IP Performance Metrics (IPPM) for spatial and multicast
draft-ietf-ippm-multimetrics-07

Status of this Memo

By submitting this Internet-Draft, each author represents that any applicable patent or other IPR claims of which he or she is aware have been or will be disclosed, and any of which he or she becomes aware will be disclosed, in accordance with Section 6 of BCP 79.
Internet-Drafts are working documents of the Internet Engineering Task Force (IETF), its areas, and its working groups. Note that other groups may also distribute working documents as Internet-Drafts.
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."
The list of current Internet-Drafts can be accessed at http://www.ietf.org/ietf/1id-abstracts.txt.
The list of Internet-Draft Shadow Directories can be accessed at http://www.ietf.org/shadow.html.
This Internet-Draft will expire on December 28, 2008.

Abstract

The IETF IP Performance Metrics (IPPM) working group has standardized metrics for measuring end-to-end performance between two points. This memo defines two new categories of metrics that extend the coverage to multiple measurement points. It defines spatial metrics for measuring the performance of segments of a source to destination path, and metrics for measuring the performance between a source and many destinations in multiparty communications (e.g., a multicast tree).

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
"SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
document are to be interpreted as described in [RFC 2119 (Bradner, S.,
"Key words for use in RFCs to Indicate Requirement Levels,"
March 1997.)](#) [RFC2119].

Table of Contents

---

1. Introduction

The IETF IP Performance Metrics (IPPM) working group has standardized metrics for measuring end-to-end performance between two points. This memo defines two new categories of metrics that extend the coverage to multiple measurement points. It defines spatial metrics for measuring the performance of segments of a source to destination path, and metrics for measuring the performance between a source and many destinations in multiparty communications (e.g., a multicast tree). The purpose of the memo is to define metrics to fulfill the new requirements of measurement involving multiple measurement points. Spatial metrics are defined to measure the performance of each segments along a path while the one-to-group metrics are aiming to provide a ruler to measure the performance of a group of users. These metrics are derived from one-way end-to-end metrics defined by IETF and follow the criteria described in the IPPM framework [RFC2330] (Paxson, V., Almes, G., Mahdavi, J., and M. Mathis, "Framework for IP Performance Metrics," May 1998.).
New terms are introduced to extend the terminology of the IPPM framework to spatial metrics and one-to-group metrics. Then a section motivates the need of defining each category of metrics. After, each category is defined in a separate section. Then the memo discusses the impact of the measurement methods on the scalability and proposes an information model for reporting the measurements. Finally the document

discusses security aspects related to measurement and registers the metrics in the IANA IP Performance Metrics Registry [RFC4148] (Stephan, E., "IP Performance Metrics (IPPM) Metrics Registry," August 2005.). Note that all these metrics are based on observations of packets dedicated to testing, a process which is called Active measurement. Purely passive spatial measurement (for example, a spatial metric based on the observation of user traffic) is beyond the scope of this memo. Following is a summary of the metrics defined.

This memo firstly defines metrics for spatial measurement based on the decomposition of standard end-to-end metrics defined by IETF in [[RFC2679] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Delay Metric for IPPM," September 1999.), [RFC2680] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Packet Loss Metric for IPPM," September 1999.), [RFC3393] (Demichelis, C. and P. Chimento, "IP Packet Delay Variation Metric for IP Performance Metrics (IPPM)," November 2002.), [RFC3432] (Raisanen, V., Grotefeld, G., and A. Morton, "Network performance measurement with periodic streams," November 2002.). Seven metrics are defined including their names, parameters, units and measurement methodologies. Each definion includes a specific section discussing measurements constraints and issues, and proposing guidance to increase results accucacy. These spatial metrics are:

   *A 'Vector', called Type-P-Spatial-One-way-Delay-Vector, will be introduced to divide an end-to-end Type-P-One-way-Delay [RFC2679] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Delay Metric for IPPM," September 1999.) into a spatial sequence of one-way delay metrics.

   *A 'Vector', called Type-P-Spatial-One-way-Packet-Loss-Vector, will be introduced to divide an end-to-end Type-P-One-way-Packet-Loss [RFC2680] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Packet Loss Metric for IPPM," September 1999.) in a spatial sequence of packet loss metrics.

   *Using the Type-P-Spatial-One-way-Delay-Vector metric, a 'vector', called Type-P-Spatial-One-way-ipdv-Vector, will be introduced to divide an end-to-end Type-P-One-way-ipdv in a spatial sequence of ipdv metrics.

   *Using the Type-P-Spatial-One-way-Delay-Vector metric, a 'sample', called Type-P-Segment-One-way-Delay-Stream, will be introduced to collect one-way delay metrics over time between two points of interest of the path;

   *Using the Type-P-Spatial-Packet-Loss-Vector metric, a 'sample', called Type-P-Segment-Packet-Loss-Stream, will be introduced to collect packet loss metrics over time between two points of interest of the path;

*Using the Type-P-Spatial-One-way-Delay-Vector metric, a 'sample', called Type-P-Segment-ipdv-prev-Stream, will be introduced to compute ipdv metrics over time between two points of interest of the path using the previous packet selection function;

*Using the Type-P-Spatial-One-way-Delay-Vector metric, a 'sample', called Type-P-Segment-ipdv-min-Stream, will be introduced to compute ipdv metrics over time between two points of interest of the path using the shortest delay selection function;

Then the memo defines one-to-group metrics and one-to-group statistics. Three one-to-group metrics are defined to measure the one-way performance between a source and a group of receivers. Definitions derive from one-way metrics definitions of RFCs in [RFC2679] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Delay Metric for IPPM," September 1999.), [RFC2680] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Packet Loss Metric for IPPM," September 1999.), [RFC3393] (Demichelis, C. and P. Chimento, "IP Packet Delay Variation Metric for IP Performance Metrics (IPPM)," November 2002.), [RFC3432] (Raisanen, V., Grotefeld, G., and A. Morton, "Network performance measurement with periodic streams," November 2002.):

*A 'Vector', called Type-P-One-to-Group-One-way-Delay-Vector, will be introduced to collect the set of Type-P-one-way-delay singletons between one sender and N receivers;

*A 'Vector', called Type-P-One-to-Group-One-way-Packet-Loss-Vector, will be introduced to collect the set of Type-P-One-way-Packet-Loss singletons between one sender and N receivers;

*A 'Vector', called Type-P-One-to-Group-One-way-ipdv-Vector, will be introduced to collect the set of Type-P-One-way-ipdv singletons between one sender and N receivers.

Then, based on the One-to-group vector metrics listed above, statistics are defined to capture single receiver performance, group performance and relative performance situation inside a multiparty communication for each packet sent during the test interval between one sender and N receivers:

*Using the Type-P-One-to-Group-One-way-Delay-Vector, a metric called Type-P-One-to-Group-Receiver-n-Mean-Delay will be introduced to present the mean of delays between one sender and a receiver 'n'. Then, based on this definition, 3 metrics will be defined to characterize the mean delay over the entire group during this interval:

-a metric called Type-P-One-to-Group-Mean-Delay, will be introduced to present the mean of delays;

-a metric called Type-P-One-to-Group-Range-Mean-Delay will be
         introduced to present the range of mean delays;

        -a metric called Type-P-One-to-Group-Max-Mean-Delay will be
         introduced to present the maximum of mean delays;

    *Using the Type-P-one-to-group-One-way-Packet-Loss-Vector, a
     metric called Type-P-One-to-Group-Receiver-n-Loss-Ratio will be
     introduced to capture packet loss ratio between one sender and a
     receiver 'n'. Then based on this definition, 2 metrics will be
     defined to characterize packet loss over the entire group during
     this interval:

        -a metric called Type-P-One-to-Group-Loss-Ratio will be
         introduced to capture packet loss ratio overall over the
         entire group or all receivers;

        -a metric called Type-P-One-to-Group-Range-Loss-Ratio will be
         introduced to present comparative packet loss ratio for each
         packet during the test interval between one sender and N
         Receivers.

    *Using Type-P-one-to-group-One-way-ipdv-Vector, a metric called
     Type-P-One-to-Group-Range-Delay-Variation will be introduced to
     present the range of delay variation between one sender and a
     group of receivers.

---

2. Terminology

2.1. Path Digest Hosts

The list of the hosts on a path from the source to the destination.

2.2. Multiparty metric

A metric is said to be multiparty if the topology involves more than
one measurement collection point. All multiparty metrics define a set
of hosts called "points of interest", where one host is the source and
other hosts are the measurement collection points. For example, if the
set of points of interest is < ha, hb, hc, ..., hn >, where ha is the

source and < hb, hc, ..., hn > are the destinations, then measurements
may be conducted between < ha, hb>, < ha, hc>, ..., <ha, hn >.
For the purposes of this memo (reflecting the scope of a single
source), the only multiparty metrics are one-to-group metrics.

2.3. Spatial metric

A metric is said to be spatial if one of the hosts (measurement
collection points) involved is neither the source nor a destination of
the measured packet.

2.4. One-to-group metric

A metric is said to be one-to-group if the measured packet is sent by
one source and (potentially) received by several destinations. Thus,
the topology of the communication group can be viewed as a centre-
distributed or server-client topology with the source as the centre/
server in the topology.

2.5. Points of interest

Points of interest are the hosts* (as per RFC2330 definition, that
includes routing nodes) that are measurement collection points, a sub-
set of the set of hosts involved in the delivery of the packets (in
addition to the source itself). Note that the points of interest are a
possibly arbitrary sub-set of all the hosts involved in the path.
Points of interest of one-to-group metrics are the intended destination
hosts for packets from the source (in addition to the source itself).

```
        Src                  Recv
         `.              ,-.
           `.         ,'    `....... 1
             `.   ;        :
               `. ;        :
                 ;        :... 2
                 |        |
                 :        ;
                 :        ;.... 3
                 :        ;
                  `.    ,'
                    `-'........ N
```
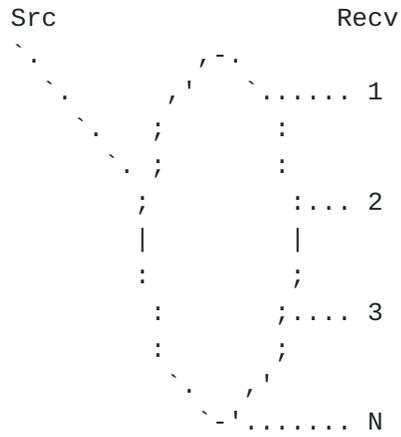
Figure 1: One-to-group points of interest

A candidate point of interest for spatial metrics is a host from the
set of hosts involved in the delivery of the packets from the source.

```
        Src ------.            Hosts
                   \
                    `---X    ... 1
                     \
                      x
                     /
          .---------X    .... 2
         /
        x
         \
          `---X           .... 3
             \
              \
               \
                X       .... N
                 \
                  \
                   \
                    `---- Dst
```
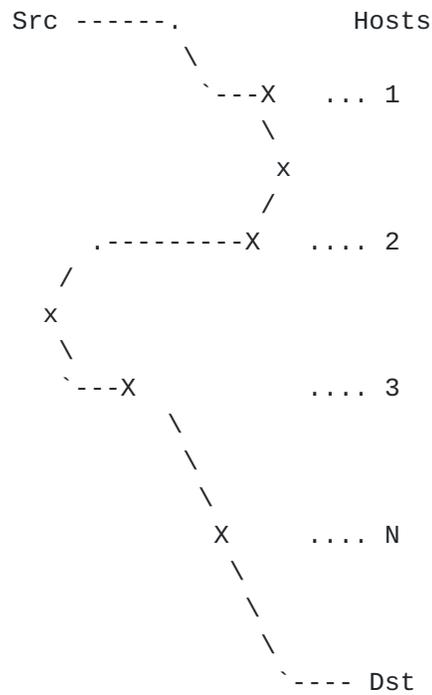
Note: 'x' are nodes which are not points of interest

Figure 2: Spatial points of interest

2.6. Reference point

A reference point is defined as the server where the statistical calculations will be carried out. A centre/server in the multimetrics measurement that is controlled by a network operator is a good example of a reference point, where measurement data can be collected for further processing. However, the actual measurements have to be carried out at all points of interest.

2.7. Vector

A Vector is a set of singletons, which are a set of results of the observation of the behaviour of the same packet at different places of a network at different times. For instance, if one-way delay singletons observed at N receivers for Packet P sent by the source Src are dT1, dT2,…, dTN, it can be say that a vector V with N elements can be organized as {dT1, dT2,…, dTN}. The elements in one vector are singletons distinct with each other in terms of both measurement point and sending time. Given the vector V as an example, the element dT1 is distinct from all others as the singleton at receiver 1 in response to a packet sent from the source at time T1. The complete Vector gives information over the dimension of space.

2.8. Matrix

Several vectors form a Matrix, which contains results observed in a sampling interval at different places in a network at different times. For instance, given One-way delay vectors V1={dT11, dT12,..., dT1N}, V2={dT21, dT22,…, dT2N},…, Vm={dTm1, dTm2,…, dTmN} for Packet P1, P2,…,Pm, we can have a One-way delay Matrix {V1, V2,…,Vm}. Additional to the information given by a Vector, a Matrix is more powerful to present network performance in both space and time dimensions. It normally corresponds to a sample in simple point-to-point measurement. The relation among Singleton, Vector and Matrix can be shown in the following Figure 3 (Relation beween Singletons, vectors and matrix).

```
           Point of          Singleton
           interest            /         Samples
          ,----.      ^       /
         /   R1.....|  / R1dT1   R1dT2   R1dT3 ... R3dTk \
        /         \ | |                                   |
       ;  R2........| |  R2dT1   R2dT2   R2dT3 ... R3dTk  |
   Src  |          || |                                   |
        |       R3....| |  R3dT1   R3dT2   R3dT3 ... R3dTk  |
        |          || |                                   |
        :          ;| |                                   |
         \         / | |                                   |
          \  Rn......|  \ RndT1   RndT2   RndT3 ... RndTk /
           `-----'    +------------------------------------> time


                  Vector            Matrix
                  (space)           (time)
```
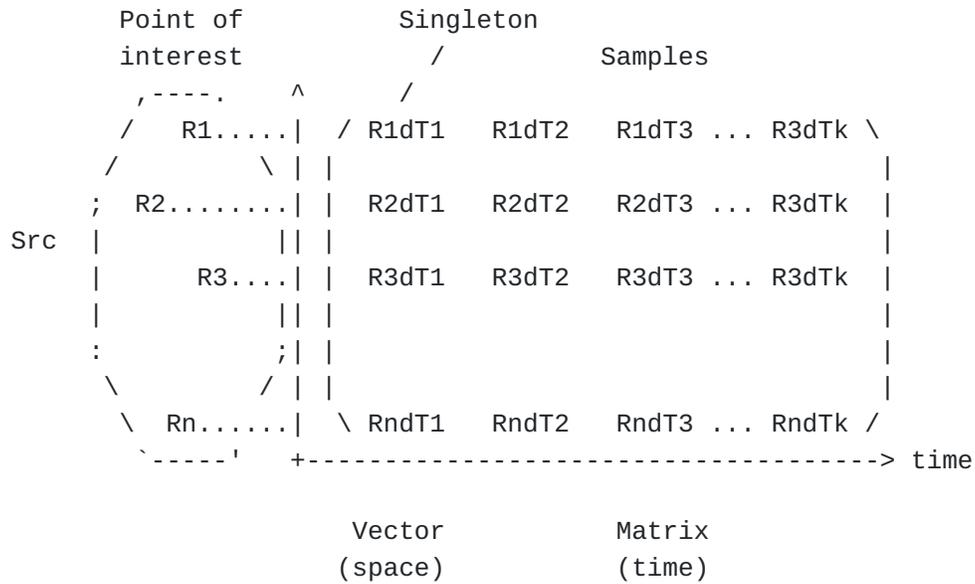
Figure 3: Relation beween Singletons, vectors and matrix

---

3. Motivations

All IPPM metrics are defined for end-to-end (source to destination)
measurement of point-to-point paths. It is a logical extension to
define metrics for multiparty measurements such as one to one
trajectory metrics and one to multipoint metrics.

3.1. Motivations for spatial metrics

Decomposition of instantaneous end-to-end measures is needed:

   *Decomposing the performance of interdomain path is desirable to
    quantify the per-AS contribution to the performance. It is
    valuable to define standard spatial metrics before pursuing
    inter-domain path performance specifications.

   *Traffic engineering and troubleshooting applications benefit from
    spatial views of one-way delay and ipdv consumption, and
    identification of the location of the lost of packets.

   *Monitoring the performance of a multicast tree composed of MPLS
    point-to-multipoint and inter-domain communication require
```

spatial decomposition of the one-way delay, ipdv, and packet
loss.

*Composition of metrics is needed to help measurement systems
reach large scale coverage. Spatial measures typically give the
individual performance of an intra domain segment and provide an
elementary piece of information needed to estimate interdomain
performance based on composition of metrics.

---

### 3.2.  Motivations for One-to-group metrics

While the node-to-node based spatial measures can provide very useful
data in the view of each connection, we also need measures to present
the performance of a multiparty communication topology. A simple one-
way metric cannot completely describe the multiparty situation. New
one-to-group metrics assess performance of all the paths for further
statistical analysis. The new metrics proposed in this stage are named
one-to-group performance metrics, and they are based on the unicast
metrics defined in IPPM WG. One-to-group metrics are one-way metrics
from one source to a group of destinations. The metrics are helpful for
judging the network performance of multiparty communications and can
also be used to describe the variation of performance delivered to a
group of destination hosts and their users.
One-to-group performance metrics are needed for several reasons:

*For designing and engineering multicast trees and MPLS point-to-
multipoint LSP;

*For evaluating and controlling of the quality of the multicast
services;

*For controlling the performance of the inter domain multicast
services;

*For presenting and evaluating the performance requirements for
multiparty communications and overlay multicast.

To understand the packet transfer performance between one source and
any one receiver in the multiparty communication group, we need to
collect instantaneous end-to-end metrics, or singletons. It will give a
very detailed insight into each branch of the multicast tree in terms
of end-to-end absolute performance. This detail can provide clear and
helpful information for engineers to identify the sub-path with
problems in a complex multiparty routing tree.
The one-to-group metrics described in this memo introduce the
multiparty topology to the IPPM working group; the goal is to measure

the performance delivered to a group of users who are receiving packets from the same source. The concept extends the "path" in the one-way measurement to "path tree" to cover both one-to-one and one-to-many communications. If applied to one-to-one communications, the one-to-group metrics provide exactly the same results as the corresponding one-to-one metrics.

---

### 3.3. Discussion on Group-to-one and Group-to-group metrics

We note that points of interest can also be selected to define measurements on group-to-one and group-to-group topologies. These topologies are currently beyond the scope of this memo, because they would involve multiple packets launched from different sources. However, we can give some clues here on these two cases.
The measurements for group-to-one topology can be easily derived from the one-to-group measurement. The measurement point is the reference point that is acting as a receiver while all of clients/receivers defined for one-to-group measurement act as sources in this case.
For the group-to-group connection topology, it is difficult to define the reference point and therefore it is difficult to define the measurement points. However, we can always avoid this confusion by treating the connections as one-to-group or group-to-one in our measurements without consideration on how the real communication will be carried out. For example, if one group of hosts < ha, hb, hc, ..., hn > are acting as sources to send data to another group of hosts < Ha, Hb, Hc, ..., Hm >, we can always decompose them into n one-to-group communications as < ha, Ha, Hb, Hc, ..., Hm >, < hb, Ha, Hb, Hc, ..., Hm >, <hc, Ha, Hb, Hc, ..., Hm >, ..., < hn, Ha, Hb, Hc, ..., Hm >.

---

### 4. Spatial vectors metrics definitions

This section defines vectors for the decomposition of end-to-end singleton metrics over a path.
Spatial vectors metrics are based on the decomposition of standard end-to-end metrics defined by the IPPM WG in [RFC2679] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Delay Metric for IPPM," September 1999.), [RFC2680] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Packet Loss Metric for IPPM," September 1999.), [RFC3393] (Demichelis, C. and P. Chimento, "IP Packet Delay Variation Metric for IP Performance Metrics (IPPM)," November 2002.) and [RFC3432] (Raisanen, V., Grotefeld, G., and A. Morton, "Network performance measurement with periodic streams," November 2002.).

Definitions are coupled with the corresponding end-to-end metrics.
Methodology specificities are common to all the vectors defined and are
consequently discussed in a common section.

---

### 4.1.  A Definition for Spatial One-way Delay Vector

This section is coupled with the definition of Type-P-One-way-Delay of
the section 3 of [RFC2679] (Almes, G., Kalidindi, S., and M. Zekauskas,
"A One-way Delay Metric for IPPM," September 1999.). When a parameter
of this definition is first used in this section, it will be tagged
with a trailing asterisk.
Sections 3.5 to 3.8 of [RFC2679] (Almes, G., Kalidindi, S., and M.
Zekauskas, "A One-way Delay Metric for IPPM," September 1999.) give
requirements and applicability statements for end-to-end one-way-delay
measurements. They are applicable to each point of interest Hi involved
in the measure. Spatial one-way-delay measurement SHOULD be respectful
of them, especially those related to methodology, clock, uncertainties
and reporting.

---

### 4.1.1.  Metric Name

Type-P-Spatial-One-way-Delay-Vector

---

### 4.1.2.  Metric Parameters

*Src*, the IP address of the sender.

*Dst*, the IP address of the receiver.

*i, An integer in the ordered list <1,2,...,n> of hosts in the
 path.

*Hi, A host* of the path digest.

*T*, a time, the sending (or initial observation) time for a
 measured packet.

*dT*, a delay, the one-way delay for a measured packet.

*<dT1,..., dTn> a list of delay.

*P*, the specification of the packet type.

*<H1, H2,..., Hn>, hosts path digest.

---

### 4.1.3.  Metric Units

The value of Type-P-Spatial-One-way-Delay-Vector is a sequence of
times.

---

### 4.1.4.  Definition

Given a Type-P packet sent by the sender Src at wire-time (first bit) T
to the receiver Dst in the path <H1, H2,..., Hn>. Given the sequence of
values <T+dT1,T+dT2,...,T+dTn,T+dT> such that dT is the Type-P-One-way-
Delay from Src to Dst and such that for each Hi of the path, T+dTi is
either a real number corresponding to the wire-time the packet passes
(last bit received) Hi, or undefined if the packet never passes Hi.
Type-P-Spatial-One-way-Delay-Vector metric is defined for the path
<Src, H1, H2,..., Hn, Dst> as the sequence of values
<T,dT1,dT2,...,dTn,dT>.

---

### 4.1.5.  Discussion

Following are specific issues which may occur:

    *the delay looks to decrease: dTi > DTi+1. This may occur despite
     it does not make sense per definition:

      -This is frequently due to some clock synchronization issue.
       This point is discussed in the section 3.7.1. "Errors or
       uncertainties related to Clocks" of [RFC2679] (Almes, G.,
       Kalidindi, S., and M. Zekauskas, "A One-way Delay Metric for
       IPPM," September 1999.). Consequently, times of a measure at
       different hosts do not guaranty the ordering of the hosts on
       the path of a measure.

      -During some change of routes the order of 2 hosts may change
       on the main path;

      -The location of the point of interest in the device influences
       the result. If the packet is not observed directly on the
       input interface the delay includes buffering time and

>      consequently an uncertainty due to the difference between
>      'wire time' and 'host time'

---

## 4.2.  A Definition for Spatial One-way Packet Loss Vector

This section is coupled with the definition of Type-P-One-way-Packet-Loss. Then when a parameter from the section 2 of [RFC2680] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Packet Loss Metric for IPPM," September 1999.) is first used in this section, it will be tagged with a trailing asterisk.
Sections 2.5 to 2.8 of [RFC2680] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Packet Loss Metric for IPPM," September 1999.) give requirements and applicability statements for end-to-end one-way packet loss measurements. They are applicable to each point of interest Hi involved in the measure. Spatial packet loss measurement SHOULD be respectful of them, especially those related to methodology, clock, uncertainties and reporting.
Following we define the spatial metric, then we adapt some of the points above and introduce points specific to spatial measurement.

---

### 4.2.1.  Metric Name

Type-P-Spatial-One-way-Packet-Loss-Vector

---

### 4.2.2.  Metric Parameters

>    *Src*, the IP address of the sender.

>    *Dst*, the IP address of the receiver.

>    *i, an integer which ordered the hosts in the path.

>    *Hi, points of interests of the path digest.

>    *T*, a time, the sending time for a measured packet.

>    *<dT1,..., dTn, dT>, a list of delay.

>    *P*, the specification of the packet type.

>    *<H1, H2,..., Hn>, hosts path digest.

*<L1, L2, ...,Ln>, a list of Boolean values.

---

### 4.2.3.  Metric Units

The value of Type-P-Spatial-One-way-Packet-Loss-Vector is a sequence of
Boolean values.

---

### 4.2.4.  Definition

Given a Type-P packet sent by the sender Src at time T to the receiver
Dst in the path <H1, H2, ..., Hn>. Given the sequence of times
<T+dT1,T+dT2,...,T+dTn> the packet passes in <H1, H2 ..., Hn>, we
define Type-P-One-way-Packet-Lost-Vector metric as the sequence of
values <L1, L2, ..., Ln> such that for each Hi of the path, a value of
0 for Li means that dTi is a finite value, and a value of 1 means that
dTi is undefined.

---

### 4.2.5.  Discussion

Following are specific issues which may occur:

    *The result includes the sequence 1,0. This may occur under
     specific situations:

       -During some change of routes a packet may be seen by a host
        but not by it successor on the main path;

       -A packet may not be observed in a host due to some buffer or
        CPU overflow in the point of interest;

---

### 4.3.  A Definition for Spatial One-way Ipdv Vector

This section uses parameters from the definition of Type-P-One-way-
ipdv. When a parameter from section 2 of [RFC3393] (Demichelis, C. and
P. Chimento, "IP Packet Delay Variation Metric for IP Performance
Metrics (IPPM)," November 2002.) is first used in this section, it will
be tagged with a trailing asterisk.

In the following we adapt some of them and introduce points specific to spatial measurement.

---

### 4.3.1. Metric Name

Type-P-Spatial-One-way-ipdv-Vector

---

### 4.3.2. Metric Parameters

*Src*, the IP address of the sender.

*Dst*, the IP address of the receiver.

*i, An integer in the ordered list <1,2,...,n> of hosts in the path.

*Hi, A host* of the path digest.

*T1*, a time, the sending time for a first measured packet.

*T2*, a time, the sending time for a second measured packet.

*dT*, a delay, the one-way delay for a measured packet.

*P*, the specification of the packets type.

*P1, the first packet sent at time T1.

*P2, the second packet sent at time T2.

*<H1, H2,..., Hn>, hosts path digest.

*<T1,dT1.1, dT1.2,..., dT1.n,dT1>, the Type-P-Spatial-One-way-Delay-Vector for packet sent at time T1.

*<T2,dT2.1, dT2.2,..., dT2.n,dT2>, the Type-P-Spatial-One-way-Delay-Vector for packet sent at time T2.

*L*, a packet length in bits. The packets of a Type P packet stream from which the Type-P-Spatial-One-way-Delay-Vector metric is taken MUST all be of the same length.

---

### 4.3.3.  Metric Units

The value of Type-P-Spatial-One-way-ipdv-Vector is a sequence of times.

---

### 4.3.4.  Definition

Given P1 the Type-P packet sent by the sender Src at wire-time (first bit) T1 to the receiver Dst and <T1, dT1.1, dT1.2,..., dT1.n, dT1> its Type-P-Spatial-One-way-Delay-Vector over the path <H1, H2,..., Hn>. Given P2 the Type-P packet sent by the sender Src at wire-time (first bit) T2 to the receiver Dst and <T2, dT2.1, dT2.2,..., dT2.n, dT2> its Type-P-Spatial-One-way-Delay-Vector over the same path. Type-P-Spatial-One-way-ipdv-Vector metric is defined as the sequence of values <T2-T1, dT2.1-dT1.1, dT2.2-dT1.2 ,..., dT2.n-dT1.n, dT2-dT1> such that for each Hi of the path <H1, H2,..., Hn>, dT2.i-dT1.i is either a real number if the packets P1 and P2 passe Hi at wire-time (last bit) dT1.i, respectively dT2.i, or undefined if at least one of them never passes Hi. T2-T1 is the inter-packet emission interval and dT2-dT1 is ddT* the Type-P-One-way-ipdv at T1,T2*.

---

### 4.4.  Spatial Methodology

Methodology, reporting and uncertainties points specified in section 3 of [RFC2679] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Delay Metric for IPPM," September 1999.) applies to each point of interest Hi measuring a element of a spatial delay vector. Methodology, reporting and uncertainties points specified in section 2 of [RFC2680] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Packet Loss Metric for IPPM," September 1999.) applies to each point of interest Hi measuring a element of a spatial packet loss vector. Sections 3.5 to 3.7 of [RFC3393] (Demichelis, C. and P. Chimento, "IP Packet Delay Variation Metric for IP Performance Metrics (IPPM)," November 2002.) give requirements and applicability statements for end-to-end One-way ipdv measurements. They are applicable to each point of interest Hi involved in the measure. Spatial One-way ipdv measurement SHOULD be respectful of methodology, clock, uncertainties and reporting aspects given in this section.
Generally, for a given Type-P of length L, in a given Hi, the methodology for spatial vector metrics may proceed as follows:

> *At each Hi, points of interest prepare to capture the packet sent a time T, take a timestamp Ti', determine the internal delay correction dTi' (See section 3.7.1. "Errors or uncertainties

related to Clocks" of [RFC2679] (Almes, G., Kalidindi, S., and M.
Zekauskas, "A One-way Delay Metric for IPPM," September 1999.)),

   *Each Hi extracts the path ordering information from the packet
    (e.g. time-to-live);

   *Each Hi compute the wiretime from Src to Hi: Ti = Ti' - dTi'.
    This arrival time is undefined (infinite) if the packet is not
    detected after the 'loss threshold' duration;

   *Each Hi extracts the timestamp T from the packet;

   *Each Hi computes the one-way-delay from Src to Hi: dTi = Ti - T;

   *The reference point gathers the result of each Hi and order them
    according to the path ordering information received to build the
    type-P spatial one-way vector (e.g. Type-P-Spatial-One-way-Delay-
    Vector metric <T, dT1, dT2,..., dTn, dT> ) over the path <Src,
    H1, H2,..., Hn, Dst> at time T.

---

### 4.4.1.  Loss threshold

Loss threshold is the centrality of any methodology because it
determines the presence the packet in the measurement process of the
point of interest and consequently determines any ground truth metric
result. It determines the presence of an effective delay, and bias the
measure of ipdv, of packet loss and of the statistics.
This is consistent for end-to-end but impacts spatial measure:
depending on the consistency of the loss threshold among the points of
interest, a packet may be considered loss a one host but present in
another one, or may be observed by the last host (last hop) of the path
but considered lost by Dst. The analysis of such results is not
deterministic: Has the path change? Does the packet arrive at
destination or was it lost during the last mile? The same applies, of
course, for one-way-delay measures: a delay measured may be infinite at
one host but a real value in another one, or may be measured as a real
value by the last host of the path but observed as infinite by Dst. The
loss threshold should be set up with the same value in each host of the
path and in the destination. The loss threshold must be systematically
reported to permit careful introspection and to avoid the introduction
of any contradiction in the statistic computation process.

---

### 4.4.2. Host Path Digest

The methodology given above relies on the order of the points of
interest over the path to [RFC2679] (Almes, G., Kalidindi, S., and M.
Zekauskas, "A One-way Delay Metric for IPPM," September 1999.) one's.
A test packets may cross several times the same host resulting in the
repetition of one or several hosts in the Path Digest.
As an example. This occurs typically during rerouting phases which
introduce temporary micro loops. During such an event the host path
digest for a packet crossing Ha and Hb may include the pattern <Hb, Ha,
Hb, Ha, Hb> meaning that Ha ended the computation of the new path
before Hb and that the initial path wath from Ha to Hb and that the new
path is from Hb to Ha.
Consequently, duplication of hosts in the Path Digest of a vectors MUST
be identified before statistics computation to avoid corrupted results'
production.

---

### 5.  Spatial Segments metrics definitions                    TOC

This section defines samples to measure the performance of a segment of
a path over time. Definitions rely on matrix of the spatial vector
metrics defined above.
Firstly it defines a sample of one-way delay, Type-P-Segment-One-way-
Delay-Stream, and a sample of packet loss, Type-P-segment-Packet-loss-
Stream.
Then it defines 2 different samples of ipdv. The first metric, Type-P-
Segment-One-way-ipdv-prev-Stream, uses the previous packet as the
selection function. The second metric, Type-P-Segment-One-way-ipdv-min-
Stream, uses the minimum delay as the selection.

---

### 5.1.  A Definition of a sample of One-way Delay of a segment of     TOC
the path

This metric defines a sample of One-way delays over time between a pair
of hosts of a path.
As its semantic is very close to the metric Type-P-Packet-loss-Stream
defined in section 4 of [RFC2679] (Almes, G., Kalidindi, S., and M.
Zekauskas, "A One-way Delay Metric for IPPM," September 1999.),
sections 4.5 to 4.8 of [RFC2679] (Almes, G., Kalidindi, S., and M.
Zekauskas, "A One-way Delay Metric for IPPM," September 1999.) are part
of the current definition.

---

### 5.1.1.  Metric Name

Type-P-Segment-One-way-Delay-Stream

---

### 5.1.2.  Metric Parameters

*Src*, the IP address of the sender.

*Dst*, the IP address of the receiver.

*P*, the specification of the packet type.

*i, an integer in the ordered list <1,2,...,n> of hosts in the
 path.

*k, an integer which orders the packets sent.

*a and b, 2 integers where b > a.

*Hi, a host* of the path digest.

*<H1,..., Ha, ..., Hb, ...., Hn>, hosts path digest.

*<T1, T2, ..., Tm>, a list of times.

---

### 5.1.3.  Metric Units

The value of a Type-P-Segment-One-way-Delay-Stream is a pair of

list of times <T1, T2, ..., Tm>;

sequence of delays.

---

### 5.1.4.  Definition

Given 2 hosts, Ha and Hb, of the path <H1, H2,..., Ha, ..., Hb, ...,
Hn>, given the matrix of Type-P-Spatial-One-way-Delay-Vector for the
packets sent from Src to Dst at times <T1, T2, ..., Tm-1, Tm> :

<T1, dT1.1, dT1.2, ..., dT1.a, ..., dT1.b,..., dT1.n, dT1>;

```
<T2, dT2.1, dT2.2, ..., dT2.a, ..., dT2.b,..., dT2.n, dT2>;

...

<Tm, dTm.1, dTm.2, ..., dTm.a, ..., dTm.b,..., dTm.n, dTm>.
```

We define the sample Type-P-segment-One-way-Delay-Stream as the
sequence <dT1.ab, dT2.ab, ..., dTk.ab, ..., dTm.ab> such that for each
time Tk, 'dTk.ab' is either the real number 'dTk.b - dTk.a' if the
packet send a time Tk passes Ha and Hb or undefined if this packet
never passes Ha or (inclusive) never passes Hb.

5.1.5. Discussion

Following are specific issues which may occur:

*the delay looks to decrease: $dT_i > DT_{i+1}$:

-This is typically due to clock synchronization issue. this
 point is discussed in the section 3.7.1. "Errors or
 uncertainties related to Clocks" of of [RFC2679] (Almes, G.,
 Kalidindi, S., and M. Zekauskas, "A One-way Delay Metric for
 IPPM," September 1999.);

-This may occurs too when the clock resolution of one probe is
 bigger than the minimum delay of a path. As an example this
 happen when measuring the delay of a path which is 500 km long
 with one probe synchronized using NTP having a clock
 resolution of 8ms.

The metric can not be performed on < T1 , T2, ..., Tm-1, Tm> in the
following cases:

*Ha or Hb disappears from the path due to some change of routes;

*The order of Ha and Hb changes in the path;

5.2. A Definition of a sample of Packet Loss of a segment of the path

This metric defines a sample of packet lost over time between a pair of
hosts of a path. As its semantic is very close to the metric Type-P-
Packet-loss-Stream defined in section 3 of [RFC2680] (Almes, G.,
Kalidindi, S., and M. Zekauskas, "A One-way Packet Loss Metric for

[IPPM,” September 1999.)](#), sections 3.5 to 3.8 of [[RFC2680] (Almes, G., Kalidindi, S., and M. Zekauskas, “A One-way Packet Loss Metric for IPPM,” September 1999.)](#) are part of the current definition.

5.2.1. Metric Name

Type-P-segment-Packet-loss-Stream

5.2.2. Metric Parameters

Src, the IP address of the sender.

Dst, the IP address of the receiver.

P, the specification of the packet type.

*k, an integer which orders the packets sent.

*n, an integer which orders the hosts on the path.

*a and b, 2 integers where b > a.

*<H1, H2, ..., Ha, ..., Hb, ...,Hn>, hosts path digest.

*Hi, exchange points of the path digest.

*<T1, T2, ..., Tm>, a list of times.

*<L1, L2, ..., Ln> a list of boolean values.

5.2.3. Metric Units

The value of a Type-P-segment-Packet-loss-Stream is a pair of

> The list of times <T1, T2, ..., Tm>;
>
> a sequence of booleans.

5.2.4. Definition

Given 2 hosts, Ha and Hb, of the path <H1, H2,..., Ha, ..., Hb, ...,
Hn>, given the matrix of Type-P-Spatial-Packet-loss-Vector for the
packets sent from Src to Dst at times <T1, T2, ..., Tm-1, Tm> :

> <L1.1, L1.2,..., L1.a, ..., L1.b, ..., L1.n, L>,
>
> <L2.1, L2.2,..., L2.a, ..., L2.b, ..., L2.n, L>,
>
> ...,
>
> <Lm.1, Lm.2,..., Lma, ..., Lm.b, ..., Lm.n, L>.

We define the value of the sample Type-P-segment-Packet-Lost-Stream
from Ha to Hb as the sequence of booleans <L1.ab, L2.ab,..., Lk.ab,
..., Lm.ab> such that for each Tk:

> *A value of Lk of 0 means that Ha and Hb observed the packet sent
> at time Tk (Lk.a and Lk.b have a value of 0);
>
> *A value of Lk of 1 means that Ha observed the packet sent at time
> Tk (Lk.a has a value of 0) and that Hb did not observed the
> packet sent at time Tk (Lk.b have a value of 1);
>
> *The value of Lk is undefined when Neither Ha or Hb observe the
> packet;

5.2.5. Discussion

Unlike Type-P-Packet-loss-Stream, Type-P-Segment-Packet-loss-Stream
relies on the stability of the host path digest. The metric can not be
performed on < T1 , T2, ..., Tm-1, Tm> in the following cases:

> *Ha or Hb disappears from the path due to some change of routes;
>
> *the order of Ha and Hb changes in the path;
>
> *Lk.a or Lk.b is undefined;
>
> *Lk.a has the value 1 (not observed) and Lk.b has the value 0
> (observed);
>
> *L has the value 0 (the packet was received by Dst) and Lk.ab has
> the value 1 (the packet was lost between Ha and Hb).

5.3. A Definition of a sample of ipdv of a segment using the previous packet selection function

This metric defines a sample of ipdv [RFC3393] (Demichelis, C. and P. Chimento, "IP Packet Delay Variation Metric for IP Performance Metrics (IPPM)," November 2002.) over time between a pair of hosts using the previous packet as the selection function.

5.3.1. Metric Name

Type-P-Segment-One-way-ipdv-prev-Stream

5.3.2. Metric Parameters

Src, the IP address of the sender.

Dst, the IP address of the receiver.

P, the specification of the packet type.

*k, an integer which orders the packets sent.

*n, an integer which orders the hosts on the path.

*a and b, 2 integers where b > a.

*<H1, H2, ..., Ha, ..., Hb, ...,Hn>, the hosts path digest.

*<T1, T2, ..., Tm-1, Tm>, a list of times.

*<Tk, dTk.1, dTk.2, ..., dTk.a, ..., dTk.b,..., dTk.n, dTk>, a
 Type-P-Spatial-One-way-Delay-Vector.

5.3.3. Metric Units

The value of a Type-P-Segment-One-way-ipdv-prev-Stream is a pair of:

The list of <T1, T2, ..., Tm-1, Tm>;

A list of pairs of interval of times and delays;

5.3.4. Definition

Given 2 hosts, Ha and Hb, of the path <H1, H2,..., Ha, ..., Hb, ...,
Hn>, given the matrix of Type-P-Spatial-One-way-Delay-Vector for the
packets sent from Src to Dst at times <T1, T2, ..., Tm-1, Tm> :

<T1, dT1.1, dT1.2, ..., dT1.a, ..., dT1.b,..., dT1.n, dT1>,

<T2, dT2.1, dT2.2, ..., dT2.a, ..., dT2.b,..., dT2.n, dT2>,

...

<Tm, dTm.1, dTm.2, ..., dTm.a, ..., dTm.b,..., dTm.n, dTm>.

We define the Type-P-Segment-One-way-ipdv-prev-Stream as the sequence
of pair of packet intervals and delay variations <(dT2_1.a , dT2.ab -
dT1.ab) ,..., (dTk_k-1.a, dTk.ab - dTk-1.ab), ..., (dTm_m-1.a, dTm.ab -
dTm-1.ab)> such that for each Tk:

   *dTk_k-1.a is either undefined if the delay dTk.a or the delay
    dTk-1.a is undefined, or the interval of time, 'dTk.a - dTk-1.a',
    between the 2 packets at Ha;

   *dTk_k-1.ab, is either undefined if one of the delays dTk.b,
    dTk.a, dTk-1.b or dTk-1.a is undefined, or , (dTk.b - dTk.a) -
    (dTk-1.b - dTk-1.a), the delay variation from Ha to Hb between
    the 2 packets sent at time Tk and Tk-1.

5.3.5. Discussion

This metric belongs to the family of inter packet delay variation
metrics (IPDV in upper case) which results can be extremely sensitive
to the inter-packet interval.
The inter-packet interval of a end-to-end IPDV metric is under the
control of the ingress point of interest which corresponds exactly to
the Source of the packet. Unlikely, the inter-packet interval of a
segment IPDV metric is not under the control the ingress point of
interest of the measure, Ha. However, the interval will vary if there
is delay variation between the Source and Ha. Therefore, the actual
inter-packet interval must be known at Ha in order to fully comprehend
the delay variation between Ha and Hb.

5.4. A Definition of a sample of ipdv of a segment using the minimum delay selection function

This metric defines a sample of ipdv [RFC3393] (Demichelis, C. and P. Chimento, "IP Packet Delay Variation Metric for IP Performance Metrics (IPPM)," November 2002.) over time between a pair of hosts of a path using the shortest delay as the selection function.

5.4.1. Metric Name

Type-P-Segment-One-way-ipdv-min-Stream

5.4.2. Metric Parameters

Src, the IP address of the sender.

Dst, the IP address of the receiver.

P, the specification of the packet type.

*k, an integer which orders the packets sent.

*i, an integer which identifies a packet sent.

*n, an integer which orders the hosts on the path.

*a and b, 2 integers where b > a.

*<H1, H2, ..., Ha, ..., Hb, ...,Hn>, the hosts path digest.

*<T1, T2, ..., Tm-1, Tm>, a list of times.

*<Tk, dTk.1, dTk.2, ..., dTk.a, ..., dTk.b,..., dTk.n, dTk>, a Type-P-Spatial-One-way-Delay-Vector.

5.4.3. Metric Units

The value of a Type-P-Segment-One-way-ipdv-min-Stream is a pair of:

```
The list of <T1, T2, ..., Tm-1, Tm>;

A list of times;
```

5.4.4. Definition

Given 2 hosts, Ha and Hb, of the path <H1, H2,..., Ha, ..., Hb, ...,
Hn>, given the matrix of Type-P-Spatial-One-way-Delay-Vector for the
packets sent from Src to Dst at times <T1, T2, ..., Tm-1, Tm> :

```
<T1, dT1.1, dT1.2, ..., dT1.a, ..., dT1.b,..., dT1.n, dT1>,

<T2, dT2.1, dT2.2, ..., dT2.a, ..., dT2.b,..., dT2.n, dT2>,

...

<Tm, dTm.1, dTm.2, ..., dTm.a, ..., dTm.b,..., dTm.n, dTm>.
```

We define the Type-P-Segment-One-way-ipdv-min-Stream as the sequence of
times <dT1.ab - min(dTi.ab) ,..., dTk.ab - min(dTi.ab), ..., dTm.ab -
min(dTi.ab)> such that:

```
min(dTi.ab) is the minimum value of the tuples (dTk.b - dTk.a);

for each time Tk, dTk.ab is undefined if dTk.a or (inclusive) dTk.b
is undefined, or the real number (dTk.b - dTk.a).
```

5.4.5. Discussion

This metric belongs to the family of packet delay variation metrics
(PDV). PDV distributions are less sensitive to inter-packet interval
variations than IPDV results.
In principle, the PDV distribution reflects the variation over many
different inter-packet intervals, from the smallest inter-packet
interval, up to the length of the evaluation interval, Tm - T1.
Therefore, when delay variation occurs and disturbs the packet spacing
observed at Ha, the PDV results will likely compare favorably to a PDV
measurement where the source is Ha and the destination is Hb.

6. One-to-group metrics definitions

This metric defines metrics to measure the performance between a source and a group of receivers.

6.1. A Definition for One-to-group One-way Delay

This metric defines a metric to measure one-way delay between a source and a group of receivers.

6.1.1. Metric Name

Type-P-One-to-group-One-way-Delay-Vector

6.1.2. Metric Parameters

   *Src, the IP address of a host acting as the source.

   *Recv1,..., RecvN, the IP addresses of the N hosts acting as
    receivers.

   *T, a time.

   *dT1,...,dTn a list of time.

   *P, the specification of the packet type.

   *Gr, the receiving group identifier. The parameter Gr is the
    multicast group address if the measured packets are transmitted
    over IP multicast. This parameter is to differentiate the
    measured traffic from other unicast and multicast traffic. It is
    optional in the metric to avoid losing any generality, i.e. to
    make the metric also applicable to unicast measurement where
    there is only one receiver.

6.1.3. Metric Units

The value of a Type-P-One-to-group-One-way-Delay-Vector is a set of Type-P-One-way-Delay singletons [RFC2679] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Delay Metric for IPPM," September 1999.).

6.1.4. Definition

Given a Type P packet sent by the source Src at Time T, given the N hosts { Recv1,...,RecvN } which receive the packet at the time { T+dT1,...,T+dTn }, a Type-P-One-to-group-One-way-Delay-Vector is defined as the set of the Type-P-One-way-Delay singleton between Src and each receiver with value of { dT1, dT2,...,dTn }.

6.2. A Definition for One-to-group One-way Packet Loss

6.2.1. Metric Name

Type-P-One-to-group-One-way-Packet-Loss-Vector

6.2.2. Metric Parameters

   *Src, the IP address of a host acting as the source.

   *Recv1,..., RecvN, the IP addresses of the N hosts acting as
    receivers.

   *T, a time.

   *T1,...,Tn a list of time.

   *P, the specification of the packet type.

   *Gr, the receiving group identifier.

6.2.3. Metric Units

The value of a Type-P-One-to-group-One-way-Packet-Loss-Vector is a set of Type-P-One-way-Packet-Loss singletons [RFC2680] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Packet Loss Metric for IPPM," September 1999.).

6.2.4. Definition

Given a Type P packet sent by the source Src at T and the N hosts, Recv1,...,RecvN, which should receive the packet at T1,...,Tn, a Type-P-One-to-group-One-way-Packet-Loss-Vector is defined as a set of the Type-P-One-way-Packet-Loss singleton between Src and each of the receivers {<T1,0|1>,<T2,0|1>,..., <Tn,0|1>}.

6.3. A Definition for One-to-group One-way Ipdv

6.3.1. Metric Name

Type-P-One-to-group-One-way-ipdv-Vector

6.3.2. Metric Parameters

*Src, the IP address of a host acting as the source.

*Recv1,..., RecvN, the IP addresses of the N hosts acting as
 receivers.

*T1, a time.

*T2, a time.

*ddT1, ...,ddTn, a list of time.

*P, the specification of the packet type.

*F, a selection function defining unambiguously the two packets
 from the stream selected for the metric.

*Gr, the receiving group identifier. The parameter Gr is the
 multicast group address if the measured packets are transmitted
 over IP multicast. This parameter is to differentiate the
 measured traffic from other unicast and multicast traffic. It is
 optional in the metric to avoid losing any generality, i.e. to
 make the metric also applicable to unicast measurement where
 there is only one receiver.

6.3.3. Metric Units

The value of a Type-P-One-to-group-One-way-ipdv-Vector is a set of
Type-P-One-way-ipdv singletons [RFC3393] (Demichelis, C. and P.
Chimento, "IP Packet Delay Variation Metric for IP Performance Metrics
(IPPM)," November 2002.).

6.3.4. Definition

Given a Type P packet stream, Type-P-One-to-group-One-way-ipdv-Vector
is defined for two packets from the source Src to the N hosts
{Recv1,...,RecvN },which are selected by the selection function F, as
the difference between the value of the Type-P-One-to-group-One-way-
Delay-Vector from Src to { Recv1,..., RecvN } at time T1 and the value
of the Type-P-One-to-group-One-way-Delay-Vector from Src to {
Recv1,...,RecvN } at time T2. T1 is the wire-time at which Src sent the
first bit of the first packet, and T2 is the wire-time at which Src
sent the first bit of the second packet. This metric is derived from
the Type-P-One-to-group-One-way-Delay-Vector metric.
Therefore, for a set of real number {ddT1,...,ddTn},Type-P-One-to-
group-One-way-ipdv-Vector from Src to { Recv1,...,RecvN } at T1, T2 is
{ddT1,...,ddTn} means that Src sent two packets, the first at wire-time
T1 (first bit), and the second at wire-time T2 (first bit) and the
packets were received by { Recv1,...,RecvN } at wire-time
{dT1+T1,...,dTn+T1}(last bit of the first packet), and at wire-time
{dT'1+T2,...,dT'n+T2} (last bit of the second packet), and that {dT'1-
dT1,...,dT'n-dTn} ={ddT1,...,ddTn}.

7. One-to-Group Sample Statistics

The defined one-to-group metrics above can all be directly achieved
from the relevant unicast one-way metrics. They collect all unicast

measurement results of one-way metrics together in one profile and sort them by receivers and packets in a receiving group. They provide sufficient information regarding the network performance in terms of each receiver and guide engineers to identify potential problem happened on each branch of a multicast routing tree. However, these metrics cannot be directly used to conveniently present the performance in terms of a group and neither to identify the relative performance situation.

From the performance point of view, the multiparty communication services not only require the absolute performance support but also the relative performance. The relative performance means the difference between absolute performance of all users. Directly using the one-way metrics cannot present the relative performance situation. However, if we use the variations of all users one-way parameters, we can have new metrics to measure the difference of the absolute performance and hence provide the threshold value of relative performance that a multiparty service might demand. A very good example of the high relative performance requirement is the online gaming. A very light difference in delay might result in failure in the game. We have to use multicast specific statistic metrics to define exactly how small the relative delay the online gaming requires. There are many other services, e.g. online biding, online stock market, etc., that require multicast metrics in order to evaluate the network against their requirements. Therefore, we can see the importance of new, multicast specific, statistic metrics to feed this need.

We might also use some one-to-group statistic conceptions to present and report the group performance and relative performance to save the report transmission bandwidth. Statistics have been defined for One-way metrics in corresponding RFCs. They provide the foundation of definition for performance statistics. For instance, there are definitions for minimum and maximum One-way delay in [RFC2679]. However, there is a dramatic difference between the statistics for one-to-one communications and for one-to-many communications. The former one only has statistics over the time dimension while the later one can have statistics over both time and space dimensions. This space dimension is introduced by the Matrix concept as illustrated in Figure 4 (Matrix M (n*m)). For a Matrix M each row is a set of One-way singletons spreading over the time dimension and each column is another set of One-way singletons spreading over the space dimension.

```
        Receivers
         Space
           ^
        1 |    / R1dT1   R1dT2      R1dT3 ... R3dTk \
          |    |                                     |
        2 |    |  R2dT1   R2dT2      R2dT3 ... R3dTk  |
          |    |                                     |
        3 |    |  R3dT1   R3dT2      R3dT3 ... R3dTk  |
        . |    |                                     |
        . |    |                                     |
        . |    |                                     |
        n |    \ RndT1   RndT2      RndT3 ... RndTk /
          +--------------------------------------------> time
         T0
```

Figure 4: Matrix M (n*m)

In Matrix M, each element is a one-way delay singleton. Each column is
a delay vector contains the One-way delays of the same packet observed
at M points of interest. It implies the geographical factor of the
performance within a group. Each row is a set of One-way delays
observed during a sampling interval at one of the points of interest.
It presents the delay performance at a receiver over the time
dimension.
Therefore, one can either calculate statistics by rows over the space
dimension or by columns over the time dimension. It's up to the
operators or service provides which dimension they are interested in.
For example, a TV broadcast service provider might want to know the
statistical performance of each user in a long term run to make sure
their services are acceptable and stable. While for an online gaming
service provider, he might be more interested to know if all users are
served fairly by calculating the statistics over the space dimension.
This memo does not intend to recommend which of the statistics are
better than the other.
To save the report transmission bandwidth, each point of interest can
send statistics in a pre-defined time interval to the reference point
rather than sending every one-way singleton it observed. As long as an
appropriate time interval is decided, appropriate statistics can
represent the performance in a certain accurate scale. How to decide
the time interval and how to bootstrap all points of interest and the
reference point depend on applications. For instance, applications with
lower transmission rate can have the time interval longer and ones with
higher transmission rate can have the time interval shorter. However,
this is out of the scope of this memo.
Moreover, after knowing the statistics over the time dimension, one
might want to know how this statistics distributed over the space

dimension. For instance, a TV broadcast service provider had the performance Matrix M and calculated the One-way delay mean over the time dimension to obtain a delay Vector as {V1,V2,..., VN}. He then calculated the mean of all the elements in the Vector to see what level of delay he has served to all N users. This new delay mean gives information on how good the service has been delivered to a group of users during a sampling interval in terms of delay. It needs twice calculation to have this statistic over both time and space dimensions. We name this kind of statistics 2-level statistics to distinct with those 1-level statistics calculated over either space or time dimension. It can be easily prove that no matter over which dimension a 2-level statistic is calculated first, the results are the same. I.e. one can calculate the 2-level delay mean using the Matrix M by having the 1-level delay mean over the time dimension first and then calculate the mean of the obtained vector to find out the 2-level delay mean. Or, he can do the 1-level statistic calculation over the space dimension first and then have the 2-level delay mean. Both two results will be exactly the same. Therefore, when define a 2-level statistic, there is no need to specify in which procedure the calculation should follow. Comment: The above statement depends on whether the order of operations has any affect on the outcome.
Many statistics can be defined for the proposed one-to-group metrics over either the space dimension or the time dimension or both. This memo treats the case where a stream of packets from the Source results in a sample at each of the Receivers in the Group, and these samples are each summarized with the usual statistics employed in one-to-one communication. New statistic definitions are presented, which summarize the one-to-one statistics over all the Receivers in the Group.

7.1. Discussion on the Impact of packet loss on statistics

The packet loss does have effects on one-way metrics and their statistics. For example, the lost packet can result an infinite one-way delay. It is easy to handle the problem by simply ignoring the infinite value in the metrics and in the calculation of the corresponding statistics. However, the packet loss has so strong impact on the statistics calculation for the one-to-group metrics that it can not be solved by the same method used for one-way metrics. This is due to the complex of building a Matrix, which is needed for calculation of the statistics proposed in this memo.
The situation is that measurement results obtained by different end users might have different packet loss pattern. For example, for User1, packet A was observed lost. And for User2, packet A was successfully received but packet B was lost. If the method to overcome the packet loss for one-way metrics is applied, the two singleton sets reported by User1 and User2 will be different in terms of the transmitted packets.

Moreover, if User1 and User2 have different number of lost packets, the size of the results will be different. Therefore, for the centralized calculation, the reference point will not be able to use these two results to build up the group Matrix and can not calculate the statistics. In an extreme situation, no single packet arrives all users in the measurement and the Matrix will be empty. One of the possible solutions is to replace the infinite/undefined delay value by the average of the two adjacent values. For example, if the result reported by user1 is { R1dT1 R1dT2 R1dT3 … R1dTK-1 UNDEF R1dTK+1… R1DM } where "UNDEF" is an undefined value, the reference point can replace it by R1dTK = {(R1dTK-1)+(R1dTK+1)}/2. Therefore, this result can be used to build up the group Matrix with an estimated value R1dTK. There are other possible solutions such as using the overall mean of the whole result to replace the infinite/undefined value, and so on. However this is out of the scope of this memo.

For the distributed calculation, the reported statistics might have different "weight" to present the group performance, which is especially true for delay and ipdv relevant metrics. For example, User1 calculates the Type-P-Finite-One-way-Delay-Mean R1DM as shown in Figure. 8 without any packet loss and User2 calculates the R2DM with N-2 packet loss. The R1DM and R2DM should not be treated with equal weight because R2DM was calculated only based on 2 delay values in the whole sample interval. One possible solution is to use a weight factor to mark every statistic value sent by users and use this factor for further statistic calculation.

7.2. General Metric Parameters

  *Src, the IP address of a host;

  *G, the receiving group identifier;

  *N, the number of Receivers (Recv1, Recv2, ... RecvN);

  *T, a time (start of test interval);

  *Tf, a time (end of test interval);

  *K, the number of packets sent from the source during the test
   interval;

  *J[n], the number of packets received at a particular Receiver, n,
   where 1<=n<=N;

  *lambda, a rate in reciprocal seconds (for Poisson Streams);

*incT, the nominal duration of inter-packet interval, first bit to
 first bit (for Periodic Streams);

*T0, a time that MUST be selected at random from the interval [T,
 T+I] to start generating packets and taking measurements (for
 Periodic Streams);

*TstampSrc, the wire time of the packet as measured at MP(Src)
 (the Source Measurement Point);

*TstampRecv, the wire time of the packet as measured at MP(Recv),
 assigned to packets that arrive within a "reasonable" time;

*Tmax, a maximum waiting time for packets at the destination, set
 sufficiently long to disambiguate packets with long delays from
 packets that are discarded (lost), thus the distribution of delay
 is not truncated;

*dT, shorthand notation for a one-way delay singleton value;

*L, shorthand notation for a one-way loss singleton value, either
 zero or one, where L=1 indicates loss and L=0 indicates arrival
 at the destination within TstampSrc + Tmax, may be indexed over n
 Receivers;

*DV, shorthand notation for a one-way delay variation singleton
 value;

7.3. One-to-Group one-way Delay Statistics

This section defines the overall one-way delay statistics for a
receiver and for an entire group as illustrated by the matrix below.

```
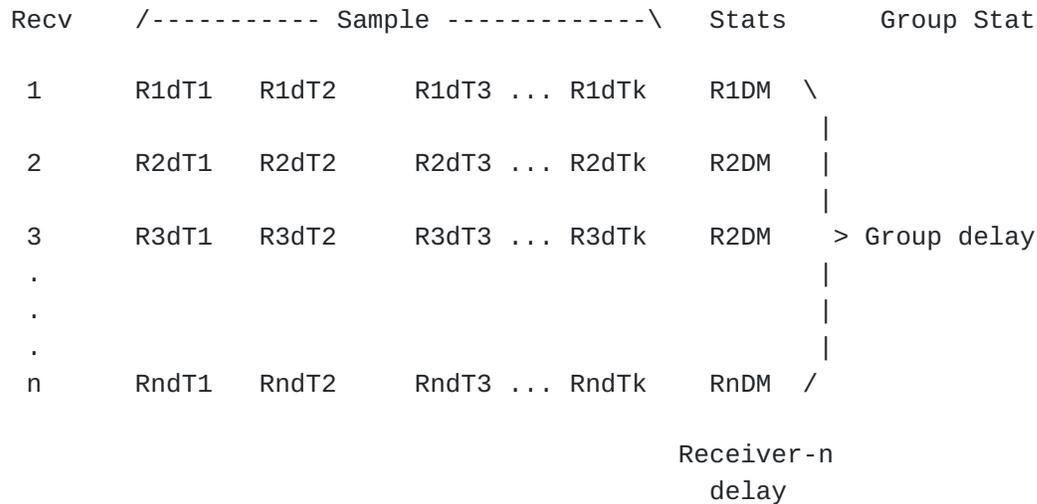    Recv     /----------- Sample -------------\    Stats       Group Stat

     1       R1dT1   R1dT2      R1dT3 ... R1dTk    R1DM  \
                                                          |
     2       R2dT1   R2dT2      R2dT3 ... R2dTk    R2DM   |
                                                          |
     3       R3dT1   R3dT2      R3dT3 ... R3dTk    R2DM    > Group delay
     .                                                    |
     .                                                    |
     .                                                    |
     n       RndT1   RndT2      RndT3 ... RndTk    RnDM   /

                                                 Receiver-n
                                                   delay
```

Figure 5: One-to-Group Mean Delay

Statistics are computed on the finite One-way delays of the matrix
above.
All One-to-group delay statistics are expressed in seconds with
sufficient resolution to convey 3 significant digits.

7.3.1. Type-P-One-to-Group-Receiver-n-Mean-Delay

This section defines Type-P-One-to-Group-Receiver-n-Mean-Delay the
Delay Mean at each Receiver N, also named RnDM.
We obtain the value of Type-P-One-way-Delay singleton for all packets
sent during the test interval at each Receiver (Destination), as per
[RFC2679] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Delay
Metric for IPPM," September 1999.). For each packet that arrives within
Tmax of its sending time, TstampSrc, the one-way delay singleton (dT)
will be the finite value TstampRecv[i] - TstampSrc[i] in units of
seconds. Otherwise, the value of the singleton is Undefined.

```
                       J[n]
                       ---
             1     \
   RnDM =    --- *  >  TstampRecv[i] - TstampSrc[i]
            J[n]   /
                   ---
                   i = 1
```

Figure 6: Type-P-One-to-Group-Receiver-Mean-Delay

---

where all packets i= 1 through J[n] have finite singleton delays.

7.3.2. Type-P-One-to-Group-Mean-Delay

This section defines Type-P-One-to-Group-Mean-Delay, the Mean One-way delay calculated over the entire Group, also named GMD.

```
                   N
                   ---
             1     \
   GMD =    - *    >   RnDM
             N     /
                   ---
                   n = 1
```

Figure 7: Type-P-One-to-Group-Mean-Delay

Note that the Group Mean Delay can also be calculated by summing the Finite one-way Delay singletons in the Matrix, and dividing by the number of Finite One-way Delay singletons.

7.3.3. Type-P-One-to-Group-Range-Mean-Delay

This section defines a metric for the range of mean delays over all N receivers in the Group, (R1DM, R2DM,...RnDM).
Type-P-One-to-Group-Range-Mean-Delay = GRMD = max(RnDM) - min(RnDM)

7.3.4. Type-P-One-to-Group-Max-Mean-Delay

This section defines a metric for the maximum of mean delays over all N
receivers in the Group, (R1DM, R2DM,...RnDM).
Type-P-One-to-Group-Max-Mean-Delay = GMMD = max(RnDM)

7.4. One-to-Group one-way Loss Statistics

This section defines the overall one-way loss statistics for a receiver
and for an entire group as illustrated by the matrix below.

```
   Recv     /----------- Sample ----------\   Stats      Group Stat

    1       R1L1    R1L2     R1L3 ... R1Lk     R1LR \
                                                     |
    2       R2L1    R2L2     R2L3 ... R2Lk     R2LR  |
                                                     |
    3       R3L1    R3L2     R3L3 ... R3Lk     R3LR   > Group Loss Ratio
    .                                                |
    .                                                |
    .                                                |
    n       RnL1    RnL2     RnL3 ... RnLk     RnLR  /

                                          Receiver-n
                                          Loss Ratio
```

Figure 8: One-to-Group Loss Ratio

Statistics are computed on the sample of Type-P-One-way-Packet-Loss
[RFC2680] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way
Packet Loss Metric for IPPM," September 1999.) of the matrix above.
All loss ratios are expressed in units of packets lost to total packets
sent.

7.4.1. Type-P-One-to-Group-Receiver-n-Loss-Ratio

Given a Matrix of loss singletons as illustrated above, determine the
Type-P-One-way-Packet-Loss-Average for the sample at each receiver,

according to the definitions and method of [RFC2680] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Packet Loss Metric for IPPM," September 1999.). The Type-P-One-way-Packet-Loss-Average and the Type-P-One-to-Group-Receiver-n-Loss-Ratio, also named RnLR, are equivalent metrics. In terms of the parameters used here, these metrics definitions can be expressed as

$$RnLR = \frac{1}{K} * \sum_{k=1}^{K} RnLk$$

Figure 9: Type-P-One-to-Group-Receiver-n-Loss-Ratio

7.4.2. Type-P-One-to-Group-Receiver-n-Comp-Loss-Ratio

Usually, the number of packets sent is used in the denominator of packet loss ratio metrics. For the comparative metrics defined here, the denominator is the maximum number of packets received at any receiver for the sample and test interval of interest.
The Comparative Loss Ratio, also named, RnCLR, is defined as

```
                    K
                   ---
                    \
                     >   Ln(k)
                    /
                   ---
                   k=1
    RnCLR =  -----------------------------
                   /    K         \
                   |   ---         |
                   |    \          |
           K - Min |     >   Ln(k) |
                   |    /          |
                   |   ---         |
                   \   k=1         / N
```

Figure 10: Type-P-One-to-Group-Receiver-n-Comp-Loss-Ratio

7.4.3. Type-P-One-to-Group-Loss-Ratio

Type-P-One-to-Group-Loss-Ratio, the overall Group loss ratio, also
named GLR, is defined as

```
                    K,N
                    ---
            1        \
    GLR = --- *      >   L(k,n)
          K*N       /
                    ---
                  k,n = 1
```

Figure 11: Type-P-One-to-Group-Loss-Ratio

7.4.4. Type-P-One-to-Group-Range-Loss-Ratio

The One-to-Group Loss Ratio Range is defined as:
Type-P-One-to-Group-Range-Loss-Ratio = max(RnLR) - min(RnLR)
It is most effective to indicate the range by giving both the max and
minimum loss ratios for the Group, rather than only reporting the
difference between them.

7.5. One-to-Group one-way Delay Variation Statistics

This section defines one-way delay variation (DV) statistics for an
entire group as illustrated by the matrix below.

```
   Recv    /------------- Sample --------------\   Stats

    1      R1ddT1   R1ddT2     R1ddT3 ... R1ddTk   R1DV  \
                                                         |
    2      R2ddT1   R2ddT2     R2ddT3 ... R2ddTk   R2DV   |
                                                         |
    3      R3ddT1   R3ddT2     R3ddT3 ... R3ddTk   R3DV    > Group Stat
    .                                                     |
    .                                                     |
    .                                                     |
    n      RnddT1   RnddT2     RnddT3 ... RnddTk   RnDV   /
```

Figure 12: One-to-Group Delay Variation Matrix (DVMa)

Statistics are computed on the sample of Type-P-One-way-Delay-Variation
singletons of the group delay variation matrix above where RnddTk is
the Type-P-One-way-Delay-Variation singleton evaluated at Receiver n
for the packet k and where RnDV is the point-to-point one-way packet
delay variation for Receiver n.
All One-to-group delay variation statistics are expressed in seconds
with sufficient resolution to convey 3 significant digits.

7.5.1. Type-P-One-to-Group-Delay-Variation-Range

This section defines a metric for the range of delays variation over
all N receivers in the Group.

Maximum DV and minimum DV over all receivers summarize the performance over the Group (where DV is a point-to-point metric). For each receiver, the DV is usually expressed as the $1-10^{(-3)}$ quantile of one-way delay minus the minimum one-way delay.

Type-P-One-to-Group-Delay-Variation-Range = GDVR =

= max(RnDV) – min(RnDV) for all n receivers

This range is determined from the minimum and maximum values of the point-to-point one-way IP Packet Delay Variation for the set of Destinations in the group and a population of interest, using the Packet Delay Variation expressed as the $1-10^{-3}$ quantile of one-way delay minus the minimum one-way delay. If a more demanding service is considered, one alternative is to use the $1-10^{-5}$ quantile, and in either case the quantile used should be recorded with the results. Both the minimum and the maximum delay variation are recorded, and both values are given to indicate the location of the range.

---

8. Measurement Methods: Scalability and Reporting

Virtually all the guidance on measurement processes supplied by the earlier IPPM RFCs (such as [RFC2679] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Delay Metric for IPPM," September 1999.) and [RFC2680] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Packet Loss Metric for IPPM," September 1999.)) for one-to-one scenarios is applicable here in the spatial and multiparty measurement scenario. The main difference is that the spatial and multiparty configurations require multiple points of interest where a stream of singletons will be collected. The amount of information requiring storage grows with both the number of metrics and the points of interest, so the scale of the measurement architecture multiplies the number of singleton results that must be collected and processed.

It is possible that the architecture for results collection involves a single reference point with connectivity to all the points of interest. In this case, the number of points of interest determines both storage capacity and packet transfer capacity of the host acting as the reference point. However, both the storage and transfer capacity can be reduced if the points of interest are capable of computing the summary statistics that describe each measurement interval. This is consistent with many operational monitoring architectures today, where even the individual singletons may not be stored at each point of interest.

In recognition of the likely need to minimize form of the results for storage and communication, the Group metrics above have been constructed to allow some computations on a per-Receiver basis. This means that each Receiver's statistics would normally have an equal weight with all other Receivers in the Group (regardless of the number of packets received).

8.1. Computation methods

The scalability issue can be raised when there are thousands of points of interest in a group who are trying to send back the measurement results to the reference point for further processing and analysis. The points of interest can send either the whole measured sample or only the calculated statistics. The former one is a centralized statistic calculation method and the latter one is a distributed statistic calculation method. The sample should include all metrics parameters, the values and the corresponding sequence numbers. The transmission of the whole sample can cost much more bandwidth than the transmission of the statistics that should include all statistic parameters specified by policies and the additional information about the whole sample, such as the size of the sample, the group address, the address of the point of interest, the ID of the sample session, and so on. Apparently, the centralized calculation method can require much more bandwidth than the distributed calculation method when the sample size is big. This is especially true when the measurement has huge number of the points of interest. It can lead to a scalability issue at the reference point by over load the network resources. The distributed calculation method can save much more bandwidth and release the pressure of the scalability issue at the reference point side. However, it can result in the lack of information because not all measured singletons are obtained for building up the group matrix. The performance over time can be hidden from the analysis. For example, the loss pattern can be missed by simply accepting the loss ratio as well as the delay pattern. This tradeoff between the bandwidth consuming and the information acquiring has to be taken into account when design the measurement campaign to optimize the measurement results delivery. The possible solution could be to transit the statistic parameters to the reference point first to obtain the general information of the group performance. If the detail results are required, the reference point should send the requests to the points of interest, which could be particular ones or the whole group. This procedure can happen in the off peak time and can be well scheduled to avoid delivery of too many points of interest at the same time. Compression techniques can also be used to minimize the bandwidth required by the transmission. This could be a measurement protocol to report the measurement results. However, this is out of the scope of this memo.

8.2. Measurement

To prevent any bias in the result, the configuration of a one-to-many measure must take in consideration that implicitly more packets will to

be routed than send and selects a test packets rate that will not
impact the network performance.

8.3. Effect of Time and Space Aggregation Order on Stats

This section presents the impact of the aggregation order on the
scalability of the reporting and of the computation. It makes the
hypothesis that receivers are managed remotely and not co-located.
multimetrics samples represented a matrix as illustrated below

---

```
    Point of
    interest
     1      R1S1   R1S1      R1S1 ... R1Sk     \
                                               |
     2      R2S1   R2S2      R2S3 ... R2Sk     |
                                               |
     3      R3S1   R3S2      R3S3 ... R3Sk      >  sample over space
     .                                         |
     .                                         |
     .                                         |
     n      RnS1   RnS2      RnS3 ... RnSk     /

            S1M    S2M       S3M  ... SnM     Stats over space

            \-------------  ------------/
                        \/
              Stat over space and time
```

Figure 13: Impact of space aggregation on multimetrics Stat

---

2 methods are available to compute statistics on the resulting matrix:

   *metric is computed over time and then over space;

   *metric is computed over space and then over time.

They differ only by the order of the time and of the space aggregation.
View as a matrix this order is neutral as does not impact the result,
but the impact on a measurement deployment is critical.
In both cases the volume of data to report is proportional to the
number of probes. But there is a major difference between these 2
methods:

method2: In space and time aggregation mode the volume of data to collect is proportional to the number of test packets received; Each received packet RiSi triggers out a block of data that must be reported to a common place for computing the stat over space;

method1: In time and space aggregation mode the volume of data to collect is proportional to the period of aggregation, so it does not depend on the number of packet received;

Method 2 property has severe drawbacks in terms of security and dimensioning:

The increasing of the rate of the test packets may result in a sort of DoS toward the computation points;

The dimensioning of a measurement system is quite impossible to validate.

The time aggregation interval provides the reporting side with a control of various collecting aspects such as bandwidth and computation and storage capacities. So this draft defines metrics based on method 1.
Note: In some specific cases one may need sample of singletons over space. To address this need it is suggested firstly to limit the number of test and the number of test packets per seconds. Then reducing the size of the sample over time to one packet give sample of singleton over space..

8.3.1. Impact on spatial statistics

2 methods are available to compute spatial statistics:

*method 1: spatial segment metrics and statistics are preferably computed over time by each points of interest;

*method 2: Vectors metrics are intrinsically instantaneous space metrics which must be reported using method2 whenever instantaneous metrics information is needed.

8.3.2. Impact on one-to-group statistics

2 methods are available to compute group statistics:

>   *method1: [Figure 5 (One-to-Group Mean Delay)](#) and[Figure 8 (One-to-Group Loss Ratio)](#) illustrate the method chosen: the one-to-one statistic is computed per interval of time before the computation of the mean over the group of receivers;

>   *method2: [Figure 13 (Impact of space aggregation on multimetrics Stat)](#) presents the second one, metric is computed over space and then over time.

---

9. Manageability Considerations

Usually IPPM WG documents defines each metric reporting within its definition. This document defines the reporting of all the metrics introduced in a single section to provide consistent information, to avoid repetitions and to conform to IESG recommendation of gathering manageability considerations in a dedicated section.
Information models of spatial metrics and of one-to-group metrics are similar excepted that points of interests of spatial vectors must be ordered.
The complexity of the reporting relies on the number of points of interests.

9.1. Reporting spatial metric

The reporting of spatial metrics shares a lot of aspects with RFC2679-80. New ones are common to all the definitions and are mostly related to the reporting of the path and of methodology parameters that may bias raw results analysis. This section presents these specific parameters and then lists exhaustively the parameters that shall be reported.

9.1.1. Path

End-to-end metrics can't determine the path of the measure despite IPPM RFCs recommend it to be reported (See Section 3.8.4 of [RFC2679] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Delay Metric for IPPM," September 1999.)). Spatial metrics vectors provide this

path. The report of a spatial vector must include the points of interests involved: the sub set of the hosts of the path participating to the instantaneous measure.

9.1.2. Host order

A spatial vector must order the points of interest according to their order in the path. It is highly suggested to use the TTL in IPv4, the Hop Limit in IPv6 or the corresponding information in MPLS.
The report of a spatial vector must include the ordered list of the hosts involved in the instantaneous measure.

9.1.3. Timestamping bias

The location of the point of interest inside a node influences the timestamping skew and accuracy. As an example, consider that some internal machinery delays the timestamping up to 3 milliseconds then the minimal uncertainty reported be 3 ms if the internal delay is unknown at the time of the timestamping.
The report of a spatial vector must include the uncertainty of the timestamping compared to wire time.

9.1.4. Reporting spatial One-way Delay

The reporting includes information to report for one-way-delay as the Section 3.6 of [RFC2679] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Delay Metric for IPPM," September 1999.). The same apply for packet loss and ipdv.

9.2. Reporting One-to-group metric

All reporting rules described in RFC2679-80 apply to the corresponding One-to-group metrics. Following are specific parameters that should be reported.

9.2.1. Path

As suggested by the RFC2679-80, the path traversed by the packet SHOULD be reported, if possible. For One-to-group metrics, there is a path tree SHOULD be reported rather than A path. This is even more impractical. If, by anyway, partial information is available to report, it might not be as valuable as it is in the one-to-one case because the incomplete path might be difficult to identify its position in the path tree. For example, how many points of interest are reached by the packet traveled through this incomplete path?

9.2.2. Group size

The group size should be reported as one of the critical management parameters. Unlike the spatial metrics, there is no need of order of points of interests.

9.2.3. Timestamping bias

It is the same as described in section 9.1.3.

9.2.4. Reporting One-to-group One-way Delay

It is the same as described in section 9.1.4.

9.2.5. Measurement method

As explained in section 8, the measurement method will have impact on the analysis of the measurement result. Therefore, it should be reported.

9.3. Metric identification

IANA assigns each metric defined by the IPPM WG with a unique identifier as per [RFC4148] (Stephan, E., "IP Performance Metrics

(IPPM) Metrics Registry," August 2005.) in the IANA-IPPM-METRICS-REGISTRY-MIB.

9.4. Information model

This section presents the elements of information and the usage of the information reported for network performance analysis. It is out of the scope of this section to define how the information is reported. The information model is build with pieces of information introduced and explained in one-way delay definitions [RFC2679] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Delay Metric for IPPM," September 1999.), in packet loss definitions [RFC2680] (Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Packet Loss Metric for IPPM," September 1999.) and in IPDV definitions of [RFC3393] (Demichelis, C. and P. Chimento, "IP Packet Delay Variation Metric for IP Performance Metrics (IPPM)," November 2002.) and [RFC3432] (Raisanen, V., Grotefeld, G., and A. Morton, "Network performance measurement with periodic streams," November 2002.). It includes not only information given by "Reporting the metric" sections but by sections "Methodology" and "Errors and Uncertainties" sections. Following are the elements of information taken from end-to-end definitions referred in this memo and from spatial and multicast metrics it defines:

*Packet_type, The Type-P of test packets (Type-P);

*Packet_length, a packet length in bits (L);

*Src_host, the IP address of the sender;

*Dst_host, the IP address of the receiver;

*Hosts_serie: <H1, H2,..., Hn>, a list of points of interest;

*Loss_threshold: The threshold of infinite delay;

*Systematic_error: constant delay between wire time and timestamping;

*Calibration_error: maximal uncertainty;

*Src_time, the sending time for a measured packet;

*Dst_time, the receiving time for a measured packet;

*Result_status : an indicator of usability of a result 'Resource exhaustion' 'infinite', 'lost';

*Delays_serie: <dT1,..., dTn> a list of delays;

*Losses_serie: <B1, B2, ..., Bi, ..., Bn>, a list of Boolean
 values (spatial) or a set of Boolean values (one-to-group);

*Result_status_serie: a list of results status;

*dT: a delay;

*Singleton_number: a number of singletons;

*Observation_duration: An observation duration;

*metric_identifier.

Following is the information of each vector that should be available to
compute samples:

*Packet_type;

*Packet_length;

*Src_host, the sender of the packet;

*Dst_host, the receiver of the packet, apply only for spatial
 vectors;

*Hosts_serie: not ordered for one-to-group;

*Src_time, the sending time for the measured packet;

*dT, the end-to-end one-way delay for the measured packet, apply
 only for spatial vectors;

*Delays_serie: apply only for delays and ipdv vector, not ordered
 for one-to-group;

*Losses_serie: apply only for packets loss vector, not ordered for
 one-to-group;

*Result_status_serie;

*Observation_duration: the difference between the time of the last
 singleton and the time of the first singleton.

*Following is the context information (measure, points of
 interests) that should be available to compute samples :

   -Loss threshold;

-Systematic error: constant delay between wire time and
         timestamping;

        -Calibration error: maximal uncertainty;

A spatial or a one-to-group sample is a collection of singletons giving
the performance from the sender to a single point of interest.
Following is the information that should be available for each sample
to compute statistics:

     *Packet_type;

     *Packet_length;

     *Src_host, the sender of the packet;

     *Dst_host, the receiver of the packet;

     *Start_time, the sending time of the first packet;

     *Delays_serie: apply only for delays and ipdv samples;

     *Losses_serie: apply only for packets loss samples;

     *Result_status_serie;

     *Observation_duration: the difference between the time of the last
      singleton of the last sample and the time of the first singleton
      of the first sample.

     *Following is the context information (measure, points of
      interests) that should be available to compute statistics :

        -Loss threshold;

        -Systematic error: constant delay between wire time and
         timestamping;

        -Calibration error: maximal uncertainty;

Following is the information of each statistic that should be reported:

     *Result;

     *Start_time;

     *Duration;

     *Result_status;

*Singleton_number, the number of singletons the statistic is
 computed on;

---

10. Security Considerations

Spatial and one-to-group metrics are defined on the top of end-to-end
metrics. Security considerations discussed in One-way delay metrics
definitions of [RFC2679] (Almes, G., Kalidindi, S., and M. Zekauskas,
"A One-way Delay Metric for IPPM," September 1999.) , in packet loss
metrics definitions of [RFC2680] (Almes, G., Kalidindi, S., and M.
Zekauskas, "A One-way Packet Loss Metric for IPPM," September 1999.)
and in IPDV metrics definitions of[RFC3393] (Demichelis, C. and P.
Chimento, "IP Packet Delay Variation Metric for IP Performance Metrics
(IPPM)," November 2002.) and [RFC3432] (Raisanen, V., Grotefeld, G.,
and A. Morton, "Network performance measurement with periodic streams,"
November 2002.) apply to metrics defined in this memo.

10.1. Spatial metrics

Malicious generation of packets with spoofing addresses may corrupt the
results without any possibility to detect the spoofing.
Malicious generation of packets which match systematically the hash
function used to detect the packets may lead to a DoS attack toward the
point of reference.

10.2. one-to-group metric

Reporting of measurement results from a huge number of probes may
overload reference point ressources (network, network interfaces,
computation capacities ...).
The configuration of a measurement must take in consideration that
implicitly more packets will to be routed than send and selects a test
packets rate accordingly. Collecting statistics from a huge number of
probes may overload any combination of the network where the
measurement controller is attached to, measurement controller network
interfaces and measurement controller computation capacities.
One-to-group metrics measurement should consider using source
authentication protocols, standardized in the MSEC group, to avoid
fraud packet in the sampling interval. The test packet rate could be

negotiated before any measurement session to avoid deny of service
attacks.

---

11. Acknowledgments

Lei would like to acknowledge Prof. Zhili Sun from CCSR, University of
Surrey, for his instruction and helpful comments on this work.

---

12. IANA Considerations

Metrics defined in this memo Metrics defined in this memo are designed
to be registered in the IANA IPPM METRICS REGISTRY as described in
initial version of the registry [RFC4148] (Stephan, E., "IP Performance
Metrics (IPPM) Metrics Registry," August 2005.) :
IANA is asked to register the following metrics in the IANA-IPPM-
METRICS-REGISTRY-MIB :
ietfSpatialOneWayDelayVector OBJECT-IDENTITY

    STATUS current

    DESCRIPTION

       "Type-P-Spatial-One-way-Delay-Vector"

    REFERENCE

       "Reference "RFCyyyy, section 4.1."

       -- RFC Ed.: replace yyyy with actual RFC number & remove this
       note

    := { ianaIppmMetrics nn } -- IANA assigns nn

ietfSpatialPacketLossVector OBJECT-IDENTITY

    STATUS current

    DESCRIPTION

       "Type-P-Spatial-Packet-Loss-Vector"

    REFERENCE

       "Reference "RFCyyyy, section 4.2."

```
    -- RFC Ed.: replace yyyy with actual RFC number & remove this
    note

:= { ianaIppmMetrics nn } -- IANA assigns nn

ietfSpatialOneWayIpdvVector OBJECT-IDENTITY

    STATUS current

    DESCRIPTION

        "Type-P-Spatial-One-way-ipdv-Vector"

    REFERENCE

        "Reference "RFCyyyy, section 4.3."

        -- RFC Ed.: replace yyyy with actual RFC number & remove this
        note

:= { ianaIppmMetrics nn } -- IANA assigns nn

ietfSegmentOneWayDelayStream OBJECT-IDENTITY

    STATUS current

    DESCRIPTION

        "Type-P-Segment-One-way-Delay-Stream"

    REFERENCE

        "Reference "RFCyyyy, section 5.1."

        -- RFC Ed.: replace yyyy with actual RFC number & remove this
        note

:= { ianaIppmMetrics nn } -- IANA assigns nn

ietfSegmentPacketLossStream OBJECT-IDENTITY

    STATUS current

    DESCRIPTION

        "Type-P-Segment-Packet-Loss-Stream"

    REFERENCE

        "Reference "RFCyyyy, section 5.2."
```

```
      -- RFC Ed.: replace yyyy with actual RFC number & remove this
      note

   := { ianaIppmMetrics nn } -- IANA assigns nn

ietfSegmentOneWayIpdvPrevStream OBJECT-IDENTITY

   STATUS current

   DESCRIPTION

      "Type-P-Segment-One-way-ipdv-prev-Stream"

   REFERENCE

      "Reference "RFCyyyy, section 5.3."

      -- RFC Ed.: replace yyyy with actual RFC number & remove this
      note

   := { ianaIppmMetrics nn } -- IANA assigns nn

ietfSegmentOneWayIpdvMinStream OBJECT-IDENTITY

   STATUS current

   DESCRIPTION

      "Type-P-Segment-One-way-ipdv-min-Stream"

   REFERENCE

      "Reference "RFCyyyy, section 5.4."

      -- RFC Ed.: replace yyyy with actual RFC number & remove this
      note

   := { ianaIppmMetrics nn } -- IANA assigns nn

-- One-to-group metrics
ietfOneToGroupOneWayDelayVector OBJECT-IDENTITY

   STATUS current

   DESCRIPTION

      "Type-P-One-to-group-One-way-Delay-Vector"

   REFERENCE

      "Reference "RFCyyyy, section 6.1."
```

```
        -- RFC Ed.: replace yyyy with actual RFC number & remove this
        note

    := { ianaIppmMetrics nn } -- IANA assigns nn

ietfOneToGroupOneWayPktLossVector OBJECT-IDENTITY

    STATUS current

    DESCRIPTION

        "Type-P-One-to-Group-One-way-Packet-Loss-Vector"

    REFERENCE

        "Reference "RFCyyyy, section 6.2."

        -- RFC Ed.: replace yyyy with actual RFC number & remove this
        note

    := { ianaIppmMetrics nn } -- IANA assigns nn

ietfOneToGroupOneWayIpdvVector OBJECT-IDENTITY

    STATUS current

    DESCRIPTION

        "Type-P-One-to-Group-One-way-ipdv-Vector"

    REFERENCE

        "Reference "RFCyyyy, section 6.3."

        -- RFC Ed.: replace yyyy with actual RFC number & remove this
        note

    := { ianaIppmMetrics nn } -- IANA assigns nn

-- One to group statistics
--
ietfOnetoGroupReceiverNMeanDelay OBJECT-IDENTITY

    STATUS current

    DESCRIPTION

        "Type-P-One-to-Group-Receiver-n-Mean-Delay"

    REFERENCE
```

```
         "Reference "RFCyyyy, section 7.3.1."

         -- RFC Ed.: replace yyyy with actual RFC number & remove this
         note

      := { ianaIppmMetrics nn } -- IANA assigns nn

   ietfOneToGroupMeanDelay OBJECT-IDENTITY

      STATUS current

      DESCRIPTION

         "Type-P-One-to-Group-Mean-Delay"

      REFERENCE

         "Reference "RFCyyyy, section 7.3.2."

         -- RFC Ed.: replace yyyy with actual RFC number & remove this
         note

      := { ianaIppmMetrics nn } -- IANA assigns nn

   ietfOneToGroupRangeMeanDelay OBJECT-IDENTITY

      STATUS current

      DESCRIPTION

         "Type-P-One-to-Group-Range-Mean-Delay"

      REFERENCE

         "Reference "RFCyyyy, section 7.3.3."

         -- RFC Ed.: replace yyyy with actual RFC number & remove this
         note

      := { ianaIppmMetrics nn } -- IANA assigns nn

   ietfOneToGroupMaxMeanDelay OBJECT-IDENTITY

      STATUS current

      DESCRIPTION

         "Type-P-One-to-Group-Max-Mean-Delay"

      REFERENCE
```

```
            "Reference "RFCyyyy, section 7.3.4."

            -- RFC Ed.: replace yyyy with actual RFC number & remove this
            note

        := { ianaIppmMetrics nn } -- IANA assigns nn

    ietfOneToGroupReceiverNLossRatio OBJECT-IDENTITY

        STATUS current

        DESCRIPTION

            "Type-P-One-to-Group-Receiver-n-Loss-Ratio"

        REFERENCE

            "Reference "RFCyyyy, section 7.4.1."

            -- RFC Ed.: replace yyyy with actual RFC number & remove this
            note

        := { ianaIppmMetrics nn } -- IANA assigns nn

    --
    ietfOneToGroupReceiverNCompLossRatio OBJECT-IDENTITY

        STATUS current

        DESCRIPTION

            "Type-P-One-to-Group-Receiver-n-Comp-Loss-Ratio"

        REFERENCE

            "Reference "RFCyyyy, section 7.4.2."

            -- RFC Ed.: replace yyyy with actual RFC number & remove this
            note

        := { ianaIppmMetrics nn } -- IANA assigns nn

    ietfOneToGroupLossRatio OBJECT-IDENTITY

        STATUS current

        DESCRIPTION

            "Type-P-One-to-Group-Loss-Ratio"

        REFERENCE
```

```
         "Reference "RFCyyyy, section 7.4.3."

         -- RFC Ed.: replace yyyy with actual RFC number & remove this
         note

      := { ianaIppmMetrics nn } -- IANA assigns nn

--
ietfOneToGroupRangeLossRatio OBJECT-IDENTITY

      STATUS current

      DESCRIPTION

         "Type-P-One-to-Group-Range-Loss-Ratio"

      REFERENCE

         "Reference "RFCyyyy, section 7.4.4."

         -- RFC Ed.: replace yyyy with actual RFC number & remove this
         note

      := { ianaIppmMetrics nn } -- IANA assigns nn

ietfOneToGroupRangeDelayVariation OBJECT-IDENTITY

      STATUS current

      DESCRIPTION

         "Type-P-One-to-Group-Range-Delay-Variation"

      REFERENCE

         "Reference "RFCyyyy, section 7.5.1."

         -- RFC Ed.: replace yyyy with actual RFC number & remove this
         note

      := { ianaIppmMetrics nn } -- IANA assigns nn

--
```

13. References

13.1. Normative References

[RFC2119]	Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels," BCP 14, RFC 2119, March 1997 (TXT, HTML, XML).
[RFC2679]	Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Delay Metric for IPPM," RFC 2679, September 1999 (TXT).
[RFC2680]	Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Packet Loss Metric for IPPM," RFC 2680, September 1999 (TXT).
[RFC3393]	Demichelis, C. and P. Chimento, "IP Packet Delay Variation Metric for IP Performance Metrics (IPPM)," RFC 3393, November 2002 (TXT).
[RFC4148]	Stephan, E., "IP Performance Metrics (IPPM) Metrics Registry," BCP 108, RFC 4148, August 2005 (TXT).

13.2. Informative References

[RFC2330]	Paxson, V., Almes, G., Mahdavi, J., and M. Mathis, "Framework for IP Performance Metrics," RFC 2330, May 1998 (TXT, HTML, XML).
[RFC3432]	Raisanen, V., Grotefeld, G., and A. Morton, "Network performance measurement with periodic streams," RFC 3432, November 2002 (TXT).

Authors' Addresses

	Stephan Emile
	France Telecom Division R&D
	2 avenue Pierre Marzin
	Lannion, F-22307
Fax:	+33 2 96 05 18 52
Email:	emile.stephan@orange-ftgroup.com
	Lei Liang
	CCSR, University of Surrey
	Guildford
	Surrey, GU2 7XH
Fax:	+44 1483 683641
Email:	L.Liang@surrey.ac.uk
	Al Morton
	200 Laurel Ave. South

	Middletown, NJ 07748
	USA
Phone:	+1 732 420 1571
Email:	acmorton@att.com

Full Copyright Statement

Intellectual Property