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IS-IS Topology-Transparent Zone
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Abstract

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

Status of this Memo

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Table of Contents

1. Introduction 3
2. Conventions Used in This Document 4
3. Requirements 4
4. Topology-Transparent Zone 4
  4.1. Overview of Topology-Transparent Zone 4
  4.2. An Example of TTZ 5
5. Extensions to IS-IS Protocols 6
  5.1. TTZ TLV 6
6. Updating LSPs for TTZ 9
  6.1. Updating LSP for a TTZ Internal Router 9
  6.2. Updating LSP for a TTZ Edge Router 9
7. Establishing Adjacencies 10
  7.1. Discover TTZ Neighbor over Normal Adjacency 10
  7.2. Establishing TTZ Adjacencies 10
  7.3. Adjacency between TTZ Edge and Router outside 10
8. Distribution of LSPs 11
  8.1. Distribution of LSPs within TTZ 11
  8.2. Distribution of LSPs through TTZ 11
9. Computation of Routing Table 12
10. Operations 12
  10.1. Configuring TTZ 12
  10.2. Smooth Migration to TTZ 13
  10.3. Adding a Router into TTZ 14
11. Security Considerations 14
12. IANA Considerations 14
13. Contributors 15
14. Acknowledgement 15
15. Normative References 15
Authors' Addresses 16

1. Introduction

ISO/IEC 10589 describes IS-IS areas or levels in an Autonomous System (AS). Each level 1 area has a number of level 1 and level 2 routers connected to the level 2 area. Each level 1 and level 2 router may summarize the topology of its attached level 1 areas to the level 2 area or vice versa.

The number of routers in a network becomes larger and larger as the Internet traffic keeps growing. Through splitting the 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 a network from one area into multiple areas or from a number of existing areas to even more areas is a very challenging and time consuming task since it is involved in significant network architecture changes.

Secondly, the services carried by the network may be interrupted while the network is being split from one area into multiple areas or from a number of existing areas into even more areas.

Furthermore, it is complex for a Multi-Protocol Label Switching (MPLS) Traffic Engineering (TE) Label Switching Path (LSP) crossing multiple areas to be setup. In one option, 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.

This document presents a topology-transparent zone in a domain or an area and describes extensions to IS-IS for supporting the topology-transparent zone, which is scalable and resolves the issues above.

A topology-transparent zone comprises a group of routers and a number of circuits connecting these routers. Any router outside of the zone is not aware of the zone. The information about the circuits and routers inside the zone is not distributed to any router outside of the zone. Any link state change such as a circuit 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 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 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 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) is identified by an Identifier (ID), and it includes a group of routers and a number of circuits connecting the routers. A TTZ is in an IS-IS domain (area).

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

In addition to having the functions of an IS-IS level or area, an IS-IS TTZ makes some improvements on an IS-IS level or area, which include:

- o An IS-IS TTZ is virtualized as the TTZ edge routers connected.

- o An IS-IS 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

The figure below illustrates an example of a routing domain containing a TTZ: TTZ 600.

```
                 TTZ 600
                   \
                    \ ^~^~^~^~^~^~^~^~^~^~^~^~
                     (                        )
    ===[R15]========(==[R61]------------[R63]==)======[R29]===
        ||         (   |    \          /    |   )       ||
        ||         (   |     \        /     |   )       ||
        ||         (   |      \      /      |   )       ||
        ||         (   |    ___\    /       |   )       ||
        ||         (   |   /   [R71]        |   )       ||
        ||         (   | [R73] /    \       |   )       ||
        ||         (   |      /      \      |   )       ||
        ||         (   |     /        \     |   )       ||
        ||         (   |    /          \    |   )       ||
    ===[R17]========(==[R65]------------[R67]==)======[R31]===
         \\          (//                    \\)       //
          ||         //v~v~v~v~v~v~v~v~v~v~v~\\      ||
          ||        //                        \\     ||
          ||       //                          \\    ||
           \\     //                            \\  //
       ======[R23]==============================[R25]=====
             //                                     \\
            //                                       \\
```

Figure 1: An Example of TTZ

The routing domain comprises routers R15, R17, R23, R25, R29 and R31. It also contains TTZ 600, which comprises routers R61, R63, R65, R67, R71 and R73, and the circuits connecting them.

There are two types of routers in a TTZ: TTZ internal routers and TTZ edge routers. A TTZ internal router is a router inside the TTZ and its adjacent routers are 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 circuit between TTZ router R61 and R65 to any router outside of the TTZ.

In order to create a TTZ, we MUST configure the same TTZ ID on the edge routers and identify the TTZ internal circuits on them. In addition, we SHOULD configure the TTZ ID on every TTZ internal router which indicates that every circuit of the router is a TTZ internal circuit.

From a router outside of the TTZ, a TTZ is seen as a group of routers fully 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.

5. Extensions to IS-IS Protocols

5.1. TTZ TLV

A new TLV, which is called TTZ TLV, may be added into a link state PDU(LSP) or a Hello PDU for a TTZ node. It has the following format.

```
                   TTZ TLV          Length in Byte
             +----------------------+
             |      Type = TBD      |  1
             +----------------------+
             |        Length        |  1
             +----------------------+
             |         Flags        |  2
             +----------------------+
             |        TTZ  ID       |  4
             +----------------------+
             |       Sub-TLVs       |  Length of Sub-TLVs
             +----------------------+
```

Figure 2: TTZ TLV

A TTZ TLV has 1 byte of Type, 1 byte of Length of the value field of the TLV, which is followed by 2 bytes of Flags and 4 bytes of TTZ ID. A TTZ TLV in an LSP may contains a number of sub TLVs and have Flags defined as follows.

```
     0                   1
     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |E|T|M|N|R|    0                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    E = 1: Edge router of TTZ
    T = 1: Distributing TTZ Topology Information for Migration
    M = 1: Migrating to TTZ
    N = 1: Distributing Normal Topology Information for Rollback
    R = 1: Rolling back from TTZ
```

When a router in a TTZ receives a CLI command triggering TTZ information distribution for migration, it updates its LSP by adding a TTZ TLV with T set to 1. When a router in a TTZ receives a CLI command activating migration to TTZ, it sets M to 1 in the TTZ TLV in its LSP.

Two new sub-TLVs are defined, which may be added into a TTZ TLV in an LSP. One is TTZ IS Neighbor sub-TLV, or TTZ ISN sub-TLV for short. The other is TTZ ES Neighbor sub-TLV, or TTZ ESN sub-TLV for short. A TTZ ISN sub-TLV contains the information about a number of TTZ IS neighbors connected to a TTZ edge router. It has the format below.

```
    TTZ ISN sub-TLV      Length in Byte
+----------------------+
|    Sub-Type = 1      |  1
+----------------------+
|        Length        |  n*(IDLength + 5)
+----------------------+
|   Default Metric(i)  |  1
+----------------------+
|   Delay Metric(i)    |  1
+----------------------+
|   Expense Metric(i)  |  1
+----------------------+
|   Error Metric(i)    |  1
+----------------------+
|    Neighbor ID(i)    |  IDLength + 1
+----------------------+
```

Figure 3: TTZ ISN sub TLV

A TTZ ESN sub-TLV contains the information about a number of TTZ ES neighbors connected to a TTZ edge router. It has the format below.

```
    TTZ ESN sub-TLV      Length in Byte
+----------------------+
|    Sub-Type = 2      |  1
+----------------------+
|        Length        |  4 + n*IDLength
+----------------------+
|    Default Metric    |  1
+----------------------+
|    Delay Metric      |  1
+----------------------+
|    Expense Metric    |  1
+----------------------+
|    Error Metric      |  1
+----------------------+
|    Neighbor ID       |  IDLength
+----------------------+
|    . . . . . .       |
+----------------------+
|    Neighbor ID       |  IDLength
+----------------------+
```

Figure 4: TTZ ESN sub TLV

6. Updating LSPs for TTZ

6.1. Updating LSP for a TTZ Internal Router

A TTZ internal router adds a TTZ TLV into its LSP after it receives an LSP containing a TTZ TLV with T = 1 or a CLI command triggering TTZ information distribution for migration. The TLV has a TTZ ID set to the ID of the TTZ and E bit in Flags set to 0 indicating TTZ internal router. The router floods its LSP to its neighbors in the TTZ.

When a router inside the TTZ receives a link state packet (LSP) containing a TTZ TLV 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.

6.2. Updating LSP for a TTZ Edge Router

For every edge router of a TTZ, it updates its LSP in three steps and floods the LSP to all its neighbors.

At first, a TTZ edge router adds a TTZ TLV into its LSP after it receives an LSP containing a TTZ TLV with T = 1 or a CLI command triggering TTZ information distribution for migration. The TLV has a TTZ ID set to the ID of the TTZ, E bit in Flags set to 1 indicating TTZ edge router and a TTZ ISN sub TLV. The sub TLV contains the information about the TTZ IS neighbors connected to the TTZ edge router. In addition, the TLV may has a TTZ ESN sub TLV comprising the information about the TTZ end systems connected to the TTZ edge router.

Secondly, it adds each of the other TTZ edge routers as an IS neighbor into the Intermediate System Neighbors TLV in the LSP after it receives an LSP containing a TTZ TLV with M = 1 or a CLI command activating migration to TTZ. The metric to the neighbor is the metric of the shortest path to the edge router within the TTZ.

In addition, it adds a Prefix Neighbors TLV into its LSP. The TLV contains a number of address prefixes in the TTZ to be reachable from outside of the TTZ.

And then it removes the IS neighbors corresponding to the IS neighbors in the TTZ TLV (i.e., in the TTZ ISN sub TLV) from Intermediate System Neighbors TLV in the LSP, and the ES neighbors corresponding to the ES neighbors in the TTZ TLV (i.e., in the TTZ ESN sub TLV) from End System Neighbors TLV in the LSP. This SHOULD be done after it receives the LSPs for virtualizing TTZ from the other TTZ edges for a given time.

7. Establishing Adjacencies

7.1. Discover TTZ Neighbor over Normal Adjacency

For two routers A and B connected by a P2P circuit and having a normal adjacency, they discover TTZ each other through including a TTZ TLV containing a TTZ ID in their hello packets. If two ends of the circuit have the same TTZ ID, A and B are TTZ neighbors; otherwise, they are not TTZ neighbors, but normal neighbors.

For a number of routers connected through a broadcast circuit and having normal adjacencies among them, they also discover TTZ each other through including a TTZ TLV containing a TTZ ID in their hello packets. The DIS for the circuit "forms" TTZ adjacency with each of the other routers if all the routers attached to the circuit have the same TTZ ID configured on the connections to the circuit and included in their hello packets; otherwise, they are not TTZ neighbors, but still normal neighbors.

7.2. Establishing TTZ Adjacencies

When a router (say A) is connected via a P2P circuit to another router (say B) and there is not any adjacency between them over the circuit, a user configures TTZ on two ends of the circuit to form a TTZ adjacency.

Routers A and B include a TTZ TLV containing a TTZ ID in their hello packets. If two routers have the same TTZ IDs in their hellos, an adjacency between these two routers is to be formed; otherwise, no adjacency is formed.

For a number of routers connected through a broadcast circuit and having no adjacency among them, they start to form TTZ adjacencies after TTZ is configured on the circuit and a TTZ TLV with a TTZ ID is included in their hello packets. The DIS for the circuit forms TTZ adjacency with each of the other routers if all the routers attached to the circuit have the same TTZ ID configured on the connections to the circuit and included in the hello packets; otherwise, the DIS does not form any adjacency with any router attached to the circuit.

7.3. Adjacency between TTZ Edge and Router outside

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 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 LSPs except for the LSPs 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 LSP and sends this LSP to the router outside of the TTZ. This LSP contains two groups of circuits.

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

8. Distribution of LSPs

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

8.1. Distribution of LSPs within TTZ

Any LSP generated for a TTZ internal router in a TTZ is distributed within the TTZ. It will not be distributed to any router outside of the TTZ.

Any pseudo node LSP generated for a broadcast network inside a TTZ, is distributed within the TTZ. It will not be distributed to any router outside of the TTZ.

8.2. Distribution of LSPs through TTZ

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

For example, when an edge router of a TTZ receives an LSP 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 LSP may be any LSP such as a router LSP that is distributed in a domain.

The routers in the TTZ continue to flood the LSP. When another edge router of the TTZ receives the LSP, it floods the LSP to its neighboring routers both outside of the TTZ and inside 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 ISO/SEC 10589. On a router in a TTZ, the computation of the routing table has the same procedure flow as that described in ISO/SEC 10589, with one exception. A router in a TTZ MUST ignore the circuits in the router LSPs generated by the edge routers of the TTZ for virtualizing the TTZ.

The routing table on a router inside the TTZ is computed through using the link state database (LSDB) containing the LSPs for the topology of the TTZ and the LSPs 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 circuits including the circuits inside the TTZ and the circuits outside of the TTZ.

10. Operations

10.1. Configuring TTZ

This section proposes some options for configuring a TTZ.

1. Configuring TTZ on Every Circuit in TTZ

If every circuit in a TTZ is configured with a same TTZ ID as a TTZ circuit, the TTZ is determined. A router with some TTZ circuits and some normal circuits is a TTZ edge router. A router with only TTZ circuits is a TTZ internal router.

2. Configuring TTZ on Every Router in TTZ

We may configure a same TTZ ID on every router in the TTZ, and on every edge router’s circuits connecting to the routers in the TTZ.

A router configured with the TTZ ID on some of its circuits is a TTZ edge router. A router configured with the TTZ ID only is a TTZ internal router. All the circuits on a TTZ internal router are TTZ circuits. This option is simpler than the above one.

10.2. Smooth Migration to TTZ

For a group of routers and a number of circuits connecting the routers in an area, making them transfer to work as a TTZ without any service interruption may take a few of steps.

At first, users configure the TTZ feature on every router in the TTZ. In this stage, a router does not update its LSPs. It will discover its TTZ neighbors.

Secondly, after configuring the TTZ, users issue a CLI command on one router in the TTZ, which triggers every router in the TTZ to distribute TTZ information among the routers in the TTZ. When the router receives the command, it updates its LSP by adding a TTZ TLV, and distributes the LSP to its TTZ neighbors. The LSP has T = 1 in Flags in the TTZ TLV (indicating TTZ information generation and distribution for migration). When a router in the TTZ receives the LSP with T = 1, it updates its LSP by adding a TTZ TLV. In this stage, every router in the TTZ has dual roles. One is to function as a normal router. The other is to generate and distribute TTZ information.

Thirdly, users may check whether every router in the TTZ is ready for transferring to work as a TTZ router. A router in the TTZ is ready after it has received all the necessary information from all the routers in the TTZ. This information may be displayed on a router through a CLI command.

And then users activate the TTZ through using a CLI command such as migrate to TTZ on one router in the TTZ. The router transfers to work as a TTZ router, updates its LSP with M = 1 in the TTZ TLV (indicating Migrating to TTZ) after it receives the command.

After a router in the TTZ receives the LSP with M = 1, it also transfers to work as a TTZ router. Thus, activating the TTZ on one TTZ router makes every router in the TTZ transfer to work as a TTZ router, which computes routes through using the TTZ topology and the topology outside of the TTZ.

For an edge router of the TTZ, transferring to work as a TTZ router comprises updating its LSP to virtualize the TTZ by adding each of the other TTZ edge routers as an IS neighbor and flooding this LSP to all its direct neighboring routers. And then, the TTZ edge router removes the IS neighbors corresponding to the IS neighbors in the TTZ TLV (i.e., in the TTZ ISN sub TLV) from Intermediate System Neighbors TLV in the LSP

10.3. Adding a Router into TTZ

When a non TTZ router (say R1) is connected via a P2P circuit to a TTZ router (say T1) working as TTZ and there is a normal adjacency between them over the circuit, a user can configure TTZ on two ends of the circuit to add R1 into the TTZ to which T1 belongs. They discover TTZ each other in the same way as described in section 7.1.

When a number of non TTZ routers are connected via a broadcast circuit to a TTZ router (say T1) working as TTZ and there are normal adjacencies among them, a user configures TTZ on the connection to the circuit on every router to add the non TTZ routers into the TTZ to which T1 belongs. The DIS for the circuit "forms" TTZ adjacency with each of the other routers if all the routers have the same TTZ ID configured on the connections to the circuit.

When a router (say R1) is connected via a P2P circuit to a TTZ router (say T1) and there is not any adjacency between them over the circuit, a user can configure TTZ on two ends of the circuit to add R1 into the TTZ to which T1 belongs. R1 and T1 will form an adjacency in the same way as described in section 7.2.

When a router (say R1) is connected via a broadcast circuit to a group of TTZ routers on the circuit and there is not any adjacency between R1 and any over the circuit, a user can configure TTZ on the connection to the circuit on R1 to add R1 into the TTZ to which the TTZ routers belong. R1 starts to form an adjacency with the DIS for the circuit after the configuration.

11. Security Considerations

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

12. IANA Considerations

This document requires the allocation for a new TLV and a couple of new sub TLVs in the new TLV. IANA is requested to assign a new Type (value 150 is suggested) for new TLV TTZ as follows:

Type	Name	IIH	LSP	SNP	Purge
150	TTZ	Y	Y	N	N

This document defines two new Sub-TLVs in TLV 150. The values below are suggested for them subject to assignment by IANA or Expert review.

Type	Name and Description
1	TTZ ISN, TTZ IS Neighbors
2	TTZ ESN, TTZ ES Neighbors

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15. Normative References

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

[RFC7142] Shand, M. and L. Ginsberg, "Reclassification of RFC 1142 to Historic", RFC 7142, February 2014.

[RFC1195] Callon, R., "Use of OSI IS-IS for routing in TCP/IP and dual environments", RFC 1195, December 1990.

[RFC5305] Li, T. and H. Smit, "IS-IS Extensions for Traffic Engineering", RFC 5305, October 2008.

[RFC5029] Vasseur, JP. and S. Previdi, "Definition of an IS-IS Link Attribute Sub-TLV", RFC 5029, September 2007.

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