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January 2006

**Terminology for Benchmarking
IGP Data Plane Route Convergence**

<draft-ietf-bmwg-igp-dataplane-conv-term-09.txt>

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ABSTRACT
   This document describes the terminology for benchmarking IGP
   Route Convergence as described in Applicability document [1] and
   Methodology document [2]. The methodology and terminology are to
   be used for benchmarking Convergence Time and can be applied to
   any link-state IGP such as ISIS [3] and OSPF [4]. The data plane
   is measured to obtain the convergence benchmarking metrics
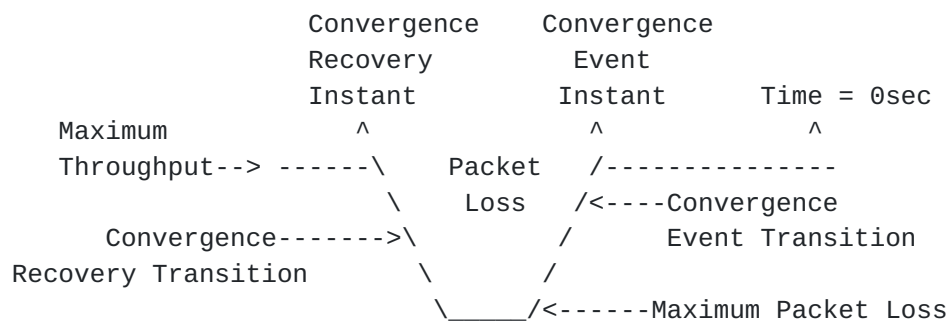   described in [2].

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1. Introduction
   This draft describes the terminology for benchmarking IGP Route
   Convergence. The motivation and applicability for this
   benchmarking is provided in [1]. The methodology to be used for
   this benchmarking is described in [2]. The methodology and
   terminology to be used for benchmarking Route Convergence can be
   applied to any link-state IGP such as ISIS [3] and OSPF [4]. The
   data plane is measured to obtain black-box (externally observable)
   convergence benchmarking metrics. The purpose of this document is
   to introduce new terms required to complete execution of the IGP
   Route Convergence Methodology [2]. These terms apply to IPv4 and
   IPv6 traffic as well as IPv4 and IPv6 IGPs.

   An example of Route Convergence as observed and measured from the
   data plane is shown in Figure 1. The graph in Figure 1 shows
   Throughput versus Time. Time 0 on the X-axis is on the far
   right of the graph. The components of the graph and metrics are

defined in the Term Definitions section.

```
                         Convergence     Convergence
                         Recovery          Event
                         Instant          Instant       Time = 0sec
       Maximum               ^               ^               ^
       Throughput--> ------\    Packet   /---------------
                            \    Loss   /<----Convergence
          Convergence------->\         /       Event Transition
     Recovery Transition      \       /
                               \_____/<------Maximum Packet Loss


     X-axis = Time
     Y-axis = Throughput
                      Figure 1. Convergence Graph
```

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. 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. The term Throughput is defined in RFC 2544.

3. Term Definitions

3.1 Convergence Event

Definition:
The occurrence of a planned or unplanned action in the network that results in a change in the egress interface of the Device Under Test (DUT) for routed packets.

Discussion:
Convergence Events include link loss, routing protocol session loss, router failure, configuration change, and better next-hop learned via a routing protocol.

Measurement Units:
N/A

Issues:
None

See Also:
Convergence Packet Loss
Convergence Event Instant

3.2 Route Convergence

     Definition:
     Recovery from a Convergence Event indicated by the DUT
     Throughput equal to the offered load.

     Discussion:
     Route Convergence is the action of all components of the router
     being updated with the most recent route change(s) including the
     Routing Information Base (RIB) and Forwaridng Information Base
     (FIB), along with software and hardware tables. Route
     Convergence can be observed externally by the rerouting of data
     Traffic to a new egress interface.

     Measurement Units:
     N/A

     Issues:
     None

     See Also:
     Network Convergence
     Full Convergence
     Convergence Event

3.3 Network Convergence

     Definition:
     The completion of updating of all routing tables, including the
     FIB, in all routers throughout the network.

     Discussion:
     Network Convergence is bounded by the sum of Route Convergence
     for all routers in the network. Network Convergence can be
     determined by recovery of the Throughput to equal the
     offered load, with no Stale Forwarding, and no blenders[5][6].

     Measurement Units:
     N/A

     Issues:
     None

     See Also:
     Route Convergence
     Stale Forwarding

   3.4 Full Convergence

        Definition:
        Route Convergence for an entire FIB.

        Discussion:
        When benchmarking convergence, it is useful to measure
        the time to converge an entire FIB. For example,
        a Convergence Event can be produced for an OSPF table of
        5000 routes so that the time to converge routes 1 through
        5000 is measured. Full Convergence is externally observable
        from the data plane when the Throughput of the data
        plane traffic on the Next-Best Egress Interface equals the
        offered load.

        Measurement Units:
        N/A

        Issues: None

        See Also:
        Network Convergence
        Route Convergence
        Convergence Event

   3.5 Convergence Packet Loss

        Definition:
        The amount of packet loss produced by a Convergence Event
        until Route Convergence occurs.

        Discussion:
        Packet loss can be observed as a reduction of forwarded traffic
        from the maximum Throughput. Convergence Packet Loss
        includes packets that were lost and packets that were delayed
        due to buffering. The maximum Convergence Packet Loss observed
        in a Packet Sampling Interval may or may not reach 100% during
        Route Convergence (see Figure 1).

        Measurement Units:
        number of packets

        Issues: None

        See Also:
        Route Convergence
        Convergence Event
        Rate-Derived Convergence Time
        Loss-Derived Convergence Time
        Packet Sampling Interval

   3.6 Convergence Event Instant

        Definition:
        The time instant that a Convergence Event becomes observable in
        the data plane.

        Discussion:
        Convergence Event Instant is observable from the data
        plane as the precise time that the device under test begins
        to exhibit packet loss.

        Measurement Units:
        hh:mm:ss:nnn, where 'nnn' is milliseconds

        Issues:
        None

        See Also:
        Convergence Event
        Convergence Packet Loss
        Convergence Recovery Instant

   3.7 Convergence Recovery Instant

        Definition:
        The time instant that Full Convergence is measured
        and then maintained for an interval of duration equal to
        the Sustained Forwarding Convergence Time

        Discussion:
        Convergence Recovery Instant is measurable from the data
        plane as the precise time that the device under test
        achieves Full Convergence.

        Measurement Units:
        hh:mm:ss:uuu

        Issues:
        None

        See Also:
        Sustained Forwarding Convergence Time
        Convergence Packet Loss
        Convergence Event Instant

    3.8 Rate-Derived Convergence Time
         Definition:
         The amount of time for Convergence Packet Loss to persist upon
         occurrence of a Convergence Event until occurrence of Route
         Convergence.

         Rate-Derived Convergence Time can be measured as the time
         difference from the Convergence Event Instant to the
         Convergence Recovery Instant, as shown with Equation 1.

         (eq 1)   Rate-Derived Convergence Time =
               Convergence Recovery Instant - Convergence Event Instant.

         Discussion:
         Rate-Derived Convergence Time should be measured at the maximum
         Throughput. Failure to achieve Full Convergence results in
         a Rate-Derived Convergence Time benchmark of infinity.

         Measurement Units:
         seconds/milliseconds

         Issues:
         None

         See Also:
         Convergence Packet Loss
         Convergence Recovery Instant
         Convergence Event Instant
         Full Convergence

    3.9 Convergence Event Transition
         Definition:
         The characteristic of a router in which Throughput
         gradually reduces to zero after a Convergence Event.

         Discussion:
         The Convergence Event Transition is best observed for
         Full Convergence. The Convergence Event Transition may
         not be linear.

         Measurement Units:
         seconds/milliseconds

         Issues:
         None

         See Also:
         Convergence Event
         Rate-Derived Convergence Time

Convergence Packet Loss
Convergence Recovery Transition

3.10 Convergence Recovery Transition

     Definition:
     The characteristic of a router in which Throughput
     gradually increases to equal the offered load.

     Discussion:
     The Convergence Recovery Transition is best observed for
     Full Convergence. The Convergence Event Transition may
     not be linear.

     Measurement Units:
     seconds/milliseconds

     Issues:
     None

     See Also:
     Full Convergence
     Rate-Derived Convergence Time
     Convergence Packet Loss
     Convergence Event Transition

3.11 Loss-Derived Convergence Time

     Definition:
     The amount of time it takes for Route Convergence to
     to be achieved as calculated from the Convergence Packet
     Loss. Loss-Derived Convergence Time can be calculated
     from Convergence Packet Loss that occurs due to a
     Convergence Event and Route Convergence.as shown with
     Equation 2.

     (eq 2) Loss-Derived Convergence Time =
             Convergence Packets Loss / Offered Load
             NOTE: Units for this measurement are
             packets / packets/second = seconds

     Discussion:
     Loss-Derived Convergence Time gives a better than
     actual result when converging many routes simultaneously.
     Rate-Derived Convergence Time takes the Convergence Recovery
     Transition into account, but Loss-Derived Convergence Time
     ignores the Route Convergence Recovery Transition because
     it is obtained from the measured Convergence Packet Loss.
     Ideally, the Convergence Event Transition and Convergence
    Recovery Transition are instantaneous so that the
     Rate-Derived Convergence Time = Loss-Derived Convergence Time.
     However, router implementations are less than ideal.

For these reasons the preferred reporting benchmark for IGP
Route Convergence is the Rate-Derived Convergence Time.

Guidelines for reporting Loss-Derived Convergence Time are
provided in [2].

Measurement Units:
seconds/milliseconds

Issues:
None

See Also:
Route Convergence
Convergence Packet Loss
Rate-Derived Convergence Time
Convergence Event Transition
Convergence Recovery Transition

3.12 Sustained Forwarding Convergence Time

Definition:
The amount of time for which Full Convergence is maintained
without additional packet loss.

Discussion:
The purpose of the Sustained Forwarding Convergence Time is to
produce Convergence benchmarks protected against fluctuation
in Throughput after Full Convergence is observed. The
Sustained Forwarding Convergence Time to be used is calculated
as shown in Equation 3.

(eq 3)
Sustained Forwarding Convergence Time = 5 packets/Offered Load
    units are packets/pps = sec

for which at least one packet per route in the FIB for all
routes in the FIB MUST be offered to the DUT per second.

Measurement Units:
seconds or milliseconds

Issues: None

See Also:
Full Convergence
Convergence Recovery Instant

3.13 Restoration Convergence Time
Definition:
The amount of time for the router under test to restore

traffic to the original outbound port after recovery from
a Convergence Event.

        Discussion:
        Restoration Convergence Time is the amount of time for routes
        to converge to the original outbound port. This is achieved
        by recovering from the Convergence Event, such as restoring
        the failed link. Restoration Convergence Time is measured
        using the Rate-Derived Convergence Time calculation technique,
        as provided in Equation 1. It is possible to have the
        Restoration Convergence Time differ from the Rate-Derived
        Convergence Time.

        Measurement Units:
        seconds or milliseconds

        Issues:
        None

        See Also:
        Convergence Event
        Rate-Derived Convergence Time

   3.14 Packet Sampling Interval
        Definition:
        The interval at which the tester (test equipment) polls to make
        measurements for arriving packet flows.

        Discussion:
        Metrics measured at the Packet Sampling Interval may include
        Throughput and Convergence Packet Loss.

        Measurement Units:
        seconds or milliseconds

        Issues:
        Packet Sampling Interval can influence the Convergence Graph.
        This is particularly true when implementations achieve Full
        Convergence in less than 1 second. The Convergence Event
        Transition and Convergence Recovery Transition can become
        exaggerated when the Packet Sampling Interval is too long.
        This will produce a larger than actual Rate-Derived
        Convergence Time. The recommended value for configuration
        of the Packet Sampling Interval is provided in [2].

        See Also:
        Convergence Packet Loss
        Convergence Event Transition
        Convergence Recovery Transition

     3.15 Local Interface

          Definition:
          An interface on the DUT.

          Discussion:
          None

          Measurement Units:
          N/A

          Issues:
          None

          See Also:
          Neighbor Interface
           Remote Interface

     3.16 Neighbor Interface

          Definition:
          The interface on the neighbor router or tester that is
          directly linked to the DUT's Local Interface.

          Discussion:
          None

          Measurement Units:
          N/A

          Issues:
          None

          See Also:
          Local Interface
          Remote Interface

     3.17 Remote Interface

          Definition:
          An interface on a neighboring router that is not directly
          connected to any interface on the DUT.

          Discussion:
          None

          Measurement Units:
          N/A

Issues:
None

         See Also:
         Local Interface
         Neighbor Interface

   3.18 Preferred Egress Interface

         Definition:
         The outbound interface from the DUT for traffic routed to the
         preferred next-hop.

         Discussion:
         The Preferred Egress Interface is the egress interface prior
         to a Convergence Event.

         Measurement Units:
         N/A

         Issues:
         None

         See Also:
         Next-Best Egress Interface

   3.19 Next-Best Egress Interface

         Definition:
         The outbound interface from the DUT for traffic routed to the
         second-best next-hop. It is the same media type and link speed
         as the Preferred Egress Interface

         Discussion:
         The Next-Best Egress Interface becomes the egress interface
         after a Convergence Event.

         Measurement Units:
         N/A

         Issues:
         None

         See Also:
         Preferred Egress Interface

   3.20 Stale Forwarding

         Definition:
         Forwarding of traffic to route entries that no longer exist
         or to route entries with next-hops that are no longer preferred.

         Discussion:
         Stale Forwarding can be caused by a Convergence Event and is
         also known as a "black-hole" since it may produce packet loss.
         Stale Forwarding exists until Network Convergence is achieved.

         Measurement Units:
         N/A

         Issues:
         None

         See Also:
         Network Convergence

   3.21 Nested Convergence Events

         Definition:
         The occurence of Convergence Event while the route table
         is converging from a prior Convergence Event.

         Discussion:
         The Convergence Events for a Nested Convergence Events
         MUST occur with different neighbors. A common
         observation from a Nested Convergence Event will be
         the withdrawal of routes from one neighbor while the
         routes of another neighbor are being installed.

         Measurement Units:
         N/A

         Issues:
         None

         See Also:
         Convergence Event

4. IANA Considerations

   This document requires no IANA considerations.

5. Security Considerations

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

6. References
6.1 Normative References

[1]   Poretsky, S., "Benchmarking Applicability for IGP Data Plane
       Route Convergence", draft-ietf-bmwg-igp-dataplane-conv-app-09,
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[2]   Poretsky, S., "Benchmarking Methodology for IGP Data Plane
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[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.

6.2 Informative References

[5]   S. Casner, C. Alaettinoglu, and C. Kuan, "A Fine-Grained View
       of High Performance Networking", NANOG 22, June 2001.

[6]   L. Ciavattone, A. Morton, and G. Ramachandran, "Standardized
       Active Measurements on a Tier 1 IP Backbone", IEEE
       Communications Magazine, pp90-97, May 2003.

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Acknowledgement

Funding for the RFC Editor function is currently provided by the
Internet Society.