising Router                      |
                      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                      |                               ...                             |
```
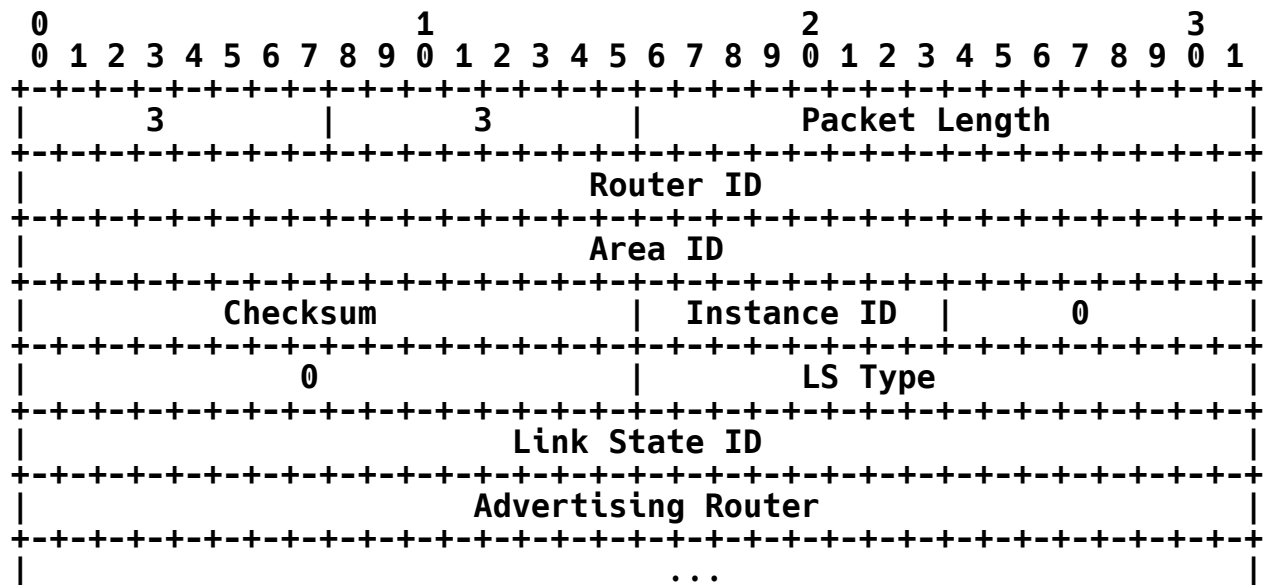
                    The OSPF Link State Request Packet

   Each LSA requested is specified by its LS type, Link State ID, and
   Advertising Router. This uniquely identifies the LSA without
   specifying its instance. Link State Request packets are understood
   to be requests for the most recent instance of the specified LSAs.

A.3.5. The Link State Update Packet

   Link State Update packets are OSPF packet type 4. These packets
   implement the flooding of LSAs. Each Link State Update packet
   carries a collection of LSAs one hop further from their origin.
   Several LSAs may be included in a single packet.

   Link State Update packets are multicast on those physical networks
   that support multicast/broadcast. In order to make the flooding
   procedure reliable, flooded LSAs are acknowledged in Link State
   Acknowledgment packets. If retransmission of certain LSAs is
   necessary, the retransmitted LSAs are always carried by unicast Link
   State Update packets. For more information on the reliable flooding
   of LSAs, consult Section 4.5.

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |       3       |       4       |         Packet Length         |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                           Router ID                           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                            Area ID                            |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |           Checksum            |  Instance ID  |       0       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                            # LSAs                             |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                                                               |
    +-                                                            +-+
    |                            LSAs                               |
    +-                                                            +-+
    |                             ...                               |
```
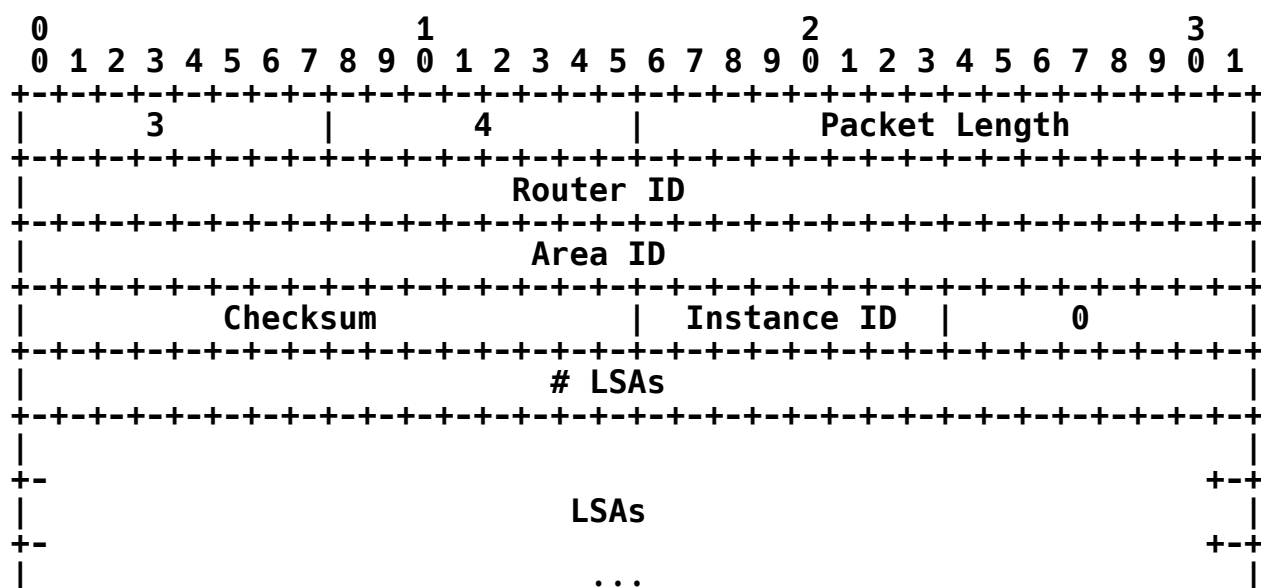
          The OSPF Link State Update Packet

   # LSAs
      The number of LSAs included in this update.

   The body of the Link State Update packet consists of a list of LSAs.
   Each LSA begins with a common 20-byte header, described in
   Appendix A.4.2. Detailed formats of the different types of LSAs are
   described Appendix A.4.

A.3.6. The Link State Acknowledgment Packet

   Link State Acknowledgment packets are OSPF packet type 5. To make
   the flooding of LSAs reliable, flooded LSAs are explicitly or
   implicitly acknowledged. Explicit acknowledgment is accomplished
   through the sending and receiving of Link State Acknowledgment
   packets. The sending of Link State Acknowledgment packets is
   documented in Section 13.5 of [OSPFV2]. The reception of Link State
   Acknowledgment packets is documented in Section 13.7 of [OSPFV2].

   Multiple LSAs MAY be acknowledged in a single Link State
   Acknowledgment packet. Depending on the state of the sending
   interface and the sender of the corresponding Link State Update
   packet, a Link State Acknowledgment packet is sent to the multicast
   address AllSPFRouters, the multicast address AllDRouters, or to a
   neighbor's unicast address (see Section 13.5 of [OSPFV2] for
   details).

The format of this packet is similar to that of the Data Description
packet. The body of both packets is simply a list of LSA headers.

```
   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
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |       3       |       5       |         Packet Length         |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                         Router ID                             |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                          Area ID                              |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |          Checksum            |   Instance ID |       0        |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                                                               |
  +-                                                             -+
  |                                                               |
  +-                      An LSA Header                          -+
  |                                                               |
  +-                                                             -+
  |                                                               |
  +-                                                             -+
  |                                                               |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                             ...                               |
```
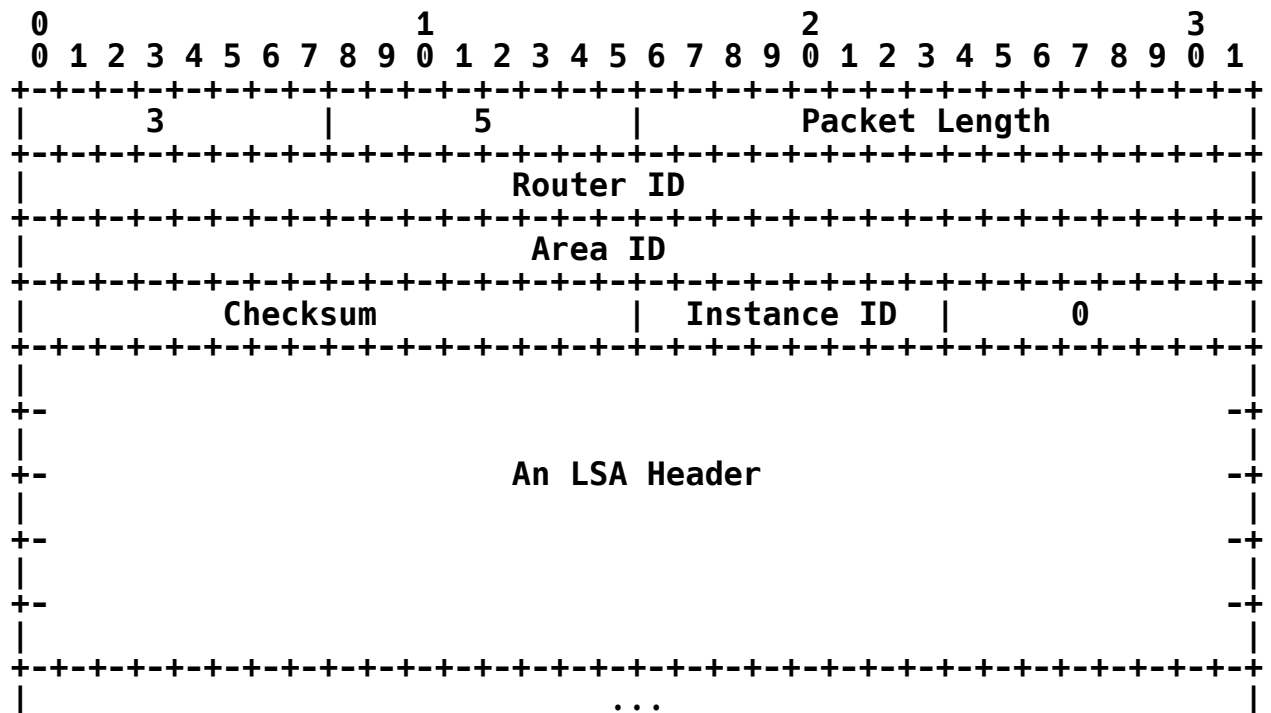
             The OSPF Link State Acknowledgment Packet

   Each acknowledged LSA is described by its LSA header. The LSA header
   is documented in Appendix A.4.2. It contains all the information
   required to uniquely identify both the LSA and the LSA's current
   instance.

A.4. LSA Formats

   This document defines eight distinct types of LSAs. Each LSA begins
   with a standard 20-byte LSA header. This header is explained in
   Appendix A.4.2. Succeeding sections describe each LSA type
   individually.

   Each LSA describes a piece of the OSPF routing domain. Every router
   originates a router-LSA. A network-LSA is advertised for each link
   by its Designated Router. A router's link-local addresses are
   advertised to its neighbors in link-LSAs. IPv6 prefixes are
   advertised in intra-area-prefix-LSAs, inter-area-prefix-LSAs, AS-
   external-LSAs, and NSSA-LSAs. Location of specific routers can be
   advertised across area boundaries in inter-area-router-LSAs. All
   LSAs are then flooded throughout the OSPF routing domain. The

flooding algorithm is reliable, ensuring that all routers common to a
flooding scope have the same collection of LSAs associated with that
flooding scope. (See Section 4.5 for more information concerning the
flooding algorithm.) This collection of LSAs is called the link-
state database.

From the link-state database, each router constructs a shortest-path
tree with itself as root. This yields a routing table (see Section
11 of [OSPFV2]). For details on the routing table build process, see
Section 4.8.

A.4.1. IPv6 Prefix Representation

IPv6 addresses are bit strings of length 128. IPv6 routing
protocols, and OSPF for IPv6 in particular, advertise IPv6 address
prefixes. IPv6 address prefixes are bit strings whose length ranges
between 0 and 128 bits (inclusive).

Within OSPF, IPv6 address prefixes are always represented by a
combination of three fields: PrefixLength, PrefixOptions, and Address
Prefix. PrefixLength is the length in bits of the prefix.
PrefixOptions is an 8-bit field describing various capabilities
associated with the prefix (see Appendix A.4.1.1). Address Prefix is
an encoding of the prefix itself as an even multiple of 32-bit words,
padding with zero bits as necessary. This encoding consumes
((PrefixLength + 31) / 32) 32-bit words.

The default route is represented by a prefix of length 0.

Examples of IPv6 Prefix representation in OSPF can be found in
Appendix A.4.5, Appendix A.4.7, Appendix A.4.8, Appendix A.4.9, and
Appendix A.4.10.

A.4.1.1. Prefix Options

Each prefix is advertised along with an 8-bit field of capabilities.
These serve as input to the various routing calculations. For
example, they can indicate that prefixes are to be ignored in some
cases or are to be marked as not readvertisable in others.

```
          0  1  2  3  4  5  6  7
         +--+--+--+--+--+--+--+--+
         |  |  |  |DN| P|x|LA|NU|
         +--+--+--+--+--+--+--+--+
```

                  The PrefixOptions Field

NU-bit
    The "no unicast" capability bit. If set, the prefix should be
    excluded from IPv6 unicast calculations. If not set, it should be
    included.

LA-bit
    The "local address" capability bit. If set, the prefix is
    actually an IPv6 interface address of the Advertising Router.
    Advertisement of local interface addresses is described in
    Section 4.4.3.9. An implementation MAY also set the LA-bit for
    prefixes advertised with a host PrefixLength (128).

x-bit
    This bit was previously defined as a "multicast" capability bit.
    However, the use was never adequately specified and has been
    deprecated for OSPFv3. The bit should be set to 0 and ignored
    when received. It may be reassigned in the future.

P-bit
    The "propagate" bit. Set on NSSA area prefixes that should be
    readvertised by the translating NSSA area border [NSSA].

DN-bit
    This bit controls an inter-area-prefix-LSAs or AS-external-LSAs
    re-advertisement in a VPN environment as specified in [DN-BIT].

A.4.2. The LSA Header

All LSAs begin with a common 20-byte header. This header contains
enough information to uniquely identify the LSA (LS type, Link State
ID, and Advertising Router). Multiple instances of the LSA may exist
in the routing domain at the same time. It is then necessary to
determine which instance is more recent. This is accomplished by
examining the LS age, LS sequence number, and LS checksum fields that
are also contained in the LSA header.

```
    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              |            LS Type            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                         Link State ID                         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      Advertising Router                       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      LS Sequence Number                       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |         LS Checksum           |             Length            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
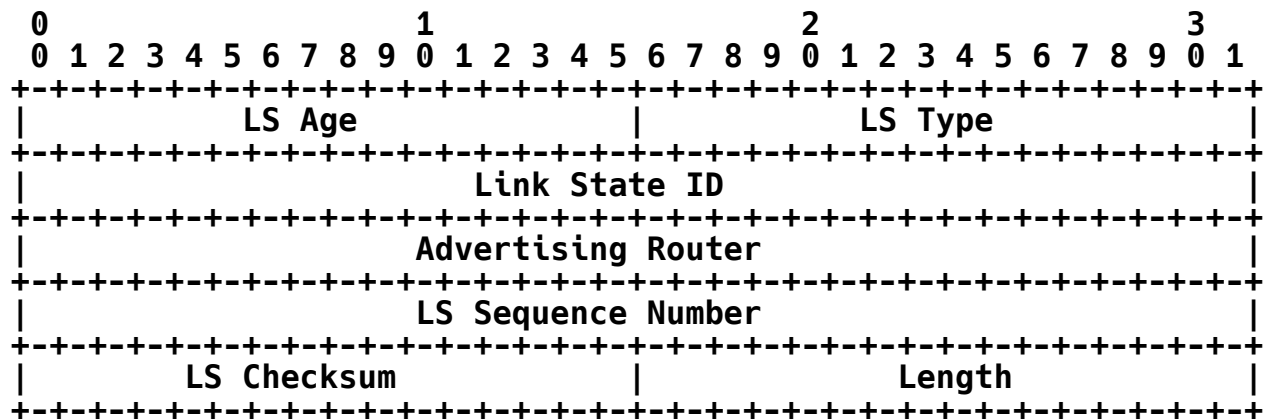
                          The LSA Header

   LS Age
      The time in seconds since the LSA was originated.

   LS Type
      The LS type field indicates the function performed by the LSA.
      The high-order three bits of LS type encode generic properties of
      the LSA, while the remainder (called LSA function code) indicate
      the LSA's specific functionality. See Appendix A.4.2.1 for a
      detailed description of LS type.

   Link State ID
      The originating router's identifier for the LSA. The combination
      of the Link State ID, LS type, and Advertising Router uniquely
      identify the LSA in the link-state database.

   Advertising Router
      The Router ID of the router that originated the LSA. For example,
      in network-LSAs this field is equal to the Router ID of the
      network's Designated Router.

   LS sequence number
      Successive instances of an LSA are given successive LS sequence
      numbers. The sequence number can be used to detect old or
      duplicate LSA instances. See Section 12.1.6 in [OSPFV2] for more
      details.

   LS checksum
      The Fletcher checksum of the complete contents of the LSA,
      including the LSA header but excluding the LS age field. See
      Section 12.1.7 in [OSPFV2] for more details.

length
     The length in bytes of the LSA. This includes the 20-byte LSA
     header.

A.4.2.1. LSA Type

The LS type field indicates the function performed by the LSA. The
high-order three bits of LS type encode generic properties of the
LSA, while the remainder (called LSA function code) indicate the
LSA's specific functionality. The format of the LS type is as
follows:

```
                0  1  2  3  4  5  6  7  8  9  0  1  2  3  4  5
               +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
               |U |S2|S1|            LSA Function Code         |
               +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```
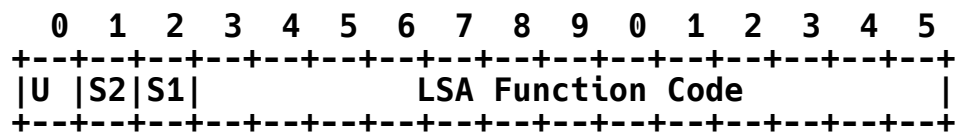
                                 LSA Type

The U-bit indicates how the LSA should be handled by a router that
does not recognize the LSA's function code. Its values are:

     U-bit   LSA Handling
     ----
     0   Treat the LSA as if it had link-local flooding scope
     1   Store and flood the LSA as if the type is understood

                                  U-Bit

The S1 and S2 bits indicate the flooding scope of the LSA. The
values are:

     S2 S1   Flooding Scope
     ----
     0   0   Link-Local Scoping - Flooded only on originating link
     0   1   Area Scoping - Flooded only in originating area
     1   0   AS Scoping - Flooded throughout AS
     1   1   Reserved

                              Flooding Scope

The LSA function codes are defined as follows. The origination and
processing of these LSA function codes are defined elsewhere in this
document, except for the NSSA-LSA (see [NSSA]) and 0x2006, which was
previously used by MOSPF (see [MOSPF]). MOSPF has been deprecated
for OSPFv3. As shown below, each LSA function b code also implies a
specific setting for the U, S1, and S2 bits.

```
              LSA Function Code   LS Type   Description
              ------------------------------------------------------
              1                   0x2001    Router-LSA
              2                   0x2002    Network-LSA
              3                   0x2003    Inter-Area-Prefix-LSA
              4                   0x2004    Inter-Area-Router-LSA
              5                   0x4005    AS-External-LSA
              6                   0x2006    Deprecated (may be reassigned)
              7                   0x2007    NSSA-LSA
              8                   0x0008    Link-LSA
              9                   0x2009    Intra-Area-Prefix-LSA
```

                          LSA Function Code

A.4.3. Router-LSAs

   Router-LSAs have LS type equal to 0x2001. Each router in an area
   originates one or more router-LSAs. The complete collection of
   router-LSAs originated by the router describe the state and cost of
   the router's interfaces to the area. For details concerning the
   construction of router-LSAs, see Section 4.4.3.2. Router-LSAs are
   only flooded throughout a single area.

```
                      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   |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                       |
                     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                     |                            ...                               |
```
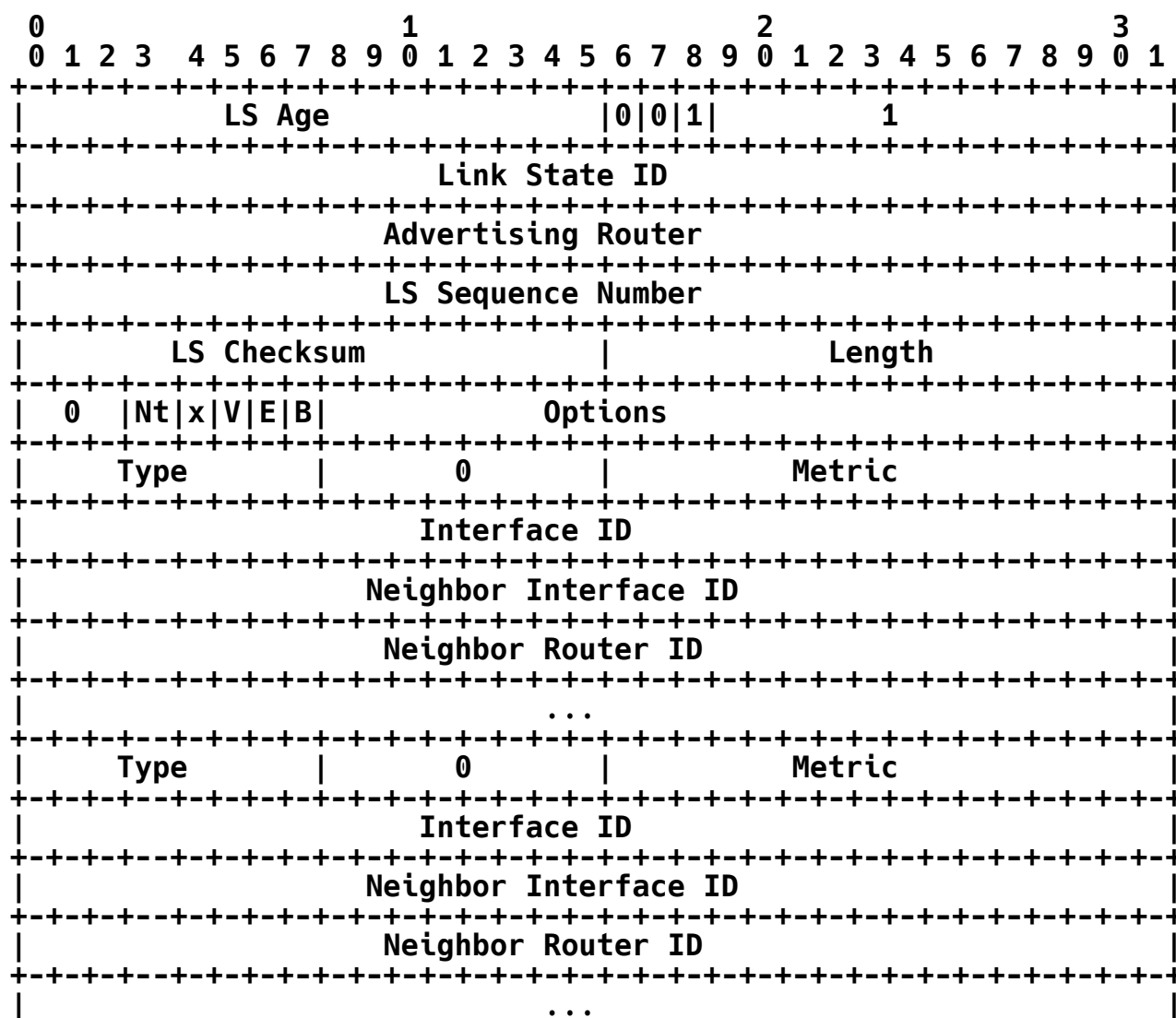
                              Router-LSA Format

   A single router may originate one or more router-LSAs, distinguished
   by their Link State IDs (which are chosen arbitrarily by the
   originating router). The Options field and V, E, and B bits should
   be the same in all router-LSAs from a single originator. However, in
   the case of a mismatch, the values in the LSA with the lowest Link
   State ID take precedence. When more than one router-LSA is received
   from a single router, the links are processed as if concatenated into
   a single LSA.

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 x
  This bit was previously used by MOSPF (see [MOSPF]) and has been
  deprecated for OSPFv3. The bit should be set to 0 and ignored
  when received. It may be reassigned in the future.

Bit Nt
  When set, the router is an NSSA border router that is
  unconditionally translating NSSA-LSAs into AS-external-LSAs (Nt
  stands for NSSA translation). Note that such routers have their
  NSSATranslatorRole area configuration parameter set to Always.
  (See [NSSA].)

Options
  The optional capabilities supported by the router, as documented
  in Appendix A.2.

The following fields are used to describe each router interface. The
Type field indicates the kind of interface being described. It may
be an interface to a transit network, a point-to-point connection to
another router, or a virtual link. The values of all the other
fields describing a router interface depend on the interface's Type
field.

Type
  The kind of interface being described. One of the following:

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

                        Router Link Types

Metric
    The cost of using this router interface for outbound traffic.

Interface ID
    The Interface ID assigned to the interface being described. See
    Section 4.1.2 and Appendix C.3.

Neighbor Interface ID
    The Interface ID the neighbor router has associated with the link,
    as advertised in the neighbor's Hello packets. For transit (type
    2) links, the link's Designated Router is the neighbor described.
    For other link types, the sole adjacent neighbor is described.

Neighbor Router ID
    The Router ID the of the neighbor router. For transit (type 2)
    links, the link's Designated Router is the neighbor described.
    For other link types, the sole adjacent neighbor is described.

For transit (Type 2) links, the combination of Neighbor Interface ID
and Neighbor Router ID allows the network-LSA for the attached link
to be found in the link-state database.

A.4.4. Network-LSAs

Network-LSAs have LS type equal to 0x2002. A network-LSA is
originated for each broadcast and NBMA link in the area that includes
two or more adjacent routers. The network-LSA is originated by the
link's Designated Router. The LSA describes all routers attached to
the link including the Designated Router itself. The LSA's Link
State ID field is set to the Interface ID that the Designated Router
has been advertising in Hello packets on the link.

The distance from the network to all attached routers is zero. This
is why the Metric fields need not be specified in the network-LSA.
For details concerning the construction of network-LSAs, see
Section 4.4.3.3.

```
                     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|             2            |
                    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                    |                         Link State ID                         |
                    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                    |                      Advertising Router                       |
                    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                    |                      LS Sequence Number                       |
                    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                    |         LS Checksum           |            Length             |
                    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                    |      0        |                 Options                       |
                    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                    |                       Attached Router                         |
                    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                    |                             ...                               |
```
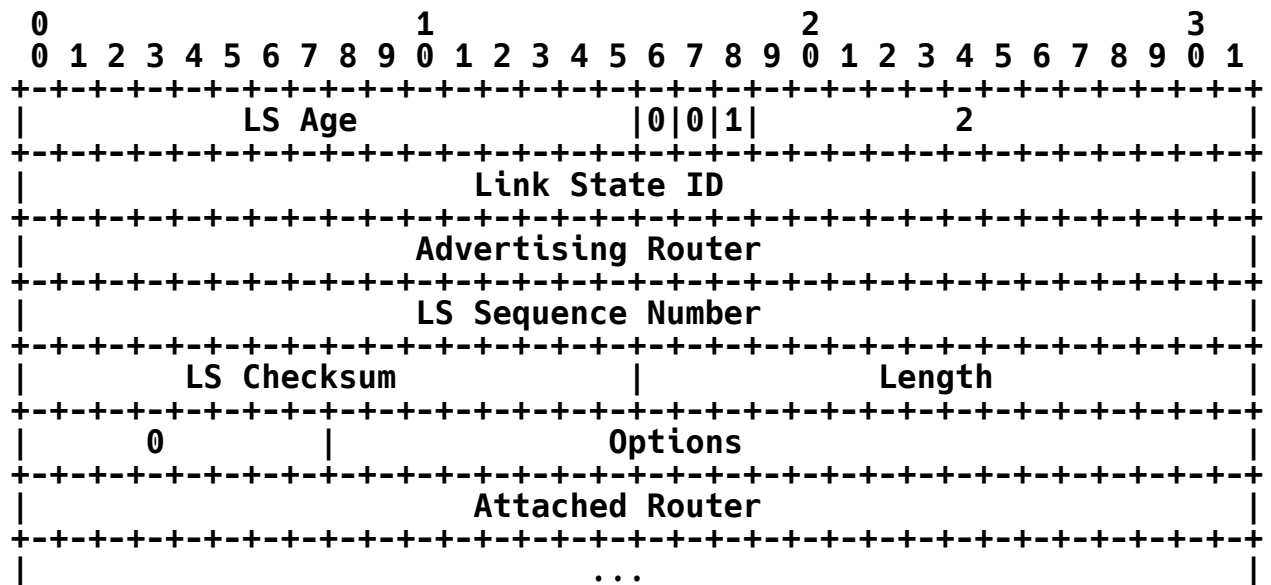
                                  Network-LSA Format

      Attached Router
           The Router IDs of each of the routers attached to the link.
           Actually, only those routers that are fully adjacent to the
           Designated Router are listed. The Designated Router includes
           itself in this list. The number of routers included can be
           deduced from the LSA header's length field.

A.4.5.   Inter-Area-Prefix-LSAs

      Inter-area-prefix-LSAs have LS type equal to 0x2003. These LSAs are
      the IPv6 equivalent of OSPF for IPv4's type 3 summary-LSAs (see
      Section 12.4.3 of [OSPFV2]). Originated by area border routers, they
      describe routes to IPv6 address prefixes that belong to other areas.
      A separate inter-area-prefix-LSA is originated for each IPv6 address
      prefix. For details concerning the construction of inter-area-
      prefix-LSAs, see Section 4.4.3.4.

      For stub areas, inter-area-prefix-LSAs can also be used to describe a
      (per-area) default route. Default summary routes are used in stub
      areas instead of flooding a complete set of external routes. When
      describing a default summary route, the inter-area-prefix-LSA's
      PrefixLength is set to 0.

```
       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|          3            |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                        Link State ID                          |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                      Advertising Router                       |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                      LS Sequence Number                       |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |         LS Checksum            |             Length           |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |       0       |                  Metric                       |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      | PrefixLength  | PrefixOptions |               0               |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                        Address Prefix                         |
      |                             ...                               |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
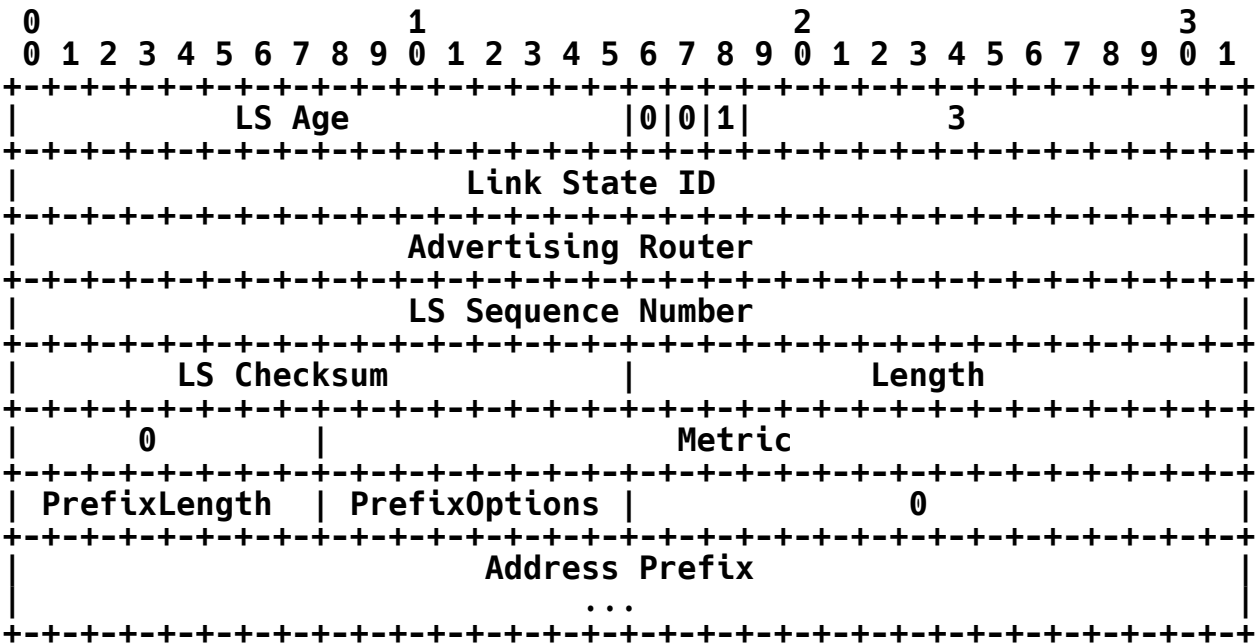
                    Inter-Area-Prefix-LSA Format

   Metric
       The cost of this route. Expressed in the same units as the
       interface costs in router-LSAs. When the inter-area-prefix-LSA is
       describing a route to a range of addresses (see Appendix C.2), the
       cost is set to the maximum cost to any reachable component of the
       address range.

   PrefixLength, PrefixOptions, and Address Prefix
       Representation of the IPv6 address prefix, as described in
       Appendix A.4.1.

A.4.6. Inter-Area-Router-LSAs

   Inter-area-router-LSAs have LS type equal to 0x2004. These LSAs are
   the IPv6 equivalent of OSPF for IPv4's type 4 summary-LSAs (see
   Section 12.4.3 of [OSPFV2]). Originated by area border routers, they
   describe routes to AS boundary routers in other areas. To see why it
   is necessary to advertise the location of each ASBR, consult Section
   16.4 in [OSPFV2]. Each LSA describes a route to a single router.
   For details concerning the construction of inter-area-router-LSAs,
   see Section 4.4.3.5.

```
     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|           4           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                        Link State ID                         |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                      Advertising Router                      |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                      LS Sequence Number                      |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |         LS Checksum            |             Length          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |       0        |                  Options                    |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |       0        |                  Metric                     |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                      Destination Router ID                   |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
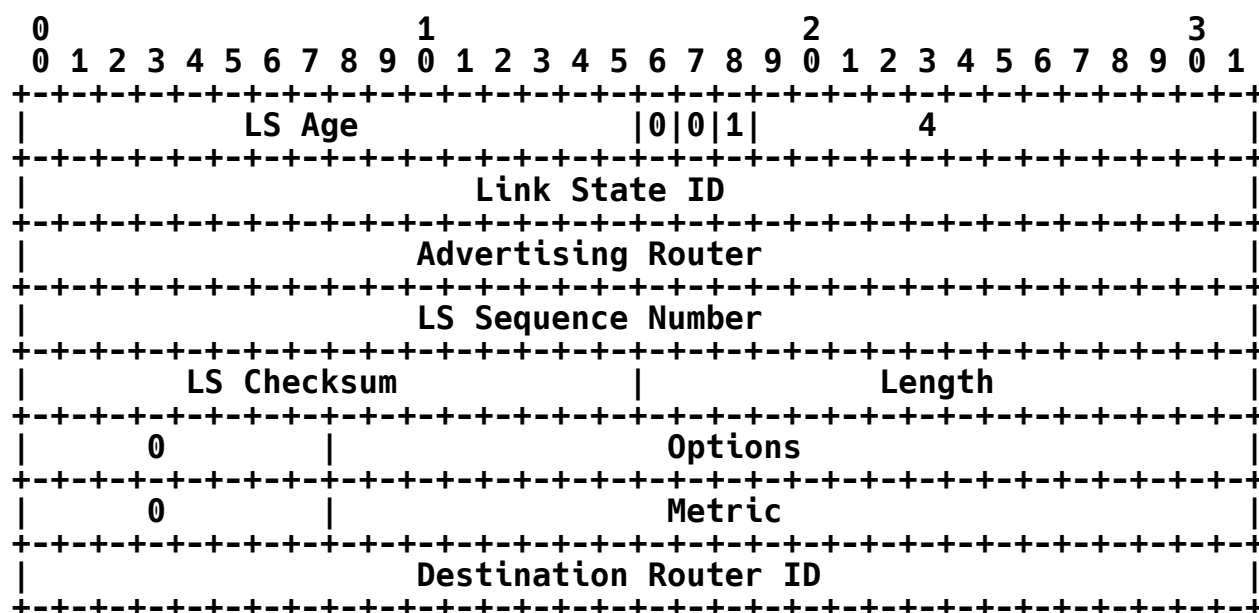
                    Inter-Area-Router-LSA Format

   Options
      The optional capabilities supported by the router, as documented
      in Appendix A.2.

   Metric
      The cost of this route. Expressed in the same units as the
      interface costs in router-LSAs.

   Destination Router ID
      The Router ID of the router being described by the LSA.

A.4.7. AS-External-LSAs

   AS-external-LSAs have LS type equal to 0x4005. These LSAs are
   originated by AS boundary routers and describe destinations external
   to the AS. Each LSA describes a route to a single IPv6 address
   prefix. For details concerning the construction of AS-external-LSAs,
   see Section 4.4.3.6.

   AS-external-LSAs can be used to describe a default route. Default
   routes are used when no specific route exists to the destination.
   When describing a default route, the AS-external-LSA's PrefixLength
   is set to 0.

```
     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|1|0|          5            |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                        Link State ID                          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                      Advertising Router                       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                      LS Sequence Number                       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |         LS Checksum           |             Length            |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |      |E|F|T|                  Metric                          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    | PrefixLength  | PrefixOptions |        Referenced LS Type     |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                       Address Prefix                          |
    |                            ...                                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                                                              |
    +-                                                            -+
    |                                                              |
    +-             Forwarding Address (Optional)                  -+
    |                                                              |
    +-                                                            -+
    |                                                              |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |              External Route Tag (Optional)                    |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |            Referenced Link State ID (Optional)                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
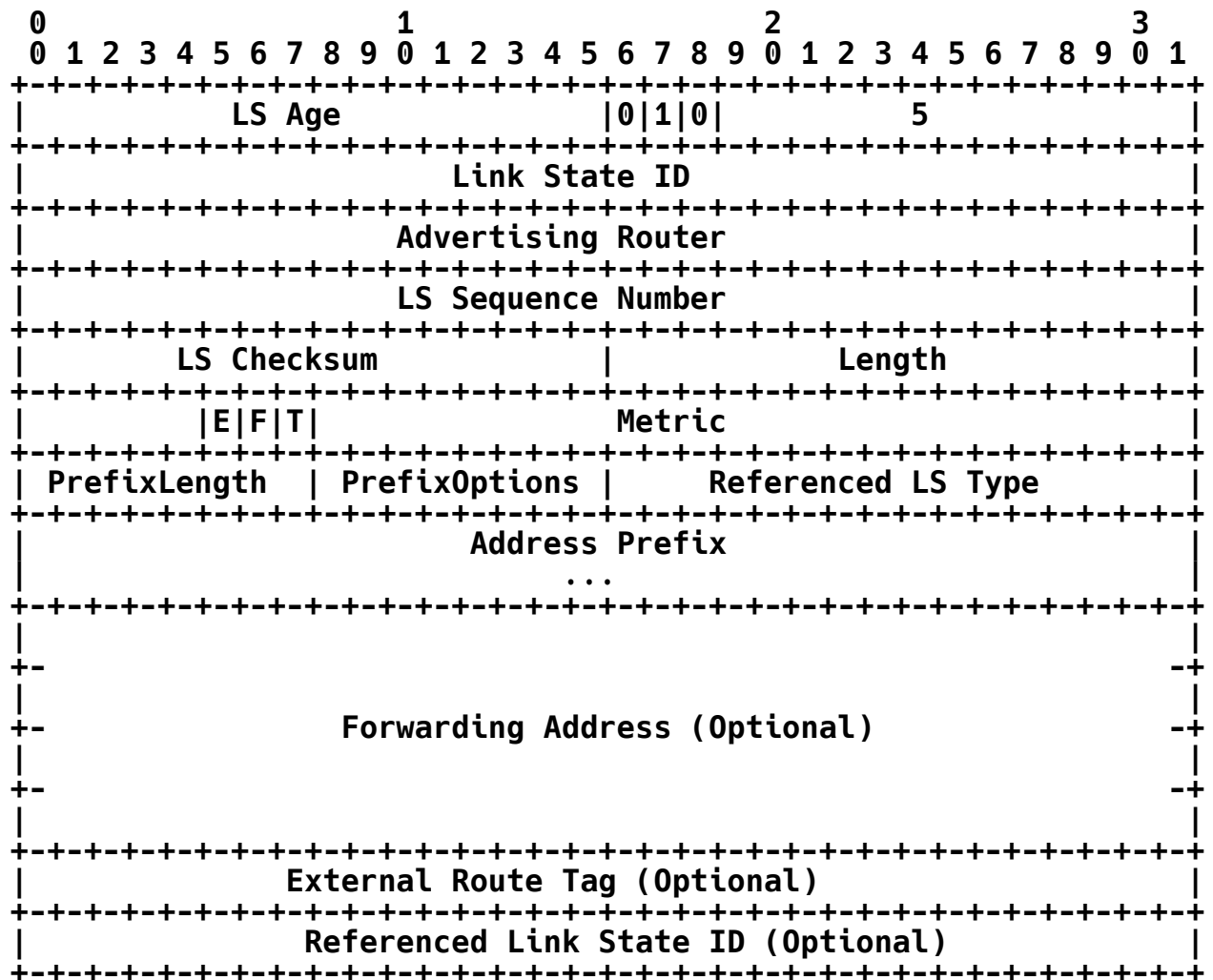
                     AS-external-LSA Format

    bit E
       The type of external metric. If bit E is set, the metric
       specified is a Type 2 external metric. This means the metric is
       considered larger than any intra-AS path. If bit E is zero, the
       specified metric is a Type 1 external metric. This means that it
       is expressed in the same units as other LSAs (i.e., the same units
       as the interface costs in router-LSAs).

    bit F
       If set, a Forwarding Address has been included in the LSA.

    bit T
       If set, an External Route Tag has been included in the LSA.

Metric
    The cost of this route. Interpretation depends on the external
    type indication (bit E above).

PrefixLength, PrefixOptions, and Address Prefix
    Representation of the IPv6 address prefix, as described in
    Appendix A.4.1.

Referenced LS Type
    If non-zero, an LSA with this LS type is to be associated with
    this LSA (see Referenced Link State ID below).

Forwarding address
    A fully qualified IPv6 address (128 bits). Included in the LSA if
    and only if bit F has been set. If included, data traffic for the
    advertised destination will be forwarded to this address. It MUST
    NOT be set to the IPv6 Unspecified Address (0:0:0:0:0:0:0:0) or an
    IPv6 Link-Local Address (Prefix FE80/10). While OSPFv3 routes are
    normally installed with link-local addresses, an OSPFv3
    implementation advertising a forwarding address MUST advertise a
    global IPv6 address. This global IPv6 address may be the next-hop
    gateway for an external prefix or may be obtained through some
    other method (e.g., configuration).

External Route Tag
    A 32-bit field that MAY be used to communicate additional
    information between AS boundary routers. Included in the LSA if
    and only if bit T has been set.

Referenced Link State ID
    Included if and only if Reference LS Type is non-zero. If
    included, additional information concerning the advertised
    external route can be found in the LSA having LS type equal to
    "Referenced LS Type", Link State ID equal to "Referenced Link
    State ID", and Advertising Router the same as that specified in
    the AS-external-LSA's link-state header. This additional
    information is not used by the OSPF protocol itself. It may be
    used to communicate information between AS boundary routers. The
    precise nature of such information is outside the scope of this
    specification.

All, none, or some of the fields labeled Forwarding address, External
Route Tag, and Referenced Link State ID MAY be present in the AS-
external-LSA (as indicated by the setting of bit F, bit T, and
Referenced LS Type respectively). When present, Forwarding Address
always comes first, External Route Tag next, and the Referenced Link
State ID last.

A.4.8. NSSA-LSAs

   NSSA-LSAs have LS type equal to 0x2007. These LSAs are originated by
   AS boundary routers within an NSSA and describe destinations external
   to the AS that may or may not be propagated outside the NSSA (refer
   to [NSSA]). Other than the LS type, their format is exactly the same
   as AS-external LSAs as described in Appendix A.4.7.

   A global IPv6 address MUST be selected as forwarding address for
   NSSA-LSAs that are to be propagated by NSSA area border routers. The
   selection should proceed the same as OSPFv2 NSSA support [NSSA] with
   additional checking to ensure IPv6 link-local address are not
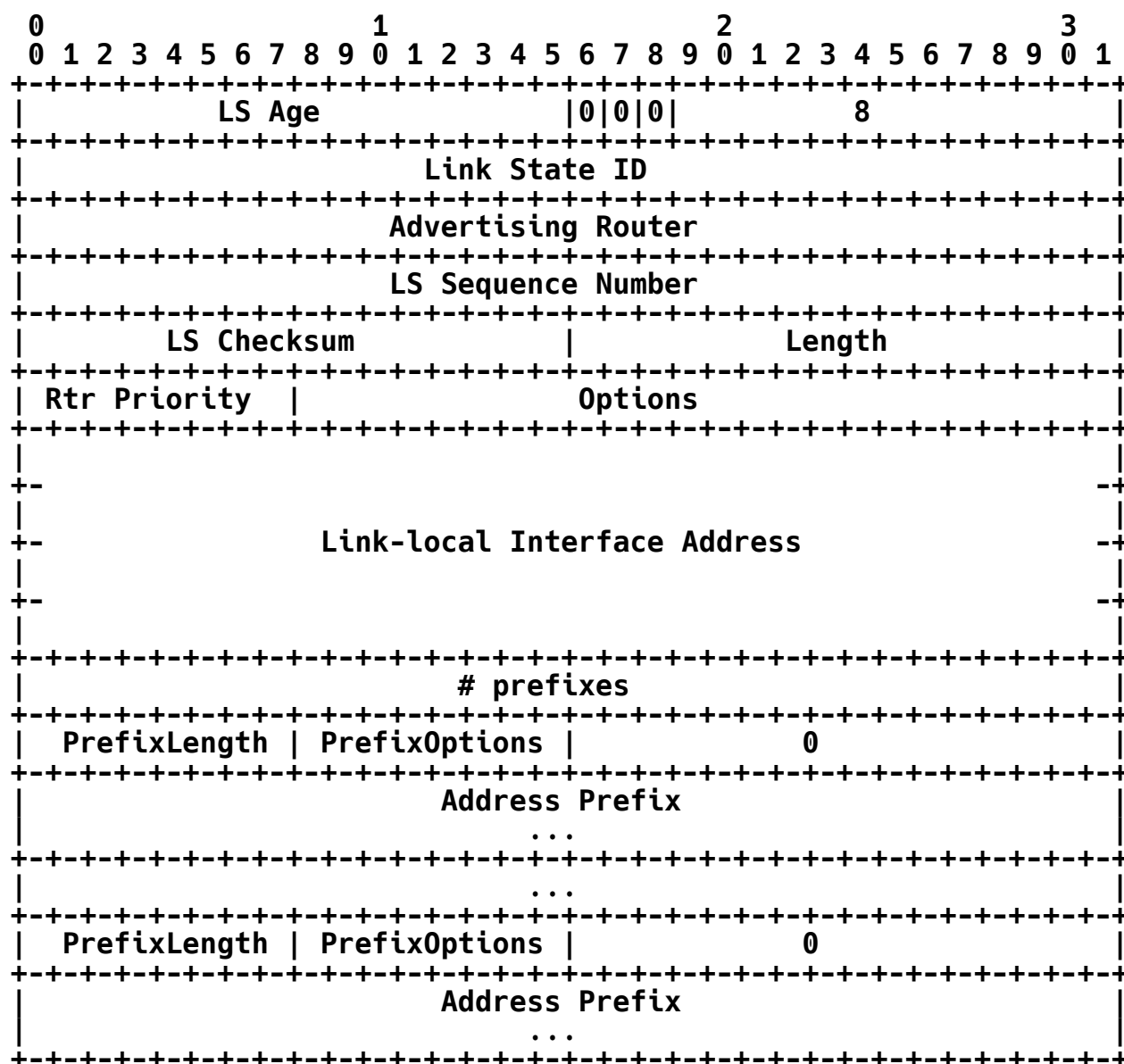   selected.

A.4.9. Link-LSAs

   Link-LSAs have LS type equal to 0x0008. A router originates a
   separate link-LSA for each attached physical link. These LSAs have
   link-local flooding scope; they are never flooded beyond the
   associated link. Link-LSAs have three purposes:

   1. They provide the router's link-local address to all other routers
       attached to the link.

   2. They inform other routers attached to the link of a list of IPv6
       prefixes to associate with the link.

   3. They allow the router to advertise a collection of Options bits
       in the network-LSA originated by the Designated Router on a
       broadcast or NBMA link.

   For details concerning the construction of links-LSAs, see
   Section 4.4.3.8.

   A link-LSA's Link State ID is set equal to the originating router's
   Interface ID on the link.

```
      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|0|            8            |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                          Link State ID                        |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                       Advertising Router                      |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                       LS Sequence Number                      |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |         LS Checksum            |              Length           |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     | Rtr Priority  |                  Options                       |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                                                               |
     +-                                                             -+
     |                                                               |
     +-             Link-local Interface Address                    -+
     |                                                               |
     +-                                                             -+
     |                                                               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                           # prefixes                          |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     | PrefixLength  | PrefixOptions |              0                 |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                         Address Prefix                        |
     |                             ...                               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                             ...                               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     | PrefixLength  | PrefixOptions |              0                 |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                         Address Prefix                        |
     |                             ...                               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

                          Link-LSA Format

   Rtr Priority
      The Router Priority of the interface attaching the originating
      router to the link.

   Options
      The set of Options bits that the router would like set in the
      network-LSA that will be originated by the Designated Router on
      broadcast or NBMA links.

Link-local Interface Address
    The originating router's link-local interface address on the link.

prefixes
    The number of IPv6 address prefixes contained in the LSA.

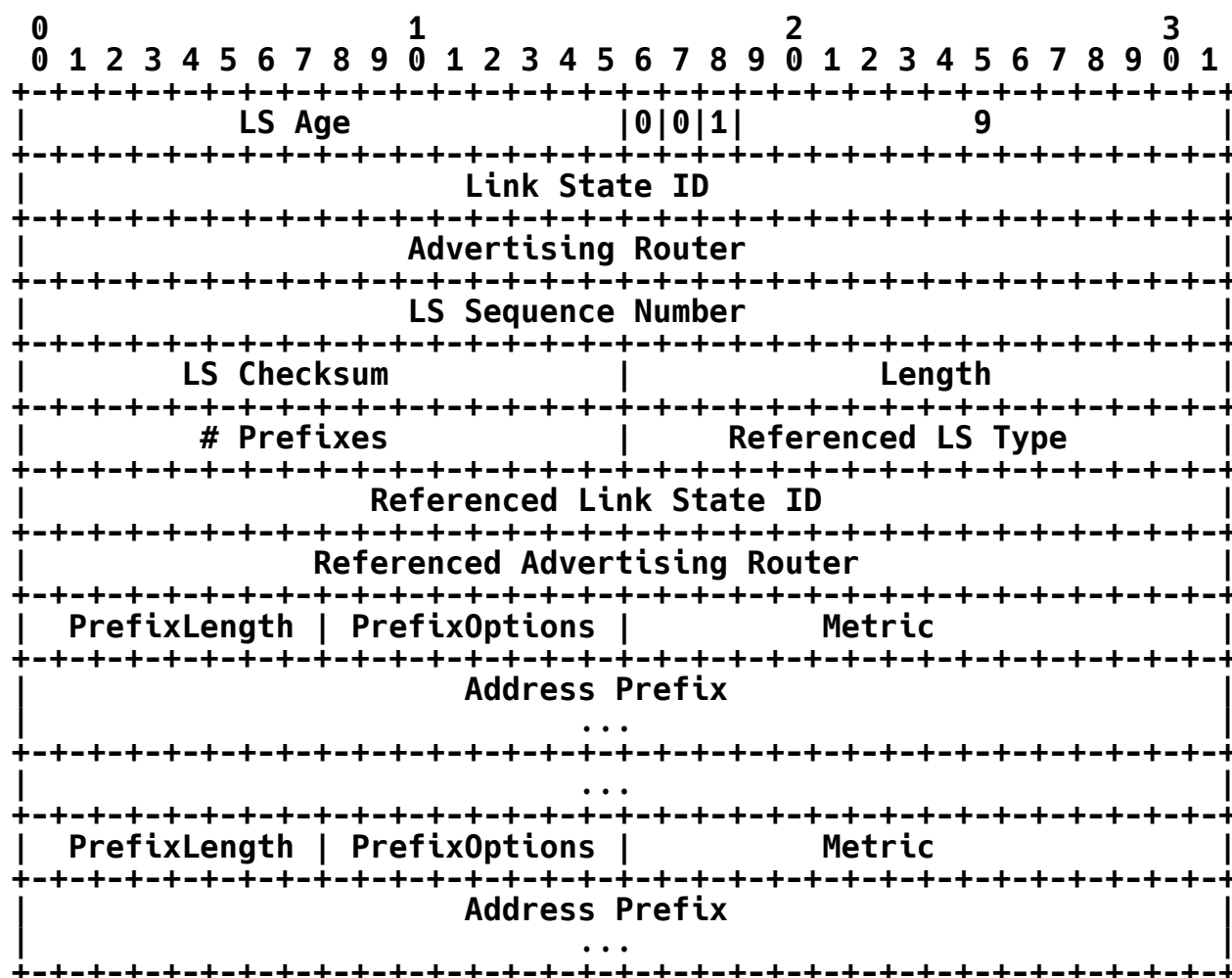The rest of the link-LSA contains a list of IPv6 prefixes to be
associated with the link.

PrefixLength, PrefixOptions, and Address Prefix
    Representation of an IPv6 address prefix, as described in
    Appendix A.4.1.

A.4.10. Intra-Area-Prefix-LSAs

Intra-area-prefix-LSAs have LS type equal to 0x2009. A router uses
intra-area-prefix-LSAs to advertise one or more IPv6 address prefixes
that are associated with a local router address, an attached stub
network segment, or an attached transit network segment. In IPv4,
the first two were accomplished via the router's router-LSA and the
last via a network-LSA. In OSPF for IPv6, all addressing information
that was advertised in router-LSAs and network-LSAs has been removed
and is now advertised in intra-area-prefix-LSAs. For details
concerning the construction of intra-area-prefix-LSA, see
Section 4.4.3.9.

A router can originate multiple intra-area-prefix-LSAs for each
router or transit network. Each such LSA is distinguished by its
unique Link State ID.

```
    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|            9            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                         Link State ID                         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      Advertising Router                       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      LS Sequence Number                       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |         LS Checksum           |             Length            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |          # Prefixes           |      Referenced LS Type       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                   Referenced Link State ID                    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                Referenced Advertising Router                  |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | PrefixLength  | PrefixOptions |            Metric             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                        Address Prefix                         |
   |                             ...                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                             ...                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | PrefixLength  | PrefixOptions |            Metric             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                        Address Prefix                         |
   |                             ...                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

                      Intra-Area-Prefix LSA Format

   # prefixes
      The number of IPv6 address prefixes contained in the LSA.

   Referenced LS Type, Referenced Link State ID, and Referenced
      Advertising Router
      Identifies the router-LSA or network-LSA with which the IPv6
      address prefixes should be associated. If Referenced LS Type is
      0x2001, the prefixes are associated with a router-LSA, Referenced
      Link State ID should be 0, and Referenced Advertising Router
      should be the originating router's Router ID. If Referenced LS
      Type is 0x2002, the prefixes are associated with a network-LSA,
      Referenced Link State ID should be the Interface ID of the link's
      Designated Router, and Referenced Advertising Router should be the
      Designated Router's Router ID.

   The rest of the intra-area-prefix-LSA contains a list of IPv6
   prefixes to be associated with the router or transit link, as well as
   their associated costs.

   PrefixLength, PrefixOptions, and Address Prefix
      Representation of an IPv6 address prefix, as described in
      Appendix A.4.1.

   Metric
      The cost of this prefix. Expressed in the same units as the
      interface costs in router-LSAs.

Appendix B. Architectural Constants

   Architectural constants for the OSPF protocol are defined in Appendix
   B of [OSPFV2]. The only difference for OSPF for IPv6 is that
   DefaultDestination is encoded as a prefix with length 0 (see
   Appendix A.4.1).

Appendix C. Configurable Constants

   The OSPF protocol has quite a few configurable parameters. These
   parameters are listed below. They are grouped into general
   functional categories (area parameters, interface parameters, etc.).
   Sample values are given for some of the parameters.

   Some parameter settings need to be consistent among groups of
   routers. For example, all routers in an area must agree on that
   area's parameters. Similarly, all routers attached to a network must
   agree on that network's HelloInterval and RouterDeadInterval.

   Some parameters may be determined by router algorithms outside of
   this specification (e.g., the address of a host connected to the
   router via a SLIP line). From OSPF's point of view, these items are
   still configurable.

C.1. Global Parameters

   In general, a separate copy of the OSPF protocol is run for each
   area. Because of this, most configuration parameters are defined on
   a per-area basis. The few global configuration parameters are listed
   below.

Router ID
   This is a 32-bit number that uniquely identifies the router in the
   Autonomous System. If a router's OSPF Router ID is changed, the
   router's OSPF software should be restarted before the new Router
   ID takes effect. Before restarting due to a Router ID change, the
   router should flush its self-originated LSAs from the routing
   domain (see Section 14.1 of [OSPFV2]). Otherwise, they will
   persist for up to MaxAge seconds.

Because the size of the Router ID is smaller than an IPv6 address, it
cannot be set to one of the router's IPv6 addresses (as is commonly
done for IPv4). Possible Router ID assignment procedures for IPv6
include: a) assign the IPv6 Router ID as one of the router's IPv4
addresses or b) assign IPv6 Router IDs through some local
administrative procedure (similar to procedures used by manufacturers
to assign product serial numbers).

The Router ID of 0.0.0.0 is reserved and SHOULD NOT be used.

C.2. Area Parameters

All routers belonging to an area must agree on that area's
configuration. Disagreements between two routers will lead to an
inability for adjacencies to form between them, with a resulting
hindrance to the flow of both routing protocol information and data
traffic. The following items must be configured for an area:

Area ID
   This is a 32-bit number that identifies the area. The Area ID of
   0 is reserved for the backbone.

List of address ranges
   Address ranges control the advertisement of routes across area
   boundaries. Each address range consists of the following items:

   [IPv6 prefix, prefix length]
      Describes the collection of IPv6 addresses contained in the
      address range.

   Status
      Set to either Advertise or DoNotAdvertise. Routing information
      is condensed at area boundaries. External to the area, at most
      a single route is advertised (via a inter-area-prefix-LSA) for
      each address range. The route is advertised if and only if the
      address range's Status is set to Advertise. Unadvertised
      ranges allow the existence of certain networks to be
      intentionally hidden from other areas. Status is set to
      Advertise by default.

ExternalRoutingCapability
    Whether AS-external-LSAs will be flooded into/throughout the area.
    If AS-external-LSAs are excluded from the area, the area is called
    a stub area or NSSA. Internal to stub areas, routing to external
    destinations will be based solely on a default inter-area route.
    The backbone cannot be configured as a stub or NSSA area. Also,
    virtual links cannot be configured through stub or NSSA areas.
    For more information, see Section 3.6 of [OSPFV2] and [NSSA].

StubDefaultCost
    If the area has been configured as a stub area, and the router
    itself is an area border router, then the StubDefaultCost
    indicates the cost of the default inter-area-prefix-LSA that the
    router should advertise into the area. See Section 12.4.3.1 of
    [OSPFV2] for more information.

NSSATranslatorRole and TranslatorStabilityInterval
    These area parameters are described in Appendix D of [NSSA].
    Additionally, an NSSA Area Border Router (ABR) is also required to
    allow configuration of whether or not an NSSA default route is
    advertised in an NSSA-LSA. If advertised, its metric and metric
    type are configurable. These requirements are also described in
    Appendix D of [NSSA].

ImportSummaries
    When set to enabled, prefixes external to the area are imported
    into the area via the advertisement of inter-area-prefix-LSAs.
    When set to disabled, inter-area routes are not imported into the
    area. The default setting is enabled. This parameter is only
    valid for stub or NSSA areas.

C.3. Router Interface Parameters

    Some of the configurable router interface parameters (such as Area
    ID, HelloInterval, and RouterDeadInterval) actually imply properties
    of the attached links. Therefore, these parameters must be
    consistent across all the routers attached to that link. The
    parameters that must be configured for a router interface are:

    IPv6 link-local address
        The IPv6 link-local address associated with this interface. May
        be learned through auto-configuration.

Area ID
   The OSPF area to which the attached link belongs.

Instance ID
   The OSPF protocol instance associated with this OSPF interface.
   Defaults to 0.

Interface ID
   32-bit number uniquely identifying this interface among the
   collection of this router's interfaces. For example, in some
   implementations it may be possible to use the MIB-II IfIndex
   ([INTFMIB]).

IPv6 prefixes
   The list of IPv6 prefixes to associate with the link. These will
   be advertised in intra-area-prefix-LSAs.

Interface output cost(s)
   The cost of sending a packet on the interface, expressed in the
   link-state metric. This is advertised as the link cost for this
   interface in the router's router-LSA. The interface output cost
   MUST always be greater than 0.

RxmtInterval
   The number of seconds between LSA retransmissions for adjacencies
   belonging to this interface. Also used when retransmitting
   Database Description and Link State Request packets. This should
   be well over the expected round-trip delay between any two routers
   on the attached link. The setting of this value should be
   conservative or needless retransmissions will result. Sample
   value for a local area network: 5 seconds.

InfTransDelay
   The estimated number of seconds it takes to transmit a Link State
   Update packet over this interface. LSAs contained in the update
   packet must have their age incremented by this amount before
   transmission. This value should take into account the
   transmission and propagation delays of the interface. It MUST be
   greater than 0. Sample value for a local area network: 1 second.

Router Priority
   An 8-bit unsigned integer. When two routers attached to a network
   both attempt to become the Designated Router, the one with the
   highest Router Priority takes precedence. If there is still a
   tie, the router with the highest Router ID takes precedence. A
   router whose Router Priority is set to 0 is ineligible to become
   the Designated Router on the attached link. Router Priority is
   only configured for interfaces to broadcast and NBMA networks.

HelloInterval
   The length of time, in seconds, between Hello packets that the
   router sends on the interface. This value is advertised in the
   router's Hello packets. It MUST be the same for all routers
   attached to a common link. The smaller the HelloInterval, the
   faster topological changes will be detected. However, more OSPF
   routing protocol traffic will ensue. Sample value for a X.25 PDN:
   30 seconds. Sample value for a local area network (LAN): 10
   seconds.

RouterDeadInterval
   After ceasing to hear a router's Hello packets, the number of
   seconds before its neighbors declare the router down. This is
   also advertised in the router's Hello packets in their
   RouterDeadInterval field. This should be some multiple of the
   HelloInterval (e.g., 4). This value again MUST be the same for
   all routers attached to a common link.

LinkLSASuppression
   Indicates whether or not origination of a link-LSA is suppressed.
   If set to "enabled" and the interface type is not broadcast or
   NBMA, the router will not originate a link-LSA for the link. This
   implies that other routers on the link will ascertain the router's
   next-hop address using a mechanism other than the link-LSA (see
   Section 4.8.2). The default value is "disabled" for interface
   types described in this specification. It is implicitly
   "disabled" if the interface type is broadcast or NBMA. Future
   interface types MAY specify a different default.

C.4. Virtual Link Parameters

   Virtual links are used to restore/increase connectivity of the
   backbone. Virtual links may be configured between any pair of area
   border routers having interfaces to a common (non-backbone) area.
   The virtual link appears as a point-to-point link with no global IPv6
   addresses in the graph for the backbone. The virtual link must be
   configured in both of the area border routers.

   A virtual link appears in router-LSAs (for the backbone) as if it
   were a separate router interface to the backbone. As such, it has
   most of the parameters associated with a router interface (see
   Appendix C.3). Virtual links do not have link-local addresses, but
   instead use one of the router's global-scope IPv6 addresses as the IP
   source in OSPF protocol packets it sends on the virtual link. Router
   Priority is not used on virtual links. Interface output cost is not
   configured on virtual links, but is dynamically set to be the cost of
   the transit area intra-area path between the two endpoint routers.
   The parameter RxmtInterval may be configured and should be well over

the expected round-trip delay between the two routers. This may be
hard to estimate for a virtual link; it is better to err on the side
of making it too long.

A virtual link is defined by the following two configurable
parameters: the Router ID of the virtual link's other endpoint and
the (non-backbone) area that the virtual link traverses (referred to
as the virtual link's transit area). Virtual links cannot be
configured through stub or NSSA areas. Additionally, an Instance ID
may be configured for virtual links from different protocol instances
in order to utilize the same transit area (without requiring
different Router IDs for demultiplexing).

C.5. NBMA Network Parameters

OSPF treats an NBMA network much like it treats a broadcast network.
Since there may be many routers attached to the network, a Designated
Router is selected for the network. This Designated Router then
originates a network-LSA listing all routers attached to the NBMA
network.

However, due to the lack of broadcast capabilities, it may be
necessary to use configuration parameters in the Designated Router
selection. These parameters will only need to be configured in those
routers that are themselves eligible to become the Designated Router
(i.e., those routers whose Router Priority for the network is non-
zero), and then only if no automatic procedure for discovering
neighbors exists:

List of all other attached routers
    The list of all other routers attached to the NBMA network. Each
    router is configured with its Router ID and IPv6 link-local
    address on the network. Also, for each router listed, that
    router's eligibility to become the Designated Router must be
    defined. When an interface to an NBMA network first comes up, the
    router only sends Hello packets to those neighbors eligible to
    become the Designated Router until such time that a Designated
    Router is elected.

PollInterval
    If a neighboring router has become inactive (Hello packets have
    not been seen for RouterDeadInterval seconds), it may still be
    necessary to send Hello packets to the dead neighbor. These Hello
    packets will be sent at the reduced rate PollInterval, which
    should be much larger than HelloInterval. Sample value for a PDN
    X.25 network: 2 minutes.

C.6. Point-to-Multipoint Network Parameters

   On point-to-multipoint networks, it may be necessary to configure the
   set of neighbors that are directly reachable over the point-to-
   multipoint network. Each neighbor is configured with its Router ID
   and IPv6 link-local address on the network. Designated Routers are
   not elected on point-to-multipoint networks, so the Designated Router
   eligibility of configured neighbors is not defined.

C.7. Host Route Parameters

   Host prefixes are advertised in intra-area-prefix-LSAs. They
   indicate either local router addresses, router interfaces to point-
   to-point networks, looped router interfaces, or IPv6 hosts that are
   directly connected to the router (e.g., via a PPP connection). For
   each host directly connected to the router, the following items must
   be configured:

   Host IPv6 prefix
      An IPv6 prefix belonging to the directly connected host. This
      must not be a valid IPv6 global prefix.

   Cost of link to host
      The cost of sending a packet to the host, in terms of the link-
      state metric. However, since the host probably has only a single
      connection to the Internet, the actual configured cost(s) in many
      cases is unimportant (i.e., will have no effect on routing).

   Area ID
      The OSPF area to which the host's prefix belongs.

Authors' Addresses

    Rob Coltun
    Acoustra Productions
    3204 Brooklawn Terrace
    Chevy Chase, MD 20815
    USA

    Dennis Ferguson
    Juniper Networks
    1194 N. Mathilda Avenue
    Sunnyvale, CA 94089
    USA

    EMail: dennis@juniper.net

    John Moy
    Sycamore Networks, Inc
    10 Elizabeth Drive
    Chelmsford, MA 01824
    USA

    EMail: jmoy@sycamorenet.com

    Acee Lindem (editor)
    Redback Networks
    102 Carric Bend Court
    Cary, NC 27519
    USA

    EMail: acee@redback.com

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