Internet Engineering Task Force   H. Chen
Internet-Draft   R. Li
Intended status: Standards Track   A. Kumar S N
Expires: April 29, 2015   Huawei Technologies
                                                         G. Cauchie

                                                          A. Retana
                                                Cisco Systems, Inc.
                                                             N. So
                                                Tata Communications
                                                            V. Liu
                                                       China Mobile
                                                            M. Toy
                                                           Comcast
                                                            L. Liu
                                                           UC Davis
                                                  October 26, 2014

                     OSPF Topology-Transparent Zone
                        draft-chen-ospf-ttz-09.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.

Copyright Notice

Table of Contents

[1](#). **Introduction**

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. Considering the one area case, originally the network has only one area, which is the backbone. This original backbone area will be split into a new backbone and a number of non backbone areas. In general, each of the non backbone areas is connected to the new backbone area through the area border routers between the non backbone and the backbone area. There is not any direct connection between any two non backbone areas. Each area border router summarizes the topology of its attached non backbone area for transmission on the backbone area, and hence to all other area border routers.

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 an area and describes extensions to OSPF 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 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 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 links
   connecting the routers. A TTZ is in an OSPF 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 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 the TTZ edge routers connected.

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 the TTZ.

4.2. An Example of TTZ

The figure below shows an area 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]=====
          //                                      \\
         //                                        \\
```
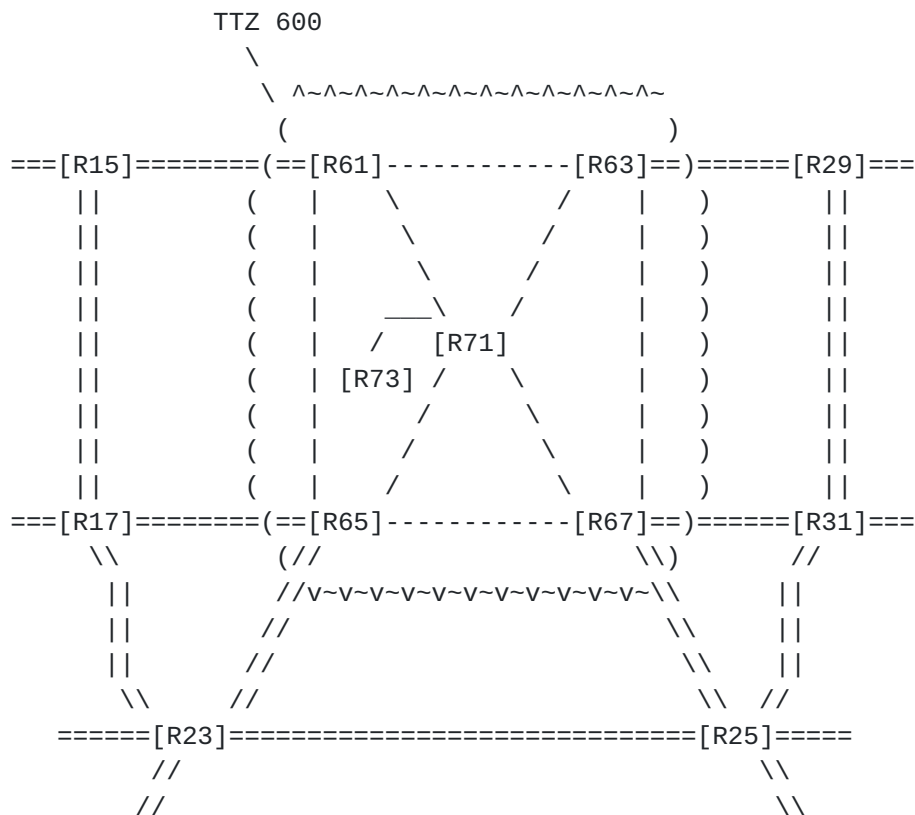
Figure 1: An Example of TTZ

The area 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 links 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 in 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 in 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 TTZ, we MUST configure the same TTZ ID on the
edge routers and identify the TTZ internal links on them. In
addition, we SHOULD configure the TTZ ID on every TTZ internal router
which indicates that every link of the router is a TTZ internal link.

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 OSPF Protocols

5.1. Opaque LSAs for TTZ

The link state information about a TTZ includes router LSAs and
network LSAs describing the TTZ topology. These LSAs can be
contained and distributed in opaque LSAs within the TTZ. Some
control information on a TTZ can also be contained and distributed in
opaque LSAs within the TTZ. These opaque LSAs are called TTZ opaque
LSAs or TTZ LSAs for short.

The following is a general form of a TTZ LSA. It has an LS type = 10
and TTZ-LSA-Type, and contains a number of TLVs.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |            LS age              |    Options    | LS Type = 10  |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | TTZ-LSA-type  |                 Opaque ID                     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      Advertising Router                       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      LS Sequence Number                       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        LS checksum             |            Length            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                                                              |
   ~                            TLVs                              ~
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where TTZ-LSA-type may be TBD1 (TTZ-RT-LSA-type) for TTZ Router LSA,
TBD2 (TTZ-NW-LSA-type) for TTZ Network LSA, and TBD3 (TTZ-CT-LSA-
type) for TTZ Control LSA.

There are four types of TLVs: TTZ ID TLV, TTZ Router TLV, TTZ network
TLV and TTZ Options TLV. A TTZ ID TLV has the following format. It
contains a TTZ ID.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        TTZ-ID-TLV-type         |           Length = 4          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                             TTZ ID                            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The format of a TTZ Router TLV is as follows. It contains the
contents of a normal router LSA. A TTZ router LSA includes a TTZ ID
TLV and a TTZ Router TLV.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        TTZ-RT-TLV-type        |           TLV-Length          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |G|   0   |V|E|B|       0       |            # links            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                            Link ID                            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                           Link Data                           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     Type      |    # TOS      |            metric             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   ~                             ...                               ~
```

Where G = 1/0 indicates that the router is an edge/internal router of
TTZ. For a router link, 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: Router link is an internal link to a router inside TTZ.
     0: This indicates that the router link is an external link.
   Type-1: The kind of the link.
```

For a link inside a TTZ, 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, I bit flag is set to zero,
indicating that this link is an external TTZ link.

The value of Type-1 may be 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.

A TTZ Network TLV has the following format. It contains the contents
of a normal network LSA. A TTZ network LSA includes a TTZ ID TLV and
a TTZ network TLV.

```
  0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |          TTZ-NW-TLV-type           |            TLV-Length          |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                           Network Id                            |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                          Network Mask                           |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                         Attached Router                         |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 ~                             ...                              ~
```

Where Network ID is the interface address of the DR, which is
followed by the contents of a network LSA.

The format of TTZ Options TLV is as follows. A TTZ control LSA
contains a TTZ ID TLV and a TTZ Options TLV.

```
  0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |         TTZ-OP-TLV-type            |             Length = 4           |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |T|M|N|R|     0                                                   |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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

5.2. A TTZ Capability TLV in Router Information LSA

A new bit such as bit 6 for TTZ capability may be defined in the
Router Informational Capabilities TLV as follows:

```
      Bit      Capabilities
      0        OSPF graceful restart capable [GRACE]
      :        ...
      5        OSPF Experimental TE [EXP-TE]
      6        OSPF TTZ capable [OSPF-TTZ]
      7-31     Unassigned (Standards Action)
```

When the OSPF TTZ capable bit is set to one, a TTZ capability TLV
must follow the Router Informational Capabilities TLV to indicate a
link/router's TTZ capability and the TTZ to which the link/router

belongs. It has the following format.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     TTZ-CAP-TLV-Type = 2      |             Length = 8        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                            TTZ ID                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |M|                           0                                 |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

It contains a TTZ ID and a number of TTZ bits. The following bits in
the TLV are assigned:

```
     Bit     Meaning
     M       Have Migrated to TTZ (i.e., works as TTZ)
     1-31    Unassigned (Standards Action)
```

A link scope RI LSA with a OSPF TTZ capable bit set to one and a TTZ
Capability TLV will be used to discover a TTZ neighbor.

6. Constructing LSAs for TTZ

There are three types of LSAs for representing a TTZ: TTZ router LSA,
TTZ network LSA and Router LSA for virtualizing TTZ. The first two
may be generated by a TTZ router, and the third by a TTZ edge router.

A TTZ router LSA generated by a TTZ router has a TTZ ID TLV and a TTZ
Router TLV. The former includes the ID of the TTZ to which the
router belongs. The latter contains the links to the router.

A TTZ network LSA for a broadcast link is generated by the DR for the
link. It contains a TTZ ID TLV and a TTZ network TLV. The former
has the ID of the TTZ to which the link belongs. The latter includes
the DR's address, the network mask, and the routers attached.

A router LSA for virtualizing a TTZ generated by an edge router of
the TTZ comprises three groups of links in general.

The first group are the router links connecting the routers outside
of the TTZ. 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 are the "virtual" router links. For each of the
other TTZ edge routers, there is a point-to-point router link to it.

The cost of the link may be the cost of the shortest path from this
TTZ edge router to it within the TTZ.

In addition, the LSA may contain a third group of links, which are
stub links for other destinations inside the TTZ. They may be the
loopback addresses to be accessed by a node outside of the TTZ.

[7](#). Establishing Adjacencies

This section describes the adjacencies in some different cases.

[7.1](#). Discover TTZ Neighbor over Normal Adjacency

For two routers A and B connected by a P2P link and having a normal
adjacency, they discover TTZ each other through a link scope RI LSA
with an OSPF TTZ capable bit and a TTZ ID. We call this LSA D-LSA
for short. If two ends of the link have the same TTZ ID, A and B are
TTZ neighbors. The following is a sequence of events related to TTZ.

```
          A                                    B
   Configure TTZ                          Configure TTZ
              D-LSA (TTZ-ID=100)
              --------------------------> Same TTZ ID
                                          A is B's TTZ Neighbor
              D-LSA (TTZ-ID=100)
   Same TTZ ID  <--------------------------
   B is A's TTZ Neighbor
```


A sends B a D-LSA with TTZ-ID after the TTZ is configured on it. B
sends A a D-LSA with TTZ-ID after the TTZ is configured on it. When
A receives the D-LSA from B and determines they have the same TTZ ID,
B is A's TTZ neighbor. When B receives the D-LSA from A and
determines they have the same TTZ ID, A is B's TTZ neighbor.

For a number of routers connected through a broadcast link and having
normal adjacencies among them, they also discover TTZ each other
through D-LSAs. The DR for the link "forms" TTZ adjacency with each
of the other routers if all the routers attached to the link have the
same TTZ ID configured on the connections to the link.

[7.2](#). Establishing TTZ Adjacencies

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

While A and B are forming an adjacency, they start to discover TTZ
each other through D-LSAs in the same way as described above after
the normal adjacency is greater than ExStart. When the normal
adjacency is full and B becomes A's TTZ neighbor, A forms a TTZ
adjacency with B. Similarly, B forms a TTZ adjacency with A.

For a number of routers connected through a broadcast link and having
no adjacency among them, they start to form TTZ adjacencies after TTZ
is configured on the link. While forming adjacencies, they discover
TTZ each other through D-LSAs in the same way as described above
after the normal adjacency is greater than ExStart. The DR for the
link forms TTZ adjacency with each of the other routers if all the
routers attached to the link have the same TTZ ID configured on the
connections to the link. Otherwise, the DR does not form any
adjacency with any router attached to the link.

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 LLS of a hello packet. The procedure for handling
hellos is changed to consider TTZ ID. 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.

7.3. Adjacency between TTZ Edge and Router outside

For an edge router in a TTZ, it forms an adjacency with any router
outside of the TTZ that has a connection with it.

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 belonging 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 for virtualizing the TTZ and
sends this LSA to the router outside of the TTZ.

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.

8. Distribution of LSAs

LSAs can be divided into a couple of classes according to their

distributions. The first class of LSAs is distributed within a TTZ.
The second 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 is not distributed to any router outside of the TTZ. For example,
a router LSA generated for a router in a TTZ is distributed within
the TTZ and not distributed to any router outside of the TTZ.

Any network LSA generated for a broadcast or NBMA network in a TTZ is
distributed in the TTZ and not sent to a router outside of the TTZ.

Any opaque LSA generated for a TTZ internal TE link is distributed
within the TTZ and not 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. For example, when
an edge router of a TTZ receives an LSA 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
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.

9. Computation of Routing Table

The computation of the routing table on a router is the same as that
described in RFC 2328, with one exception. A router in a TTZ MUST
ignore the router LSAs generated by the edge routers of the TTZ for
virtualizing the TTZ. It computes routes through using the TTZ
topology represented by TTZ LSAs and the topology outside of the TTZ.

10. Operations

10.1. Configuring TTZ

This section proposes some options for configuring a TTZ.

1. Configuring TTZ on Every Link in TTZ

If every link in a TTZ is configured with a same TTZ ID as a TTZ

   link, the TTZ is determined. A router with some TTZ links and some
   normal links is a TTZ edge router. A router with only TTZ links 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 links connecting to the routers in the TTZ.

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

10.2. Smooth Migration to TTZ

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

   At first, users configure the TTZ feature on every router in the TTZ.
   In this stage, a router does not originate its TTZ router LSA or TTZ
   network LSAs. It will discover its TTZ neighbors.

   Secondly, after configuring the TTZ, users may issue a CLI command on
   one router in the TTZ, which triggers every router in the TTZ to
   generate and distribute TTZ information among the routers in the TTZ.
   When the router receives the command, it originates its TTZ router
   LSA and TTZ network LSAs as needed, and distributes them to its TTZ
   neighbors. It also originates a TTZ control LSA with T=1 (indicating
   TTZ information generation and distribution for migration). When a
   router in the TTZ receives the LSA with T=1, it originates its TTZ
   router LSA and TTZ network LSAs as needed. 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 SHOULD 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 may 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, generates and distributes a TTZ control LSA
   with M=1 (indicating Migrating to TTZ) after it receives the command.

   After a router in the TTZ receives the TTZ control LSA 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 flushes its normal router LSA and network LSAs,
computes routes through using the TTZ topology represented by TTZ
LSAs and the topology outside of the TTZ.

For an edge router of the TTZ, transferring to work as a TTZ router
comprises generating a router LSA to virtualize the TTZ and flooding
this LSA to all its neighboring routers.

10.3. Adding a Router into TTZ

When a non TTZ router (say R1) is connected via a P2P link to a TTZ
router (say T1) working as TTZ and there is a normal adjacency
between them over the link, a user can configure TTZ on two ends of
the link 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 link
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 link on every router to add the non TTZ routers into the TTZ to
which T1 belongs. The DR for the link "forms" TTZ adjacency with
each of the other routers if all the routers have the same TTZ ID
configured on the connections to the link.

When a router (say R1) is connected via a P2P link to a TTZ router
(say T1) and there is not any adjacency between them over the link, a
user can configure TTZ on two ends of the link 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 link to a group
of TTZ routers on the link and there is not any adjacency between R1
and any over the link, a user can configure TTZ on the connection to
the link on R1 to add R1 into the TTZ to which the TTZ routers
belong. R1 starts to form an adjacency with the DR for the link
after the configuration.

11. Prototype Implementation

11.1. What are Implemented and Tested

   1. CLI Commands for TTZ

The CLIs implemented and tested include:

   o the CLIs of the simpler option for configuring TTZ, and

   o the CLIs for controlling migration to TTZ.

2. Extensions to OSPF Protocols for TTZ

All the extensions defined in section "Extensions to OSPF Protocols"
are implemented and tested except for rolling back from TTZ. The
testing results illustrate:

  o A TTZ is virtualized to outside as its edge routers fully
    connected. Any router outside of the TTZ sees the edge routers
    (as normal routers) connecting each other and to some other
    routers.

  o The link state information about the routers and links inside the
    TTZ is contained within the TTZ. It is not distributed to any
    router outside of the TTZ.

  o TTZ is transparent. From a router inside a TTZ, it sees the
    topology (link state) outside of the TTZ. From a router outside
    of the TTZ, it sees the topology beyond the TTZ. The link state
    information outside of the TTZ is distributed through the TTZ.

  o TTZ is backward compatible. Any router outside of a TTZ does not
    need to support or know TTZ.

3. Smooth Migration to TTZ

The procedures and related protocol extensions for smooth migration
to TTZ are implemented and tested. The testing results show:

  o A part of an area is smoothly migrated to a TTZ without any
    routing disruptions. The routes on every router are stable while
    the part of the area is being migrated to the TTZ.

  o Migration to TTZ is very easy to operate.

4. Add a Router to TTZ

Adding a router into TTZ is implemented and tested. The testing
results illustrate:

  o A router can be easily added into a TTZ and becomes a TTZ router.

   o The router added into the TTZ is not seen on any router outside of
     the TTZ, but it is a part of the TTZ.

   5. Leak TTZ Loopbacks Outside

   Leaking loopback addresses in a TTZ to routers outside of the TTZ is
   implemented and tested. The testing results illustrate:

   o The loopback addresses inside the TTZ are distributed to the
     routers outside of the TTZ.

   o The loopback addresses are accessable from a router outside of the
     TTZ.

11.2. Implementation Experience

   The implementation of TTZ is relatively easy compared to other
   features of OSPF. Re-using the existing OSPF code along with
   additional simple logic does the work. A couple of engineers started
   to work on implementing the TTZ from the middle of June, 2014 and
   finished coding it just before IETF 90. After some testing and bug
   fixes, it works as expected.

   In our implementation, the link state information in a TTZ opaque LSA
   is stored in the same link state database as the link state
   information in a normal LSA. For each TTZ link in the TTZ opaque LSA
   stored, there is an additional flag, which is used to differentiate
   between a TTZ link and a Normal link.

   Before migration to TTZ, every router in the TTZ computes its routing
   table using the normal links. After migration to TTZ, every router
   in the TTZ computes its routing table using the TTZ links and normal
   links. In the case that there are one TTZ link and one normal link
   to select, the TTZ link is used. In SPF calculation, the back-link
   check passes if and only if the corresponding new additional bit
   matches. If link type bit is TTZ link, then the lookup is for
   corresponding TTZ LSA. In case of normal link, the lookup is based
   on normal link.

12. Security Considerations

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

13. IANA Considerations

   TBD

14. Contributors

         Veerendranatha Reddy Vallem
         Huawei Technologies
         Banglore
         India
         Email: veerendranatharv@huawei.com

15. Acknowledgement

   The author would like to thank Acee Lindem, Abhay Roy, Dean Cheng,
   Russ White, William McCall, Tony Przygienda, Lin Han and Yang Yu for
   their valuable comments on this draft.

16. References

16.1. Normative References

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

   [RFC2328] Moy, J., "OSPF Version 2", STD 54, RFC 2328, April 1998.

   [RFC4970] Lindem, A., Shen, N., Vasseur, JP., Aggarwal, R., and S.
              Shaffer, "Extensions to OSPF for Advertising Optional
              Router Capabilities", RFC 4970, July 2007.

   [RFC2370] Coltun, R., "The OSPF Opaque LSA Option", RFC 2370,
              July 1998.

   [RFC5613] Zinin, A., Roy, A., Nguyen, L., Friedman, B., and D.
              Yeung, "OSPF Link-Local Signaling", RFC 5613, August 2009.

16.2. Informative References

   [RFC5441] Vasseur, JP., Zhang, R., Bitar, N., and JL. Le Roux, "A
              Backward-Recursive PCE-Based Computation (BRPC) Procedure
              to Compute Shortest Constrained Inter-Domain Traffic
              Engineering Label Switched Paths", RFC 5441, April 2009.

   [RFC5440]   Vasseur, JP. and JL. Le Roux, "Path Computation Element
               (PCE) Communication Protocol (PCEP)", RFC 5440,
               March 2009.

Authors' Addresses

   Huaimo Chen
   Huawei Technologies
   Boston, MA
   USA

   Email: huaimo.chen@huawei.com

   Renwei Li
   Huawei Technologies
   2330 Central expressway
   Santa Clara, CA
   USA

   Email: renwei.li@huawei.com

   Anil Kumar S N
   Huawei Technologies
   Banglore
   India

   Email: anil.sn@huawei.com

   Gregory Cauchie
   FRANCE

   Email: greg.cauchie@gmail.com

   Alvaro Retana
   Cisco Systems, Inc.
   7025 Kit Creek Rd.
   Raleigh, NC 27709
   USA

   Email: aretana@cisco.com

Ning So
Tata Communications
2613 Fairbourne Cir.
Plano, TX 75082
USA

Email: ningso01@gmail.com

Vic Liu
China Mobile
No.32 Xuanwumen West Street, Xicheng District
Beijing,   100053
China

Email: liuzhiheng@chinamobile.com

Mehmet Toy
Comcast
1800 Bishops Gate Blvd.
Mount Laurel, NJ 08054
USA

Email: mehmet_toy@cable.comcast.com

Lei Liu
UC Davis
CA
USA

Email: liulei.kddi@gmail.com