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Benchmarking Methodology for
IGP Data Plane Route Convergence

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ABSTRACT
This draft describes the methodology for benchmarking IGP Route
Convergence as described in Applicability document [1] and
Terminology document [2]. The methodology and terminology are
to be used for benchmarking route convergence and can be applied
to any link-state IGP such as ISIS [3] and OSPF [4]. The terms
used in the procedures provided within this document are
defined in [2].

 Table of Contents

    1. Introduction
    This draft describes the methodology for benchmarking IGP Route
    Convergence. The applicability of this testing is described in
    [1] and the new terminology that it introduces is defined in [2].
    Service Providers use IGP Convergence time as a key metric of
    router design and architecture. Customers of Service Providers
    observe convergence time by packet loss, so IGP Route Convergence
    is considered a Direct Measure of Quality (DMOQ). The test cases
    in this document are black-box tests that emulate the network
    events that cause route convergence, as described in [1]. The
    black-box test designs benchmark the data plane accounting for
    all of the factors contributing to convergence time, as discussed
    in [1]. The methodology (and terminology) for benchmarking route
    convergence can be applied to any link-state IGP such as ISIS [3]
    and OSPF [4]. These methodologies apply to IPv4 and IPv6 traffic
    as well as IPv4 and IPv6 IGPs.

    2. Existing definitions
    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 BCP 14, RFC 2119
    [Br97]. RFC 2119 defines the use of these key words to help make the
    intent of standards track documents as clear as possible. While this
    document uses these keywords, this document is not a standards track

document.

3. Test Setup
3.1 Test Topologies
Figure 1 shows the test topology to measure IGP Route Convergence due
to local Convergence Events such as SONET Link Failure, Layer 2 Session
Failure, IGP Adjacency Failure, Route Withdrawal, and route cost
change. These test cases discussed in section 4 provide route
convergence times that account for the Event Detection time, SPF
Processing time, and FIB Update time. These times are measured
by observing packet loss in the data plane.

```
        ---------          Ingress Interface       ---------
        |        |<----------------------------|          |
        |        |                             |          |
        |        | Preferred Egress Interface  |          |
        |   DUT  |---------------------------->|Tester |
        |        |                             |          |
        |        |~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~>|          |
        |        | Next-Best Egress Interface  |          |
        ---------                               ---------
```
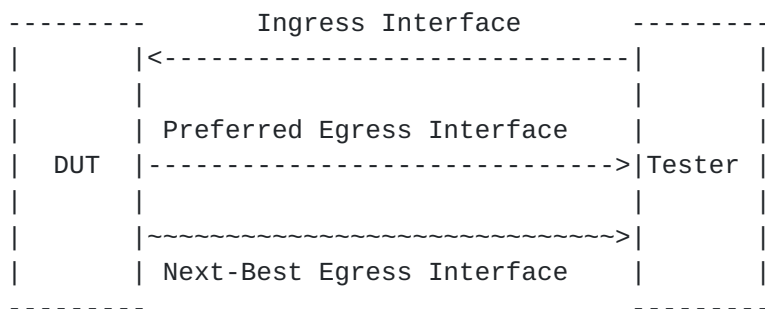
        Figure 1. IGP Route Convergence Test Topology for Local Changes

   Figure 2 shows the test topology to measure IGP Route Convergence
   time due to remote changes in the network topology. These times are
   measured by observing packet loss in the data plane. In this
   topology the three routers are considered a System Under Test (SUT).
   NOTE: All routers in the SUT must be the same model and identically
configured.

```
            -----                      -----------
            |   |   Preferred          |         |
    -----   |R2 |--------------------->|         |
    |   |-->|   | Egress Interface     |         |
    |   |   -----                      |         |
    |R1 |                              | Tester |
    |   |   -----                      |         |
    |   |-->|   |   Next-Best          |         |
    -----   |R3 |~~~~~~~~~~~~~~~~~~~~~>|         |
      ^     |   |   Egress Interface   |         |
      |     -----                      -----------
      |                                     |
      |------------------------------------
            Ingress Interface
```
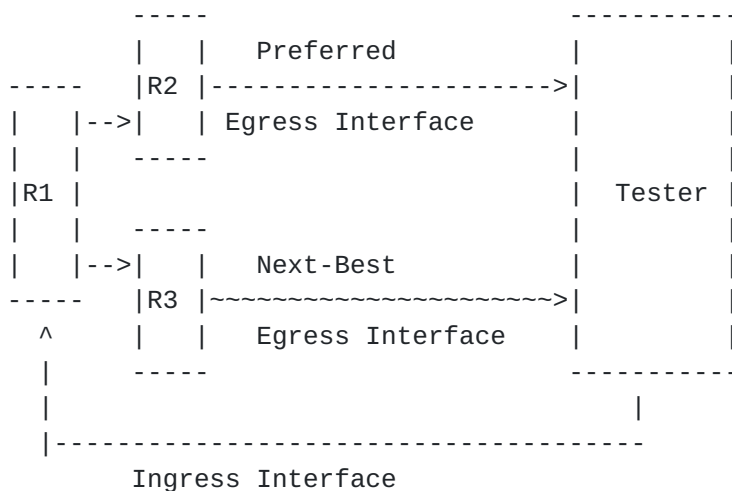
        Figure 2. IGP Route Convergence Test Topology
                    for Remote Changes

   Figure 3 shows the test topology to measure IGP Route Convergence

time with members of an Equal Cost Multipath (ECMP) Set. These times are
measured by observing packet loss in the data plane. In this topology,
the DUT

is configured with each Egress interface as a member of an ECMP set
and the Tester emulates multiple next-hop routers (emulates one
router for each member).

```
        ---------           Ingress Interface        ---------
        |        |<-------------------------------|        |
        |        |                                |        |
        |        |      ECMP Set Interface 1      |        |
        |   DUT  |------------------------------->| Tester|
        |        |                .               |        |
        |        |                .               |        |
        |        |                .               |        |
        |        |~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~>|        |
        |        |      ECMP Set Interface N      |        |
        ---------                                 ---------
```
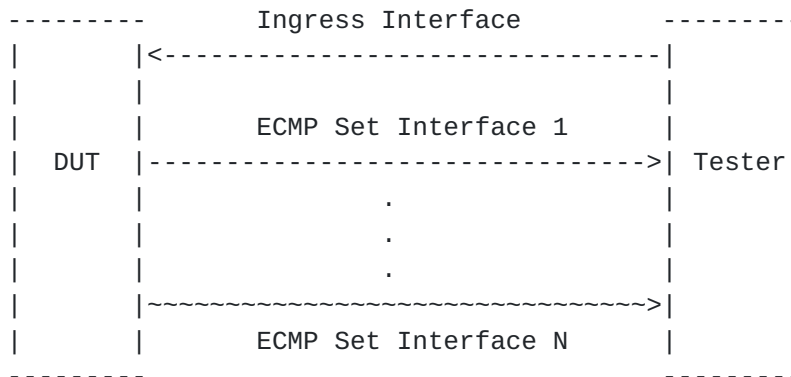
          Figure 3. IGP Route Convergence Test Topology
                      for ECMP Convergence

Figure 4 shows the test topology to measure IGP Route Convergence
time with members of a Parallel Link. These times are measured by
observing packet loss in the data plane. In this topology, the DUT
is configured with each Egress interface as a member of a Parallel
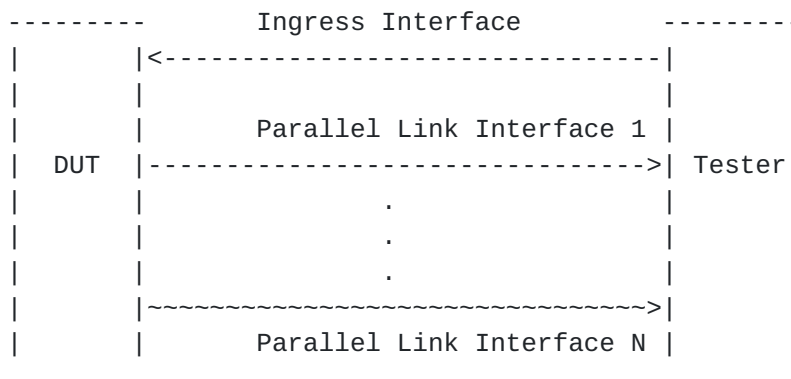Link and the Tester emulates the single next-hop router.

```
        ---------           Ingress Interface        ---------
        |        |<------------------------------|        |
        |        |                               |        |
        |        |    Parallel Link Interface 1 |        |
        |   DUT  |------------------------------>| Tester|
        |        |                .              |        |
        |        |                .              |        |
        |        |                .              |        |
        |        |~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~>|        |
        |        |    Parallel Link Interface N |        |
        ---------                                ---------
```

          Figure 4. IGP Route Convergence Test Topology
                     for Parallel Link Convergence

3.2 Test Considerations
3.2.1 IGP Selection
The test cases described in [section 4](#) can be used for ISIS or
OSPF. The Route Convergence test methodology for both is
identical. The IGP adjacencies are established on the Preferred
Egress Interface and Next-Best Egress Interface.

3.2.2 BGP Configuration

The obtained results for IGP Route Convergence may vary if
BGP routes are installed. It is recommended that the IGP
Convergence times be benchmarked without BGP routes installed.

3.2.3 IGP Route Scaling

The number of IGP routes will impact the measured IGP Route
Convergence because convergence for the entire IGP route table is
measured.   For results similar to those that would be observed in
an operational network it is recommended that the number of
installed routes closely approximate that for routers in the
network. The number of areas (for OSPF) and levels (for ISIS) can
impact the benchmark results.

3.2.4 Timers

There are some timers that will impact the measured IGP Convergence
time. The following timers should be configured to the minimum value
prior to beginning execution of the test cases:

Timer	Recommended Value
Failure Indication Delay	<10milliseconds
IGP Hello Timer	1 second
IGP Dead-Interval	3 seconds
LSA Generation Delay	0
LSA Flood Packet Pacing	0
LSA Retransmission Packet Pacing	0
SPF Delay	0

3.2.5 Convergence Time Metrics

The recommended value for the Packet Sampling Interval [2] is
100 milliseconds. Rate-Derived Convergence Time [2] is the
preferred benchmark for IGP Route Convergence. This benchmark
must always be reported when the Packet Sampling Interval [2]
<= 100 milliseconds. If the test equipment does not permit
the Packet Sampling Interval to be set as low as 100 msec,
then both the Rate-Derived Convergence Time and Loss-Derived
Convergence Time [2] must be reported. The Packet Sampling
Interval value is the smallest measurable convergence time.

3.2.6 Offered Load

An offered Load of maximum forwarding rate at a fixed packet size
is recommended for accurate measurement. Forwarding Rate must be
measured at the Preferred Egress Interface and the Next-Best
Egress Interface. The duration of offered load must be greater
than the convergence time. The destinations for the offered load
must be distributed such that all routes are matched. This
enables Full Convergence [2] to be observed.

3.2.7 Interface Types

All test cases in this methodology document may be executed with
any interface type. All interfaces MUST BE the same media and
link speed for each test case. Media and protocols MUST be

configured for minimum failure detection delay to minimize the
contribution to the measured Convergence time. For example,
configure SONET with minimum carrier-loss-delay.

3.3 Reporting Format
For each test case, it is recommended that the following reporting
format be completed:

```
     Parameter                             Units
     ---------                             -----
     IGP                                   (ISIS or OSPF)
     Interface Type                        (GigE, POS, ATM, etc.)
     Packet Size                           bytes
     IGP Routes                            number of IGP routes
     Packet Sampling Interval              seconds or milliseconds
     IGP Timer Values
           SONET Failure Indication Delay  seconds or milliseconds
           IGP Hello Timer                 seconds or milliseconds
           IGP Dead-Interval               seconds or milliseconds
           LSA Generation Delay            seconds or milliseconds
           LSA Flood Packet Pacing         seconds or milliseconds
           LSA Retransmission Packet Pacing  seconds or milliseconds
           SPF Delay                       seconds or milliseconds
     Benchmarks
           Rate-Derived Convergence Time   seconds or milliseconds
           Loss-Derived Convergence Time   seconds or milliseconds
           Restoration Convergence Time    seconds or milliseconds
```

4. Test Cases
4.1 Convergence Due to Link Failure
4.1.1 Convergence Due to Local Interface Failure
     Objective
     To obtain the IGP Route Convergence due to a local link
     failure event at the DUT's Local Interface.

     Procedure
     1. Advertise matching IGP routes from Tester to DUT on
        Preferred Egress Interface [2] and Next-Best Egress Interface
        [2] using the topology shown in Figure 1. Set the cost of the
        routes so that the Preferred Egress Interface is the preferred
        next-hop.
     2. Send traffic at maximum forwarding rate to destinations
        matching all IGP routes from Tester to DUT on Ingress Interface
        [2].
     3. Verify traffic routed over Preferred Egress Interface.
     4. Remove SONET on DUT's Local Interface [2] by performing an
        administrative shutdown of the interface.
     5. Measure Rate-Derived Convergence Time [2] as DUT detects the
        link down event and converges all IGP routes and traffic over
        the Next-Best Egress Interface.
     6. Stop offered load. Wait 30 seconds for queues to drain.
        Restart Offered Load.

7. Restore SONET on DUT's Local Interface by administratively
   enabling the interface.

8. Measure Restoration Convergence Time [2] as DUT detects the link
   up event and converges all IGP routes and traffic back to the
   Preferred Egress Interface.

Results
The measured IGP Convergence time is influenced by the Local
SONET indication, SPF delay, SPF Holdtime, SPF Execution
Time, Tree Build Time, and Hardware Update Time.

4.1.2 Convergence Due to Neighbor Interface Failure
Objective
To obtain the IGP Route Convergence due to a local link
failure event at the Tester's Neighbor Interface.

Procedure
1. Advertise matching IGP routes from Tester to DUT on
   Preferred Egress Interface [2] and Next-Best Egress Interface
   [2] using the topology shown in Figure 1. Set the cost of
   the routes so that the Preferred Egress Interface is the
   preferred next-hop.
2. Send traffic at maximum forwarding rate to destinations matching
   all IGP routes from Tester to DUT on Ingress Interface [2].
3. Verify traffic routed over Preferred Egress Interface.
4. Remove SONET on Tester's Neighbor Interface [2] connected to
   DUT' s Preferred Egress Interface.
5. Measure Rate-Derived Convergence Time [2] as DUT detects the
   link down event and converges all IGP routes and traffic over
   the Next-Best Egress Interface.
6. Stop offered load. Wait 30 seconds for queues to drain.
   Restart Offered Load.
7. Restore SONET on Tester's Neighbor Interface connected to
   DUT's Preferred Egress Interface.
8. Measure Restoration Convergence Time [2] as DUT detects the
   link up event and converges all IGP routes and traffic back to
   the Preferred Egress Interface.

Results
The measured IGP Convergence time is influenced by the Local
SONET indication, SPF delay, SPF Holdtime, SPF Execution
Time, Tree Build Time, and Hardware Update Time.

4.1.3 Convergence Due to Remote Interface Failure
Objective
To obtain the IGP Route Convergence due to a Remote Interface
Failure event.

Procedure
1. Advertise matching IGP routes from Tester to SUT on

Preferred Egress Interface [2] and Next-Best Egress Interface
[2] using the topology shown in Figure 2. Set the cost of the
routes so that the Preferred Egress Interface is the preferred
next-hop.

2. Send traffic at maximum forwarding rate to destinations matching
   all IGP routes from Tester to DUT on Ingress Interface [2].
3. Verify traffic is routed over Preferred Egress Interface.
4. Remove SONET on Tester's Neighbor Interface [2] connected to
   SUT' s Preferred Egress Interface.
5. Measure Rate-Derived Convergence Time [2] as SUT detects
   the link down event and converges all IGP routes and traffic
   over the Next-Best Egress Interface.
6. Stop offered load. Wait 30 seconds for queues to drain.
   Restart Offered Load.
7. Restore SONET on Tester's Neighbor Interface connected to
   DUT's Preferred Egress Interface.
8. Measure Restoration Convergence Time [2] as DUT detects the
   link up event and converges all IGP routes and traffic back to
   the Preferred Egress Interface.

Results
The measured IGP Convergence time is influenced by the
SONET failure indication, LSA/LSP Flood Packet Pacing,
LSA/LSP Retransmission Packet Pacing, LSA/LSP Generation
time, SPF delay, SPF Holdtime, SPF Execution Time, Tree
Build Time, and Hardware Update Time. The additional
convergence time contributed by LSP Propagation can be
obtained by subtracting the Rate-Derived Convergence Time
measured in 4.1.2 (Convergence Due to Neighbor Interface
Failure) from the Rate-Derived Convergence Time measured in
this test case.

4.2 Convergence Due to Layer 2 Session Failure
Objective
To obtain the IGP Route Convergence due to a Local Layer 2 Session
failure event.

Procedure
1. Advertise matching IGP routes from Tester to DUT on
   Preferred Egress Interface [2] and Next-Best Egress Interface
   [2] using the topology shown in Figure 1. Set the cost of
   the routes so that the IGP routes along the Preferred Egress
   Interface is the preferred next-hop.
2. Send traffic at maximum forwarding rate to destinations
   matching all IGP routes from Tester to DUT on Ingress
   Interface [2].
3. Verify traffic routed over Preferred Egress Interface.
4. Remove Layer 2 session from Tester's Neighbor Interface [2]
   connected to Preferred Egress Interface.
5. Measure Rate-Derived Convergence Time [2] as DUT detects the
   Layer 2 session down event and converges all IGP routes and
   traffic over the Next-Best Egress Interface.

6. Restore Layer 2 session on DUT's Preferred Egress Interface.
        7. Measure Restoration Convergence Time [2] as DUT detects the
           session up event and converges all IGP routes and traffic over
           the Preferred Egress Interface.

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Results
The measured IGP Convergence time is influenced by the Layer 2
failure indication, SPF delay, SPF Holdtime, SPF Execution
Time, Tree Build Time, and Hardware Update Time.

4.3 Convergence Due to IGP Adjacency Failure

Objective
To obtain the IGP Route Convergence due to a Local IGP Adjacency
failure event.

Procedure
1. Advertise matching IGP routes from Tester to DUT on
   Preferred Egress Interface [2] and Next-Best Egress Interface
   [2] using the topology shown in Figure 1. Set the cost of
   the routes so that the Preferred Egress Interface is the
   preferred next-hop.
2. Send traffic at maximum forwarding rate to destinations
   matching all IGP routes from Tester to DUT on Ingress
   Interface [2].
3. Verify traffic routed over Preferred Egress Interface.
4. Remove IGP adjacency from Tester's Neighbor Interface [2]
   connected to Preferred Egress Interface.
5. Measure Rate-Derived Convergence Time [2] as DUT detects the
   IGP session failure event and converges all IGP routes and
   traffic over the Next-Best Egress Interface.
6. Stop offered load. Wait 30 seconds for queues to drain.
   Restart Offered Load.
7. Restore IGP session on DUT's Preferred Egress Interface.
8. Measure Restoration Convergence Time [2] as DUT detects the
   session up event and converges all IGP routes and traffic over
   the Preferred Egress Interface.

Results
The measured IGP Convergence time is influenced by the IGP
Hello Interval, IGP Dead Interval, SPF delay, SPF Holdtime,
SPF Execution Time, Tree Build Time, and Hardware Update
Time.

4.4 Convergence Due to Route Withdrawal

Objective
To obtain the IGP Route Convergence due to Route Withdrawal.

Procedure
1. Advertise matching IGP routes from Tester to DUT on
    Preferred Egress Interface [2] and Next-Best Egress Interface
   [2] using the topology shown in Figure 1. Set the cost of
   the routes so that the Preferred Egress Interface is the

preferred next-hop.

    2. Send traffic at maximum forwarding rate to destinations
       matching all IGP routes from Tester to DUT on Ingress
       Interface [2].

3. Verify traffic routed over Preferred Egress Interface.
4. Tester withdraws all IGP routes from DUT's Local Interface
   on Preferred Egress Interface.
6. Stop offered load. Wait 30 seconds for queues to drain.
   Restart Offered Load.
7. Re-advertise IGP routes to DUT's Preferred Egress Interface.
8. Measure Restoration Convergence Time [2] as DUT converges all
   IGP routes and traffic over the Preferred Egress Interface.

Results
The measured IGP Convergence time is the SPF Processing and FIB
Update time as influenced by the SPF delay, SPF Holdtime,
SPF Execution Time, Tree Build Time, and Hardware Update Time.

4.5 Convergence Due to Cost Change

Objective
To obtain the IGP Route Convergence due to route cost change.

Procedure
1. Advertise matching IGP routes from Tester to DUT on
   Preferred Egress Interface [2] and Next-Best Egress Interface
   [2] using the topology shown in Figure 1. Set the cost of
   the routes so that the Preferred Egress Interface is the
   preferred next-hop.
2. Send traffic at maximum forwarding rate to destinations
   matching all IGP routes from Tester to DUT on Ingress
   Interface [2].
3. Verify traffic routed over Preferred Egress Interface.
4. Tester increases cost for all IGP routes at DUT's Preferred
   Egress Interface so that the Next-Best Egress Interface
   has lower cost and becomes preferred path.
5. Measure Rate-Derived Convergence Time [2] as DUT detects the
   cost change event and converges all IGP routes and traffic
   over the Next-Best Egress Interface.
6. Stop offered load. Wait 30 seconds for queues to drain.
   Restart Offered Load.
7. Re-advertise IGP routes to DUT's Preferred Egress Interface
   with original lower cost metric.
8. Measure Restoration Convergence Time [2] as DUT converges all
   IGP routes and traffic over the Preferred Egress Interface.

Results
There should be no measured packet loss for this case.

 4.6 Convergence Due to ECMP Member Interface Failure

Objective
        To obtain the IGP Route Convergence due to a local link
        failure event of an ECMP Member.

Procedure
1. Configure ECMP Set as shown in Figure 3.
2. Advertise matching IGP routes from Tester to DUT on
   each ECMP member.
3. Send traffic at maximum forwarding rate to destinations
   matching all IGP routes from Tester to DUT on Ingress
   Interface [2].
4. Verify traffic routed over all members of ECMP Set.
5. Remove SONET on Tester's Neighbor Interface [2] connected to
   one of the DUT's ECMP member interfaces.
6. Measure Rate-Derived Convergence Time [2] as DUT detects the
   link down event and converges all IGP routes and traffic
   over the other ECMP members.
7. Stop offered load. Wait 30 seconds for queues to drain.
   Restart Offered Load.
8. Restore SONET on Tester's Neighbor Interface connected to
   DUT's ECMP member interface.
9. Measure Restoration Convergence Time [2] as DUT detects the
   link up event and converges IGP routes and some distribution
   of traffic over the restored ECMP member.

Results
The measured IGP Convergence time is influenced by the Local
SONET indication, Tree Build Time, and Hardware Update Time.

4.7 Convergence Due to Parallel Link Interface Failure

Objective
To obtain the IGP Route Convergence due to a local link failure
event for a Member of a Parallel Link. The links can be used for
data Load Balancing

Procedure
1. Configure Parallel Link as shown in Figure 4.
2. Advertise matching IGP routes from Tester to DUT on
   each Parallel Link member.
3. Send traffic at maximum forwarding rate to destinations
   matching all IGP routes from Tester to DUT on Ingress
   Interface [2].
4. Verify traffic routed over all members of Parallel Link.
5. Remove SONET on Tester's Neighbor Interface [2] connected to
   one of the DUT's Parallel Link member interfaces.
6. Measure Rate-Derived Convergence Time [2] as DUT detects the
   link down event and converges all IGP routes and traffic over
   the other Parallel Link members.
7. Stop offered load. Wait 30 seconds for queues to drain.
   Restart Offered Load.
8. Restore SONET on Tester's Neighbor Interface connected to

DUT's Parallel Link member interface.

9. Measure Restoration Convergence Time [2] as DUT detects the
   link up event and converges IGP routes and some distribution
   of traffic over the restored Parallel Link member.

Results
The measured IGP Convergence time is influenced by the Local
SONET indication, Tree Build Time, and Hardware Update Time.

5. Security Considerations

   Documents of this type do not directly affect the security of
   the Internet or corporate networks as long as benchmarking
   is not performed on devices or systems connected to operating
   networks.

6. Normative References

   [1] Poretsky, S., "Benchmarking Applicability for IGP
       Convergence", draft-ietf-bmwg-igp-dataplane-conv-app-05, work
       in progress, February 2005.

   [2] Poretsky, S., Imhoff, B., "Benchmarking Terminology for IGP
       Convergence", draft-ietf-bmwg-igp-dataplane-conv-term-05, work
       in progress, February 2005

   [3] Callon, R., "Use of OSI IS-IS for Routing in TCP/IP and Dual
       Environments", RFC 1195, December 1990.

   [4] Moy, J., "OSPF Version 2", RFC 2328, IETF, April 1998.

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