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Dynamic Flooding on Dense Graphs

Abstract

Routing with link state protocols in dense network topologies can result in sub-optimal convergence times due to the overhead associated with flooding. This can be addressed by decreasing the flooding topology so that it is less dense.

This document discusses the problem in some depth and an architectural solution. Specific protocol changes for IS-IS, OSPFv2, and OSPFv3 are described in this document.

Status of This Memo

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1. Introduction

In recent years, there has been increased focus on how to address the dynamic routing of networks that have a bipartite (a.k.a. spine-leaf or leaf-spine), Clos [Clos], or Fat Tree [Leiserson] topology. Conventional Interior Gateway Protocols (IGPs, i.e., IS-IS [ISO10589], OSPFv2 [RFC2328], and OSPFv3 [RFC5340]) under-perform, redundantly flooding information throughout the dense topology, leading to overloaded control plane inputs and thereby creating operational issues. For practical considerations, network architects have resorted to applying unconventional techniques to address the problem, e.g., applying BGP in the data center [RFC7938]. However it is very clear that using an Exterior Gateway Protocol as an IGP is sub-optimal, if only due to the configuration overhead.

The primary issue that is demonstrated when conventional mechanisms are applied is the poor reaction of the network to topology changes. Normal link state routing protocols rely on a flooding algorithm for state distribution within an area. In a dense topology, this flooding algorithm is highly redundant, resulting in unnecessary overhead. Each node in the topology receives each link state update multiple times. Ultimately, all of the redundant copies will be discarded, but only after they have reached the control plane and been processed. This creates issues because significant link state database updates can become queued behind many redundant copies of another update. This delays convergence as the link state database does not stabilize promptly.

In a real world implementation, the packet queues leading to the control plane are necessarily of finite size, so if the flooding rate exceeds the update processing rate for long enough, the control plane will be obligated to drop incoming updates. If these lost updates are of significance, this will further delay stabilization of the link state database and the convergence of the network.

This is not a new problem. Historically, when routing protocols have been deployed in networks where the underlying topology is a complete graph, there have been similar issues. This was more common when the underlying link layer fabric presented the network layer with a full mesh of virtual connections. This was addressed by reducing the flooding topology through IS-IS Mesh Groups [RFC2973], but this approach requires careful configuration of the flooding topology.

Thus, the root problem is not limited to massively scalable data centers. It exists with any dense topology at scale.

This problem is not entirely surprising. Link state routing protocols were conceived when links were very expensive and topologies were sparse. The fact that those same designs are sub-optimal in a dense topology should not come as a huge surprise. The fundamental premise that was addressed by the original designs was an environment of extreme cost and scarcity. Technology has progressed to the point where links are cheap and common. This represents a complete reversal in the economic fundamentals of network engineering. The original designs are to be commended for continuing to provide correct operation to this point, and optimizations for operation in today's environment are to be expected.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

2. Problem Statement

In a dense topology, the flooding algorithm that is the heart of conventional link state routing protocols causes a great deal of redundant messaging. This is exacerbated by scale. While the protocol can survive this combination, the redundant messaging is unnecessary overhead and delays convergence. Thus, the problem is to provide routing in dense, scalable topologies with rapid convergence.

3. Solution Requirements

A solution to this problem must then meet the following requirements:

Requirement 1 Provide a dynamic routing solution. Reachability must be restored after any topology change.

Requirement 2 Provide a significant improvement in convergence.

Requirement 3 The solution should address a variety of dense topologies. Just addressing a complete bipartite topology such as K5,8 is insufficient. Multi-stage Clos topologies must also be addressed, as well as topologies that are slight variants. Addressing complete graphs is a good demonstration of generality.

Requirement 4 There must be no single point of failure. The loss of any link or node should not unduly hinder convergence.

Requirement 5 Dense topologies are subgraphs of much larger topologies. Operational efficiency requires that the dense subgraph not operate in a radically different manner than the remainder of the topology. While some operational differences are permissible, they should be minimized. Changes to nodes outside of the dense subgraph are not acceptable. These situations occur when massively scaled data centers are part of an overall larger wide-area network. Having a second protocol operating just on this subgraph would add much more complexity at the edge of the subgraph where the two protocols would have to inter-operate.

4. Dynamic Flooding

We have observed that the combination of the dense topology and flooding on the physical topology in a scalable network is sub-optimal. However, if we decouple the flooding topology from the physical topology and only flood on a greatly reduced portion of that topology, we can have efficient flooding and retain all of the resilience of existing protocols. A node that supports flooding on the decoupled flooding topology is said to support dynamic flooding.

In this idea, the flooding topology is computed within an IGP area with the dense topology either centrally on an elected node, termed the Area Leader, or in a distributed manner on all nodes that are supporting Dynamic Flooding. If the flooding topology is computed centrally, it is encoded into and distributed as part of the normal link state database. We call this the centralized mode of operation. If the flooding topology is computed in a distributed fashion, we call this the distributed mode of operation. Nodes within such an IGP area would only flood on the flooding topology. On links outside of the normal flooding topology, normal database synchronization mechanisms (i.e., OSPF database exchange, IS-IS CSNPs) would apply, but flooding may not. Details are described in Section 6. New link state information that arrives from outside of the flooding topology suggests that the sender has a different or no flooding topology information and that the link state update should be flooded on the flooding topology as well.

The flooding topology covers the full set of nodes within the area, but excludes some of the links that standard flooding would employ.

Since the flooding topology is computed prior to topology changes, it does not factor into the convergence time and can be done when the topology is stable. The speed of the computation and its distribution, in the case of a centralized mode, is not a significant issue.

If a node does not have any flooding topology information when it receives new link state information, it should flood according to standard flooding rules. This situation will occur when the dense topology is first established, but is unlikely to recur.

When centralized mode is used and if, during a transient, there are multiple flooding topologies being advertised, then nodes should flood link state updates on all of the flooding topologies. Each node should locally evaluate the election of the Area Leader for the IGP area and first flood on its flooding topology. The rationale behind this is straightforward: if there is a transient and there has been a recent change in Area Leader, then propagating topology

information promptly along the most likely flooding topology should be the priority.

During transients, it is possible that loops will form in the flooding topology. This is not problematic, as the legacy flooding rules would cause duplicate updates to be ignored. Similarly, during transients, it is possible that the flooding topology may become disconnected. Section 6.8.11 discusses how such conditions are handled.

4.1. Applicability

In a complete graph, this approach is appealing because it drastically decreases the flooding topology without the manual configuration of mesh groups. By controlling the diameter of the flooding topology, as well as the maximum degree node in the flooding topology, convergence time goals can be met and the stability of the control plane can be assured.

Similarly, in a massively scaled data center, where there are many opportunities for redundant flooding, this mechanism ensures that flooding is redundant, with each leaf and spine well connected, while ensuring that no update need make too many hops and that no node shares an undue portion of the flooding effort.

In a network where only a portion of the nodes support Dynamic Flooding, the remaining nodes will continue to perform standard flooding. This is not an issue for correctness, as no node can become isolated.

Flooding that is initiated by nodes that support Dynamic Flooding will remain within the flooding topology until it reaches a legacy node, which will resume legacy flooding. Standard flooding will be bounded by nodes supporting Dynamic Flooding, which can help limit the propagation of unnecessary flooding. Whether or not the network can remain stable in this condition is unknown and may be very dependent on the number and location of the nodes that support Dynamic Flooding.

During incremental deployment of dynamic flooding an area will consist of one or more sets of connected nodes that support dynamic flooding and one or more sets of connected nodes that do not, i.e., nodes that support standard flooding. The flooding topology is the union of these sets of nodes. Each set of nodes that does not support dynamic flooding needs to be part of the flooding topology and such a set of nodes may provide connectivity between two or more sets of nodes that support dynamic flooding.

4.2. Leader election

A single node within the dense topology is elected as an Area Leader.

A generalization of the mechanisms used in existing Designated Router (OSPF) or Designated Intermediate-System (IS-IS) elections suffices. The elected node is known as the Area Leader.

In the case of centralized mode, the Area Leader is responsible for computing and distributing the flooding topology. When a new Area Leader is elected and has distributed new flooding topology information, then any prior Area Leaders should withdraw any of their flooding topology information from their link state database entries.

In the case of distributed mode, the distributed algorithm advertised by the Area Leader MUST be used by all nodes that participate in Dynamic Flooding.

Not every node needs to be a candidate to be Area Leader within an area, as a single candidate is sufficient for correct operation. For redundancy, however, it is strongly RECOMMENDED that there be multiple candidates.

4.3. Computing the Flooding Topology

There is a great deal of flexibility in how the flooding topology may be computed. For resilience, it needs to at least contain a cycle of all nodes in the dense subgraph. However, additional links could be added to decrease the convergence time. The trade-off between the density of the flooding topology and the convergence time is a matter for further study. The exact algorithm for computing the flooding topology in the case of the centralized computation need not be standardized, as it is not an interoperability issue. Only the encoding of the result needs to be documented. In the case of distributed mode, all nodes in the IGP area need to use the same algorithm to compute the flooding topology. It is possible to use private algorithms to compute flooding topology, so long as all nodes in the IGP area use the same algorithm.

While the flooding topology should be a covering cycle, it need not be a Hamiltonian cycle where each node appears only once. In fact, in many relevant topologies this will not be possible e.g., K5,8. This is fortunate, as computing a Hamiltonian cycle is known to be NP-complete.

A simple algorithm to compute the topology for a complete bipartite graph is to simply select unvisited nodes on each side of the graph

until both sides are completely visited. If the number of nodes on each side of the graph are unequal, then revisiting nodes on the less populated side of the graph will be inevitable. This algorithm can run in O(N) time, so is quite efficient.

While a simple cycle is adequate for correctness and resiliency, it may not be optimal for convergence. At scale, a cycle may have a diameter that is half the number of nodes in the graph. This could cause an undue delay in link state update propagation. Therefore it may be useful to have a bound on the diameter of the flooding topology. Introducing more links into the flooding topology would reduce the diameter, but at the trade-off of possibly adding redundant messaging. The optimal trade-off between convergence time and graph diameter is for further study.

Similarly, if additional redundancy is added to the flooding topology, specific nodes in that topology may end up with a very high degree. This could result in overloading the control plane of those nodes, resulting in poor convergence. Thus, it may be optimal to have an upper bound on the degree of nodes in the flooding topology. Again, the optimal trade-off between graph diameter, node degree, and convergence time, and topology computation time is for further study.

If the leader chooses to include a multi-node broadcast LAN segment as part of the flooding topology, all of the connectivity to that LAN segment should be included as well. Once updates are flooded onto the LAN, they will be received by every attached node.

4.4. Topologies on Complete Bipartite Graphs

Complete bipartite graph topologies have become popular for data center applications and are commonly called leaf-spine or spine-leaf topologies. In this section, we discuss some flooding topologies that are of particular interest in these networks.

4.4.1. A Minimal Flooding Topology

We define a Minimal Flooding Topology on a complete bipartite graph as one in which the topology is connected and each node has at least degree two. This is of interest because it guarantees that the flooding topology has no single points of failure.

In practice, this implies that every leaf node in the flooding topology will have a degree of two. As there are usually more leaves than spines, the degree of the spines will be higher, but the load on the individual spines can be evenly distributed.

This type of flooding topology is also of interest because it scales well. As the number of leaves increases, we can construct flooding

topologies that perform well. Specifically, for n spines and m leaves, if m >= n(n/2-1), then there is a flooding topology that has a diameter of four.

4.4.2. Xia Topologies

We define a Xia Topology on a complete bipartite graph as one in which all spine nodes are bi-connected through leaves with degree two, but the remaining leaves all have degree one and are evenly distributed across the spines.

Constructively, we can create a Xia topology by iterating through the spines. Each spine can be connected to the next spine by selecting any unused leaf. Since leaves are connected to all spines, all leaves will have a connection to both the first and second spine and we can therefore choose any leaf without loss of generality. Continuing this iteration across all of the spines, selecting a new leaf at each iteration, will result in a path that connects all spines. Adding one more leaf between the last and first spine will produce a cycle of n spines and n leaves.

At this point, m-n leaves remain unconnected. These can be distributed evenly across the remaining spines, connected by a single link.

Xia topologies represent a compromise that trades off increased risk and decreased performance for lower flooding amplification. Xia topologies will have a larger diameter. For m spines, the diameter will be m + 2.

In a Xia topology, some leaves are singly connected. This represents a risk in that in some failures, convergence may be delayed. However, there may be some alternate behaviors that can be employed to mitigate these risks. If a leaf node sees that its single link on the flooding topology has failed, it can compensate by performing a database synchronization check with a different spine. Similarly, if a leaf determines that its connected spine on the flooding topology has failed, it can compensate by performing a database synchronization check with a different spine. In both of these cases, the synchronization check is intended to ameliorate any delays in link state propagation due to the fragmentation of the flooding topology.

The benefit of this topology is that flooding load is easily understood. Each node in the spine cycle will never receive an update more than twice. For m leaves and n spines, a spine never transmits more than (m/n +1) updates.

4.4.3. Optimization

If two nodes are adjacent on the flooding topology and there are a set of parallel links between them, then any given update MUST be flooded over a single one of those links. Selection of the specific link is implementation specific.

4.5. Encoding the Flooding Topology

There are a variety of ways that the flooding topology could be encoded efficiently. If the topology was only a cycle, a simple list of the nodes in the topology would suffice. However, this is insufficiently flexible as it would require a slightly different encoding scheme as soon as a single additional link is added. Instead, we choose to encode the flooding topology as a set of intersecting paths, where each path is a set of connected edges.

Advertisement of the flooding topology includes support for multi-access LANs. When a LAN is included in the flooding topology, all edges between the LAN and nodes connected to the LAN are assumed to be part of the flooding topology. In order to reduce the size of the flooding topology advertisement, explicit advertisement of these edges is optional. Note that this may result in the possibility of "hidden nodes" existing which are actually part of the flooding topology but which are not explicitly mentioned in the flooding topology advertisements. These hidden nodes can be found by examination of the Link State database where connectivity between a LAN and nodes connected to the LAN is fully specified.

Note that while all nodes MUST be part of the advertised flooding topology not all multi-access LANs need to be included. Only those LANs which are part of the flooding topology need to be included in the advertised flooding topology.

Other encodings are certainly possible. We have attempted to make a useful trade off between simplicity, generality, and space.

4.6. Advertising the Local Edges Enabled for Flooding

Correct operation of the flooding topology requires that all nodes which participate in the flooding topology choose local links for flooding which are consistent with the calculated flooding topology. Failure to do so could result in unexpected partition of the flooding topology and/or sub-optimal flooding reduction. As an aid to diagnosing problems when dynamic flooding is in use, this document defines a means of advertising what local edges are enabled for flooding (LEEF). The protocol specific encodings are defined in Sections 5.1.6 and 5.2.8.

The following guidelines apply:

Advertisement of LEEFs is optional.

As the flooding topology is defined by edges (not by links), in cases where parallel adjacencies to the same neighbor exist, the advertisement SHOULD indicate that all such links have been enabled.

LEEF advertisements MUST NOT include edges enabled for temporary flooding (Section 6.7).

LEEF advertisements MUST NOT be used either when calculating a flooding topology or when determining what links to add temporarily to the flooding topology when the flooding topology is temporarily partitioned.

5. Protocol Elements

5.1. IS-IS TLVs

The following TLVs/sub-TLVs are added to IS-IS:

1. A sub-TLV that an IS may inject into its LSP to indicate its preference for becoming Area Leader.

2. A sub-TLV that an IS may inject into its LSP to indicate that it supports Dynamic Flooding and the algorithms that it supports for distributed mode, if any.

3. A TLV to carry the list of system IDs that compromise the flooding topology for the area.

4. A TLV to carry a path which is part of the flooding topology

5. A TLV that requests flooding from the adjacent node

5.1.1. IS-IS Area Leader Sub-TLV

The Area Leader Sub-TLV allows a system to:

1. Indicate its eligibility and priority for becoming Area Leader.

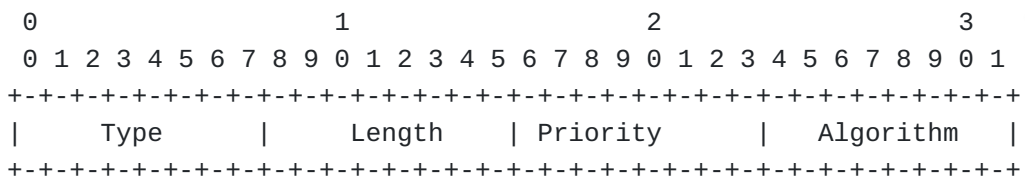
2. Indicate whether centralized or distributed mode is to be used to compute the flooding topology in the area.

3. Indicate the algorithm identifier for the algorithm that is used to compute the flooding topology in distributed mode.

Intermediate Systems (nodes) that are not advertising this Sub-TLV are not eligible to become Area Leader.

The Area Leader is the node with the numerically highest Area Leader priority in the area. In the event of ties, the node with the numerically highest system ID is the Area Leader. Due to transients during database flooding, different nodes may not agree on the Area Leader.

The Area Leader Sub-TLV is advertised as a Sub-TLV of the IS-IS Router Capability TLV-242 that is defined in [RFC7981] and has the following format:



Type: TBD1

Length: 2

Priority: 0-255, unsigned integer

Algorithm: a numeric identifier in the range 0-255 that identifies the algorithm used to calculate the flooding topology. The following values are defined:

- 0: Centralized computation by the Area Leader.

- 1-127: Standardized distributed algorithms. Individual values are are to be assigned according to the "Specification Required" policy defined in [RFC8126] (see Section 7.3).

- 128-254: Private distributed algorithms. Individual values are are to be assigned according to the "Private Use" policy defined in [RFC8126] (see Section 7.3).

- 255: Reserved

5.1.2. IS-IS Dynamic Flooding Sub-TLV

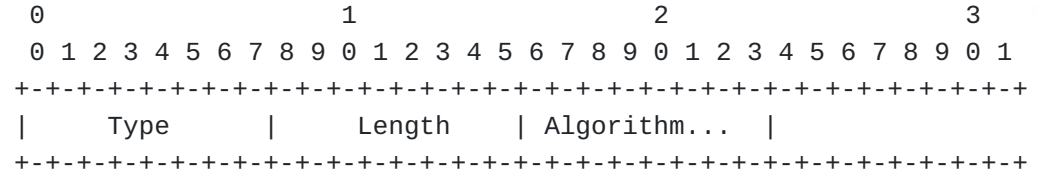
The Dynamic Flooding Sub-TLV allows a system to:

1. Indicate that it supports Dynamic Flooding. This is indicated by the advertisement of this Sub-TLV.

2. Indicate the set of algorithms that it supports for distributed mode, if any.

In incremental deployments, understanding which nodes support Dynamic Flooding can be used to optimize the flooding topology. In distributed mode, knowing the capabilities of the nodes can allow the Area Leader to select the optimal algorithm.

The Dynamic Flooding Sub-TLV is advertised as a Sub-TLV of the IS-IS Router Capability TLV (242) [RFC7981] and has the following format:



Type: TBD7

Length: 0-255; number of Algorithms

Algorithm: zero or more numeric identifiers in the range 0-255 that identifies the algorithm used to calculate the flooding topology, as described in Section 5.1.1.

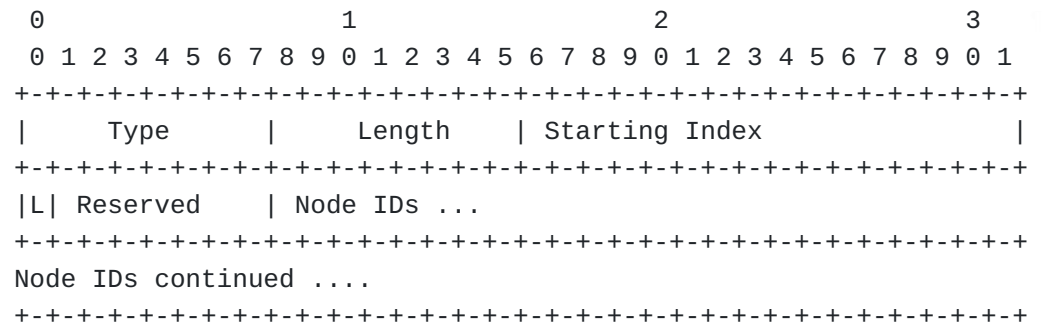
5.1.3. IS-IS Area Node IDs TLV

The IS-IS Area Node IDs TLV is only used in centralized mode.

The Area Node IDs TLV is used by the Area Leader to enumerate the Node IDs (System ID + pseudo-node ID) that it has used in computing the area flooding topology. Conceptually, the Area Leader creates a list of node IDs for all nodes in the area (including pseudo-nodes for all LANs in the topology), assigning indices to each node, starting with index 0.

Because the space in a single TLV is limited, more than one TLV may be required to encode all of the node IDs in the area. This TLV may be present in multiple LSPs.

The format of the Area Node IDs TLV is:



Type: TBD2

Length: 3 + ((System ID Length + 1) * (number of node IDs))

Starting index: The index of the first node ID that appears in this TLV.

L (Last): This bit is set if the index of the last node ID that appears in this TLV is equal to the last index in the full list of node IDs for the area.

Node IDs: A concatenated list of node IDs for the area

If there are multiple IS-IS Area Node IDs TLVs with the L bit set advertised by the same node, the TLV which specifies the smaller maximum index is used and the other TLV(s) with L bit set are ignored. TLVs which specify node IDs with indices greater than that specified by the TLV with the L bit set are also ignored.

5.1.4. IS-IS Flooding Path TLV

IS-IS Flooding Path TLV is only used in centralized mode.

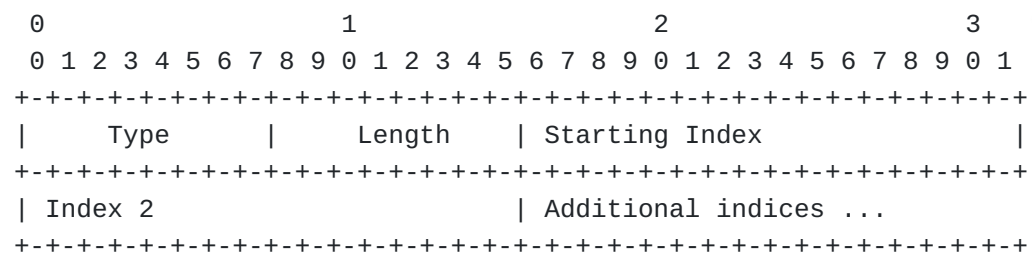
The Flooding Path TLV is used to denote a path in the flooding topology. The goal is an efficient encoding of the links of the topology. A single link is a simple case of a path that only covers two nodes. A connected path may be described as a sequence of indices: (I1, I2, I3, ...), denoting a link from the system with index 1 to the system with index 2, a link from the system with index 2 to the system with index 3, and so on.

If a path exceeds the size that can be stored in a single TLV, then the path may be distributed across multiple TLVs by the replication of a single system index.

Complex topologies that are not a single path can be described using multiple TLVs.

The Flooding Path TLV contains a list of system indices relative to the systems advertised through the Area Node IDs TLV. At least 2 indices must be included in the TLV. Due to the length restriction of TLVs, this TLV can contain at most 126 system indices.

The Flooding Path TLV has the format:



Type: TBD3

Length: 2 * (number of indices in the path)

Starting index: The index of the first system in the path.

Index 2: The index of the next system in the path.

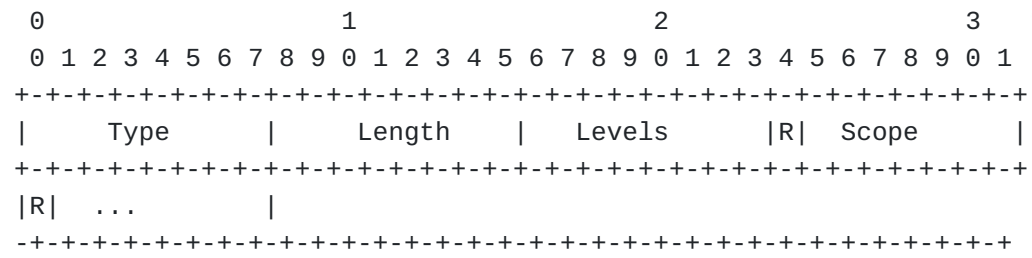
Additional indices (optional): A sequence of additional indices to systems along the path.

5.1.5. IS-IS Flooding Request TLV

The Flooding Request TLV allows a system to request an adjacent node to enable flooding towards it on a specific link in the case where the connection to adjacent node is not part of the existing flooding topology.

Nodes that support Dynamic Flooding MAY include the Flooding Request TLV in its IIH PDUs.

The Flooding Request TLV has the format:



Type: TBD9

Length: 1 + number of advertised Flooding Scopes

Levels - the level(s) for which flooding is requested. Levels are encoded as the circuit type specified in IS-IS [ISO10589]

R bit: MUST be 0 and is ignored on receipt.

Scope: Flooding Scope for which the flooding is requested as defined by LSP Flooding Scope Identifier Registry defined by

[RFC7356]. Inclusion of flooding scopes is optional and is only necessary if [RFC7356] is supported. Multiple flooding scopes MAY be included.

Circuit Flooding Scope MUST NOT be sent in the Flooding Request TLV and MUST be ignored if received.

When the TLV is received in a level specific LAN-Hello PDU (L1-LAN-IIH or L2-LAN-IIH) only levels which match the PDU type are valid. Levels which do not match the PDU type MUST be ignored on receipt.

When the TLV is received in a Point-to-Point Hello (P2P-IIH) only levels which are supported by the established adjacency are valid. Levels which are not supported by the adjacency MUST be ignored on receipt.

If flooding was disabled on the received link due to Dynamic Flooding, then flooding MUST be temporarily enabled over the link for the specified Circuit Type(s) and Flooding Scope(s) received in the in the Flooding Request TLV. Flooding MUST be enabled until the Circuit Type or Flooding Scope is no longer advertised in the Flooding Request TLV or the TLV no longer appears in IIH PDUs received on the link.

When the flooding is temporarily enabled on the link for any Circuit Type or Flooding Scope due to received Flooding Request TLV, the receiver MUST perform standard database synchronization for the corresponding Circuit Type(s) and Flooding Scope(s) on the link. In the case of IS-IS, this results in setting SRM bit for all related LSPs on the link and sending CSNPs.

So long as the Flooding Request TLV is being received flooding MUST NOT be disabled for any of the Circuit Types or Flooding Scopes present in the Flooding Request TLV even if the connection between the neighbors is removed from the flooding topology. Flooding for such Circuit Types or Flooding Scopes MUST continue on the link and be considered as temporarily enabled.

5.1.6. IS-IS LEEF Advertisement

In support of advertising which edges are currently enabled in the flooding topology, an implementation MAY indicate that a link is part of the flooding topology by advertising a bit value in the Link Attributes sub-TLV defined by [RFC5029].

The following bit value is defined by this document:

Local Edge Enabled for Flooding (LEEF) - suggested value 4 (to be assigned by IANA)

5.2. OSPF LSAs and TLVs

This section defines new LSAs and TLVs for both OSPFv2 and OSPFv3.

Following objects are added:

1. A TLV that is used to advertise the preference for becoming Area Leader.

2. A TLV that is used to indicate the support for Dynamic Flooding and the algorithms that the advertising node supports for distributed mode, if any.

3. OSPFv2 Opaque LSA and OSPFv3 LSA to advertise the flooding topology for centralized mode.

4. A TLV to carry the list of Router IDs that comprise the flooding topology for the area.

5. A TLV to carry a path which is part of the flooding topology.

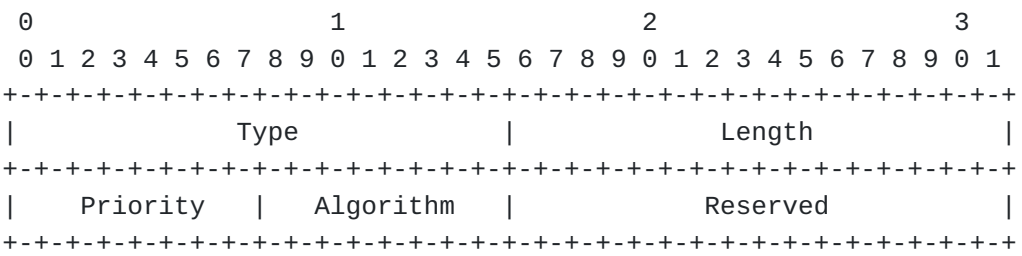
6. The bit in the LLS Type 1 Extended Options and Flags requests flooding from the adjacent node.

5.2.1. OSPF Area Leader Sub-TLV

The usage of the OSPF Area Leader Sub-TLV is identical to IS-IS and is described in Section 5.1.1.

The OSPF Area Leader Sub-TLV is used by both OSPFv2 and OSPFv3.

The OSPF Area Leader Sub-TLV is advertised as a top-level TLV of the RI LSA that is defined in [RFC7770] and has the following format:



Type: TBD4

Length: 4 octets

Priority: 0-255, unsigned integer

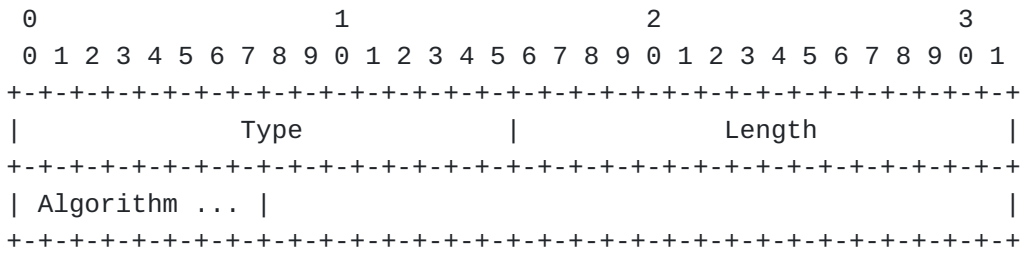
Algorithm: as defined in Section 5.1.1.

5.2.2. OSPF Dynamic Flooding Sub-TLV

The usage of the OSPF Dynamic Flooding Sub-TLV is identical to IS-IS and is described in Section 5.1.2.

The OSPF Dynamic Flooding Sub-TLV is used by both OSPFv2 and OSPFv3.

The OSPF Dynamic Flooding Sub-TLV is advertised as a top-level TLV of the RI LSA that is defined in [RFC7770] and has the following format:



Type: TBD8

Length: number of Algorithms

Algorithm: as defined in Section 5.1.1.

5.2.3. OSPFv2 Dynamic Flooding Opaque LSA

The OSPFv2 Dynamic Flooding Opaque LSA is only used in centralized mode.

The OSPFv2 Dynamic Flooding Opaque LSA is used to advertise additional data related to the dynamic flooding in OSPFv2. OSPFv2 Opaque LSAs are described in [RFC5250].

Multiple OSPFv2 Dynamic Flooding Opaque LSAs can be advertised by an OSPFv2 router. The flooding scope of the OSPFv2 Dynamic Flooding Opaque LSA is area-local.

The format of the OSPFv2 Dynamic Flooding Opaque LSA is as follows:

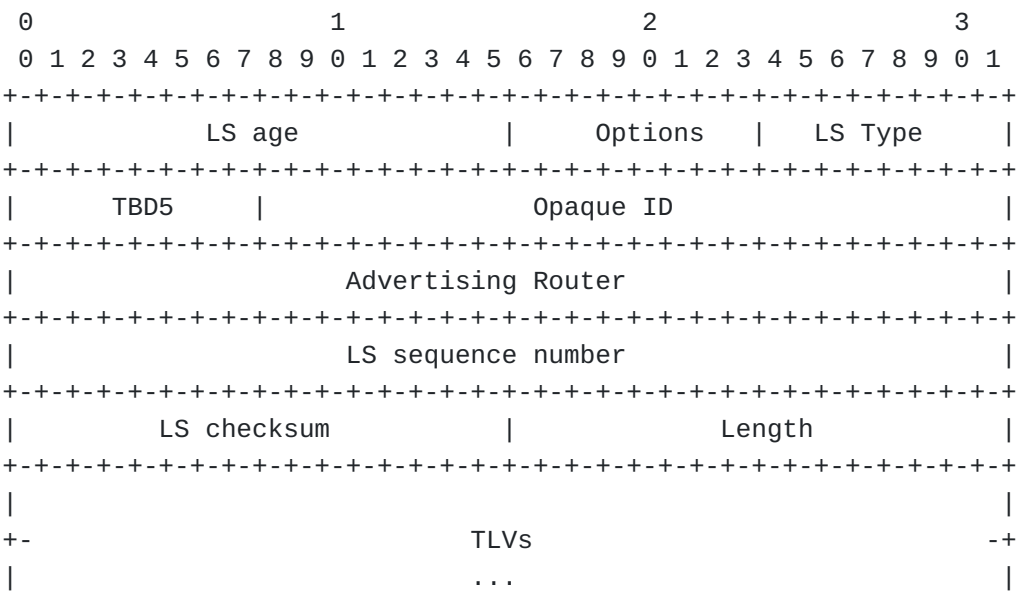


Figure 1: OSPFv2 Dynamic Flooding Opaque LSA

The opaque type used by OSPFv2 Dynamic Flooding Opaque LSA is TBD. The opaque type is used to differentiate the various type of OSPFv2 Opaque LSAs and is described in section 3 of [RFC5250]. The LS Type is 10. The LSA Length field [RFC2328] represents the total length (in octets) of the Opaque LSA including the LSA header and all TLVs (including padding).

The Opaque ID field is an arbitrary value used to maintain multiple Dynamic Flooding Opaque LSAs. For OSPFv2 Dynamic Flooding Opaque LSAs, the Opaque ID has no semantic significance other than to differentiate Dynamic Flooding Opaque LSAs originated by the same OSPFv2 router.

The format of the TLVs within the body of the OSPFv2 Dynamic Flooding Opaque LSA is the same as the format used by the Traffic Engineering Extensions to OSPF [RFC3630].

The Length field defines the length of the value portion in octets (thus a TLV with no value portion would have a length of 0). The TLV is padded to 4-octet alignment; padding is not included in the length field (so a 3-octet value would have a length of 3, but the total size of the TLV would be 8 octets). Nested TLVs are also 32-bit aligned. For example, a 1-octet value would have the length field set to 1, and 3 octets of padding would be added to the end of the value portion of the TLV. The padding is composed of zeros.

5.2.4. OSPFv3 Dynamic Flooding LSA

The OSPFv3 Dynamic Flooding Opaque LSA is only used in centralized mode.

The OSPFv3 Dynamic Flooding LSA is used to advertise additional data related to the dynamic flooding in OSPFv3.

The OSPFv3 Dynamic Flooding LSA has a function code of TBD. The flooding scope of the OSPFv3 Dynamic Flooding LSA is area-local. The U bit will be set indicating that the OSPFv3 Dynamic Flooding LSA should be flooded even if it is not understood. The Link State ID (LSID) value for this LSA is the Instance ID. OSPFv3 routers MAY advertise multiple Dynamic Flooding Opaque LSAs in each area.

The format of the OSPFv3 Dynamic Flooding LSA is as follows:

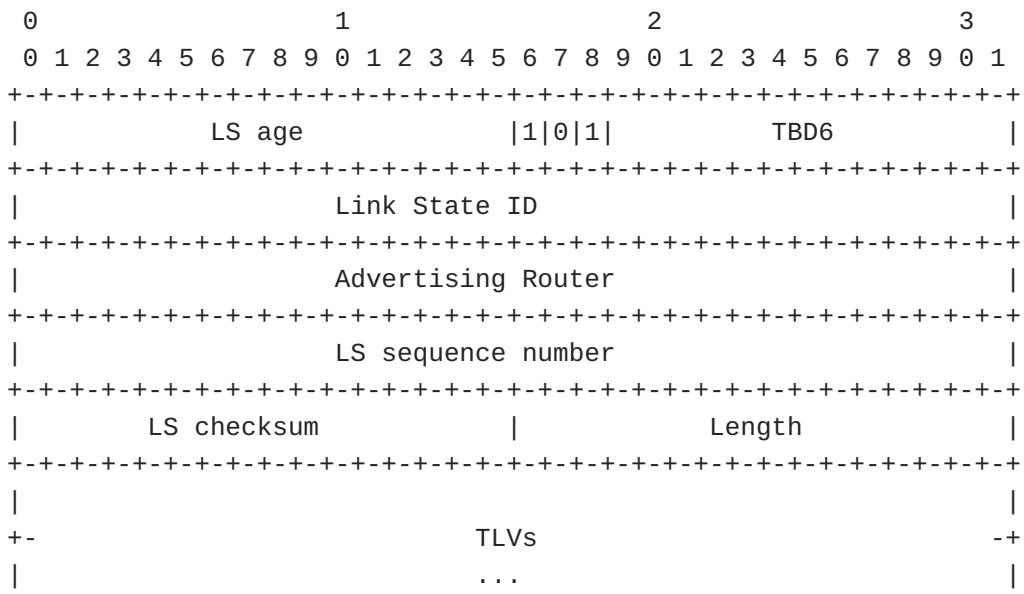


Figure 2: OSPFv3 Dynamic Flooding LSA

5.2.5. OSPF Area Router ID TLVs

In OSPF new TLVs are introduced to advertise indeces associated with nodes and Broadcast/NBMA networks. Due to identifier differences between OSPFv2 and OSPFv3 two different TLVs are defined as decribed in the following sub-sections.

The OSPF Area Router ID TLVs are used by the Area Leader to enumerate the Router IDs that it has used in computing the flooding topology. This includes the identifiers associated with Broadcast/ NBMA networks as defined for Network LSAs. Conceptually, the Area Leader creates a list of Router IDs for all routers in the area, assigning indices to each router, starting with index 0.

5.2.5.1. OSPFv2 Area Router ID TLV

This TLV is a top level TLV of the OSPFv2 Dynamic Flooding Opaque LSA.

Because the space in a single OSPFv2 Area Router IDs TLV is limited, more than one TLV may be required to encode all of the Router IDs in the area. This TLV may also occur in multiple OSPFv2 Dynamic Flooding Opaque LSAs so that all Router IDs can be advertised.

Each entry in the OSPFv2 Area Router IDs TLV represents either a node or a Broadcast/NBMA network identifier. An entry has the following format:

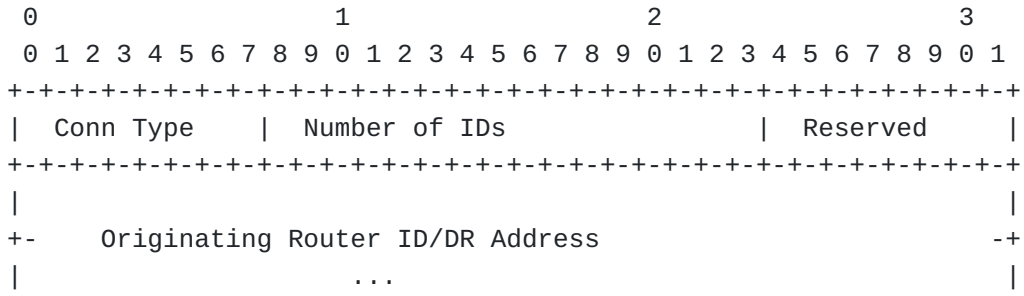


Figure 3: OSPFv2 Router IDs TLV Entry

Conn Type: 1 byte

- The following values are defined:
- 1 - Router
- 2 - Designated Router

Number of IDs: 2 bytes

Reserved: 1 byte, MUST be transmitted as 0 and MUST be ignored on receipt

Originating Router ID/DR Address:(4 * Number of IDs) bytes as indicated by the ID Type

The format of the Area Router IDs TLV is:

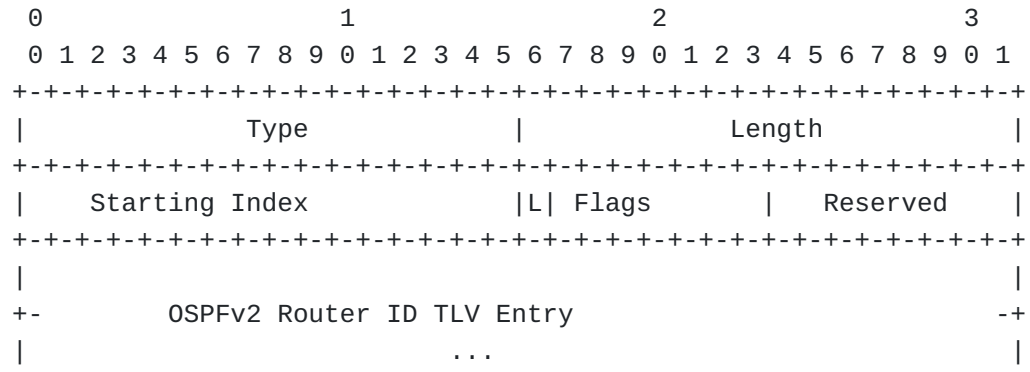


Figure 4: OSPFv2 Area Router IDs TLV

TLV Type: 1

TLV Length: 4 + (8 * the number TLV entries)

Starting index: The index of the first Router/Designated Router ID that appears in this TLV.

L (Last): This bit is set if the index of the last Router/ Designated ID that appears in this TLV is equal to the last index in the full list of Rourer IDs for the area.

OSPFv2 Router ID TLV Entries: A concatenated list of Router ID TLV Entries for the area.

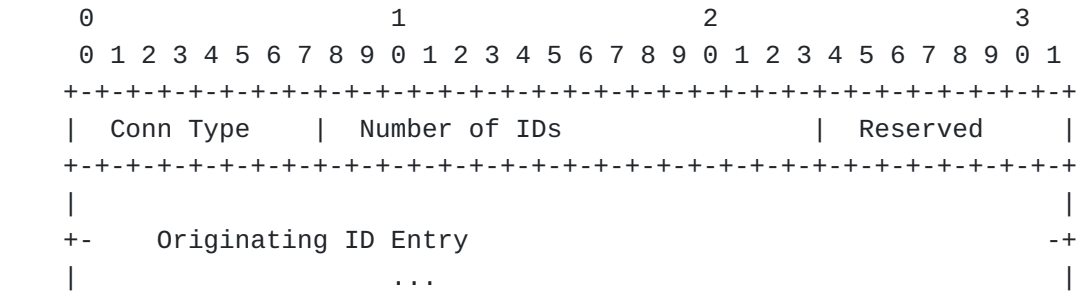
If there are multiple OSPFv2 Area Router ID TLVs with the L bit set advertised by the same router, the TLV which specifies the smaller maximum index is used and the other TLV(s) with L bit set are ignored. TLVs which specify Router IDs with indices greater than that specified by the TLV with the L bit set are also ignored.

5.2.5.2. OSPFv3 Area Router ID TLV

This TLV is a top level TLV of the OSPFv3 Dynamic Flooding LSA.

Because the space in a single OSPFv3 Area Router ID TLV is limited, more than one TLV may be required to encode all of the Router IDs in the area. This TLV may also occur in multiple OSPFv3 Dynamic Flooding Opaque LSAs so that all Router IDs can be advertised.

Each entry in the OSPFv3 Area Router IDs TLV represents either a router or a Broadcast/NBMA network identifier. An entry has the following format:



where

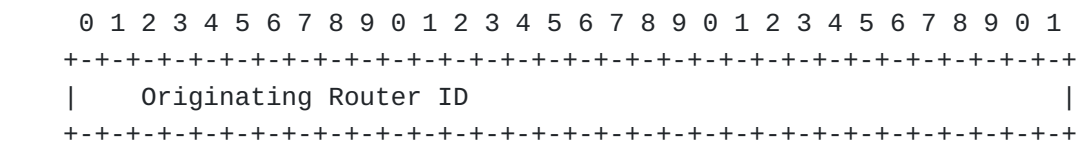
Conn Type - 1 byte
The following values are defined:
1 - Router
2 - Designated Router

Number of IDs - 2 bytes

Reserved - 1 byte
MUST be transmitted as 0 and MUST be ignored on receipt

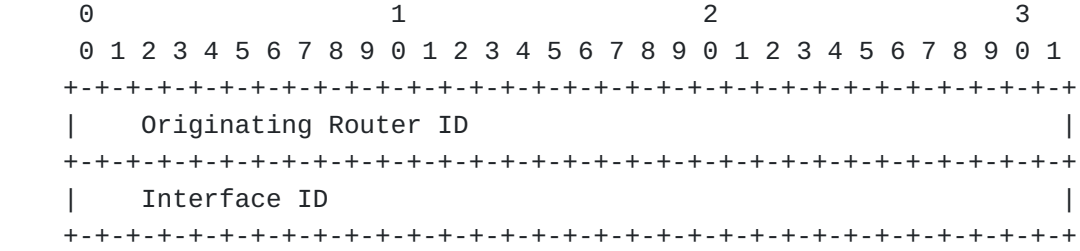
Originating ID Entry takes one of the following forms:

Router:



Length of Originating ID Entry is 4 * Number of IDs) bytes

Designated Router:



Length of Originating ID Entry is (8 * Number of IDs) bytes

Figure 5: OSPFv3 Router ID TLV Entry

The format of the OSPFv3Area Router IDs TLV is:

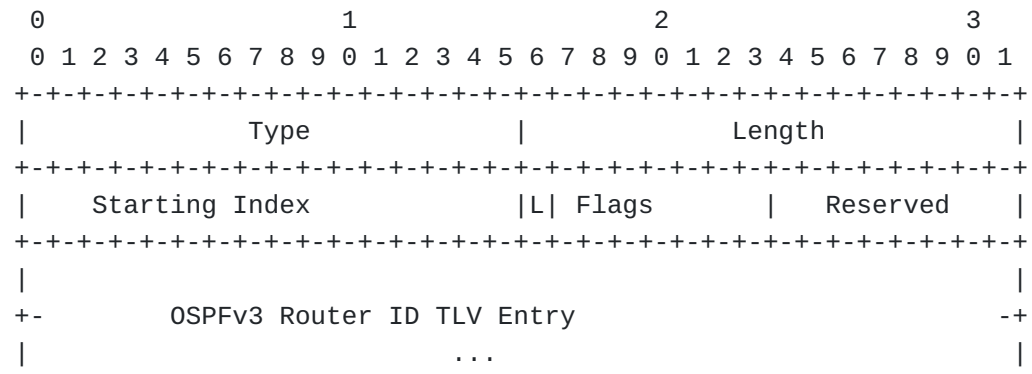


Figure 6: OSPFv3 Area Router IDs TLV

TLV Type: 1

TLV Length: 4 + sum of the lengths of all TLV entries

Starting index: The index of the first Router/Designated Router ID that appears in this TLV.

L (Last): This bit is set if the index of the last Router/ Designated Router ID that appears in this TLV is equal to the last index in the full list of Router IDs for the area.

OSPFv3 Router ID TLV Entries: A concatenated list of Router ID TLV Entries for the area.

If there are multiple OSPFv3 Area Router ID TLVs with the L bit set advertised by the same router, the TLV which specifies the smaller maximum index is used and the other TLV(s) with L bit set are ignored. TLVs which specify Router IDs with indices greater than that specified by the TLV with the L bit set are also ignored.

5.2.6. OSPF Flooding Path TLV

The OSPF Flooding Path TLV is a top level TLV of the OSPFv2 Dynamic Flooding Opaque LSAs and OSPFv3 Dynamic Flooding LSA.

The usage of the OSPF Flooding Path TLV is identical to IS-IS and is described in Section 5.1.4.

The OSPF Flooding Path TLV contains a list of Router ID indices relative to the Router IDs advertised through the OSPF Area Router IDs TLV. At least 2 indices must be included in the TLV.

Multiple OSPF Flooding Path TLVs can be advertised in a single OSPFv2 Dynamic Flooding Opaque LSA or OSPFv3 Dynamic Flooding LSA. OSPF Flooding Path TLVs can also be advertised in multiple OSPFv2

Dynamic Flooding Opaque LSAs or OSPFv3 Dynamic Flooding LSA, if they all can not fit in a single LSA.

The Flooding Path TLV has the format:

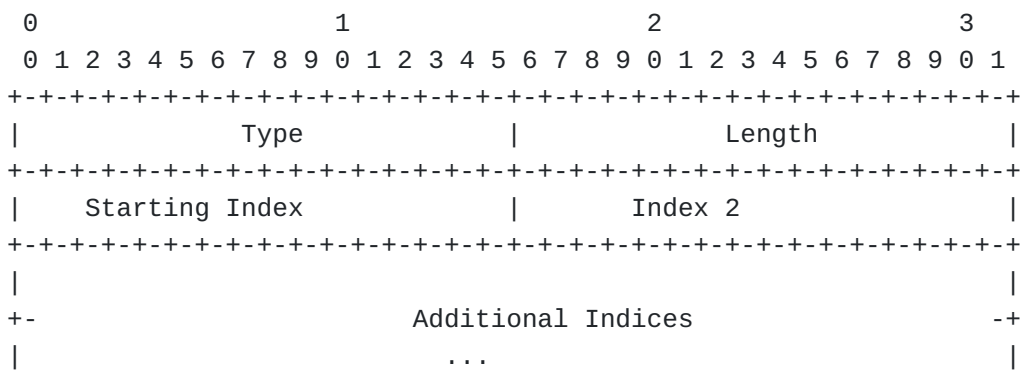


Figure 7: OSPF Flooding Path TLV

TLV Type: 2

TLV Length: 2 * (number of indices in the path)

Starting index: The index of the first Router ID in the path.

Index 2: The index of the next Router ID in the path.

Additional indices (optional): A sequence of additional indices to Router IDs along the path.

5.2.7. OSPF Flooding Request Bit

A single new option bit, the Flooding-Request (FR-bit), is defined in the LLS Type 1 Extended Options and Flags field [RFC2328]. The FR-bit allows a router to request an adjacent node to enable flooding towards it on a specific link in the case where the connection to adjacent node is not part of the current flooding topology.

Nodes that support Dynamic Flooding MAY include FR-bit in its OSPF LLS Extended Options and Flags TLV.

If FR-bit is signalled for an area for which the flooding on the link was disabled due to Dynamic Flooding, the flooding MUST be temporarily enabled over such link and area. Flooding MUST be enabled until FR-bit is no longer advertised in the OSPF LLS Extended Options and Flags TLV or the OSPF LLS Extended Options and Flags TLV no longer appears in the OSPF Hellos.

When the flooding is temporarily enabled on the link for any area due to received FR-bit in OSPF LLS Extended Options and Flags TLV, the receiver MUST perform standard database synchronization for the corresponding area(s) on the link. If the adjacency is already in the FULL state, mechanism specified in [RFC4811] MUST be used for database resynchronization.

So long as the FR-bit is being received in the OSPF LLS Extended Options and Flags TLV for an area, flooding MUST NOT be disabled in such area even if the connection between the neighbors is removed from the flooding topology. Flooding for such area MUST continue on the link and be considered as temporarily enabled.

5.2.8. OSPF LEEF Advertisement

In support of advertising which edges are currently enabled in the flooding topology, an implementation MAY indicate that a link is part of the flooding topology. The OSPF Link Attributes Bits TLV is defined to support this advertisement.

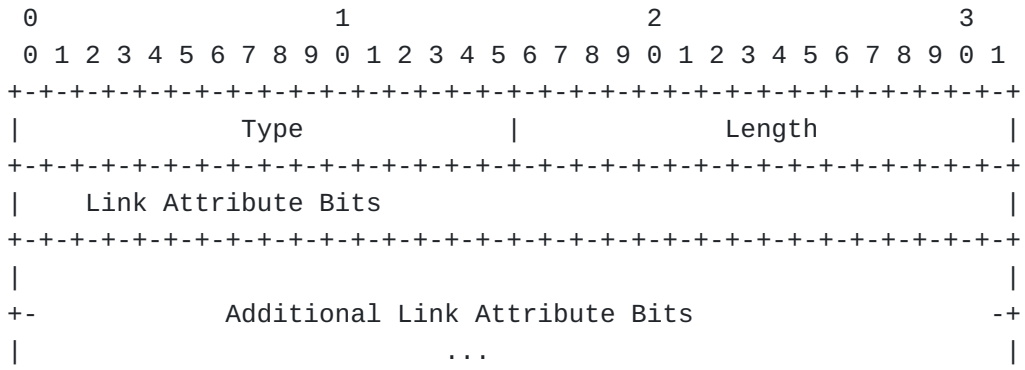


Figure 8: OSPF Link Attributes Bits TLV

Type: TBD and specific to OSPFv2 and OSPFv3

Length: size of the Link Attribute Bits in bytes. It MUST be a multiple of 4 bytes.

The following bits are defined:

Bit #0: - Local Edge Enabled for Flooding (LEEF)

OSPF Link-attribute Bits TLV appears as:

1. a sub-TLV of the OSPFv2 Extended Link TLV [RFC7684]

2. a sub-TLV of the OSPFv3 Router-Link TLV [RFC8362]

6. Behavioral Specification

In this section, we specify the detailed behaviors of the nodes participating in the IGP.

6.1. Terminology

We define some terminology here that is used in the following sections:

A node is considered reachable if it is part of the connected network graph. Note that this is independent of any constraints which may be considered when performing IGP SPT calculation (e.g., link metrics, OL bit state, etc.). Two-way-connectivity check MUST be performed before including an edge in the connected network graph.

Node is connected to the flooding topology, if it has at least one local link, which is part of the flooding topology.

Node is disconnected from the flooding topology when it is not connected to the flooding topology.

Current flooding topology - latest version of the flooding topology received (in case of the centralized mode) or calculated locally (in case of the distributed mode).

6.2. Flooding Topology

The flooding topology MUST include all reachable nodes in the area.

If a node's reachability changes, the flooding topology MUST be recalculated. In centralized mode, the Area Leader MUST advertise a new flooding topology.

If a node becomes disconnected from the current flooding topology but is still reachable then a new flooding topology MUST be calculated. In centralized mode the Area Leader MUST advertise the new flooding topology.

The flooding topology SHOULD be bi-connected.

6.3. Leader Election

Any node that is capable MAY advertise its eligibility to become Area Leader.

Nodes that are not reachable are not eligible as Area Leader. Nodes that do not advertise their eligibility to become Area Leader are not eligible. Amongst the eligible nodes, the node with the

numerically highest priority is the Area Leader. If multiple nodes all have the highest priority, then the node with the numerically highest system identifier in the case of IS-IS, or Router-ID in the case of OSPFv2 and OSPFv3 is the Area Leader.

6.4. Area Leader Responsibilities

If the Area Leader operates in centralized mode, it MUST advertise algorithm 0 in its Area Leader Sub-TLV. In order for Dynamic Flooding to be enabled it also MUST compute and advertise a flooding topology for the area. The Area Leader may update the flooding topology at any time, however, it should not destabilize the network with undue or overly frequent topology changes. If the Area Leader operates in centralized mode and needs to advertise a new flooding topology, it floods the new flooding topology on both the new and old flooding topologies.

If the Area Leader operates in distributed mode, it MUST advertise a non-zero algorithm in its Area Leader Sub-TLV.

When the Area Leader advertises algorithm 0 in its Area Leader Sub-TLV and does not advertise a flooding topology, Dynamic Flooding is disabled for the area. Note this applies whether the Area Leader intends to operate in centralized mode or in distributed mode.

Note that once Dynamic Flooding is enabled, disabling it risks destabilizing the network.

6.5. Distributed Flooding Topology Calculation

If the Area Leader advertises a non-zero algorithm in its Area Leader Sub-TLV, all nodes in the area that support Dynamic Flooding and the value of algorithm advertised by the Area Leader MUST compute the flooding topology based on the Area Leader's advertised algorithm.

Nodes that do not support the value of algorithm advertised by the Area Leader MUST continue to use standard flooding mechanism as defined by the protocol.

Nodes that do not support the value of algorithm advertised by the Area Leader MUST be considered as Dynamic Flooding incapable nodes by the Area Leader.

If the value of the algorithm advertised by the Area Leader is from the range 128-254 (private distributed algorithms), it is the responsibility of the network operator to guarantee that all nodes in the area have a common understanding of what the given algorithm value represents.

6.6. Use of LANs in the Flooding Topology

Use of LANs in the flooding topology differs depending on whether the area is operating in Centralized or Distributed mode.

6.6.1. Use of LANs in Centralized mode

As specified in Section 4.5, when a LAN is advertised as part of the flooding topology, all nodes connected to the LAN are assumed to be using the LAN as part of the flooding topology. This assumption is made to reduce the size of the Flooding Topology advertisement.

6.6.2. Use of LANs in Distributed Mode

In distributed mode, the flooding topology is NOT advertised, therefore the space consumed to advertise it is not a concern. It is therefore possible to assign only a subset of the nodes connected to the LAN to use the LAN as part of the flooding topology. Doing so may further optimize flooding by reducing the amount of redundant flooding on a LAN. However, support of flooding only by a subset of the nodes connected to a LAN requires some modest - but backwards compatible - changes in the way flooding is performed on a LAN.

6.6.2.1. Partial flooding on a LAN in IS-IS

Designated Intermediate System (DIS) for a LAN MUST use standard flooding behavior.

Non-DIS nodes whose connection to the LAN is included in the flooding topology MUST use standard flooding behavior.

Non-DIS nodes whose connection to the LAN is NOT included in the flooding topology behave as follows:

*Received CSNPs from the DIS are ignored

*PSNPs are NOT originated on the LAN

*LSPs received on the LAN which are newer than the corresponding LSP present in the LSPDB are retained and flooded on all local circuits which are part of the flooding topology (i.e., do not discard newer LSPs simply because they were received on a LAN which the receiving node is not using for flooding)

*LSPs received on the LAN which are older or same as the corresponding LSP present in the LSPDB are silently discarded

*LSPs received on links other than the LAN are NOT flooded on the LAN

NOTE: If any node connected to the LAN requests the enablement of temporary flooding all nodes revert to standard flooding behavior.

6.6.2.2. Partial Flooding on a LAN in OSPF

Designated Router (DR) and Backup Designated Router (BDR) for LANs MUST use standard flooding behavior.

Non-DR/BDR nodes whose connection to the LAN is included in the flooding topology use standard flooding behavior.

Non-DR/BDR nodes whose connection to the LAN is NOT included in the flooding topology behave as follows:

- *LSAs received on the LAN are acknowledged to DR/BDR

- *LSAs received on interfaces other than the LAN are NOT flooded on the LAN

NOTE: If any node connected to the LAN requests the enablement of temporary flooding all nodes revert to standard flooding behavior.

NOTE: The sending of LSA acks by nodes NOT using the LAN as part of the flooding topology eliminates the need for changes on the part of the DR/BDR, which might include nodes which do not support the flooding optimizations.

6.7. Flooding Behavior

Nodes that support Dynamic Flooding MUST use the flooding topology for flooding when possible, and MUST NOT revert to standard flooding when a valid flooding topology is available.

In some cases a node that supports Dynamic Flooding may need to add a local link(s) to the flooding topology temporarily, even though the link(s) is not part of the calculated flooding topology. This is termed "temporary flooding" and is discussed in Section 6.8.1.

The flooding topology is calculated locally in the case of distributed mode. In centralized mode the flooding topology is advertised in the area link state database. Received link state updates, whether received on a link that is in the flooding topology or on a link that is not in the flooding topology, MUST be flooded on all links that are in the flooding topology, except for the link on which the update was received.

In centralized mode, if multiple flooding topologies are present in the area link state database, the node SHOULD flood on each of these topologies.

When the flooding topology changes on a node, either as a result of the local computation in distributed mode or as a result of the advertisement from the Area Leader in centralized mode, the node MUST continue to flood on both the old and new flooding topology for a limited amount of time. This is required to provide all nodes sufficient time to migrate to the new flooding topology.

6.8. Treatment of Topology Events

In this section, we explicitly consider a variety of different topological events in the network and how Dynamic Flooding should address them.

6.8.1. Temporary Addition of Link to Flooding Topology

In some cases a node that supports Dynamic Flooding may need to add a local link(s) to the flooding topology temporarily, even though the link(s) is not part of the calculated flooding topology. We refer to this as "temporary flooding" on the link.

When temporary flooding is enabled on the link, the flooding needs to be enabled from both directions on the link. To achieve that, the following steps MUST be performed:

Link State Database needs to be re-synchronised on the link. This is done using the standard protocol mechanisms. In the case of IS-IS, this results in setting SRM bit for all LSPs on the circuit and sending compete set of CSNPs on it. In OSPF, the mechanism specified in [RFC4811] is used.

Flooding is enabled locally on the link.

Flooding is requested from the neighbor using the mechanism specified in section Section 5.1.5 or Section 5.2.7.

The request for temporary flooding is withdrawn on the link when all of the following conditions are met:

Node itself is connected to the current flooding topology.

Adjacent node is connected to the current flooding topology.

Any change in the flooding topology MUST result in evaluation of the above conditions for any link on which the temporary flooding was enabled.

Temporary flooding is stopped on the link when both adjacent nodes stop requesting temporary flooding on the link.

6.8.2. Local Link Addition

If a local link is added to the topology, the protocol will form a normal adjacency on the link and update the appropriate link state advertisements for the nodes on either end of the link. These link state updates will be flooded on the flooding topology.

In centralized mode, the Area Leader, upon receiving these updates, may choose to retain the existing flooding topology or may choose to modify the flooding topology. If it elects to change the flooding topology, it will update the flooding topology in the link state database and flood it using the new flooding topology.

In distributed mode, any change in the topology, including the link addition, MUST trigger the flooding topology recalculation. This is done to ensure that all nodes converge to the same flooding topology, regardless of the time of the calculation.

Temporary flooding MUST be enabled on the newly added local link, if at least one of the following conditions are met:

- The node on which the local link was added is not connected to the current flooding topology.

- The new adjacent node is not connected to the current flooding topology.

Note that in this case there is no need to perform a database synchronization as part of the enablement of the temporary flooding, because it has been part of the adjacency bring-up itself.

If multiple local links are added to the topology before the flooding topology is updated, temporary flooding MUST be enabled on a subset of these links.

6.8.3. Node Addition

If a node is added to the topology, then at least one link is also added to the topology. Section 6.8.2 applies.

A node which has a large number of neighbors is at risk for introducing a local flooding storm if all neighbors are brought up at once and temporary flooding is enabled on all links simultaneously. The most robust way to address this is to limit the rate of initial adjacency formation following bootup. This both reduces unnecessary redundant flooding as part of initial database synchronization and minimizes the need for temporary flooding as it allows time for the new node to be added to the flooding topology after only a small number of adjacencies have been formed.

In the event a node elects to bring up a large number of adjacencies simultaneously, a significant amount of redundant flooding may be introduced as multiple neighbors of the new node enable temporary flooding to the new node which initially is not part of the flooding topology.

6.8.4. Failures of Link Not on Flooding Topology

If a link that is not part of the flooding topology fails, then the adjacent nodes will update their link state advertisements and flood them on the flooding topology.

In centralized mode, the Area Leader, upon receiving these updates, may choose to retain the existing flooding topology or may choose to modify the flooding topology. If it elects to change the flooding topology, it will update the flooding topology in the link state database and flood it using the new flooding topology.

In distributed mode, any change in the topology, including the failure of the link that is not part of the flooding topology MUST trigger the flooding topology recalculation. This is done to ensure that all nodes converge to the same flooding topology, regardless of the time of the calculation.

6.8.5. Failures of Link On the Flooding Topology

If there is a failure on the flooding topology, the adjacent nodes will update their link state advertisements and flood them. If the original flooding topology is bi-connected, the flooding topology should still be connected despite a single failure.

If the failed local link represented the only connection to the flooding topology on the node where the link failed, the node MUST enable temporary flooding on a subset of its local links. This allows the node to send its updated link state advertisement(s) and also keep receiving link state updates from other nodes in the network before the new flooding topology is calculated and distributed (in the case of centralized mode).

In centralized mode, the Area Leader will notice the change in the flooding topology, recompute the flooding topology, and flood it using the new flooding topology.

In distributed mode, all nodes supporting dynamic flooding will notice the change in the topology and recompute the new flooding topology.

6.8.6. Node Deletion

If a node is deleted from the topology, then at least one link is also removed from the topology. Section 6.8.4 and Section 6.8.5 apply.

6.8.7. Local Link Addition to the Flooding Topology

If the new flooding topology is received in the case of centralized mode, or calculated locally in the case of distributed mode and the local link on the node that was not part of the flooding topology has been added to the flooding topology, the node MUST:

Re-synchronize the Link State Database over the link. This is done using the standard protocol mechanisms. In the case of IS-IS, this results in setting SRM bit for all LSPs on the circuit and sending a complete set of CSNPs. In OSPF, the mechanism specified in [RFC4811] is used.

Make the link part of the flooding topology and start flooding over it

6.8.8. Local Link Deletion from the Flooding Topology

If the new flooding topology is received in the case of centralized mode, or calculated locally in the case of distributed mode and the local link on the node that was part of the flooding topology has been removed from the flooding topology, the node MUST remove the link from the flooding topology.

The node MUST keep flooding on such link for a limited amount of time to allow other nodes to migrate to the new flooding topology.

If the removed local link represented the only connection to the flooding topology on the node, the node MUST enable temporary flooding on a subset of its local links. This allows the node to send its updated link state advertisement(s) and also keep receiving link state updates from other nodes in the network before the new flooding topology is calculated and distributed (in the case of centralized mode).

6.8.9. Treatment of Disconnected Adjacent Nodes

Every time there is a change in the flooding topology a node MUST check if there are any adjacent nodes that are disconnected from the current flooding topology. Temporary flooding MUST be enabled towards a subset of the disconnected nodes.

6.8.10. Failure of the Area Leader

The failure of the Area Leader can be detected by observing that it is no longer reachable. In this case, the Area Leader election process is repeated and a new Area Leader is elected.

In order to minimize disruption to Dynamic Flooding if the Area Leader becomes unreachable, the node which has the second highest priority for becoming Area Leader (including the system identifier/ Router-ID tie breaker if necessary) SHOULD advertise the same algorithm in its Area Leader Sub-TLV as the Area Leader and (in centralized mode) SHOULD advertise a flooding topology. This SHOULD be done even when the Area Leader is reachable.

In centralized mode, the new Area Leader will compute a new flooding topology and flood it using the new flooding topology. To minimze disruption, the new flooding topology SHOULD have as much in common as possible with the old flooding topology. This will minimize the risk of over-flooding.

In the distributed mode, the new flooding topology will be calculated on all nodes that support the algorithm that is advertised by the new Area Leader. Nodes that do not support the algorithm advertised by the new Area Leader will no longer participate in Dynamic Flooding and will revert to standard flooding.

6.8.11. Recovery from Multiple Failures

In the unlikely event of multiple failures on the flooding topology, it may become partitioned. The nodes that remain active on the edges of the flooding topology partitions will recognize this and will try to repair the flooding topology locally by enabling temporary flooding towards the nodes that they consider disconnected from the flooding topology until a new flooding topology becomes connected again.

Nodes where local failure was detected update their own link state advertisements and flood them on the remainder of the flooding topology.

In centralized mode, the Area Leader will notice the change in the flooding topology, recompute the flooding topology, and flood it using the new flooding topology.

In distributed mode, all nodes that actively participate in Dynamic Flooding will compute the new flooding topology.

Note that this is very different from the area partition because there is still a connected network graph between the nodes in the

area. The area may remain connected and forwarding may still be effective.

6.8.12. Rate Limiting Temporary Flooding

As discussed in the previous sections, there are events which require the introduction of temporary flooding on edges which are not part of the current flooding topology. This can occur regardless of whether the area is operating in centralized mode or distributed mode.

Nodes which decide to enable temporary flooding also have to decide whether to do so on a subset of the edges which are currently not part of the flooding topology or on all the edges which are currently not part of the flooding topology. Doing the former risks a longer convergence time as it is possible that the initial set of edges enabled does not fully repair the flooding topology. Doing the latter risks introducing a flooding storm which destablizes the network.

It is recommended that a node implement rate limiting on the number of edges on which it chooses to enable temporary flooding. Initial values for the number of edges to enable and the rate at which additional edges may subsequently be enabled is left as an implementation decision.

7. IANA Considerations

7.1. IS-IS

This document requests the following code points from the "sub-TLVs for TLV 242" registry (IS-IS Router CAPABILITY TLV).

Type: TBD1

Description: IS-IS Area Leader Sub-TLV

Reference: This document (Section 5.1.1)

Type: TBD7

Description: IS-IS Dynamic Flooding Sub-TLV

Reference: This document (Section 5.1.2)

This document requests that IANA allocate and assign code points from the "IS-IS TLV Codepoints" registry. One for each of the following TLVs:

Type: TBD2

Description: IS-IS Area System IDs TLV

Reference: This document (Section 5.1.3)

Type: TBD3

Description: IS-IS Flooding Path TLV

Reference: This document (Section 5.1.4)

Type: TBD9

Description: IS-IS Flooding Request TLV

Reference: This document (Section 5.1.5)

This document requests that IANA allocate a new bit value from the "link-attribute bit values for sub-TLV 19 of TLV 22" registry.

Local Edge Enabled for Flooding (LEEF) - suggested value 4 (to be assigned by IANA)

7.2. OSPF

This document requests the following code points from the "OSPF Router Information (RI) TLVs" registry:

Type: TBD4

Description: OSPF Area Leader Sub-TLV

Reference: This document (Section 5.2.1)

Type: TBD8

Description: OSPF Dynamic Flooding Sub-TLV

Reference: This document (Section 5.2.2)

This document requests the following code point from the "Opaque Link-State Advertisements (LSA) Option Types" registry:

Type: TBD5

Description: OSPFv2 Dynamic Flooding Opaque LSA

Reference: This document (Section 5.2.3)

This document requests the following code point from the "OSPFv3 LSA Function Codes" registry:

Type: TBD6

Description: OSPFv3 Dynamic Flooding LSA

Reference: This document (Section 5.2.4)

This document requests a new bit in LLS Type 1 Extended Options and Flags registry:

Bit Position: TBD10

Description: Flooding Request bit

Reference: This document (Section 5.2.7)

This document requests the following code point from the "OSPFv2 Extended Link TLV Sub-TLVs" registry:

Type: TBD11

Description: OSPFv2 Link Attributes Bits Sub-TLV

Reference: This document (Section 5.2.8)

This document requests the following code point from the "OSPFv3 Extended LSA Sub-TLVs" registry:

Type: TBD12

Description: OSPFv3 Link Attributes Bits Sub-TLV

Reference: This document (Section 5.2.8)

7.2.1. OSPF Dynamic Flooding LSA TLVs Registry

This specification also requests a new registry - "OSPF Dynamic Flooding LSA TLVs". New values can be allocated via IETF Review or IESG Approval

The "OSPF Dynamic Flooding LSA TLVs" registry will define top-level TLVs for the OSPFv2 Dynamic Flooding Opaque LSA and OSPFv3 Dynamic Flooding LSAs. It should be added to the "Open Shortest Path First (OSPF) Parameters" registries group.

The following initial values are allocated:

Type: 0

Description: Reserved

Reference: This document

Type: 1

Description: OSPF Area Router IDs TLV

Reference: This document (Section 5.2.5)

Type: 2

Description: OSPF Flooding Path TLV

Reference: This document (Section 5.2.6)

Types in the range 32768-33023 are for experimental use; these will not be registered with IANA, and MUST NOT be mentioned by RFCs.

Types in the range 33024-65535 are not to be assigned at this time. Before any assignments can be made in the 33024-65535 range, there MUST be an IETF specification that specifies IANA Considerations that covers the range being assigned.

7.2.2. OSPF Link Attributes Sub-TLV Bit Values Registry

This specification also requests a new registry - "OSPF Link Attributes Sub-TLV Bit Values". New values can be allocated via IETF Review or IESG Approval

The "OSPF Link Attributes Sub-TLV Bit Values" registry defines Link Attribute bit values for the OSPFv2 Link Attributes Sub-TLV and OSPFv3 Link Attributes Sub-TLV. It should be added to the "Open Shortest Path First (OSPF) Parameters" registries group.

The following initial value is allocated:

Bit Number: 0

Description: Local Edge Enabled for Flooding(LEEF)

Reference: This document (Section 5.2.8)

7.3. IGP

IANA is requested to set up a registry called "IGP Algorithm Type For Computing Flooding Topology" under an existing "Interior Gateway Protocol (IGP) Parameters" IANA registries.

Values in this registry come from the range 0-255.

The initial values in the IGP Algorithm Type For Computing Flooding Topology registry are:

0: Reserved for centralized mode.

1-127: Available for standards action. Individual values are to be assigned according to the "Specification Required" policy defined in [RFC8126].

128-254: Reserved for private use.

255: Reserved.

8. Security Considerations

This document introduces no new security issues. Security of routing within a domain is already addressed as part of the routing protocols themselves. This document proposes no changes to those security architectures.

It is possible that an attacker could become Area Leader and introduce a flawed flooding algorithm into the network thus compromising the operation of the protocol. Authentication methods as describe in [RFC5304] and [RFC5310] for IS-IS, [RFC2328] and [RFC7474] for OSPFv2 and [RFC5340] and [RFC4552] for OSPFv3 SHOULD be used to prevent such attack.

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