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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].

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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", "JUNE", 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 June 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 MUST be the smallest measurable convergence time.

3.2.6 Interface Types

All test cases in this methodology document June be executed with any interface type. All interfaces MUST be the same media and Throughput [5,6] 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 or Bi-directional Forwarding Detection (BFD) [7].

3.2.7 Offered Load
The offered Load MUST be the Throughput of the device as defined in [5] and benchmarked in [6] at a fixed packet size. The packet size is selectable and MUST be recorded. The Throughput 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 destination addresses for the offered load MUST be distributed such that all routes are matched. This enables Full Convergence [2] to be observed.

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 offered to DUT	bytes
IGP Routes advertised to DUT	number of IGP routes
Packet Sampling Interval on Tester	seconds or milliseconds
IGP Timer Values configured on DUT	
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 offered load at measured Throughput with fixed packet size to destinations matching all IGP routes from Tester to DUT on Ingress Interface [2].
3. Verify traffic routed over Preferred Egress Interface.
4. Remove link 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 link 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 link failure 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 offered load at measured Throughput with fixed packet
size
to destinations matching all IGP routes from Tester to DUT
on
Ingress Interface [2].

3. Verify traffic routed over Preferred Egress Interface.
4. Remove link 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 link 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 link failure 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 offered load at measured Throughput with fixed packet size 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 link 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 link 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 link failure 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 offered load at measured Throughput with fixed packet size 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.

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 offered load at measured Throughput with fixed packet
size
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 offered load at measured Throughput with fixed packet
size

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.
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. 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 offered load at measured Throughput with fixed packet size 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 offered load at measured Throughput with fixed packet size 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 link 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 link 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 link failure 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 offered load at measured Throughput with fixed packet size 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 link 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 link 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 link failure 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-06, work in progress, June 2005.

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