Initial Performance Metrics Registry Entries
draft-ietf-ippm-initial-registry-11

Abstract

   This memo defines the set of Initial Entries for the IANA Performance
   Metrics Registry. The set includes, UDP Round-trip Latency and Loss,
   Packet Delay Variation, DNS Response Latency and Loss, UDP Poisson
   One-way Delay and Loss, UDP Periodic One-way Delay and Loss, ICMP
   Round-trip Latency and Loss, and TCP round-trip Latency and Loss.

Requirements Language

   The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
   "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and
   "OPTIONAL" in this document are to be interpreted as described in BCP
   14[RFC2119] [RFC8174] when, and only when, they appear in all
   capitals, as shown here.

Status of This Memo

   This Internet-Draft is submitted in full conformance with the
   provisions of BCP 78 and BCP 79.

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   Task Force (IETF). Note that other groups may also distribute
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   Internet-Drafts are draft documents valid for a maximum of six months
   and may be updated, replaced, or obsoleted by other documents at any
   time. It is inappropriate to use Internet-Drafts as reference
   material or to cite them other than as "work in progress."

   This Internet-Draft will expire on September 29, 2019.

Table of Contents

1. Introduction

   This memo proposes an initial set of entries for the Performance
   Metrics Registry. It uses terms and definitions from the IPPM
   literature, primarily [RFC2330].

   Although there are several standard templates for organizing
   specifications of performance metrics (see [RFC2679] for an example
   of the traditional IPPM template, based to large extent on the
   Benchmarking Methodology Working Group's traditional template in
   [RFC1242], and see [RFC6390] for a similar template), none of these
   templates were intended to become the basis for the columns of an
   IETF-wide registry of metrics. While examining aspects of metric

specifications which need to be registered, it became clear that none
of the existing metric templates fully satisfies the particular needs
of a registry.

Therefore, [I-D.ietf-ippm-metric-registry] defines the overall format
for a Performance Metrics Registry. Section 5 of
[I-D.ietf-ippm-metric-registry] also gives guidelines for those
requesting registration of a Metric, that is the creation of entry(s)
in the Performance Metrics Registry: "In essence, there needs to be
evidence that a candidate Registered Performance Metric has
significant industry interest, or has seen deployment, and there is
agreement that the candidate Registered Performance Metric serves its
intended purpose." The process in [I-D.ietf-ippm-metric-registry]
also requires that new entries are administered by IANA through
Expert Review or IETF Standards action, which will ensure that the
metrics are tightly defined.

2. Scope

This document defines the initial set of Performance Metrics Registry
entries, for which IETF approval (following development in the IP
Performance Metrics (IPPM) Working Group) will satisfy the
requirement for Expert Review. Most are Active Performance Metrics,
which are based on RFCs prepared in the IPPM working group of the
IETF, according to their framework [RFC2330] and its updates.

3. Registry Categories and Columns

This memo uses the terminology defined in
[I-D.ietf-ippm-metric-registry].

This section provides the categories and columns of the registry, for
easy reference. An entry (row) therefore gives a complete
description of a Registered Metric.

Registry Categories and Columns, shown as

```
                                          Category
                                          ------------------
                                          Column |   Column |

Summary
--------------------------------------------------------------------------
Identifier | Name | URIs | Desc. | Reference | Change Controller | Ver |

Metric Definition
--------------------------------------------
Reference Definition | Fixed Parameters |

Method of Measurement
--------------------------------------------------------------------------
Reference | Packet     | Traffic | Sampling     | Run-time  | Role |
Method    | Stream     | Filter  | Distribution | Parameters |     |
          | Generation |
Output
--------------------------------------------
Type | Reference  | Units | Calibration |
     | Definition |       |             |

Administrative Information
----------------------------------
Status |Request | Rev | Rev.Date |

Comments and Remarks
--------------------
```

4. UDP Round-trip Latency and Loss Registry Entries

This section specifies an initial registry entry for the UDP Round-
trip Latency, and another entry for UDP Round-trip Loss Ratio.

Note: Each Registry entry only produces a "raw" output or a
statistical summary. To describe both "raw" and one or more
statistics efficiently, the Identifier, Name, and Output Categories
can be split and a single section can specify two or more closely-
related metrics. This section specifies two Registry entries with
many common columns. See Section 7 for an example specifying
multiple Registry entries with many common columns.

All column entries beside the ID, Name, Description, and Output
Reference Method categories are the same, thus this section proposes
two closely-related registry entries. As a result, IANA is also
asked to assign a corresponding URL to each Named Metric.

4.1. Summary

This category includes multiple indexes to the registry entry: the element ID and metric name.

4.1.1. ID (Identifier)

IANA is asked to assign different numeric identifiers to each of the two Named Metrics.

4.1.2. Name

RTDelay_Active_IP-UDP-Periodic_RFCXXXXsecY_Seconds_95Percentile

RTLoss_Active_IP-UDP-Periodic_RFCXXXXsecY_Percent_LossRatio

4.1.3. URIs

URL: http://<TBD by IANA>/<name>

4.1.4. Description

RTDelay: This metric assesses the delay of a stream of packets exchanged between two hosts (which are the two measurement points), and the Output is the Round-trip delay for all successfully exchanged packets expressed as the 95th percentile of their conditional delay distribution.

RTLoss: This metric assesses the loss ratio of a stream of packets exchanged between two hosts (which are the two measurement points), and the Output is the Round-trip loss ratio for all successfully exchanged packets expressed as a percentage.

4.1.5. Change Controller

IETF

4.1.6. Version (of Registry Format)

1.0

4.2. Metric Definition

This category includes columns to prompt the entry of all necessary details related to the metric definition, including the RFC reference and values of input factors, called fixed parameters.

4.2.1. Reference Definition

   Almes, G., Kalidindi, S., and M. Zekauskas, "A Round-trip Delay
   Metric for IPPM", RFC 2681, September 1999.

   [RFC2681]

   Section 2.4 of [RFC2681] provides the reference definition of the
   singleton (single value) Round-trip delay metric. Section 3.4 of
   [RFC2681] provides the reference definition expanded to cover a
   multi-singleton sample. Note that terms such as singleton and sample
   are defined in Section 11 of [RFC2330].

   Note that although the [RFC2681] definition of "Round-trip-Delay
   between Src and Dst" is directionally ambiguous in the text, this
   metric tightens the definition further to recognize that the host in
   the "Src" role will send the first packet to "Dst", and ultimately
   receive the corresponding return packet from "Dst" (when neither are
   lost).

   Finally, note that the variable "dT" is used in [RFC2681] to refer to
   the value of Round-trip delay in metric definitions and methods. The
   variable "dT" has been re-used in other IPPM literature to refer to
   different quantities, and cannot be used as a global variable name.

   Morton, A., "Round-trip Packet Loss Metrics", RFC 6673, August 2012.

   [RFC6673]

   Both delay and loss metrics employ a maximum waiting time for
   received packets, so the count of lost packets to total packets sent
   is the basis for the loss ratio calculation as per Section 6.1 of
   [RFC6673].

4.2.2. Fixed Parameters

   Type-P as defined in Section 13 of [RFC2330]:

   o IPv4 header values:

      * DSCP: set to 0

      * TTL: set to 255

      * Protocol: Set to 17 (UDP)

   o IPv6 header values:

    * DSCP: set to 0

    * Hop Count: set to 255

    * Protocol: Set to 17 (UDP)

   o UDP header values:

    * Checksum: the checksum MUST be calculated and included in the
       header

   o UDP Payload

    * total of 100 bytes

   Other measurement parameters:

   o Tmax: a loss threshold waiting time

    * 3.0, expressed in units of seconds, as a positive value of type
       decimal64 with fraction digits = 4 (see section 9.3 of
       [RFC6020]) and with resolution of 0.0001 seconds (0.1 ms), with
       lossless conversion to/from the 32-bit NTP timestamp as per
       section 6 of [RFC5905].

4.3. Method of Measurement

   This category includes columns for references to relevant sections of
   the RFC(s) and any supplemental information needed to ensure an
   unambiguous methods for implementations.

4.3.1. Reference Method

   The methodology for this metric is defined as Type-P-Round-trip-
   Delay-Poisson-Stream in section 2.6 of RFC 2681 [RFC2681] and section
   3.6 of RFC 2681 [RFC2681] using the Type-P and Tmax defined under
   Fixed Parameters. However, the Periodic stream will be generated
   according to [RFC3432].

   The reference method distinguishes between long-delayed packets and
   lost packets by implementing a maximum waiting time for packet
   arrival. Tmax is the waiting time used as the threshold to declare a
   packet lost. Lost packets SHALL be designated as having undefined
   delay, and counted for the RTLoss metric.

   The calculations on the delay (RTT) SHALL be performed on the
   conditional distribution, conditioned on successful packet arrival
   within Tmax. Also, when all packet delays are stored, the process

which calculates the RTT value MAY enforce the Tmax threshold on
stored values before calculations. See section 4.1 of [RFC3393] for
details on the conditional distribution to exclude undefined values
of delay, and Section 5 of [RFC6703] for background on this analysis
choice.

The reference method requires some way to distinguish between
different packets in a stream to establish correspondence between
sending times and receiving times for each successfully-arriving
packet. Sequence numbers or other send-order identification MUST be
retained at the Src or included with each packet to disambiguate
packet reordering if it occurs.

If a standard measurement protocol is employed, then the measurement
process will determine the sequence numbers or timestamps applied to
test packets after the Fixed and Runtime parameters are passed to
that process. The chosen measurement protocol will dictate the
format of sequence numbers and time-stamps, if they are conveyed in
the packet payload.

Refer to Section 4.4 of [RFC6673] for expanded discussion of the
instruction to "send a Type-P packet back to the Src as quickly as
possible" in Section 2.6 of RFC 2681 [RFC2681]. Section 8 of
[RFC6673] presents additional requirements which MUST be included in
the method of measurement for this metric.

4.3.2. Packet Stream Generation

This section gives the details of the packet traffic which is the
basis for measurement. In IPPM metrics, this is called the Stream,
and can easily be described by providing the list of stream
parameters.

Section 3 of [RFC3432] prescribes the method for generating Periodic
streams using associated parameters.

incT the nominal duration of inter-packet interval, first bit to
   first bit, with value 0.0200, expressed in units of seconds, as a
   positive value of type decimal64 with fraction digits = 4 (see
   section 9.3 of [RFC6020]) and with resolution of 0.0001 seconds
   (0.1 ms).

dT the duration of the interval for allowed sample start times, with
   value 1.0, expressed in units of seconds, as a positive value of
   type decimal64 with fraction digits = 4 (see section 9.3 of
   [RFC6020]) and with resolution of 0.0001 seconds (0.1 ms).

T0 the actual start time of the periodic stream, (format "date-and-
   time" as specified in Section 5.6 of [RFC3339], see also Section 3
   of [RFC6991]).

NOTE: an initiation process with a number of control exchanges
resulting in unpredictable start times (within a time interval) may
be sufficient to avoid synchronization of periodic streams, and
therefore a valid replacement for selecting a start time at random
from a fixed interval.

The T0 parameter will be reported as a measured parameter.
Parameters incT and dT are Fixed Parameters.

4.3.3. Traffic Filtering (observation) Details

The measured results based on a filtered version of the packets
observed, and this section provides the filter details (when
present).

NA

4.3.4. Sampling Distribution

NA

4.3.5. Run-time Parameters and Data Format

Run-time Parameters are input factors that must be determined,
configured into the measurement system, and reported with the results
for the context to be complete.

Src the IP address of the host in the Src Role (format ipv4-address-
   no-zone value for IPv4, or ipv6-address-no-zone value for IPv6,
   see Section 4 of [RFC6991])

Dst the IP address of the host in the Dst Role (format ipv4-address-
   no-zone value for IPv4, or ipv6-address-no-zone value for IPv6,
   see section 4 of [RFC6991])

T0 a time, the start of a measurement interval, (format "date-and-
   time" as specified in Section 5.6 of [RFC3339], see also Section 3
   of [RFC6991]). The UTC Time Zone is required by Section 6.1 of
   [RFC2330]. When T0 is "all-zeros", a start time is unspecified
   and Tf is to be interpreted as the Duration of the measurement
   interval. The start time is controlled through other means.

Tf a time, the end of a measurement interval, (format "date-and-time"
   as specified in Section 5.6 of [RFC3339], see also Section 3 of

[RFC6991]).   The UTC Time Zone is required by Section 6.1 of
[RFC2330].   When T0 is "all-zeros", a end time date is ignored and
Tf is interpreted as the Duration of the measurement interval.

4.3.6. **Roles**

Src   launches each packet and waits for return transmissions from
Dst.

Dst   waits for each packet from Src and sends a return packet to Src.

4.4. **Output**

This category specifies all details of the Output of measurements
using the metric.

4.4.1. **Type**

Percentile -- for the conditional distribution of all packets with a
valid value of Round-trip delay (undefined delays are excluded), a
single value corresponding to the 95th percentile, as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
[RFC6703] for background on this analysis choice.

The percentile = 95, meaning that the reported delay, "95Percentile",
is the smallest value of Round-trip delay for which the Empirical
Distribution Function (EDF), F(95Percentile) >= 95% of the singleton
Round-trip delay values in the conditional distribution. See section
11.3 of [RFC2330] for the definition of the percentile statistic
using the EDF.

LossRatio -- the count of lost packets to total packets sent is the
basis for the loss ratio calculation as per Section 6.1 of [RFC6673].

4.4.2. **Reference Definition**

For all outputs ---

T0 the start of a measurement interval, (format "date-and-time" as
specified in Section 5.6 of [RFC3339], see also Section 3 of
[RFC6991]).   The UTC Time Zone is required by Section 6.1 of
[RFC2330].

Tf the end of a measurement interval, (format "date-and-time" as
specified in Section 5.6 of [RFC3339], see also Section 3 of

      [RFC6991]).   The UTC Time Zone is required by Section 6.1 of
      [RFC2330].

   TotalPkts the count of packets sent by the Src to Dst during the
      measurement interval.

   For

   RTDelay_Active_IP-UDP-Periodic_RFCXXXXsecY_Seconds_95Percentile:

   95Percentile The time value of the result is expressed in units of
      seconds, as a positive value of type decimal64 with fraction
      digits = 9 (see section 9.3 of [RFC6020]) with resolution of
      0.000000001 seconds (1.0 ns), and with lossless conversion to/from
      the 64-bit NTP timestamp as

   For

   RTLoss_Active_IP-UDP-Periodic_RFCXXXXsecY_Percent_LossRatio:

   Percentile The numeric value of the result is expressed in units of
      lost packets to total packets times 100%, as a positive value of
      type decimal64 with fraction digits = 9 (see section 9.3 of
      [RFC6020]) with resolution of 0.0000000001.

4.4.3. Metric Units

   The 95th Percentile of Round-trip Delay is expressed in seconds.

   The Round-trip Loss Ratio is expressed as a percentage of lost
   packets to total packets sent.

4.4.4. Calibration

   Section 3.7.3 of [RFC7679] provides a means to quantify the
   systematic and random errors of a time measurement. In-situ
   calibration could be enabled with an internal loopback at the Source
   host that includes as much of the measurement system as possible,
   performs address manipulation as needed, and provides some form of
   isolation (e.g., deterministic delay) to avoid send-receive interface
   contention. Some portion of the random and systematic error can be
   characterized this way.

   When a measurement controller requests a calibration measurement, the
   loopback is applied and the result is output in the same format as a
   normal measurement with additional indication that it is a
   calibration result.

Both internal loopback calibration and clock synchronization can be
used to estimate the *available accuracy* of the Output Metric Units.
For example, repeated loopback delay measurements will reveal the
portion of the Output result resolution which is the result of system
noise, and thus inaccurate.

4.5. Administrative items

4.5.1. Status

Current

4.5.2. Requestor

This RFC numner

4.5.3. Revision

1.0

4.5.4. Revision Date

YYYY-MM-DD

4.6. Comments and Remarks

None.

5. Packet Delay Variation Registry Entry

This section gives an initial registry entry for a Packet Delay
Variation metric.

Note: If each Registry entry should only produce a "raw" output or a
statistical summary, then the "Output" Category can be split and this
section can become two closely-related metrics.

5.1. Summary

This category includes multiple indexes to the registry entries, the
element ID and metric name.

5.1.1. ID (Identifier)

<insert numeric identifier, an integer>

5.1.2. Name

OWPDV_Active_IP-UDP-Periodic_RFCXXXXsecY_Seconds_95Percentile

5.1.3. URIs

URL: http://<TBD by IANA>/<name>

5.1.4. Description

An assessment of packet delay variation with respect to the minimum
delay observed on the periodic stream, and the Output is expressed as
the 95th percentile of the packet delay variation distribution.

5.1.5. Change Controller

IETF

5.1.6. Version (of Registry Format)

1.0

5.2. Metric Definition

This category includes columns to prompt the entry of all necessary
details related to the metric definition, including the RFC reference
and values of input factors, called fixed parameters.

5.2.1. Reference Definition

Paxson, V., Almes, G., Mahdavi, J., and M. Mathis, "Framework for IP
Performance Metrics", RFC 2330, May 1998. [RFC2330]

Demichelis, C. and P. Chimento, "IP Packet Delay Variation Metric
for IP Performance Metrics (IPPM)", RFC 3393, November 2002.
[RFC3393]

Morton, A. and B. Claise, "Packet Delay Variation Applicability
Statement", RFC 5481, March 2009. [RFC5481]

Mills, D., Martin, J., Burbank, J., and W. Kasch, "Network Time
Protocol Version 4: Protocol and Algorithms Specification", RFC 5905,
June 2010.[RFC5905]

See sections 2.4 and 3.4 of [RFC3393]. Singleton delay differences
measured are referred to by the variable name "ddT" (applicable to
all forms of delay variation). However, this metric entry specifies

the PDV form defined in section 4.2 of [RFC5481], where the singleton
PDV for packet i is referred to by the variable name "PDV(i)".

5.2.2. Fixed Parameters

o IPv4 header values:

   * DSCP: set to 0

   * TTL: set to 255

   * Protocol: Set to 17 (UDP)

o IPv6 header values:

   * DSCP: set to 0

   * Hop Count: set to 255

   * Protocol: Set to 17 (UDP)

o UDP header values:

   * Checksum: the checksum MUST be calculated and included in the
      header

o UDP Payload

   * total of 200 bytes

Other measurement parameters:

Tmax: a loss threshold waiting time with value 3.0, expressed in
   units of seconds, as a positive value of type decimal64 with
   fraction digits = 4 (see section 9.3 of [RFC6020]) and with
   resolution of 0.0001 seconds (0.1 ms), with lossless conversion
   to/from the 32-bit NTP timestamp as per section 6 of [RFC5905].

F a selection function unambiguously defining the packets from the
   stream selected for the metric. See section 4.2 of [RFC5481] for
   the PDV form.

See the Packet Stream generation category for two additional Fixed
Parameters.

5.3. Method of Measurement

   This category includes columns for references to relevant sections of
   the RFC(s) and any supplemental information needed to ensure an
   unambiguous methods for implementations.

5.3.1. Reference Method

   See section 2.6 and 3.6 of [RFC3393] for general singleton element
   calculations. This metric entry requires implementation of the PDV
   form defined in section 4.2 of [RFC5481]. Also see measurement
   considerations in section 8 of [RFC5481].

   The reference method distinguishes between long-delayed packets and
   lost packets by implementing a maximum waiting time for packet
   arrival. Tmax is the waiting time used as the threshold to declare a
   packet lost. Lost packets SHALL be designated as having undefined
   delay.

   The calculations on the one-way delay SHALL be performed on the
   conditional distribution, conditioned on successful packet arrival
   within Tmax. Also, when all packet delays are stored, the process
   which calculates the one-way delay value MAY enforce the Tmax
   threshold on stored values before calculations. See section 4.1 of
   [RFC3393] for details on the conditional distribution to exclude
   undefined values of delay, and Section 5 of [RFC6703] for background
   on this analysis choice.

   The reference method requires some way to distinguish between
   different packets in a stream to establish correspondence between
   sending times and receiving times for each successfully-arriving
   packet. Sequence numbers or other send-order identification MUST be
   retained at the Src or included with each packet to disambiguate
   packet reordering if it occurs.

   If a standard measurement protocol is employed, then the measurement
   process will determine the sequence numbers or timestamps applied to
   test packets after the Fixed and Runtime parameters are passed to
   that process. The chosen measurement protocol will dictate the
   format of sequence numbers and time-stamps, if they are conveyed in
   the packet payload.

5.3.2. Packet Stream Generation

   This section gives the details of the packet traffic which is the
   basis for measurement. In IPPM metrics, this is called the Stream,
   and can easily be described by providing the list of stream
   parameters.

Section 3 of [RFC3432] prescribes the method for generating Periodic
streams using associated parameters.

incT the nominal duration of inter-packet interval, first bit to
    first bit, with value 0.0200, expressed in units of seconds, as a
    positive value of type decimal64 with fraction digits = 4 (see
    section 9.3 of [RFC6020]) and with resolution of 0.0001 seconds
    (0.1 ms).

dT the duration of the interval for allowed sample start times, with
    value 1.0, expressed in units of seconds, as a positive value of
    type decimal64 with fraction digits = 4 (see section 9.3 of
    [RFC6020]) and with resolution of 0.0001 seconds (0.1 ms).

T0 the actual start time of the periodic stream, (format "date-and-
    time" as specified in Section 5.6 of [RFC3339], see also Section 3
    of [RFC6991]).

NOTE: an initiation process with a number of control exchanges
resulting in unpredictable start times (within a time interval) may
be sufficient to avoid synchronization of periodic streams, and
therefore a valid replacement for selecting a start time at random
from a fixed interval.

The T0 parameter will be reported as a measured parameter.
Parameters incT and dT are Fixed Parameters.

5.3.3. Traffic Filtering (observation) Details

NA

5.3.4. Sampling Distribution

NA

5.3.5. Run-time Parameters and Data Format

Src the IP address of the host in the Src Role (format ipv4-address-
    no-zone value for IPv4, or ipv6-address-no-zone value for IPv6,
    see Section 4 of [RFC6991])

Dst the IP address of the host in the Dst Role (format ipv4-address-
    no-zone value for IPv4, or ipv6-address-no-zone value for IPv6,
    see section 4 of [RFC6991])

T0 a time, the start of a measurement interval, (format "date-and-
    time" as specified in Section 5.6 of [RFC3339], see also Section 3
    of [RFC6991]). The UTC Time Zone is required by Section 6.1 of

[RFC2330]. When T0 is "all-zeros", a start time is unspecified
and Tf is to be interpreted as the Duration of the measurement
interval. The start time is controlled through other means.

Tf a time, the end of a measurement interval, (format "date-and-time"
as specified in Section 5.6 of [RFC3339], see also Section 3 of
[RFC6991]). The UTC Time Zone is required by Section 6.1 of
[RFC2330]. When T0 is "all-zeros", a end time date is ignored and
Tf is interpreted as the Duration of the measurement interval.

5.3.6. Roles

5.4. Output

This category specifies all details of the Output of measurements
using the metric.

5.4.1. Type

Percentile -- for the conditional distribution of all packets with a
valid value of one-way delay (undefined delays are excluded), a
single value corresponding to the 95th percentile, as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
[RFC6703] for background on this analysis choice.

The percentile = 95, meaning that the reported delay, "95Percentile",
is the smallest value of one-way PDV for which the Empirical
Distribution Function (EDF), F(95Percentile) >= 95% of the singleton
one-way PDV values in the conditional distribution. See section 11.3
of [RFC2330] for the definition of the percentile statistic using the
EDF.

5.4.2. Reference Definition

T0 the start of a measurement interval, (format "date-and-time" as
specified in Section 5.6 of [RFC3339], see also Section 3 of
[RFC6991]). The UTC Time Zone is required by Section 6.1 of
[RFC2330].

Tf the end of a measurement interval, (format "date-and-time" as
specified in Section 5.6 of [RFC3339], see also Section 3 of
[RFC6991]). The UTC Time Zone is required by Section 6.1 of
[RFC2330].

95Percentile The time value of the result is expressed in units of
seconds, as a positive value of type decimal64 with fraction

      digits = 9 (see section 9.3 of [RFC6020]) with resolution of
      0.000000001 seconds (1.0 ns), and with lossless conversion to/from
      the 64-bit NTP timestamp as per section 6 of RFC [RFC5905]

5.4.3. Metric Units

   The 95th Percentile of one-way PDV is expressed in seconds.

5.4.4. Calibration

   Section 3.7.3 of [RFC7679] provides a means to quantify the
   systematic and random errors of a time measurement. In-situ
   calibration could be enabled with an internal loopback that includes
   as much of the measurement system as possible, performs address
   manipulation as needed, and provides some form of isolation (e.g.,
   deterministic delay) to avoid send-receive interface contention.
   Some portion of the random and systematic error can be characterized
   this way.

   For one-way delay measurements, the error calibration must include an
   assessment of the internal clock synchronization with its external
   reference (this internal clock is supplying timestamps for
   measurement). In practice, the time offsets of clocks at both the
   source and destination are needed to estimate the systematic error
   due to imperfect clock synchronization (the time offsets are
   smoothed, thus the random variation is not usually represented in the
   results).

   time_offset The time value of the result is expressed in units of
      seconds, as a signed value of type decimal64 with fraction digits
      = 9 (see section 9.3 of [RFC6020]) with resolution of 0.000000001
      seconds (1.0 ns), and with lossless conversion to/from the 64-bit
      NTP timestamp as per section 6 of RFC [RFC5905]

   When a measurement controller requests a calibration measurement, the
   loopback is applied and the result is output in the same format as a
   normal measurement with additional indication that it is a
   calibration result. In any measurement, the measurement function
   SHOULD report its current estimate of time offset as an indicator of
   the degree of synchronization.

   Both internal loopback calibration and clock synchronization can be
   used to estimate the *available accuracy* of the Output Metric Units.
   For example, repeated loopback delay measurements will reveal the
   portion of the Output result resolution which is the result of system
   noise, and thus inaccurate.

5.5. **Administrative items**

5.5.1. **Status**

   Current

5.5.2. **Requestor**

   This RFC number

5.5.3. **Revision**

   1.0

5.5.4. **Revision Date**

   YYYY-MM-DD

5.6. **Comments and Remarks**

   Lost packets represent a challenge for delay variation metrics. See
   section 4.1 of [RFC3393] and the delay variation applicability
   statement[RFC5481] for extensive analysis and comparison of PDV and
   an alternate metric, IPDV.

6. **DNS Response Latency and Loss Registry Entries**

   This section gives initial registry entries for DNS Response Latency
   and Loss from a network user's perspective, for a specific named
   resource. The metric can be measured repeatedly using different
   names. RFC 2681 [RFC2681] defines a Round-trip delay metric. We
   build on that metric by specifying several of the input parameters to
   precisely define two metrics for measuring DNS latency and loss.

   Note to IANA: Each Registry "Name" below specifies a single registry
   entry, whose output format varies in accordance with the name.

   All column entries beside the ID, Name, Description, and Output
   Reference Method categories are the same, thus this section proposes
   two closely-related registry entries. As a result, IANA is also
   asked to assign corresponding URLs to each Named Metric.

6.1. **Summary**

   This category includes multiple indexes to the registry entries, the
   element ID and metric name.

6.1.1. ID (Identifier)

   <insert numeric identifier, an integer>

   IANA is asked to assign different numeric identifiers to each of the
   two Named Metrics.

6.1.2. Name

   RTDNS_Active_IP-UDP-Poisson_RFCXXXXsecY_Seconds_Raw

   RLDNS_Active_IP-UDP-Poisson_RFCXXXXsecY_Logical_Raw

6.1.3. URI

   URI: Prefix urn:ietf:metrics:perf:<name>

   URL: http://<TBD by IANA>/<name>

6.1.4. Description

   This is a metric for DNS Response performance from a network user's
   perspective, for a specific named resource. The metric can be
   measured repeatedly using different resource names.

   RTDNS: This metric assesses the response time, the interval from the
   query transmission to the response.

   RLDNS: This metric indicates that the response was deemed lost. In
   other words, the response time exceeded the maximum waiting time.

6.1.5. Change Controller

   IETF

6.1.6. Version (of Registry Format)

   1.0

6.2. Metric Definition

   This category includes columns to prompt the entry of all necessary
   details related to the metric definition, including the RFC reference
   and values of input factors, called fixed parameters.

6.2.1. Reference Definition

   Mockapetris, P., "Domain names - implementation and specification",
   STD 13, RFC 1035, November 1987. (and updates)

   [RFC1035]

   Almes, G., Kalidindi, S., and M. Zekauskas, "A Round-trip Delay
   Metric for IPPM", RFC 2681, September 1999.

   [RFC2681]

   Section 2.4 of [RFC2681] provides the reference definition of the
   singleton (single value) Round-trip delay metric. Section 3.4 of
   [RFC2681] provides the reference definition expanded to cover a
   multi-singleton sample. Note that terms such as singleton and sample
   are defined in Section 11 of [RFC2330].

   For DNS Response Latency, the entities in [RFC1035] must be mapped to
   [RFC2681]. The Local Host with its User Program and Resolver take
   the role of "Src", and the Foreign Name Server takes the role of
   "Dst".

   Note that although the [RFC2681] definition of "Round-trip-Delay
   between Src and Dst at T" is directionally ambiguous in the text,
   this metric tightens the definition further to recognize that the
   host in the "Src" role will send the first packet to "Dst", and
   ultimately receive the corresponding return packet from "Dst" (when
   neither are lost).

   Morton, A., "Round-trip Packet Loss Metrics", RFC 6673, August 2012.

   [RFC6673]

   Both response time and loss metrics employ a maximum waiting time for
   received responses, so the count of lost packets to total packets
   sent is the basis for the loss determination as per Section 4.3 of
   [RFC6673].

6.2.2. Fixed Parameters

   Type-P as defined in Section 13 of [RFC2330]:

   o   IPv4 header values:

      *   DSCP: set to 0

      *   TTL set to 255

* Protocol: Set to 17 (UDP)

o IPv6 header values:

* DSCP: set to 0

* Hop Count: set to 255

* Protocol: Set to 17 (UDP)

o UDP header values:

* Source port: 53

* Destination port: 53

* Checksum: the checksum must be calculated and included in the
  header

o Payload: The payload contains a DNS message as defined in RFC 1035
   [RFC1035] with the following values:

* The DNS header section contains:

  + Identification (see the Run-time column)

  + QR: set to 0 (Query)

  + OPCODE: set to 0 (standard query)

  + AA: not set

  + TC: not set

  + RD: set to one (recursion desired)

  + RA: not set

  + RCODE: not set

  + QDCOUNT: set to one (only one entry)

  + ANCOUNT: not set

  + NSCOUNT: not set

  + ARCOUNT: not set

       * The Question section contains:

          + QNAME: the Fully Qualified Domain Name (FQDN) provided as
             input for the test, see the Run-time column

          + QTYPE: the query type provided as input for the test, see
             the Run-time column

          + QCLASS: set to 1 for IN

       * The other sections do not contain any Resource Records.

   Other measurement parameters:

   o Tmax: a loss threshold waiting time (and to help disambiguate
      queries)

       * 5.0, expressed in units of seconds, as a positive value of type
          decimal64 with fraction digits = 4 (see section 9.3 of
          [RFC6020]) and with resolution of 0.0001 seconds (0.1 ms), with
          lossless conversion to/from the 32-bit NTP timestamp as per
          section 6 of [RFC5905].

   Observation: reply packets will contain a DNS response and may
   contain RRs.

6.3. Method of Measurement

   This category includes columns for references to relevant sections of
   the RFC(s) and any supplemental information needed to ensure an
   unambiguous methods for implementations.

6.3.1. Reference Method

   The methodology for this metric is defined as Type-P-Round-trip-
   Delay-Poisson-Stream in section 2.6 of RFC 2681 [RFC2681] and section
   3.6 of RFC 2681 [RFC2681] using the Type-P and Timeout defined under
   Fixed Parameters.

   The reference method distinguishes between long-delayed packets and
   lost packets by implementing a maximum waiting time for packet
   arrival. Tmax is the waiting time used as the threshold to declare a
   response packet lost. Lost packets SHALL be designated as having
   undefined delay and counted for the RLDNS metric.

   The calculations on the delay (RTT) SHALL be performed on the
   conditional distribution, conditioned on successful packet arrival
   within Tmax. Also, when all packet delays are stored, the process

which calculates the RTT value MAY enforce the Tmax threshold on
stored values before calculations. See section 4.1 of [RFC3393] for
details on the conditional distribution to exclude undefined values
of delay, and Section 5 of [RFC6703] for background on this analysis
choice.

The reference method requires some way to distinguish between
different packets in a stream to establish correspondence between
sending times and receiving times for each successfully-arriving
reply.

DNS Messages bearing Queries provide for random ID Numbers in the
Identification header field, so more than one query may be launched
while a previous request is outstanding when the ID Number is used.
Therefore, the ID Number MUST be retained at the Src or included with
each response packet to disambiguate packet reordering if it occurs.

IF a DNS response does not arrive within Tmax, the response time
RTDNS is undefined, and RLDNS = 1. The Message ID SHALL be used to
disambiguate the successive queries that are otherwise identical.

Since the ID Number filed is only 16 bits in length, it places a
limit on the number of simultaneous outstanding DNS queries during a
stress test from a single Src address.

Refer to Section 4.4 of [RFC6673] for expanded discussion of the
instruction to "send a Type-P packet back to the Src as quickly as
possible" in Section 2.6 of RFC 2681 [RFC2681]. However, the DNS
Server is expected to perform all required functions to prepare and
send a response, so the response time will include processing time
and network delay. Section 8 of [RFC6673] presents additional
requirements which SHALL be included in the method of measurement for
this metric.

In addition to operations described in [RFC2681], the Src MUST parse
the DNS headers of the reply and prepare the information for
subsequent reporting as a measured result, along with the Round-Trip
Delay.

6.3.2. Packet Stream Generation

This section gives the details of the packet traffic which is the
basis for measurement. In IPPM metrics, this is called the Stream,
and can easily be described by providing the list of stream
parameters.

Section 11.1.3 of RFC 2681 [RFC2330] provides three methods to
generate Poisson sampling intervals. The reciprocal of lambda is the

   average packet rate, thus the Run-time Parameter is Reciprocal_lambda
   = 1/lambda, in seconds.

   Method 3 is used, where given a start time (Run-time Parameter), the
   subsequent send times are all computed prior to measurement by
   computing the pseudo-random distribution of inter-packet send times,
   (truncating the distribution as specified in the Run-time
   Parameters), and the Src sends each packet at the computed times.

   Note that Trunc is the upper limit on inter-packet times in the
   Poisson distribution. A random value greater than Trunc is set equal
   to Trunc instead.

6.3.3. Traffic Filtering (observation) Details

   The measured results based on a filtered version of the packets
   observed, and this section provides the filter details (when
   present).

   NA

6.3.4. Sampling Distribution

   NA

6.3.5. Run-time Parameters and Data Format

   Run-time Parameters are input factors that must be determined,
   configured into the measurement system, and reported with the results
   for the context to be complete.

   Src the IP address of the host in the Src Role (format ipv4-address-
      no-zone value for IPv4, or ipv6-address-no-zone value for IPv6,
      see Section 4 of [RFC6991])

   Dst the IP address of the host in the Dst Role (format ipv4-address-
      no-zone value for IPv4, or ipv6-address-no-zone value for IPv6,
      see section 4 of [RFC6991])

   T0 a time, the start of a measurement interval, (format "date-and-
      time" as specified in Section 5.6 of [RFC3339], see also Section 3
      of [RFC6991]). The UTC Time Zone is required by Section 6.1 of
      [RFC2330]. When T0 is "all-zeros", a start time is unspecified
      and Tf is to be interpreted as the Duration of the measurement
      interval. The start time is controlled through other means.

   Tf a time, the end of a measurement interval, (format "date-and-time"
      as specified in Section 5.6 of [RFC3339], see also Section 3 of

[RFC6991]).   The UTC Time Zone is required by Section 6.1 of
   [RFC2330]. When T0 is "all-zeros", a end time date is ignored and
   Tf is interpreted as the Duration of the measurement interval.

   Reciprocal_lambda average packet interval for Poisson Streams
      expressed in units of seconds, as a positive value of type
      decimal64 with fraction digits = 4 (see section 9.3 of [RFC6020])
      with resolution of 0.0001 seconds (0.1 ms), and with lossless
      conversion to/from the 32-bit NTP timestamp as per section 6 of
   [RFC5905].

   Trunc Upper limit on Poisson distribution expressed in units of
      seconds, as a positive value of type decimal64 with fraction
      digits = 4 (see section 9.3 of [RFC6020]) with resolution of
      0.0001 seconds (0.1 ms), and with lossless conversion to/from the
      32-bit NTP timestamp as per section 6 of [RFC5905] (values above
      this limit will be clipped and set to the limit value). (if fixed,
      Trunc = 30.0000 seconds.)

   ID The 16-bit identifier assigned by the program that generates the
      query, and which must vary in successive queries, see
      Section 4.1.1 of [RFC1035]. This identifier is copied into the
      corresponding reply and can be used by the requester (Src) to
      match-up replies to outstanding queries.

   QNAME The domain name of the Query, formatted as specified in
      section 4 of [RFC6991].

   QTYPE The Query Type, which will correspond to the IP address family
      of the query (decimal 1 for IPv4 or 28 for IPv6, formatted as a
      uint16, as per section 9.2 of [RFC6020].

6.3.6. Roles

   Src launches each packet and waits for return transmissions from
      Dst.

   Dst waits for each packet from Src and sends a return packet to Src.

6.4. Output

   This category specifies all details of the Output of measurements
   using the metric.

6.4.1. Type

   Raw -- for each DNS Query packet sent, sets of values as defined in
   the next column, including the status of the response, only assigning
   delay values to successful query-response pairs.

6.4.2. Reference Definition

   For all outputs:

   T   the time the DNS Query was sent during the measurement interval,
       (format "date-and-time" as specified in Section 5.6 of [RFC3339],
       see also Section 3 of [RFC6991]). The UTC Time Zone is required
       by Section 6.1 of [RFC2330].

   dT The time value of the round-trip delay to receive the DNS
       response, expressed in units of seconds, as a positive value of
       type decimal64 with fraction digits = 9 (see section 9.3 of
       [RFC6020]) with resolution of 0.000000001 seconds (1.0 ns), and
       with lossless conversion to/from the 64-bit NTP timestamp as per
       section 6 of RFC [RFC5905]. This value is undefined when the
       response packet is not received at Src within waiting time Tmax
       seconds.

   Rcode   The value of the Rcode field in the DNS response header,
       expressed as a uint64 as specified in section 9.2 of [RFC6020].
       Non-zero values convey errors in the response, and such replies
       must be analyzed separately from successful requests.

6.4.3. Metric Units

   RTDNS: Round-trip Delay, dT, is expressed in seconds.

   RTLDNS: the Logical value, where 1 = Lost and 0 = Received.

6.4.4. Calibration

   Section 3.7.3 of [RFC7679] provides a means to quantify the
   systematic and random errors of a time measurement. In-situ
   calibration could be enabled with an internal loopback at the Source
   host that includes as much of the measurement system as possible,
   performs address and payload manipulation as needed, and provides
   some form of isolation (e.g., deterministic delay) to avoid send-
   receive interface contention. Some portion of the random and
   systematic error can be characterized this way.

   When a measurement controller requests a calibration measurement, the
   loopback is applied and the result is output in the same format as a

normal measurement with additional indication that it is a
calibration result.

Both internal loopback calibration and clock synchronization can be
used to estimate the *available accuracy* of the Output Metric Units.
For example, repeated loopback delay measurements will reveal the
portion of the Output result resolution which is the result of system
noise, and thus inaccurate.

6.5. Administrative items

6.5.1. Status

Current

6.5.2. Requestor

This RFC number

6.5.3. Revision

1.0

6.5.4. Revision Date

YYYY-MM-DD

6.6. Comments and Remarks

Additional (Informational) details for this entry

7. UDP Poisson One-way Delay and Loss Registry Entries

This section specifies five initial registry entries for the UDP
Poisson One-way Delay, and one for UDP Poisson One-way Loss.

IANA Note: Registry "Name" below specifies a single registry entry,
whose output format varies according to the <statistic> element of
the name that specifies one form of statistical summary. There is an
additional metric name for the Loss metric.

All column entries beside the ID, Name, Description, and Output
Reference Method categories are the same, thus this section proposes
six closely-related registry entries. As a result, IANA is also
asked to assign corresponding URLs to each Named Metric.

7.1. **Summary**

   This category includes multiple indexes to the registry entries, the
   element ID and metric name.

7.1.1. **ID (Identifier)**

   IANA is asked to assign different numeric identifiers to each of the
   six Metrics.

7.1.2. **Name**

   OWDelay_Active_IP-UDP-Poisson-
   Payload250B_RFCXXXXsecY_Seconds_<statistic>

   where <statistic> is one of:

   o 95Percentile

   o Mean

   o Min

   o Max

   o StdDev

   OWLoss_Active_IP-UDP-Poisson-
   Payload250B_RFCXXXXsecY_Percent_LossRatio

7.1.3. **URI and URL**

   URL: http:\\www.iana.org\ ... <name>

7.1.4. **Description**

   OWDelay: This metric assesses the delay of a stream of packets
   exchanged between two hosts (or measurement points), and reports the
   <statistic> One-way delay for all successfully exchanged packets
   based on their conditional delay distribution.

   where <statistic> is one of:

   o 95Percentile

   o Mean

   o Min

o Max

o StdDev

OWLoss: This metric assesses the loss ratio of a stream of packets
exchanged between two hosts (which are the two measurement points),
and the Output is the One-way loss ratio for all successfully
received packets expressed as a percentage.

7.2. Metric Definition

This category includes columns to prompt the entry of all necessary
details related to the metric definition, including the RFC reference
and values of input factors, called fixed parameters.

7.2.1. Reference Definition

For Delay:

Almes, G., Kalidindi, S., Zekauskas, M., and A. Morton, Ed., "A One-
Way Delay Metric for IP Performance Metrics (IPPM)", STD 81, RFC
7679, DOI 10.17487/RFC7679, January 2016, <http://www.rfc-
editor.org/info/rfc7679>.

[RFC7679]

Morton, A., and Stephan, E., "Spatial Composition of Metrics", RFC
6049, January 2011.

[RFC6049]

Section 3.4 of [RFC7679] provides the reference definition of the
singleton (single value) One-way delay metric. Section 4.4 of
[RFC7679] provides the reference definition expanded to cover a
multi-value sample. Note that terms such as singleton and sample are
defined in Section 11 of [RFC2330].

Only successful packet transfers with finite delay are included in
the sample, as prescribed in section 4.1.2 of [RFC6049].

For loss:

Almes, G., Kalidini, S., Zekauskas, M., and A. Morton, Ed., "A One-
Way Loss Metric for IP Performance Metrics (IPPM)", RFC 7680, DOI
10.17487/RFC7680, January 2016, <http://www.rfc-editor.org/info/
rfc7680>.

Section 2.4 of [RFC7680] provides the reference definition of the
singleton (single value) one-way loss metric. Section 3.4 of
[RFC7680] provides the reference definition expanded to cover a
multi-singleton sample. Note that terms such as singleton and sample
are defined in Section 11 of [RFC2330].

7.2.2. Fixed Parameters

Type-P:

o   IPv4 header values:

    *   DSCP: set to 0

    *   TTL: set to 255

    *   Protocol: Set to 17 (UDP)

o   IPv6 header values:

    *   DSCP: set to 0

    *   Hop Count: set to 255

    *   Protocol: Set to 17 (UDP)

o   UDP header values:

    *   Checksum: the checksum MUST be calculated and included in the
        header

o   UDP Payload: TWAMP Test Packet Formats, Section 4.1.2 of [RFC5357]

    *   Security features in use influence the number of Padding
        octets.

    *   250 octets total, including the TWAMP format

Other measurement parameters:

Tmax: a loss threshold waiting time with value 3.0, expressed in
    units of seconds, as a positive value of type decimal64 with
    fraction digits = 4 (see section 9.3 of [RFC6020]) and with
    resolution of 0.0001 seconds (0.1 ms), with lossless conversion
    to/from the 32-bit NTP timestamp as per section 6 of [RFC5905].

See the Packet Stream generation category for two additional Fixed
Parameters.

7.3. Method of Measurement

   This category includes columns for references to relevant sections of
   the RFC(s) and any supplemental information needed to ensure an
   unambiguous methods for implementations.

7.3.1. Reference Method

   The methodology for this metric is defined as Type-P-One-way-Delay-
   Poisson-Stream in section 3.6 of [RFC7679] and section 4.6 of
   [RFC7679] using the Type-P and Tmax defined under Fixed Parameters.

   The reference method distinguishes between long-delayed packets and
   lost packets by implementing a maximum waiting time for packet
   arrival. Tmax is the waiting time used as the threshold to declare a
   packet lost. Lost packets SHALL be designated as having undefined
   delay, and counted for the OWLoss metric.

   The calculations on the one-way delay SHALL be performed on the
   conditional distribution, conditioned on successful packet arrival
   within Tmax. Also, when all packet delays are stored, the process
   which calculates the one-way delay value MAY enforce the Tmax
   threshold on stored values before calculations. See section 4.1 of
   [RFC3393] for details on the conditional distribution to exclude
   undefined values of delay, and Section 5 of [RFC6703] for background
   on this analysis choice.

   The reference method requires some way to distinguish between
   different packets in a stream to establish correspondence between
   sending times and receiving times for each successfully-arriving
   packet. Sequence numbers or other send-order identification MUST be
   retained at the Src or included with each packet to disambiguate
   packet reordering if it occurs.

   Since a standard measurement protocol is employed [RFC5357], then the
   measurement process will determine the sequence numbers or timestamps
   applied to test packets after the Fixed and Runtime parameters are
   passed to that process. The measurement protocol dictates the format
   of sequence numbers and time-stamps conveyed in the TWAMP-Test packet
   payload.

7.3.2. Packet Stream Generation

   This section gives the details of the packet traffic which is the
   basis for measurement. In IPPM metrics, this is called the Stream,
   and can easily be described by providing the list of stream
   parameters.

Section 11.1.3 of RFC 2681 [RFC2330] provides three methods to
generate Poisson sampling intervals. The reciprocal of lambda is the
average packet spacing, thus the Run-time Parameter is
Reciprocal_lambda = 1/lambda, in seconds.

Method 3 SHALL be used, where given a start time (Run-time
Parameter), the subsequent send times are all computed prior to
measurement by computing the pseudo-random distribution of inter-
packet send times, (truncating the distribution as specified in the
Parameter Trunc), and the Src sends each packet at the computed
times.

Note that Trunc is the upper limit on inter-packet times in the
Poisson distribution. A random value greater than Trunc is set equal
to Trunc instead.

Reciprocal_lambda average packet interval for Poisson Streams
   expressed in units of seconds, as a positive value of type
   decimal64 with fraction digits = 4 (see section 9.3 of [RFC6020])
   with resolution of 0.0001 seconds (0.1 ms), and with lossless
   conversion to/from the 32-bit NTP timestamp as per section 6 of
   [RFC5905]. Reciprocal_lambda = 1 packet per second.

Trunc Upper limit on Poisson distribution expressed in units of
   seconds, as a positive value of type decimal64 with fraction
   digits = 4 (see section 9.3 of [RFC6020]) with resolution of
   0.0001 seconds (0.1 ms), and with lossless conversion to/from the
   32-bit NTP timestamp as per section 6 of [RFC5905] (values above
   this limit will be clipped and set to the limit value). Trunc =
   30.0000 seconds.

7.3.3. Traffic Filtering (observation) Details

NA

7.3.4. Sampling Distribution

NA

7.3.5. Run-time Parameters and Data Format

Run-time Parameters are input factors that must be determined,
configured into the measurement system, and reported with the results
for the context to be complete.

Src the IP address of the host in the Src Role (format ipv4-address-
   no-zone value for IPv4, or ipv6-address-no-zone value for IPv6,
   see Section 4 of [RFC6991])

Dst the IP address of the host in the Dst Role (format ipv4-address-
     no-zone value for IPv4, or ipv6-address-no-zone value for IPv6,
     see [section 4 of [RFC6991]])

T0 a time, the start of a measurement interval, (format "date-and-
   time" as specified in [Section 5.6 of [RFC3339]], see also [Section 3
   of [RFC6991]]). The UTC Time Zone is required by [Section 6.1 of
   [RFC2330]]. When T0 is "all-zeros", a start time is unspecified
   and Tf is to be interpreted as the Duration of the measurement
   interval. The start time is controlled through other means.

Tf a time, the end of a measurement interval, (format "date-and-time"
   as specified in [Section 5.6 of [RFC3339]], see also [Section 3 of
   [RFC6991]]). The UTC Time Zone is required by [Section 6.1 of
   [RFC2330]]. When T0 is "all-zeros", a end time date is ignored and
   Tf is interpreted as the Duration of the measurement interval.

7.3.6. Roles

<lists the names of the different roles from the measurement method>

Src launches each packet and waits for return transmissions from
     Dst. This is the TWAMP Session-Sender.

Dst waits for each packet from Src and sends a return packet to Src.
     This is the TWAMP Session-Reflector.

7.4. Output

This category specifies all details of the Output of measurements
using the metric.

7.4.1. Type

See subsection titles below for Types.

7.4.2. Reference Definition

For all output types ---

T0 the start of a measurement interval, (format "date-and-time" as
   specified in [Section 5.6 of [RFC3339]], see also [Section 3 of
   [RFC6991]]). The UTC Time Zone is required by [Section 6.1 of
   [RFC2330]].

Tf the end of a measurement interval, (format "date-and-time" as
   specified in [Section 5.6 of [RFC3339]], see also [Section 3] of

[RFC6991]]). The UTC Time Zone is required by Section 6.1 of
   [RFC2330].

For LossRatio -- the count of lost packets to total packets sent is
the basis for the loss ratio calculation as per Section 4.1 of
[RFC7680].

For each <statistic>, one of the following sub-sections apply:

7.4.2.1. Percentile95

The 95th percentile SHALL be calculated using the conditional
distribution of all packets with a finite value of One-way delay
(undefined delays are excluded), a single value as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
[RFC6703] for background on this analysis choice.

See section 4.3 of [RFC3393] for details on the percentile statistic
(where Round-trip delay should be substituted for "ipdv").

The percentile = 95, meaning that the reported delay, "95Percentile",
is the smallest value of one-way delay for which the Empirical
Distribution Function (EDF), F(95Percentile) >= 95% of the singleton
one-way delay values in the conditional distribution. See section
11.3 of [RFC2330] for the definition of the percentile statistic
using the EDF.

95Percentile The time value of the result is expressed in units of
   seconds, as a positive value of type decimal64 with fraction
   digits = 9 (see section 9.3 of [RFC6020]) with resolution of
   0.000000001 seconds (1.0 ns), and with lossless conversion to/from
   the 64-bit NTP timestamp as per section 6 of RFC [RFC5905]

7.4.2.2. Mean

The mean SHALL be calculated using the conditional distribution of
all packets with a finite value of One-way delay (undefined delays
are excluded), a single value as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
[RFC6703] for background on this analysis choice.

See section 4.2.2 of [RFC6049] for details on calculating this
statistic, and 4.2.3 of [RFC6049].

Mean The time value of the result is expressed in units of seconds,
     as a positive value of type decimal64 with fraction digits = 9
     (see section 9.3 of [RFC6020]) with resolution of 0.000000001
     seconds (1.0 ns), and with lossless conversion to/from the 64-bit
     NTP timestamp as per section 6 of RFC [RFC5905]

7.4.2.3. Min

The minimum SHALL be calculated using the conditional distribution of
all packets with a finite value of One-way delay (undefined delays
are excluded), a single value as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
[RFC6703] for background on this analysis choice.

See section 4.3.2 of [RFC6049] for details on calculating this
statistic, and 4.3.3 of [RFC6049].

Min The time value of the result is expressed in units of seconds,
     as a positive value of type decimal64 with fraction digits = 9
     (see section 9.3 of [RFC6020]) with resolution of 0.000000001
     seconds (1.0 ns), and with lossless conversion to/from the 64-bit
     NTP timestamp as per section 6 of RFC [RFC5905]

7.4.2.4. Max

The maximum SHALL be calculated using the conditional distribution of
all packets with a finite value of One-way delay (undefined delays
are excluded), a single value as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
[RFC6703] for background on this analysis choice.

See section 4.3.2 of [RFC6049] for a closely related method for
calculating this statistic, and 4.3.3 of [RFC6049]. The formula is
as follows:

          Max = (FiniteDelay [j])

                  such that for some index, j, where 1 <= j <= N
                  FiniteDelay[j] >= FiniteDelay[n] for all n

Max The time value of the result is expressed in units of seconds,
     as a positive value of type decimal64 with fraction digits = 9
     (see section 9.3 of [RFC6020]) with resolution of 0.000000001

seconds (1.0 ns), and with lossless conversion to/from the 64-bit
NTP timestamp as per section 6 of RFC [RFC5905]

7.4.2.5. Std_Dev

The Std_Dev SHALL be calculated using the conditional distribution of
all packets with a finite value of One-way delay (undefined delays
are excluded), a single value as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
 [RFC6703] for background on this analysis choice.

See section 4.3.2 of [RFC6049] for a closely related method for
calculating this statistic, and 4.3.3 of [RFC6049]. The formula is
the classic calculation for standard deviation of a population.

Std_Dev The time value of the result is expressed in units of
   seconds, as a positive value of type decimal64 with fraction
   digits = 9 (see section 9.3 of [RFC6020]) with resolution of
   0.000000001 seconds (1.0 ns), and with lossless conversion to/from
   the 64-bit NTP timestamp as per section 6 of RFC [RFC5905]

7.4.3. Metric Units

The <statistic> of One-way Delay is expressed in seconds.

The One-way Loss Ratio is expressed as a percentage of lost packets
to total packets sent.

7.4.4. Calibration

Section 3.7.3 of [RFC7679] provides a means to quantify the
systematic and random errors of a time measurement. In-situ
calibration could be enabled with an internal loopback that includes
as much of the measurement system as possible, performs address
manipulation as needed, and provides some form of isolation (e.g.,
deterministic delay) to avoid send-receive interface contention.
Some portion of the random and systematic error can be characterized
this way.

For one-way delay measurements, the error calibration must include an
assessment of the internal clock synchronization with its external
reference (this internal clock is supplying timestamps for
measurement). In practice, the time offsets of clocks at both the
source and destination are needed to estimate the systematic error
due to imperfect clock synchronization (the time offsets are

smoothed, thus the random variation is not usually represented in the results).

time_offset The time value of the result is expressed in units of seconds, as a signed value of type decimal64 with fraction digits = 9 (see section 9.3 of [RFC6020]) with resolution of 0.000000001 seconds (1.0 ns), and with lossless conversion to/from the 64-bit NTP timestamp as per section 6 of RFC [RFC5905]

When a measurement controller requests a calibration measurement, the loopback is applied and the result is output in the same format as a normal measurement with additional indication that it is a calibration result. In any measurement, the measurement function SHOULD report its current estimate of time offset as an indicator of the degree of synchronization.

Both internal loopback calibration and clock synchronization can be used to estimate the *available accuracy* of the Output Metric Units. For example, repeated loopback delay measurements will reveal the portion of the Output result resolution which is the result of system noise, and thus inaccurate.

7.5. Administrative items

7.5.1. Status

Current

7.5.2. Requestor

This REFC number

7.5.3. Revision

1.0

7.5.4. Revision Date

YYYY-MM-DD

7.6. Comments and Remarks

Additional (Informational) details for this entry

8. UDP Periodic One-way Delay and Loss Registry Entries

   This section specifies five initial registry entries for the UDP
   Periodic One-way Delay, and one for UDP Periodic One-way Loss.

   IANA Note: Registry "Name" below specifies a single registry entry,
   whose output format varies according to the <statistic> element of
   the name that specifies one form of statistical summary. There is an
   additional metric name for the Loss metric.

   All column entries beside the ID, Name, Description, and Output
   Reference Method categories are the same, thus this section proposes
   six closely-related registry entries. As a result, IANA is also
   asked to assign corresponding URLs to each Named Metric.

8.1. Summary

   This category includes multiple indexes to the registry entries, the
   element ID and metric name.

8.1.1. ID (Identifier)

   IANA is asked to assign a different numeric identifiers to each of
   the six Metrics.

8.1.2. Name

   OWDelay_Active_IP-UDP-Periodic20m-
   Payload142B_RFCXXXXsecY_Seconds_<statistic>

   where <statistic> is one of:

   o 95Percentile

   o Mean

   o Min

   o Max

   o StdDev

   OWLoss_Active_IP-UDP-Periodic-
   Payload142B_RFCXXXXsecY_Percent_LossRatio

8.1.3. **URIs**

   URL: http:\\www.iana.org\ ... <name>

8.1.4. **Description**

   OWDelay: This metric assesses the delay of a stream of packets
   exchanged between two hosts (or measurement points), and reports the
   <statistic> One-way delay for all successfully exchanged packets
   based on their conditional delay distribution.

   where <statistic> is one of:

   o 95Percentile

   o Mean

   o Min

   o Max

   o StdDev

   OWLoss: This metric assesses the loss ratio of a stream of packets
   exchanged between two hosts (which are the two measurement points),
   and the Output is the One-way loss ratio for all successfully
   received packets expressed as a percentage.

8.2. **Metric Definition**

   This category includes columns to prompt the entry of all necessary
   details related to the metric definition, including the RFC reference
   and values of input factors, called fixed parameters.

8.2.1. **Reference Definition**

   For Delay:

   Almes, G., Kalidindi, S., Zekauskas, M., and A. Morton, Ed., "A One-
   Way Delay Metric for IP Performance Metrics (IPPM)", STD 81, RFC
   7679, DOI 10.17487/RFC7679, January 2016, <http://www.rfc-
   editor.org/info/rfc7679>.

   [RFC7679]

   Morton, A., and Stephan, E., "Spatial Composition of Metrics", RFC
   6049, January 2011.

[RFC6049]

Section 3.4 of [RFC7679] provides the reference definition of the
singleton (single value) One-way delay metric. Section 4.4 of
[RFC7679] provides the reference definition expanded to cover a
multi-value sample. Note that terms such as singleton and sample are
defined in Section 11 of [RFC2330].

Only successful packet transfers with finite delay are included in
the sample, as prescribed in section 4.1.2 of [RFC6049].

For loss:

Almes, G., Kalidini, S., Zekauskas, M., and A. Morton, Ed., "A One-
Way Loss Metric for IP Performance Metrics (IPPM)", RFC 7680, DOI
10.17487/RFC7680, January 2016, <http://www.rfc-editor.org/info/
rfc7680>.

Section 2.4 of [RFC7680] provides the reference definition of the
singleton (single value) one-way loss metric. Section 3.4 of
[RFC7680] provides the reference definition expanded to cover a
multi-singleton sample. Note that terms such as singleton and sample
are defined in Section 11 of [RFC2330].

8.2.2. Fixed Parameters

Type-P:

o   IPv4 header values:

    *   DSCP: set to 0

    *   TTL: set to 255

    *   Protocol: Set to 17 (UDP)

o   IPv6 header values:

    *   DSCP: set to 0

    *   Hop Count: set to 255

    *   Protocol: Set to 17 (UDP)

o   UDP header values:

    *   Checksum: the checksum MUST be calculated and included in the
        header

o UDP Payload: TWAMP Test Packet Formats, Section 4.1.2 of [RFC5357]

   * Security features in use influence the number of Padding
      octets.

   * 142 octets total, including the TWAMP format (if used)

Other measurement parameters:

Tmax: a loss threshold waiting time with value 3.0, expressed in
   units of seconds, as a positive value of type decimal64 with
   fraction digits = 4 (see section 9.3 of [RFC6020]) and with
   resolution of 0.0001 seconds (0.1 ms), with lossless conversion
   to/from the 32-bit NTP timestamp as per section 6 of [RFC5905].

See the Packet Stream generation category for two additional Fixed
Parameters.

8.3. Method of Measurement

This category includes columns for references to relevant sections of
the RFC(s) and any supplemental information needed to ensure an
unambiguous methods for implementations.

8.3.1. Reference Method

The methodology for this metric is defined as Type-P-One-way-Delay-
Poisson-Stream in section 3.6 of [RFC7679] and section 4.6 of
[RFC7679] using the Type-P and Tmax defined under Fixed Parameters.
However, a Periodic stream is used, as defined in [RFC3432].

The reference method distinguishes between long-delayed packets and
lost packets by implementing a maximum waiting time for packet
arrival. Tmax is the waiting time used as the threshold to declare a
packet lost. Lost packets SHALL be designated as having undefined
delay, and counted for the OWLoss metric.

The calculations on the one-way delay SHALL be performed on the
conditional distribution, conditioned on successful packet arrival
within Tmax. Also, when all packet delays are stored, the process
which calculates the one-way delay value MAY enforce the Tmax
threshold on stored values before calculations. See section 4.1 of
[RFC3393] for details on the conditional distribution to exclude
undefined values of delay, and Section 5 of [RFC6703] for background
on this analysis choice.

The reference method requires some way to distinguish between
different packets in a stream to establish correspondence between

sending times and receiving times for each successfully-arriving
packet. Sequence numbers or other send-order identification MUST be
retained at the Src or included with each packet to disambiguate
packet reordering if it occurs.

Since a standard measurement protocol is employed [RFC5357], then the
measurement process will determine the sequence numbers or timestamps
applied to test packets after the Fixed and Runtime parameters are
passed to that process. The measurement protocol dictates the format
of sequence numbers and time-stamps conveyed in the TWAMP-Test packet
payload.

8.3.2. Packet Stream Generation

This section gives the details of the packet traffic which is the
basis for measurement. In IPPM metrics, this is called the Stream,
and can easily be described by providing the list of stream
parameters.

Section 3 of [RFC3432] prescribes the method for generating Periodic
streams using associated parameters.

incT the nominal duration of inter-packet interval, first bit to
   first bit, with value 0.0200 expressed in units of seconds, as a
   positive value of type decimal64 with fraction digits = 4 (see
   section 9.3 of [RFC6020]) and with resolution of 0.0001 seconds
   (0.1 ms), with lossless conversion to/from the 32-bit NTP
   timestamp as per section 6 of [RFC5905].

dT the duration of the interval for allowed sample start times, with
   value 1.0000, expressed in units of seconds, as a positive value
   of type decimal64 with fraction digits = 4 (see section 9.3 of
   [RFC6020]) and with resolution of 0.0001 seconds (0.1 ms), with
   lossless conversion to/from the 32-bit NTP timestamp as per
   section 6 of [RFC5905].

T0 the actual start time of the periodic stream, determined from T0
   and dT.

NOTE: an initiation process with a number of control exchanges
resulting in unpredictable start times (within a time interval) may
be sufficient to avoid synchronization of periodic streams, and
therefore a valid replacement for selecting a start time at random
from a fixed interval.

These stream parameters will be specified as Run-time parameters.

8.3.3. Traffic Filtering (observation) Details

   NA

8.3.4. Sampling Distribution

   NA

8.3.5. Run-time Parameters and Data Format

   Run-time Parameters are input factors that must be determined,
   configured into the measurement system, and reported with the results
   for the context to be complete.

   Src the IP address of the host in the Src Role (format ipv4-address-
      no-zone value for IPv4, or ipv6-address-no-zone value for IPv6,
      see Section 4 of [RFC6991])

   Dst the IP address of the host in the Dst Role (format ipv4-address-
      no-zone value for IPv4, or ipv6-address-no-zone value for IPv6,
      see section 4 of [RFC6991])

   T0 a time, the start of a measurement interval, (format "date-and-
      time" as specified in Section 5.6 of [RFC3339], see also Section 3
      of [RFC6991]). The UTC Time Zone is required by Section 6.1 of
      [RFC2330]. When T0 is "all-zeros", a start time is unspecified
      and Tf is to be interpreted as the Duration of the measurement
      interval. The start time is controlled through other means.

   Tf a time, the end of a measurement interval, (format "date-and-time"
      as specified in Section 5.6 of [RFC3339], see also Section 3 of
      [RFC6991]). The UTC Time Zone is required by Section 6.1 of
      [RFC2330]. When T0 is "all-zeros", a end time date is ignored and
      Tf is interpreted as the Duration of the measurement interval.

8.3.6. Roles

   Src launches each packet and waits for return transmissions from
      Dst. This is the TWAMP Session-Sender.

   Dst waits for each packet from Src and sends a return packet to Src.
      This is the TWAMP Session-Reflector.

8.4. Output

   This category specifies all details of the Output of measurements
   using the metric.

8.4.1. Type

   <insert name of the output type, raw or a selected summary statistic>

   See subsection titles in Reference Definition for Latency Types.

8.4.2. Reference Definition

   For all output types ---

   T0 the start of a measurement interval, (format "date-and-time" as
      specified in Section 5.6 of [RFC3339], see also Section 3 of
      [RFC6991]). The UTC Time Zone is required by Section 6.1 of
      [RFC2330].

   Tf the end of a measurement interval, (format "date-and-time" as
      specified in Section 5.6 of [RFC3339], see also Section 3 of
      [RFC6991]). The UTC Time Zone is required by Section 6.1 of
      [RFC2330].

   For LossRatio -- the count of lost packets to total packets sent is
   the basis for the loss ratio calculation as per Section 4.1 of
   [RFC7680].

   For each <statistic>, one of the following sub-sections apply:

8.4.2.1. Percentile95

   The 95th percentile SHALL be calculated using the conditional
   distribution of all packets with a finite value of One-way delay
   (undefined delays are excluded), a single value as follows:

   See section 4.1 of [RFC3393] for details on the conditional
   distribution to exclude undefined values of delay, and Section 5 of
   [RFC6703] for background on this analysis choice.

   See section 4.3 of [RFC3393] for details on the percentile statistic
   (where Round-trip delay should be substituted for "ipdv").

   The percentile = 95, meaning that the reported delay, "95Percentile",
   is the smallest value of one-way delay for which the Empirical
   Distribution Function (EDF), F(95Percentile) >= 95% of the singleton
   one-way delay values in the conditional distribution. See section
   11.3 of [RFC2330] for the definition of the percentile statistic
   using the EDF.

   95Percentile The time value of the result is expressed in units of
      seconds, as a positive value of type decimal64 with fraction

digits = 9 (see section 9.3 of [RFC6020]) with resolution of
0.000000001 seconds (1.0 ns), and with lossless conversion to/from
the 64-bit NTP timestamp as per section 6 of RFC [RFC5905]

8.4.2.2. Mean

The mean SHALL be calculated using the conditional distribution of
all packets with a finite value of One-way delay (undefined delays
are excluded), a single value as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
[RFC6703] for background on this analysis choice.

See section 4.2.2 of [RFC6049] for details on calculating this
statistic, and 4.2.3 of [RFC6049].

Mean The time value of the result is expressed in units of seconds,
   as a positive value of type decimal64 with fraction digits = 9
   (see section 9.3 of [RFC6020]) with resolution of 0.000000001
   seconds (1.0 ns), and with lossless conversion to/from the 64-bit
   NTP timestamp as per section 6 of RFC [RFC5905]

8.4.2.3. Min

The minimum SHALL be calculated using the conditional distribution of
all packets with a finite value of One-way delay (undefined delays
are excluded), a single value as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
[RFC6703] for background on this analysis choice.

See section 4.3.2 of [RFC6049] for details on calculating this
statistic, and 4.3.3 of [RFC6049].

Min The time value of the result is expressed in units of seconds,
   as a positive value of type decimal64 with fraction digits = 9
   (see section 9.3 of [RFC6020]) with resolution of 0.000000001
   seconds (1.0 ns), and with lossless conversion to/from the 64-bit
   NTP timestamp as per section 6 of RFC [RFC5905]

8.4.2.4. Max

The maximum SHALL be calculated using the conditional distribution of
all packets with a finite value of One-way delay (undefined delays
are excluded), a single value as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
[RFC6703] for background on this analysis choice.

See section 4.3.2 of [RFC6049] for a closely related method for
calculating this statistic, and 4.3.3 of [RFC6049]. The formula is
as follows:

        Max = (FiniteDelay [j])

                such that for some index, j, where 1 <= j <= N
                FiniteDelay[j] >= FiniteDelay[n] for all n

Max The time value of the result is expressed in units of seconds,
   as a positive value of type decimal64 with fraction digits = 9
   (see section 9.3 of [RFC6020]) with resolution of 0.000000001
   seconds (1.0 ns), and with lossless conversion to/from the 64-bit
   NTP timestamp as per section 6 of RFC [RFC5905]

8.4.2.5. Std_Dev

The Std_Dev SHALL be calculated using the conditional distribution of
all packets with a finite value of One-way delay (undefined delays
are excluded), a single value as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
[RFC6703] for background on this analysis choice.

See section 4.3.2 of [RFC6049] for a closely related method for
calculating this statistic, and 4.3.3 of [RFC6049]. The formula is
the classic calculation for standard deviation of a population.

Std_Dev The time value of the result is expressed in units of
   seconds, as a positive value of type decimal64 with fraction
   digits = 9 (see section 9.3 of [RFC6020]) with resolution of
   0.000000001 seconds (1.0 ns), and with lossless conversion to/from
   the 64-bit NTP timestamp as per section 6 of RFC [RFC5905]

8.4.3. Metric Units

The <statistic> of One-way Delay is expressed in seconds, where
<statistic> is one of:

o 95Percentile

o Mean

   o Min

   o Max

   o StdDev

   The One-way Loss Ratio is expressed as a percentage of lost packets
   to total packets sent.

8.4.4. Calibration

   Section 3.7.3 of [RFC7679] provides a means to quantify the
   systematic and random errors of a time measurement. In-situ
   calibration could be enabled with an internal loopback that includes
   as much of the measurement system as possible, performs address
   manipulation as needed, and provides some form of isolation (e.g.,
   deterministic delay) to avoid send-receive interface contention.
   Some portion of the random and systematic error can be characterized
   this way.

   For one-way delay measurements, the error calibration must include an
   assessment of the internal clock synchronization with its external
   reference (this internal clock is supplying timestamps for
   measurement). In practice, the time offsets of clocks at both the
   source and destination are needed to estimate the systematic error
   due to imperfect clock synchronization (the time offsets are
   smoothed, thus the random variation is not usually represented in the
   results).

   time_offset The time value of the result is expressed in units of
      seconds, as a signed value of type decimal64 with fraction digits
      = 9 (see section 9.3 of [RFC6020]) with resolution of 0.000000001
      seconds (1.0 ns), and with lossless conversion to/from the 64-bit
      NTP timestamp as per section 6 of RFC [RFC5905]

   When a measurement controller requests a calibration measurement, the
   loopback is applied and the result is output in the same format as a
   normal measurement with additional indication that it is a
   calibration result. In any measurement, the measurement function
   SHOULD report its current estimate of time offset as an indicator of
   the degree of synchronization.

   Both internal loopback calibration and clock synchronization can be
   used to estimate the *available accuracy* of the Output Metric Units.
   For example, repeated loopback delay measurements will reveal the
   portion of the Output result resolution which is the result of system
   noise, and thus inaccurate.

8.5. Administrative items

8.5.1. Status

   Current

8.5.2. Requestor

   This RFC number

8.5.3. Revision

   1.0

8.5.4. Revision Date

   YYYY-MM-DD

8.6. Comments and Remarks

9. ICMP Round-trip Latency and Loss Registry Entries

   This section specifies three initial registry entries for the ICMP
   Round-trip Latency, and another entry for ICMP Round-trip Loss Ratio.

   This section specifies four Registry entries with many common
   columns.

   All column entries beside the ID, Name, Description, and Output
   Reference Method categories are the same, thus this section proposes
   two closely-related registry entries. As a result, IANA is also
   asked to assign four corresponding URLs to each Named Metric.

9.1. Summary

   This category includes multiple indexes to the registry entry: the
   element ID and metric name.

9.1.1. ID (Identifier)

   IANA is asked to assign different numeric identifiers to each of the
   four Named Metrics.

9.1.2. Name

   RTDelay_Active_IP-ICMP-SendOnRcv_RFCXXXXsecY_Seconds_<statistic>

   where <statistic> is one of:

o Mean

o Min

o Max

RTLoss_Active_IP-ICMP-SendOnRcv_RFCXXXXsecY_Percent_LossRatio

9.1.3. URIs

URL: http://<TBD by IANA>/<name>

9.1.4. Description

RTDelay: This metric assesses the delay of a stream of ICMP packets
exchanged between two hosts (which are the two measurement points),
and the Output is the Round-trip delay for all successfully exchanged
packets expressed as the <statistic> of their conditional delay
distribution, where <statistic> is one of:

o Mean

o Min

o Max

RTLoss: This metric assesses the loss ratio of a stream of ICMP
packets exchanged between two hosts (which are the two measurement
points), and the Output is the Round-trip loss ratio for all
successfully exchanged packets expressed as a percentage.

9.1.5. Change Controller

IETF

9.1.6. Version (of Registry Format)

1.0

9.2. Metric Definition

This category includes columns to prompt the entry of all necessary
details related to the metric definition, including the RFC reference
and values of input factors, called fixed parameters.

9.2.1. Reference Definition

   Almes, G., Kalidindi, S., and M. Zekauskas, "A Round-trip Delay
   Metric for IPPM", RFC 2681, September 1999.

   [RFC2681]

   Section 2.4 of [RFC2681] provides the reference definition of the
   singleton (single value) Round-trip delay metric. Section 3.4 of
   [RFC2681] provides the reference definition expanded to cover a
   multi-singleton sample. Note that terms such as singleton and sample
   are defined in Section 11 of [RFC2330].

   Note that although the [RFC2681] definition of "Round-trip-Delay
   between Src and Dst" is directionally ambiguous in the text, this
   metric tightens the definition further to recognize that the host in
   the "Src" role will send the first packet to "Dst", and ultimately
   receive the corresponding return packet from "Dst" (when neither are
   lost).

   Finally, note that the variable "dT" is used in [RFC2681] to refer to
   the value of Round-trip delay in metric definitions and methods. The
   variable "dT" has been re-used in other IPPM literature to refer to
   different quantities, and cannot be used as a global variable name.

   Morton, A., "Round-trip Packet Loss Metrics", RFC 6673, August 2012.

   [RFC6673]

   Both delay and loss metrics employ a maximum waiting time for
   received packets, so the count of lost packets to total packets sent
   is the basis for the loss ratio calculation as per Section 6.1 of
   [RFC6673].

9.2.2. Fixed Parameters

   Type-P as defined in Section 13 of [RFC2330]:

   o IPv4 header values:

      * DSCP: set to 0

      * TTL: set to 255

      * Protocol: Set to 01 (ICMP)

   o IPv6 header values:

     * DSCP: set to 0

     * Hop Limit: set to 255

     * Protocol: Set to 01 (ICMP)

   o ICMP header values:

     * Type: 8 (Echo Request)

     * Code: 0

     * Checksum: the checksum MUST be calculated and included in the
        header

     * (Identifier and Sequence Number set at Run-Time)

   o ICMP Payload

     * total of 32 bytes of random info

   Other measurement parameters:

   o Tmax: a loss threshold waiting time

     * 3.0, expressed in units of seconds, as a positive value of type
        decimal64 with fraction digits = 4 (see section 9.3 of
        [RFC6020]) and with resolution of 0.0001 seconds (0.1 ms), with
        lossless conversion to/from the 32-bit NTP timestamp as per
        section 6 of [RFC5905].

9.3. Method of Measurement

   This category includes columns for references to relevant sections of
   the RFC(s) and any supplemental information needed to ensure an
   unambiguous methods for implementations.

9.3.1. Reference Method

   The methodology for this metric is defined as Type-P-Round-trip-
   Delay-Poisson-Stream in section 2.6 of RFC 2681 [RFC2681] and section
   3.6 of RFC 2681 [RFC2681] using the Type-P and Tmax defined under
   Fixed Parameters.

   The reference method distinguishes between long-delayed packets and
   lost packets by implementing a maximum waiting time for packet
   arrival. Tmax is the waiting time used as the threshold to declare a

packet lost. Lost packets SHALL be designated as having undefined
delay, and counted for the RTLoss metric.

The calculations on the delay (RTD) SHALL be performed on the
conditional distribution, conditioned on successful packet arrival
within Tmax. Also, when all packet delays are stored, the process
which calculates the RTD value MAY enforce the Tmax threshold on
stored values before calculations. See section 4.1 of [RFC3393] for
details on the conditional distribution to exclude undefined values
of delay, and Section 5 of [RFC6703] for background on this analysis
choice.

The reference method requires some way to distinguish between
different packets in a stream to establish correspondence between
sending times and receiving times for each successfully-arriving
packet. Sequence numbers or other send-order identification MUST be
retained at the Src or included with each packet to disambiguate
packet reordering if it occurs.

The measurement process will determine the sequence numbers applied
to test packets after the Fixed and Runtime parameters are passed to
that process. The ICMP measurement process and protocol will dictate
the format of sequence numbers and other identifiers.

Refer to Section 4.4 of [RFC6673] for expanded discussion of the
instruction to "send a Type-P packet back to the Src as quickly as
possible" in Section 2.6 of RFC 2681 [RFC2681]. Section 8 of
[RFC6673] presents additional requirements which MUST be included in
the method of measurement for this metric.

9.3.2. Packet Stream Generation

This section gives the details of the packet traffic which is the
basis for measurement. In IPPM metrics, this is called the Stream,
and can easily be described by providing the list of stream
parameters.

The ICMP metrics use a sending discipline called "SendOnRcv" or Send
On Receive. This is a modification of Section 3 of [RFC3432], which
prescribes the method for generating Periodic streams using
associated parameters:

incT the nominal duration of inter-packet interval, first bit to
   first bit

dT the duration of the interval for allowed sample start times

T0 the actual start time of the periodic stream

The incT and T0 stream parameters will be specified as Run-time
parameters, dT is not used in SendOnRcv.

A SendOnRcv sender behaves exactly like a Periodic stream generator
while all reply packets arrive with RTD < incT, and the inter-packet
interval will be constant.

If a reply packet arrives with RTD >= incT, then the inter-packet
interval for the next sending time is nominally RTD.

If a reply packet fails to arrive within Tmax, then the inter-packet
interval for the next sending time is nominally Tmax.

If an immediate send on reply arrival is desired, then set incT=0.

9.3.3. Traffic Filtering (observation) Details

The measured results based on a filtered version of the packets
observed, and this section provides the filter details (when
present).

NA

9.3.4. Sampling Distribution

NA

9.3.5. Run-time Parameters and Data Format

Run-time Parameters are input factors that must be determined,
configured into the measurement system, and reported with the results
for the context to be complete.

Src the IP address of the host in the Src Role (format ipv4-address-
   no-zone value for IPv4, or ipv6-address-no-zone value for IPv6,
   see Section 4 of [RFC6991])

Dst the IP address of the host in the Dst Role (format ipv4-address-
   no-zone value for IPv4, or ipv6-address-no-zone value for IPv6,
   see section 4 of [RFC6991])

T0 a time, the start of a measurement interval, (format "date-and-
   time" as specified in Section 5.6 of [RFC3339], see also Section 3
   of [RFC6991]). The UTC Time Zone is required by Section 6.1 of
   [RFC2330]. When T0 is "all-zeros", a start time is unspecified
   and Tf is to be interpreted as the Duration of the measurement
   interval. The start time is controlled through other means.

Count The total count of ICMP Echo Requests to send, formatted as a
       uint16, as per section 9.2 of [RFC6020].

   (see the Packet Stream Generation section for additional Run-time
   parameters)

9.3.6. Roles

   Src launches each packet and waits for return transmissions from
        Dst.

   Dst waits for each packet from Src and sends a return packet to Src.

9.4. Output

   This category specifies all details of the Output of measurements
   using the metric.

9.4.1. Type

   See subsection titles in Reference Definition for Latency Types.

   LossRatio -- the count of lost packets to total packets sent is the
   basis for the loss ratio calculation as per Section 6.1 of [RFC6673].

9.4.2. Reference Definition

   For all output types ---

   T0 the start of a measurement interval, (format "date-and-time" as
       specified in Section 5.6 of [RFC3339], see also Section 3 of
       [RFC6991]). The UTC Time Zone is required by Section 6.1 of
       [RFC2330].

   Tf the end of a measurement interval, (format "date-and-time" as
       specified in Section 5.6 of [RFC3339], see also Section 3 of
       [RFC6991]). The UTC Time Zone is required by Section 6.1 of
       [RFC2330].

   TotalCount the count of packets actually sent by the Src to Dst
        during the measurement interval.

   For LossRatio -- the count of lost packets to total packets sent is
   the basis for the loss ratio calculation as per Section 4.1 of
   [RFC7680].

   For each <statistic>, one of the following sub-sections apply:

9.4.2.1. Mean

The mean SHALL be calculated using the conditional distribution of
all packets with a finite value of Round-trip delay (undefined delays
are excluded), a single value as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
[RFC6703] for background on this analysis choice.

See section 4.2.2 of [RFC6049] for details on calculating this
statistic, and 4.2.3 of [RFC6049].

Mean The time value of the result is expressed in units of seconds,
   as a positive value of type decimal64 with fraction digits = 9
   (see section 9.3 of [RFC6020]) with resolution of 0.000000001
   seconds (1.0 ns), and with lossless conversion to/from the 64-bit
   NTP timestamp as per section 6 of RFC [RFC5905]

9.4.2.2. Min

The minimum SHALL be calculated using the conditional distribution of
all packets with a finite value of Round-trip delay (undefined delays
are excluded), a single value as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
[RFC6703] for background on this analysis choice.

See section 4.3.2 of [RFC6049] for details on calculating this
statistic, and 4.3.3 of [RFC6049].

Min The time value of the result is expressed in units of seconds,
   as a positive value of type decimal64 with fraction digits = 9
   (see section 9.3 of [RFC6020]) with resolution of 0.000000001
   seconds (1.0 ns), and with lossless conversion to/from the 64-bit
   NTP timestamp as per section 6 of RFC [RFC5905]

9.4.2.3. Max

The maximum SHALL be calculated using the conditional distribution of
all packets with a finite value of Round-trip delay (undefined delays
are excluded), a single value as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
[RFC6703] for background on this analysis choice.

See section 4.3.2 of [RFC6049] for a closely related method for
calculating this statistic, and 4.3.3 of [RFC6049]. The formula is
as follows:

        Max = (FiniteDelay [j])

                such that for some index, j, where 1 <= j <= N
                FiniteDelay[j] >= FiniteDelay[n] for all n

Max The time value of the result is expressed in units of seconds,
   as a positive value of type decimal64 with fraction digits = 9
   (see section 9.3 of [RFC6020]) with resolution of 0.000000001
   seconds (1.0 ns), and with lossless conversion to/from the 64-bit
   NTP timestamp as per section 6 of RFC [RFC5905]

9.4.3. Metric Units

The <statistic> of Round-trip Delay is expressed in seconds, where
<statistic> is one of:

o Mean

o Min

o Max

The Round-trip Loss Ratio is expressed as a percentage of lost
packets to total packets sent.

9.4.4. Calibration

Section 3.7.3 of [RFC7679] provides a means to quantify the
systematic and random errors of a time measurement. In-situ
calibration could be enabled with an internal loopback at the Source
host that includes as much of the measurement system as possible,
performs address manipulation as needed, and provides some form of
isolation (e.g., deterministic delay) to avoid send-receive interface
contention. Some portion of the random and systematic error can be
characterized this way.

When a measurement controller requests a calibration measurement, the
loopback is applied and the result is output in the same format as a
normal measurement with additional indication that it is a
calibration result.

Both internal loopback calibration and clock synchronization can be
used to estimate the *available accuracy* of the Output Metric Units.
For example, repeated loopback delay measurements will reveal the

portion of the Output result resolution which is the result of system
noise, and thus inaccurate.

9.5. Administrative items

9.5.1. Status

Current

9.5.2. Requestor

This RFC number

9.5.3. Revision

1.0

9.5.4. Revision Date

YYYY-MM-DD

9.6. Comments and Remarks

None

10. TCP Round-Trip Delay and Loss Registry Entries

This section specifies three initial registry entries for the Passive
assessment of TCP Round-Trip Delay (RTD) and another entry for TCP
Round-trip Loss Count.

This section specifies four Registry entries with many common
columns.

All column entries beside the ID, Name, Description, and Output
Reference Method categories are the same, thus this section proposes
four closely-related registry entries. As a result, IANA is also
asked to assign four corresponding URLs to each Named Metric.

10.1. Summary

This category includes multiple indexes to the registry entry: the
element ID and metric name.

10.1.1. **ID (Identifier)**

   IANA is asked to assign different numeric identifiers to each of the
   four Named Metrics.

10.1.2. **Name**

   RTDelay_Passive_IP-TCP_RFCXXXXsecY_Seconds_<statistic>

   where <statistic> is one of:

   o Mean

   o Min

   o Max

   RTDelay_Passive_IP-TCP-HS_RFCXXXXsecY_Seconds_Singleton

   Note that a mid-point observer only has the opportuinty to compose a
   single RTDelay on the TCP Hand Shake.

   RTLoss_Passive_IP-TCP_RFCXXXXsecY_Packet_Count

10.1.3. **URIs**

   URL: http://<TBD by IANA>/<name>

10.1.4. **Description**

   RTDelay: This metric assesses the round-trip delay of TCP packets
   constituting a single connection, exchanged between two hosts. We
   consider the measurement of round-trip delay based on a single
   Observation Point [RFC7011] somewhere in the network. The Output is
   the Round-trip delay for all successfully exchanged packets expressed
   as the <statistic> of their conditional delay distribution, where
   <statistic> is one of:

   o Mean

   o Min

   o Max

   RTLoss: This metric assesses the estimated loss count for TCP packets
   constituting a single connection, exchanged between two hosts. We
   consider the measurement of round-trip delay based on a single

Observation Point [RFC7011] somewhere in the network. The Output is
the estimated Loss Count for the measurement interval.

10.1.5. Change Controller

IETF

10.1.6. Version (of Registry Format)

1.0

10.2. Metric Definition

This category includes columns to prompt the entry of all necessary
details related to the metric definition, including the RFC reference
and values of input factors, called fixed parameters.

10.2.1. Reference Definitions

Although there is no RFC that describes passive measurement of Round-
Trip Delay, the parallel definition for Active measurement is:

Almes, G., Kalidindi, S., and M. Zekauskas, "A Round-trip Delay
Metric for IPPM", RFC 2681, September 1999.

[RFC2681]

This metric definition uses the terms singleton and sample as defined
in Section 11 of [RFC2330]. (Section 2.4 of [RFC2681] provides the
reference definition of the singleton (single value) Round-trip delay
metric. Section 3.4 of [RFC2681] provides the reference definition
expanded to cover a multi-singleton sample.)

With the Observation Point [RFC7011] (OP) typically located between
the hosts participating in the TCP connection, the Round-trip Delay
metric requires two individual measurements between the OP and each
host, such that the Spatial Composition [RFC6049]of the measurements
yields a Round-trip Delay singleton (we are extending the composition
of one-way subpath delays to subpath round-trip delay).

Using the direction of TCP SYN transmission to anchor the
nomenclature, host A sends the SYN and host B replies with SYN-ACK
during connection establishment. The direction of SYN transfer is
considered the Forward direction of transmission, from A through OP
to B (Reverse is B through OP to A).

Traffic filters reduce the packet stream at the OP to a Qualified
bidirectional flow packets.

In the definitions below, Corresponding Packets are transferred in
different directions and convey a common value in a TCP header field
that establishes correspondence (to the extent possible). Examples
may be found in the TCP timestamp fields.

For a real number, RTD_fwd, >> the Round-trip Delay in the Forward
direction from OP to host B at time T' is RTD_fwd << REQUIRES that OP
observed a Qualified Packet to host B at wire-time T', that host B
received that packet and sent a Corresponding Packet back to host A,
and OP observed the Corresponding Packet at wire-time T' + RTD_fwd.

For a real number, RTD_rev, >> the Round-trip Delay in the Reverse
direction from OP to host A at time T'' is RTD_rev << REQUIRES that
OP observed a Qualified Packet to host A at wire-time T'', that host
A received that packet and sent a Corresponding Packet back to host
B, and that OP observed the Corresponding Packet at wire-time T'' +
RTD_rev.

Ideally, the packet sent from host B to host A in both definitions
above SHOULD be the same packet (or, when measuring RTD_rev first,
the packet from host A to host B in both definitions should be the
same).

The REQUIRED Composition Function for a singleton of Round-trip Delay
at time T (where T is the earliest of T' and T'' above) is:

RTDelay = RTD_fwd + RTD_rev

Note that when OP is located at host A or host B, one of the terms
composing RTDelay will be zero or negligible.

When the Qualified and Corresponding Packets are a TCP-SYN and a TCP-
SYN-ACK, then RTD_fwd == RTD_HS_fwd.

When the Qualified and Corresponding Packets are a TCP-SYN-ACK and a
TCP-ACK, then RTD_rev == RTD_HS_rev.

The REQUIRED Composition Function for a singleton of Round-trip Delay
for the connection Hand Shake:

RTDelay_HS = RTD_HS_fwd + RTD_HS_rev

The definition of Round-trip Loss Count uses the nomenclature
developed above, based on observation of the TCP header sequence
numbers and storing the sequence number gaps observed. Packet Losses
can be inferred from:

o Out-of-order segments: TCP segments are transmitted with
   monotonically increasing sequence numbers, but these segments may
   be received out of order. Section 3 of [RFC4737] describes the
   notion of "next expected" sequence numbers which can be adapted to
   TCP segments (for the purpose of detecting reordered packets).
   Observation of out-of-order segments indicates loss on the path
   prior to the OP, and creates a gap.

o Duplicate segments: Section 2 of [RFC5560] defines identical
   packets and is suitable for evaluation of TCP packets to detect
   duplication. Observation of duplicate segments *without a
   corresponding gap* indicates loss on the path following the OP
   (because they overlap part of the delivered sequence numbers
   already observed at OP).

Each observation of an out-of-order or duplicate infers a singleton
of loss, but composition of Round-trip Loss Counts will be conducted
over a measurement interval which is synonymous with a single TCP
connection.

With the above observations in the Forward direction over a
measurement interval, the count of out-of-order and duplicate
segments is defined as RTL_fwd. Comparable observations in the
Reverse direction are defined as RTL_rev.

For a measurement interval (corresponding to a single TCP
connection), T0 to Tf, the REQUIRED Composition Function for a the
two single-direction counts of inferred loss is:

RTLoss = RTL_fwd + RTL_rev

10.2.2. Fixed Parameters

<list and specify Fixed Parameters, input factors that must be
determined and embedded in the measurement system for use when
needed>

Traffic Filters:

o IPv4 header values:

   * DSCP: set to 0

   * Protocol: Set to 06 (TCP)

o IPv6 header values:

   * DSCP: set to 0

        * Protocol: Set to 06 (TCP)

   o TCP header values:

        * Flags: ACK, SYN, FIN, @@@@@ others??

        * Timestamp Option (TSopt): Set

           + Kind: 8

           + Length: 10 bytes

   o

10.3. Method of Measurement

   This category includes columns for references to relevant sections of
   the RFC(s) and any supplemental information needed to ensure an
   unambiguous methods for implementations.

10.3.1. Reference Methods

   The foundation methodology for this metric is defined in Section 4 of
   [RFC7323] using the Timestamp Option with modifications that allow
   application at a mid-path Observation Point (OP) [RFC7011]. Further
   details and applicable heuristics were derived from [Strowes] and
   [Trammell-14].

   The Traffic Filter at the OP is configured to observe a single TCP
   connection. When the SYN, SYN-ACK, ACK handshake occurs, it offers
   the first opportunity to measure both RTD_fwd (on the SYN to SYN-ACK
   pair) and RTD_rev (on the SYN-ACK to ACK pair). Label this singleton
   of RTDelay as RTDelay_HS (composed using the forward and reverse
   measurement pair). RTDelay_HS SHALL be treated separately from other
   RTDelays on data-bearing packets and their ACKs. The RTDelay_HS
   value MAY be used as a sanity check on other Composed values of
   RTDelay.

   For payload bearing packets, the OP measures the time interval
   between observation of a packet with Sequence Number s, and the
   corresponding ACK with same Sequence number. When the payload is
   transferred from host A to host B, the observed interval is RTD_fwd.

   Because many data transfers are unidirectional (say, in the Forward
   direction from host A to host B), it is necessary to use pure ACK
   packets with Timestamp (TSval) and their Timestamp value echo to
   perform a RTD_rev measurement. The time interval between observation

of the ACK from B to A, and the corresponding packet with Timestamp echo (TSecr) is the RTD_rev.

Delay Measurement Filtering Heuristics:

If Data payloads were transferred in both Forward and Reverse directions, then the Round-Trip Time Measurement Rule in Section 4.1 of [RFC7323] could be applied. This rule essentially excludes any measurement using a packet unless it makes progress in the transfer (advances the left edge of the send window, consistent with[Strowes]).

A different heuristic from [Trammell-14] is to exclude any RTD_rev that is larger than previously observed values. This would tend to exclude Reverse measurements taken when the Application has no data ready to send, because considerable time could be added to RTD_rev from this source of error.

Note that the above Heuristic assumes that host A is sending data. Host A expecting a download would mean that this heuristic should be applied to RTD_fwd.

The statistic calculations to summarize the delay (RTDelay) SHALL be performed on the conditional distribution, conditioned on successful Forward and Reverse measurements which follow the Heuristics.

Method for Inferring Loss:

The OP tracks sequence numbers and stores gaps for each direction of transmission, as well as the next-expected sequence number as in [Trammell-14] and [RFC4737]. Loss is inferred from Out-of-order segments and Duplicate segments.

Loss Measurement Filtering Heuristics:

[Trammell-14] adds a window of evaluation based on the RTDelay.

Distinguish Re-ordered from OOO due to loss, because sequence number gap is filled during the same RTDelay window. Segments detected as re-ordered according to [RFC4737] MUST reduce the Loss Count inferred from Out-of-order segments.

Spurious (unneeded) retransmissions (observed as duplicates) can also be reduced this way, as described in [Trammell-14].

Sources of Error:

The principal source of RTDelay error is the host processing time to
return a packet that defines the termination of a time interval. The
heuristics above intend to mitigate these errors by excluding
measurements where host processing time is a significant part of
RTD_fwd or RTD_rev.

A key source of RTLoss error is observation loss, described in
section 3 of [Trammell-14].

10.3.2. Packet Stream Generation

This section gives the details of the packet traffic which is the
basis for measurement. In IPPM metrics, this is called the Stream,
and can easily be described by providing the list of stream
parameters.

NA

10.3.3. Traffic Filtering (observation) Details

The measured results based on a filtered version of the packets
observed, and this section provides the filter details (when
present).

The Fixed Parameters above give a portion of the Traffic Filter.
Other aspects will be supplied as Run-time Parameters (below).

10.3.4. Sampling Distribution

This metric requires a complete sample of all packets that qualify
according to the Traffic Filter criteria.

10.3.5. Run-time Parameters and Data Format

Run-time Parameters are input factors that must be determined,
configured into the measurement system, and reported with the results
for the context to be complete.

Src the IP address of the host in the host A Role (format ipv4-
   address-no-zone value for IPv4, or ipv6-address-no-zone value for
   IPv6, see Section 4 of [RFC6991])

Dst the IP address of the host in the host B (format ipv4-address-
   no-zone value for IPv4, or ipv6-address-no-zone value for IPv6,
   see section 4 of [RFC6991])

T0 a time, the start of a measurement interval, (format "date-and-
   time" as specified in Section 5.6 of [RFC3339], see also Section 3

      of [RFC6991]). The UTC Time Zone is required by Section 6.1 of
      [RFC2330]. When T0 is "all-zeros", a start time is unspecified
      and Td is to be interpreted as the Duration of the measurement
      interval. The start time is controlled through other means.

   Td Optionally, the end of a measurement interval, (format "date-and-
      time" as specified in Section 5.6 of [RFC3339], see also Section 3
      of [RFC6991]), or the duration (see T0). The UTC Time Zone is
      required by Section 6.1 of [RFC2330]. Alternatively, the end of
      the measurement interval MAY be controlled by the measured
      connection, where the second pair of FIN and ACK packets exchanged
      between host A and B effectively ends the interval.

   TTL or Hop Limit Set at desired value.

10.3.6. Roles

   host A launches the SYN packet to open the connection, and
      synonymous with an IP address.

   host B replies with the SYN-ACK packet to open the connection, and
      synonymous with an IP address.

10.4. Output

   This category specifies all details of the Output of measurements
   using the metric.

10.4.1. Type

   See subsection titles in Reference Definition for RTDelay Types.

   For RTLoss -- the count of lost packets.

10.4.2. Reference Definition

   For all output types ---

   T0 the start of a measurement interval, (format "date-and-time" as
      specified in Section 5.6 of [RFC3339], see also Section 3 of
      [RFC6991]). The UTC Time Zone is required by Section 6.1 of
      [RFC2330].

   Tf the end of a measurement interval, (format "date-and-time" as
      specified in Section 5.6 of [RFC3339], see also Section 3 of
      [RFC6991]). The UTC Time Zone is required by Section 6.1 of
      [RFC2330]. The end of the measurement interval MAY be controlled
      by the measured connection, where the second pair of FIN and ACK

packets exchanged between host A and B effectively ends the
interval.

... ...

For RTDelay_HS -- the Round trip delay of the Handshake.

For RTLoss -- the count of lost packets.

For each <statistic>, one of the following sub-sections apply:

10.4.2.1. Mean

The mean SHALL be calculated using the conditional distribution of
all packets with a finite value of Round-trip delay (undefined delays
are excluded), a single value as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
[RFC6703] for background on this analysis choice.

See section 4.2.2 of [RFC6049] for details on calculating this
statistic, and 4.2.3 of [RFC6049].

Mean The time value of the result is expressed in units of seconds,
   as a positive value of type decimal64 with fraction digits = 9
   (see section 9.3 of [RFC6020]) with resolution of 0.000000001
   seconds (1.0 ns), and with lossless conversion to/from the 64-bit
   NTP timestamp as per section 6 of RFC [RFC5905]

10.4.2.2. Min

The minimum SHALL be calculated using the conditional distribution of
all packets with a finite value of Round-trip delay (undefined delays
are excluded), a single value as follows:

See section 4.1 of [RFC3393] for details on the conditional
distribution to exclude undefined values of delay, and Section 5 of
[RFC6703] for background on this analysis choice.

See section 4.3.2 of [RFC6049] for details on calculating this
statistic, and 4.3.3 of [RFC6049].

Min The time value of the result is expressed in units of seconds,
   as a positive value of type decimal64 with fraction digits = 9
   (see section 9.3 of [RFC6020]) with resolution of 0.000000001
   seconds (1.0 ns), and with lossless conversion to/from the 64-bit
   NTP timestamp as per section 6 of RFC [RFC5905]

10.4.2.3. **Max**

   The maximum SHALL be calculated using the conditional distribution of
   all packets with a finite value of Round-trip delay (undefined delays
   are excluded), a single value as follows:

   See section 4.1 of [RFC3393] for details on the conditional
   distribution to exclude undefined values of delay, and Section 5 of
   [RFC6703] for background on this analysis choice.

   See section 4.3.2 of [RFC6049] for a closely related method for
   calculating this statistic, and 4.3.3 of [RFC6049]. The formula is
   as follows:

           Max = (FiniteDelay [j])

                  such that for some index, j, where 1 <= j <= N
                  FiniteDelay[j] >= FiniteDelay[n] for all n

   Max The time value of the result is expressed in units of seconds,
      as a positive value of type decimal64 with fraction digits = 9
      (see section 9.3 of [RFC6020]) with resolution of 0.000000001
      seconds (1.0 ns), and with lossless conversion to/from the 64-bit
      NTP timestamp as per section 6 of RFC [RFC5905]

10.4.3. **Metric Units**

   The <statistic> of Round-trip Delay is expressed in seconds, where
   <statistic> is one of:

   o Mean

   o Min

   o Max

   The Round-trip Delay of the Hand Shake is expressed in seconds.

   The Round-trip Loss Count is expressed as a number of packets.

10.4.4. **Calibration**

   Passive measurements at an OP could be calibrated against an active
   measurement (with loss emulation) at host A or B, where the active
   measurement represents the ground-truth.

10.5. Administrative items

10.5.1. Status

   Current

10.5.2. Requestor

   This RFC

10.5.3. Revision

   1.0

10.5.4. Revision Date

   YYYY-MM-DD

10.6. Comments and Remarks

   None.

11. Security Considerations

   These registry entries represent no known implications for Internet
   Security. Each referenced Metric contains a Security Considerations
   section.

12. IANA Considerations

   IANA is requested to populate The Performance Metrics Registry
   defined in [I-D.ietf-ippm-metric-registry] with the values defined
   above.

   See the IANA Considerations section of
   [I-D.ietf-ippm-metric-registry] for additional requests and
   considerations.

13. Acknowledgements

   The authors thank Brian Trammell for suggesting the term "Run-time
   Parameters", which led to the distinction between run-time and fixed
   parameters implemented in this memo, for identifying the IPFIX metric
   with Flow Key as an example, for suggesting the Passive TCP RTD
   metric and supporting references, and for many other productive
   suggestions. Thanks to Peter Koch, who provided several useful
   suggestions for disambiguating successive DNS Queries in the DNS
   Response time metric.

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Michelle Cotton for her early IANA review, and to Amanda Barber for
answering questions related to the presentation of the registry and
accessibility of the complete template via URL.

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