

Internet Engineering Task Force  
Internet-Draft  
Intended status: Standards Track  
Expires: January 17, 2013

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July 16, 2012

**OSPF Topology-Transparent Zone**  
**draft-chen-ospf-ttz-02.txt**

**Abstract**

This document presents a topology-transparent zone in a domain. A topology-transparent zone comprises a group of routers and a number of links connecting these routers. Any router outside of the zone is not aware of the zone. The information about the links and routers inside the zone is not distributed to any router outside of the zone. Any link state change such as a link down inside the zone is not seen by any router outside of the zone.

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## **1. Introduction**

The number of routers in an Autonomous System (AS) becomes larger and larger as the Internet traffic keeps growing. Thus the Open Shortest Path First (OSPF) Link State Database (LSDB) and OSPF routing table are bigger and bigger. Any link state change in an AS leads to a number of link state distributions to every router in the AS. This triggers every router in the AS to re-calculate its OSPF routes, update its Routing Information Base (RIB) and Forwarding Information Base (FIB). All these will consume network resource including network bandwidth and Central Process Unit (CPU) time. This blocks further expansions of a network.

[RFC 2328](#) "OSPF Version 2" describes OSPF areas in an AS. Each area has a number of area border routers connected to the backbone area. Each area border router summarizes the topology of its attached non backbone areas for transmission on the backbone, and hence to all other area border routers.

Through splitting a network into multiple areas, we can extend the network further. However, there are a number of issues when a network is split further into more areas.

At first, dividing an AS or an area into multiple areas is a very challenging task since it is involved in significant network architecture changes.

Secondly, it is complex for a Multi-Protocol Label Switching (MPLS) Traffic Engineering (TE) Label Switching Path (LSP) crossing multiple areas to be setup. In general, a TE path crossing multiple areas is computed by using collaborating Path Computation Elements (PCEs) [[RFC5441](#)] through the PCE Communication Protocol (PCEP) [[RFC5440](#)], which is not easy to configure by operators since the manual configuration of the sequence of domains is required. Although this issue can be addressed by using the Hierarchical PCE, this solution may further increase the complexity of network design. Especially, the current PCE standard method may not guarantee that the path found is optimal.

Thirdly, some policies need to be configured on area border routers for reducing the number of link states such as summary Link-State Advertisements (LSAs) to be distributed to other routers in other areas.

Furthermore, route convergence may be slower. A router in an OSPF area can see all other routers in the same area. A link-state change anywhere in an OSPF area will be populated everywhere in the same area, and may even be distributed to other areas in the same AS



indirectly. For example, all the routers and links in a Point-Of-Presence (POP) in an OSPF area will be seen by all the other routers in the same area. Any link state change in the POP will be distributed to all the other routers in the same area and may be distributed to routers in other areas indirectly.

A link state change in an area will lead to every router in the same area to re-calculate its OSPF routes, update its RIB and FIB. It may also lead to a number of link state distributions to other areas. This will trigger routers in other areas to re-calculate their OSPF routes, update their RIBs and FIBs. Thus the route convergence is slower.

This document presents a topology-transparent zone in a domain or an area and describes extensions to OSPFv2 for supporting the topology-transparent zone, which may resolve the issues above.

A topology-transparent zone comprises a group of routers and a number of links connecting these routers. Any router outside of the zone is not aware of the zone. The information about the links and routers inside the zone is not distributed to any router outside of the zone. Any link state change such as a link down inside the zone is not seen by any router outside of the zone.

## **2. Conventions Used in This Document**

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

## **3. Requirements**

Topology-Transparent Zone (TTZ) may be deployed for resolving some critical issues such as scalability in existing networks and future networks. The requirements for TTZ are listed as follows:

- o TTZ MUST support at least one more levels of network hierarchies, in addition to the hierarchies supported by existing routing protocols.
- o Users SHOULD be able to easily set up an end to end service crossing TTZs.
- o TTZ MUST be backward compatible. When a TTZ is deployed on a set of routers in a network, the routers outside of the TTZ in the network do not need to know or support TTZ.



- o The configuration for a TTZ in a network SHOULD be minimum.
- o The changes on the existing protocols for supporting TTZ SHOULD be minimum.

## **4. Topology-Transparent Zone**

### **4.1. Overview of Topology-Transparent Zone**

A Topology-Transparent Zone (TTZ) comprises an Identifier (ID), a group of routers and a number of links connecting the routers. A Topology-Transparent Zone is in an OSPF domain.

The ID of a Topology-Transparent Zone (TTZ) or TTZ ID is a number that is unique for identifying an entity such as a node in an OSPF domain. It is not zero in general.

In addition to having the functions of an OSPF area, an OSPF TTZ makes some improvements on an OSPF area, which include:

- o An OSPF TTZ is virtualized as an object, which may be a group of TTZ edge routers connected or a single router.
- o An OSPF TTZ receives the link state information about the topology outside of the TTZ, stores the information in the TTZ and floods the information through the TTZ to the routers outside of TTZ.

### **4.2. An Example of TTZ**

#### **4.2.1. Creation of a TTZ**

The figure below illustrates an example of a routing domain containing a topology-transparent zone: TTZ 600.





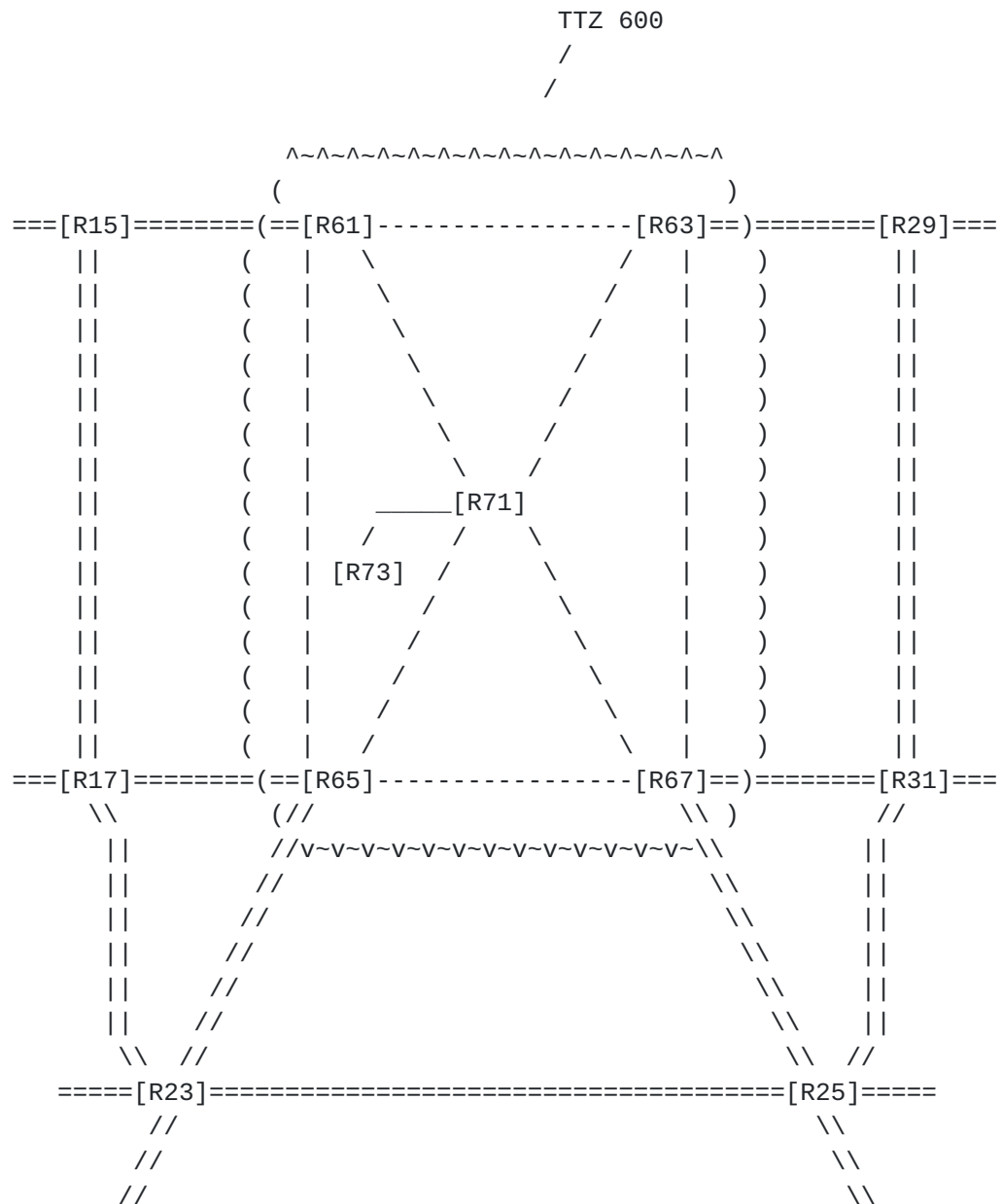


Figure 1: An Example of TTZ

The routing domain comprises routers R15, R17, R23, R25, R29 and R31. It also contains a topology-transparent zone TTZ 600. The TTZ 600 comprises routers R61, R63, R65, R67, R71 and R73, and the links connecting them.

There are two types of routers in a Topology-Transparent Zone (TTZ): TTZ internal routers and TTZ edge routers. A TTZ internal router is a router inside the TTZ and every adjacent router of the TTZ internal router is a router inside the TTZ. A TTZ edge router is a router



inside the TTZ and has at least one adjacent router that is outside of the TTZ.

The TTZ in the figure above comprises four TTZ edge routers R61, R63, R65 and R67. Each TTZ edge router is connected to at least one router outside of the TTZ. For instance, router R61 is a TTZ edge router since it is connected to router R15, which is outside of the TTZ.

In addition, the TTZ comprises two TTZ internal routers R71 and R73. A TTZ internal router is not connected to any router outside of the TTZ. For instance, router R71 is a TTZ internal router since it is not connected to any router outside of the TTZ. It is just connected to routers R61, R63, R65, R67 and R73 inside the TTZ.

A TTZ MUST hide the information inside the TTZ from the outside. It MUST NOT directly distribute any internal information about the TTZ to a router outside of the TTZ.

For instance, the TTZ in the figure above MUST NOT send the information about TTZ internal router R71 to any router outside of the TTZ in the routing domain; it MUST NOT send the information about the link between TTZ router R61 and R65 to any router outside of the TTZ.

In order to create a Topology-Transparent Zone (TTZ), we MUST configure the same TTZ ID on every link that connects routers inside the TTZ and every router in the TTZ MUST support TTZ feature.

For example, the same TTZ ID is configured on the nine links below:

- o the link between router R61 and R65,
- o the link between router R65 and R67,
- o the link between router R67 and R63,
- o the link between router R63 and R61,
- o the link between router R71 and R61,
- o the link between router R71 and R63,
- o the link between router R71 and R65,
- o the link between router R71 and R67 and



- o the link between router R71 and R73.

Thus six routers R61, R63, R65, R67, R71 and R73, and nine links among these six routers form a topology-transparent zone TTZ 600 in the figure above.

#### **4.2.2. TTZ as a Group of Edge Routers Connected**

From a router outside of the TTZ, a TTZ is seen as a group of TTZ edge routers fully connected when the TTZ is virtualized as the group of TTZ edge routers connected. For instance, router R15 in the figure above, which is outside of TTZ 600, sees TTZ 600 as a group of TTZ edge routers: R61, R63, R65 and R67. These four TTZ edge routers are fully connected.

In addition, a router outside of the TTZ sees TTZ edge routers having normal connections to the routers outside of the TTZ. For example, router R15 sees four TTZ edge routers R61, R63, R65 and R67, which have the normal connections to R15, R29, R17 and R23, R25 and R31 respectively.

#### **4.2.3. TTZ as a Single Router**

A TTZ is seen as a single router from a router outside of the TTZ when the TTZ is virtualized as a single router. For instance, router R15 in the figure above, which is outside of TTZ 600 and connected to TTZ 600 through TTZ edge router R61, sees TTZ 600 as a single router.

A router outside of a TTZ sees a number of links connected to the TTZ as a single router, each of which is connected to a router outside of the TTZ. For instance, router R15 sees TTZ 600 as a single router with six links, connecting to router R15, R17, R23, R25, R29 and R31 respectively.

A TTZ as a special single router considers every connection between a router outside of the TTZ and an edge router of the TTZ as a link. The Router ID of the virtualized representation of the TTZ SHOULD be the largest or smallest interface IP address of the TTZ-DR (see [Section 6.3.1](#)).

### **5. Changes to OSPF Protocols in Router LSA**

#### **5.1. One Bit to Indicate an Internal TTZ Link**

A router LSA contains the description of a number of router links. The existing format of a router LSA is illustrated as follows:



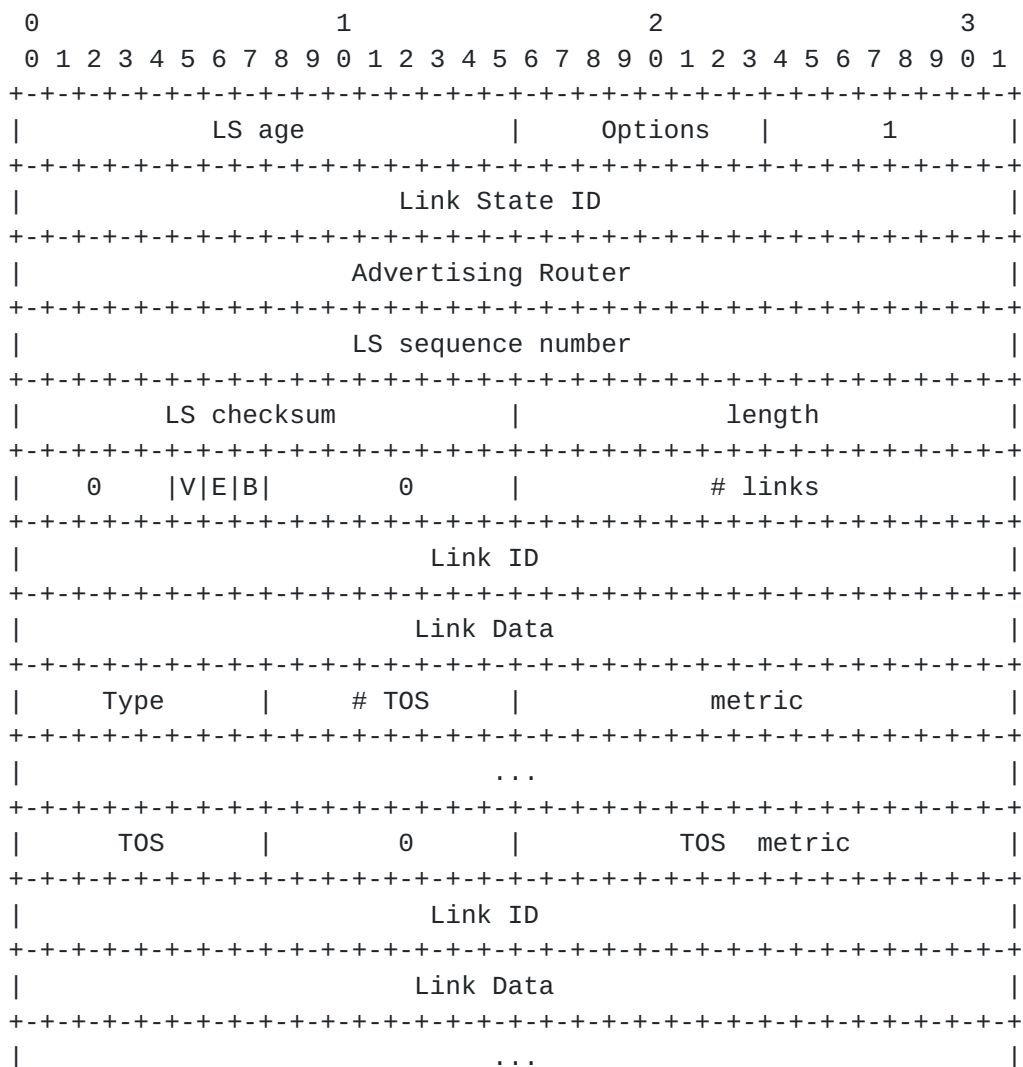


Figure 2: Format of Router LSA

For a router link, the value of an eight bit Type field indicates the kind of the link. The value of the Type field may be 1, 2, 3 or 4, which indicates that the kind of the link is a point-to-point connection to another router, a connection to a transit network, a connection to a stub network, or a virtual link respectively.

The existing eight bit Type field for a router link may be split into two fields as follows:





```

    0   1   2   3   4   5   6   7
+---+---+---+---+---+---+---+
| I |           Type-1           |
+---+---+---+---+---+---+---+

```

I bit flag:

1: This indicates that the router link is an internal link to a router inside the TTZ.

0: This indicates that the router link is an external link.

Type-1:

The kind of the link.

Figure 3: Bit to Indicate Internal TTZ Link

For a link inside a TTZ, the value of I bit flag is set to one, indicating that this link is an internal TTZ link. For a link connecting to a router outside of a TTZ from a TTZ edge router, the value of I bit flag is set to zero, indicating that this link is an external TTZ link.

The value of Type-1 field may have value 1, 2, 3, or 4, which indicates that the kind of a link being described is a point-to-point connection to another router, a connection to a transit network, a connection to a stub network, or a virtual link respectively.

## 6. Constructing Router LSA

Two types of router LSAs are generated. One is constructed by every router in a TTZ for the router to describe the links connecting to it. The other is generated by some routers in the TTZ to virtualize the TTZ as a group of edge routers connected or a single router.

### 6.1. Router LSA for a Router in TTZ

Every router in a TTZ constructs a router LSA for the router that comprises both the router links connecting the routers inside the TTZ and the router links connecting to the routers outside of the TTZ. It sends this router LSA to its neighboring routers in the TTZ. For each of the router links in the router LSA, it can be represented in one of the ways described in the previous section.



For example, when "One Bit to Indicate an Internal TTZ Link" is used as an extension to the link type, for each of the router links in the router LSA, the value of I bit flag is set to one for an internal link inside the TTZ; and the value of I bit flag is set to zero for an external link connecting to a router outside of the TTZ; the value of Type-1 field may have value 1, 2, 3, or 4, which indicates that the kind of a link being described is a point-to-point connection to another router, a connection to a transit network, a connection to a stub network, or a virtual link respectively.

When a router inside a TTZ receives a TTZ internal link state such as a router LSA from a neighboring router in the TTZ, it stores the link state and floods the link state to the other neighboring routers in the TTZ.

When a TTZ edge router receives a TTZ internal link state such as a router LSA for a router inside the TTZ from a neighboring router in the TTZ, it stores the link state and floods the link state to the other neighboring routers inside the TTZ. It does not flood the link state to any of its neighboring routers outside of the TTZ.

## **6.2. Router LSAs for TTZ as a Group of Edge Routers**

For every edge router of a TTZ, in addition to generate a router LSA described above, it constructs a second router LSA and sends this second router LSA to its neighboring routers. The second router LSA comprises two groups of links.

The first group of links are the router links connecting the routers outside of the TTZ from this TTZ edge router. These router links are normal router links. There is a router link for every adjacency between this TTZ edge router and a router outside of the TTZ.

The second group of links are the "virtual" router links. For each of the other TTZ edge routers, there is a "virtual" router link to it from this TTZ edge router. The cost of the router link from this TTZ router to one of the other TTZ edge routers may be the cost of the shortest path from this TTZ edge router to it.

In addition, the LSA may contain a third group of links, which are stub links for the routes in the TTZ to be distributed to outside of the TTZ.

## **6.3. Router LSA for TTZ as a Router**



### **6.3.1. Selection of TTZ-DR for TTZ**

Every TTZ has a TTZ Designated Router (TTZ-DR). The TTZ-DR originates LSAs for the TTZ.

The TTZ-DR for a TTZ is elected as follows: When a TTZ router first becomes functional, it checks to see whether there is currently a TTZ-DR for the TTZ. If there is, it accepts that TTZ-DR, regardless of its router ID. Otherwise, the router itself becomes TTZ-DR if it has the highest router ID among all the TTZ routers.

The procedure for selecting a TTZ-DR for a TTZ is described as follows: Call the TTZ router doing the selection Router X. The TTZ routers in the TTZ are considered.

1. Set TTZ-DR and TTZ-BDR to 0.
2. Set TTZ-BDR to the router ID of the TTZ router that has the highest router ID among all the TTZ routers and is not the TTZ-DR.
3. Set TTZ-DR to TTZ-BDR if there is not a TTZ-DR in the TTZ.
4. If router X becomes a newly elected TTZ-DR or TTZ-BDR, or is now no longer the TTZ-DR or the TTZ-BDR, then repeat step 2. and 3. above.
5. If router X becomes the TTZ-DR, then it originates LSAs for the TTZ.

The procedure for selecting the TTZ-DR is triggered by the events: a new TTZ router becomes functional or an existing TTZ router leaves the TTZ.

### **6.3.2. Constructing Router LSA for TTZ as a Router**

For the TTZ-DR in a TTZ, in addition to generate a router LSA described above, it constructs a second router LSA or special router LSA for the TTZ as a special single router and sends this second router LSA to its neighboring routers.

The second router LSA comprises all the router links connecting the routers outside of the TTZ from any TTZ edge router. The Link State ID and Advertising Router of the router LSA is the ID of the special router for the TTZ.

When the TTZ-DR in the TTZ constructs and sends an OSPF packet to its neighboring routers, it sets the Router ID in the packet header of



the packet to the router ID of the special router for the TTZ.

The router ID of the special router can be the largest interface IP address of the TTZ-DR if it is not the router ID of the TTZ-DR; otherwise, it can be the smallest interface IP address of the TTZ-DR.

A procedure for constructing all the router links of a Special Router LSA (SRL) on the TTZ-DR is described below in pseudo code. From the point of view of the router outside of the TTZ, this Special Router LSA (SRL) does not contain any TTZ specific information, it is just a normal router LSA containing router links from the router for the TTZ to the routers outside of the TTZ.

```
N = 0;
For each router LSA in the TTZ
{
  For each router link in the router LSA
  {
    If the router link is an external link
    {
      N = N + 1;
      Add the router link into router LSA SRL as a normal link;
    }
    Else If the router link is a stub link
    {
      N = N + 1;
      Add the router link into router LSA SRL and set cost to 0;
    }
  }
}
Set the value of Number of Links field in router LSA SRL to N;
```

Figure 4: Procedure for Constructing Router LSA for TTZ

In the procedure above, N is a variable for counting the number of links that the TTZ as a single router has. Each router LSA in the TTZ is a router LSA that is generated by a router inside the TTZ and is sent to routers inside the TTZ.

When "One Bit to Indicate an Internal TTZ Link" is used as an extension to the link type, the value of I bit flag is set to one for an internal link inside the TTZ, and the value of I bit flag is set to zero for an external link connecting to a node outside of the TTZ. Thus the condition of the If statement is true if the I bit flag in the router link is zero.





In the body of the If statement, the router link for the external link is added into the router LSA SRL as a normal link. The value of Type field for the router link is set to the kind of the link, which may be 1, 2, 3, or 4, indicating the kind of the link being described is a point-to-point connection to another router, a connection to a transit network, a connection to a stub network, or a virtual link respectively.

## **7. Establishing Adjacencies**

A router in a TTZ forms an adjacency with another router in the TTZ in the same way as a normal router when these two routers have a connection.

An alternative way for forming an adjacency between two routers in a TTZ is to extend hello protocol. Hello protocol is extended to include TTZ ID in hello packets. The procedure for handling hellos is changed to consider TTZ ID. When two routers have the same TTZ IDs in their hellos, an adjacency between these two routers is to be formed.

For an edge router in a TTZ, in addition to establishing adjacencies with other routers in the TTZ that have connections with the edge router, it forms an adjacency with any router outside of the TTZ that has a connection with the edge router.

When the edge router in the TTZ forms the adjacency with the router outside of the TTZ, there are a few of options. A first option is that it acts as a TTZ edge router, which is one of the group of edge routers for TTZ; A second option is that it acts as a special single router for the TTZ.

### **7.1. Group of Edge Routers for TTZ**

An edge router of a TTZ, acting as one of the group of edge routers for the TTZ, forms an adjacency with a router outside of the TTZ in a way descibed below.

During and after the adjacency establishment, every OSPF protocol packet such as Database Decription, which is sent to the router outside of the TTZ by the edge router, contains the edge router identifier (ID) as Router ID.

When the edge router synchronizes its link state database with the router outside of the TTZ, it sends the router outside of the TTZ the information about all the LSAs except for the LSAs belong to the TTZ that are hidden from any router outside of the TTZ.



At the end of the link state database synchronization, the edge router originates its own router LSA and sends this LSA to the router outside of the TTZ. This router LSA contains two groups of links.

The first group of links are the router links connecting to the routers outside of the TTZ from this TTZ edge router. The second group of links are the "virtual" router links connecting to the other TTZ edge routers from this TTZ edge router.

From the point of view of the router outside of the TTZ, it sees the other end as a normal router and forms the adjacency in the same way as a normal router. It is not aware of anything about its neighboring TTZ. From the LSAs related to the TTZ edge router in the other end, it knows that the TTZ edge router is connected to each of the other TTZ edge routers and some routers outside of the TTZ.

## **7.2. Single Router for TTZ**

An edge router of a TTZ, acting as a special single router for the TTZ, forms an adjacency with a router outside of the TTZ in a way described below.

During and after the adjacency establishment, every OSPF protocol packet such as Database Description, which is sent to the router outside of the TTZ by the edge router, contains the special single router ID as Router ID.

When the edge router synchronizes its link state database with the router outside of the TTZ, it sends the router outside of the TTZ the information about all the LSAs except for the LSAs belong to the TTZ that are hidden from any router outside of the TTZ.

At the end of the link state database synchronization, the router LSA for the TTZ is originated and sent to the router outside of the TTZ. This router LSA contains the router links from every TTZ edge router to routers outside of the TTZ.

From the point of view of the router outside of the TTZ, it sees the other end as a normal single router and forms the adjacency in the same way as a normal router. It is not aware of anything about its neighboring TTZ. From the LSAs related to the special router in the other end, it knows that the special router for the TTZ is connected to the routers outside of the TTZ having connections to edge routers of the TTZ.



## **8. Distribution of LSAs**

LSAs can be divided into two classes according to their distributions. One class of LSAs is distributed within a TTZ. The other is distributed through a TTZ.

### **8.1. Distribution of LSAs within TTZ**

Any LSA about a link state in a TTZ is distributed within the TTZ. It will not be distributed to any router outside of the TTZ.

For example, any router LSA generated for a router in a TTZ is distributed within the TTZ. It will not be distributed to any router outside of the TTZ.

Any network LSA generated for a broadcast or NBMA network inside a TTZ is distributed within the TTZ. It will not be distributed to any router outside of the TTZ.

Any opaque LSA generated for a TTZ internal TE link is distributed within the TTZ. It will not be distributed to any router outside of the TTZ.

### **8.2. Distribution of LSAs through TTZ**

Any LSA about a link state outside of a TTZ received by an edge router of the TTZ is distributed through the TTZ; and any LSA about a link state for the TTZ is distributed through the TTZ.

For example, when an edge router of a TTZ receives an LSA for a link state outside of the TTZ from a router outside of the TTZ, it floods it to its neighboring routers both inside the TTZ and outside of the TTZ. This LSA may be any LSA such as a router LSA and an opaque LSA that is distributed in a domain.

The routers in the TTZ continue to flood the LSA. When another edge router of the TTZ receives the LSA, it floods the LSA to its neighboring routers both outside of the TTZ and inside the TTZ.

In the case that a TTZ is virtualized as a group of edge routers of the TTZ connected, every edge router of the TTZ generates a router LSA for the TTZ. This LSA is distributed to the routers outside of the TTZ and to the routers inside the TTZ.

In the case that a single router is for a TTZ, the special router LSA generated for the TTZ is distributed through the TTZ.

When an edge router in a TTZ, acting as a special router for the TTZ,



generates a network LSA for a broadcast or NBMA network connecting the TTZ edge router to a router outside of the TTZ, it sends the network LSA to its neighboring routers outside of the TTZ. It also sends this network LSA to its neighboring routers inside the TTZ.

When another TTZ edge router in the same TTZ receives the network LSA generated by the TTZ edge router, it acting as the special router for the TTZ sends the network LSA to its neighboring routers outside of the TTZ.

## 9. Computation of Routing Table

The computation of the routing table on a router outside of a TTZ is the same as that described in [RFC 2328](#). On a router inside the TTZ, it has the same procedure flow as that described in [RFC 2328](#), but extends the meaning of a link and an association between two vertexes. In this section, we specify the extensions, and describe the routing table computation on a router inside the TTZ.

A link between two vertexes can be a TTZ link. It can also be a normal link.

When examining the LSA associated with vertex V, for each link described in the LSA, supposing that vertex W is the other end of the link,

- o if it is a normal link, then vertex W is an adjacent vertex of vertex V;
- o if it is an internal TTZ link and the LSA is generated by a router in a TTZ, then vertex W can be considered as an adjacent vertex of vertex V;
- o if it is an external TTZ link and the LSA is generated for the TTZ, then vertex W, which is the other end of the external TTZ link and outside of the TTZ, can be considered as an adjacent vertex of vertex V.

When a TTZ is virtualized as a group of TTZ edge routers fully connected, the routing table on a router inside the TTZ is computed through using the link state database (LSDB) containing the LSAs for the topology of the TTZ and the LSAs for the topology outside of the TTZ. That is that the shortest path to every destination both inside the TTZ and outside of the TTZ is computed over all the links including the links inside the TTZ and the links outside of the TTZ.

When a TTZ is virtualized as a special single router, the routing





table on a router inside the TTZ is computed in the following way.

The cost/metric of a link (including external TTZ link) outside of the TTZ is considered as a special type of metrics. This type of metrics is an order of magnitude larger than that of metrics of a link inside the TTZ. That is that any metric of this special type is considered greater than the cost of any path internal to the TTZ. The path to every destination is computed through constructing a shortest path tree from the router in the TTZ to every destination.

## **10. Security Considerations**

The mechanism described in this document does not raise any new security issues for the OSPF protocols.

## **11. IANA Considerations**

## **12. Acknowledgement**

The author would like to thank Acee Lindem, Dean Cheng, Lin Han and Yang Yu for their valuable comments on this draft.

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