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IP Performance Metrics (IPPM) for spatial and multicast
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Abstract

The IETF IP Performance Metrics (IPPM) working group has standardized metrics for measuring end-to-end performance between 2 points. This memo defines 2 sets of metrics to extend these end-to-end ones. It defines spatial metrics for measuring the performance of segments along a path and metrics for measuring the performance of a group of

users in multiparty communications.

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1. Introduction

The metrics specified in this memo are built on notions introduced and discussed in the IPPM Framework document, RFC 2330 [RFC2330]. The reader should be familiar with these documents.

This memo makes use of definitions of end-to-end One-way Delay Metrics defined in the RFC 2679 [RFC2679] to define metrics for decomposition of end-to-end one-way delays measurements.

This memo makes use of definitions of end-to-end One-way Packet loss Metrics defined in the RFC 2680 [RFC2680] to define metrics for decomposition of end-to-end one-way packet loss measurements.

The IPPM WG defined a framework for metric definitions and end-to-end measurements:

o A general framework for defining performance metrics, described in the Framework for IP Performance Metrics, RFC 2330 [RFC2330];

o A One-way Active Measurement Protocol Requirements, RFC 3763 [RFC3763];

o A One-way Active Measurement Protocol (OWAMP) [work in progress];

o An IP Performance Metrics Registry , RFC 4148 [RFC4148];

It specified a set of end-to-end metrics, which conform to this framework:

o The IPPM Metrics for Measuring Connectivity, RFC 2678 [RFC2678];

o The One-way Delay Metric for IPPM, RFC 2679 [RFC2679];

o The One-way Packet Loss Metric for IPPM, RFC 2680 [RFC2680];

o The Round-trip Delay Metric for IPPM, RFC 2681 [RFC2681];

o A Framework for Defining Empirical Bulk Transfer Capacity Metrics RFC 3148 [RFC3148];

o One-way Loss Pattern Sample Metrics, RFC 3357 [RFC3357];

o IP Packet Delay Variation Metric for IPPM, RFC 3393 [RFC3393];

o Network performance measurement for periodic streams, RFC 3432 [RFC3432];

o Packet Reordering Metric for IPPM [Work in progress];

Based on these works, this memo defines 2 kinds of multi party metrics.

Firstly it defines spatial metrics:

o A 'sample', called Type-P-Spatial-One-way-Delay-Vector, will be introduced to divide an end-to-end Type-P-One-way-Delay in a spatial sequence of one-way delays.

o A 'sample', called Type-P-Spatial-One-way-Packet-Loss-Vector, will be introduced to divide an end-to-end Type-P-One-way-Packet-Loss in a spatial sequence of packet loss.

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

o Using the Type-P-Spatial-One-way-Delay-Vector metric, a 'sample', called Type-P-subpath-One-way-Delay-Stream, will be introduced to define the one-way-delay between a pair of host of the path. This metric is similar to Type-P-One-way-Delay-Stream.

o Using Type-P-subpath-One-way-Delay-Stream, a 'sample' Type-P-Passive-One-way-Delay-Stream will be introduced to define passive metrics. These metrics are designed for pure passive measurement methodology as introduced by PSAMP WG.

Then it defines one-to-group metrics.

o Using one test packet sent from one sender to a group of receivers, a 'sample', called Type-P-one-to-group-One-way-Delay-Vector, will be introduced to define the list of Type-P-one-way-delay between this sender and the group of receivers.

o Using one test packet sent from one sender to a group of receivers, a 'sample', called Type-P-one-to-group-One-way-Packet-Loss-Vector, will be introduced to define the list of Type-P-One-way-Packet-Loss between this sender and the group of receivers

o Using one test packet sent from one sender to a group of receivers, a 'sample', called Type-P-one-to-group-One-way-Jitter-Vector, will be introduced to define the list of Type-P-One-way-ipdv between this sender and the group of receivers

o Then a discussion section presents the set of statistics that may be computed on the top of these metrics to present the QoS in a view of a group of users as well as the requirements of relative QoS on multiparty communications.

2. Terminology

2.1. Multiparty metric

A metric is said to be multiparty if the definition involved more than two sources or destinations in the measurements. 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 >.

2.2. Spatial metric

A metric is said to be spatial if one of the hosts involved is neither the source nor the destination of the metered packet.

2.3. Spatial metric points of interest

Points of interest of a spatial metric are the routers or sibling in the path between source and destination (in addition to the source and the destination themself).

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. One-to-group metric points of interest

Points of interest of One-to-group metrics are the set of host destinations receiving packets from the source (in addition to the source itself).

2.6. Reference point

The centre/server in the one-to-group measurement that is controlled by network operators can be a very good reference point where

measurement data can be collected for further processing although the actual measurements have to be carried out at all points of interest. I.e., the measurement points will be all clients/receivers while the reference point acts as source for the one-to-group metric. Thus, we can define the reference point as the host while the statistic calculation will be carried out.

2.7. Vector

A group of singletons is the set of results of the observation of the behaviour of the same packet at different places of a network.

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 time. For instance, if One-way delay singletons abserved 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 orgnized as {dT1, dT2,..., dTN}. The elements in one vector are singletons distinct with each other in terms of both measurement point and time. Given the vector V as an example, the element dT1 is distinct from the rest by measured at receiver 1 at time T1. Additional to a singleton, Vector gives information over a space dimension.

2.8. Matrix

Several vectors can orgnize form up a Matrix, which contains results observed in a sampling interval at different place of a network at different time. 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 corresponding to a sample.

The relation among Singleton, Vector and Matrix can be shown in the following Fig 1.

```
        one to group     Singleton
                        /            Sample
Src             Rcvr ..............................
  ..................R1dT1   R1dT2     R1dT3    R1dT4
   `:=-.._
  T   `._ ``-..__
         `.       `- R2dT1   R2dT2     R2dT3    R2dT4
           `-.
              `-.
                 `._R3dT1   R3dT2     R3dT3    R3dT4

                   Vector           Matrix
                  (space)           (time)
```

Figure 1.

3. Motivations for spatial and one-to-group metrics

All IPPM metrics are defined for end-to-end measurement. These metrics provide very good guides for measurement in the pair communications. However, further efforts should be put to define metrics for multiparty measurements such as one to one trajectory metrics and one to multipoint metrics.

3.1. spatial metrics

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

- o The PCE WG is extending existing protocols to permit remote path computation and path computation quality, including inter domain. One may say that in intra domain the decomposing the performance of a path is not whished. However such decomposition is desirable in interdomain to qualify each AS computation with the initial request. So it is necessary to define standard spatial metrics before going further in the computation of inter domain path with QoS constraint.

- o Traffic engineering and troubleshooting applications require spatial views of the one-way delay consumption, identification of the location of the lost of packets and the decomposition of the jitter over the path.

- o Monitoring the QoS of a multicast tree, of MPLS point-to-multipoint and inter-domain communication require spatial decomposition of the one-way delay, of the packet loss and of the jitter.

- o Composition of metrics is a need to scale in the measurement plane. The definition of composition metrics is a work in progress [I-D.ietf-ippm-spatial-composition]; . Spatial measure give typically the individual performance of an intra domain segment. It is the elementary piece of information to exchange for measuring interdomain performance based on composition of metrics.

- o The PSAMP WG defines capabilities to sample packets in a way to to support measurement. [I-D.boschi-ipfix-reducing-redundancy]; defines a method to collect packets information to measure the instantaneous spatial performance without injecting test traffic. Consequently it is urgent to define a set of common spatial metrics for passive and active techniques which respect the IPPM framework [RFC2330]. This need is emphases by the fact that end-to-end spatial measurement involves the 2 techniques;

3.2. 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 in the view of a group with consideration that it involves a group of people rather than two. As a consequence a simple one-way metric cannot describe the multi-connection situation. We need some new metrics to collect performance of all the connections for further statistics analysis. A group of metrics are proposed in this stage named one-to-group performance metrics based on the unicast metrics defined in IPPM WG. One-to-group metrics are trying to composite one-way metrics from one source to a group of destinations to make up new metrics. The compositions are necessary for judging the network performance of multiparty communications and can also be used to describe the difference of the QoS served among a group of users.

One-to-group performance metrics are needed for several reasons:

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

- o For evaluating and controlling of the quality of the multicast services;

- o For controlling the performance of the inter domain multicast services;

- o For presenting and evaluating the relative QoS requirements for the multiparty communications.

To understand the connection situation between one source and any one receiver in the multiparty communication group, we need the collection of instantaneous end-to-end measures. It will give us very detailed insight into each branch of the multicast tree in terms of end-to-end absolute QoS. It can provide clear and helpful information for engineers to identify the connection with problems in a complex multiparty routing tree.

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, we can hardly define the reference point and, therefore, have difficulty 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 metrics definitions

Spatial decomposition metrics are based on standard end-to-end metrics.

The definition of a spatial metric is coupled with the corresponding end-to-end metric. The methodoly is based on the measure of the same test packet and parameters of the corresponding end-to-end metric.

4.1. A Definition for Spatial One-way Delay Vector

This section is coupled with the definition of Type-P-One-way-Delay. When a parameter from section 3 of [RFC2679] is first used in this section, it will be tagged with a trailing asterisk.

Sections 3.5 to 3.8 of [RFC2679] 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.

Following we adapt some of them and introduce points specific to spatial measurement.

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 which ordered the hosts in the path.

+ Hi, exchange points 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.

+ <Src, H1, H2,..., Hn, Dst>, a path digest.

4.1.3. Metric Units

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:

o the delay looks to decrease: dTi > DTi+1. this seem typically du to some clock synchronisation issue. this point is discussed in the section 3.7.1. "Errors or uncertainties related to Clocks" of of [RFC2679];

o The location of the point of interest in the device influences the result (see [I-D.quittek-ipfix-middlebox]). If the packet is not observed on the input interface the delay includes buffering time and consequently an uncertainty due to the difference between 'wire time' and 'host time';

4.1.6. Interference with other test packet

To avoid packet collision it is preferable to include a sequence number in the packet.

4.1.7. loss threshold

To determine if a dTi is defined or undefined it is necessary to define a period of time after which a packet is considered loss.

4.1.8. Methodologies

Section 3.6 of [RFC2679] gives methodologies for end-to-end one-way-delay measurements. Most of them apply to each points interest Hi and are relevant to this section.

Generally, for a given Type-P, in a given Hi, the methodology would proceed as follows:

- At each Hi, prepare to capture the packet sent a time T, take a timestamp Ti', determine the internal delay correction dTi', extract the timestamp T from the packet, then compute the one-way-delay from Src to Hi: dTi = Ti' - dTi' - T. The one-way delay is undefined (infinite) if the packet is not detected after the 'loss threshold' duration;

- Gather the set of dTi of each Hi and order them according to the path to build the Type-P-Spatial-One-way-Delay-Vector metric <T,dT1,dT2,...,dTn,dT> over the path <H1, H2,..., Hn>.

It is out of the scope of this document to define how each Hi detects the packet.

4.1.9. Reporting the metric

Section 3.6 of [RFC2679] indicates the items to report.

4.1.10. Path

It is clear that a end-to-end Type-P-One-way-Delay can't determine the list of hosts the packet passes throught. Section 3.8.4 of [RFC2679] says that the path traversed by the packet SHOULD be reported but is practically impossible to determine.

This part of the job is provide by Type-P-Spatial-One-way-Delay-Vector metric because each points of interest Hi which capture the packet is part of the path.

4.2. A Definition of a sample of One-way Delay of a sub path

This metric is similar to the metric Type-P-One-way-Delay-Poisson-stream defined in [RFC2679] and to the metric Type-P-One-way-Delay-Periodic-Stream defined in [RFC3432].

Nevertheless its definition differs because it is based of the division of end-to-end One-way delay using the metric Type-P-Spatial-One-way-Delay-Vector defined above.

It aims is to define a sample of One-way-Delay between a pair of hosts of a path usable by active and passive measurements.

Sections 3.5 to 3.8 of [RFC2679] 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. Subpath one-way-delay measurement SHOULD be respectful of them, especially those related to methodology, clock, uncertainties and reporting.

4.2.1. Metric Name

Type-P-subpath-One-way-Delay-Stream

4.2.2. Metric Parameters

+ Src*, the IP address of the sender.

+ Dst*, the IP address of the receiver.

+ i, An integer which orders exchange points in the path.

+ k, An integer which orders the packets sent.

+ <Src, H1, H2,..., Hn, Dst>, a path digest.

+ Ha, a host of the path digest different from Dst and Hb;

+ Hb, a host of the path digest different from Src and Ha. Hb order in the path must greater that Ha;

+ Hi, exchange points of the path digest.

+ dT1,..., dTn a list of delay.

+ P*, the specification of the packet type.

4.2.3. Metric Units

A sequence of pairs <Tk,dt>.

T is one of time of the sequence T1...Tn;

dt is a delay.

4.2.4. Definition

Given 2 hosts Ha and Hb of the path <Src, H1, H2,..., Hn, Dst>, given a flow of packets of Type-P sent from Src to Dst at the times T1, T2... Tn. At each of these times, we obtain a Type-P-Spatial-One-way-Delay-Vector <T1,dT1.1, dT1.2,..., dT1.n,dT1>. We define the value of the sample Type-P-subpath-One-way-Delay-Stream as the sequence made up of the couples <Tk,dTk.b - dTk.a>. dTk.a is the delay between Src and Ha. dTk.b is the delay between Src and Hb. 'dTk.b - dTk.a' is the one-way delay experienced by the packet sent at the time Tk by Src when going from Ha to Hb.

4.2.5. Discussion

Following are specific issues which may occur:

- When a is Src <Tk,dTk.b - dTk.a> is the measure of the first hop.

- When b is Dst <Tk,dTk.b - dTk.a> is the measure of the last hop.

- the delay looks to decrease: dTi > DTi+1:

  * This is typically du to clock synchronisation issue. this point is discussed in the section 3.7.1. "Errors or uncertainties related to Clocks" of of [RFC2679];

  * This may occurs too when the clock resolution of one probe is bigger than the minimun 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 location of the point of interest in the device influences the result (see [I-D.quittek-ipfix-middlebox]). If the packet is not observed on the input interface the delay includes buffering time and consequently an uncertainty due to the difference between 'wire time' and 'host time';

- dTk.b may be observed and not dTk.a.

- Tk is unknown if the flow is made of end user packets, that is pure passive measure. In this case Tk may be forced to Tk+dTk.a. This motivate separate metrics names for pure passive measurement or specific reporting information.

- Pure passive measure should consider packets of the same size and of the same Type-P.

4.2.6. Interference with other packet

4.2.7. loss threshold

To determine if a dTi is defined or undefined it is necessary to define a period of time after which a packet is considered loss.

4.2.8. Methodologies

Both active and passive method should discussed.

4.2.9. Reporting the metric

Section 3.6 of [RFC2679] indicates the items to report.

4.2.10. Path

4.3. 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] is first used in this section, it will be tagged with a trailing asterisk.

Sections 2.5 to 2.8 of [RFC2680] 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, uncertainities and reporting.

Following we define the spatial metric, then we adapt some of the points above and introduce points specific to spatial measurement.

4.3.1. Metric Name

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

4.3.2. 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, exchange points of the path digest.

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

+ dT1,..., dTn, dT, a list of delay.

+ P*, the specification of the packet type.

+ <Src, H1, H2,..., Hn, Dst>, a path digest.

+ B1, B2, ..., Bi, ..., Bn, a list of boolean values.

4.3.3. Metric Units

A sequence of boolean values.

4.3.4. 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,T+dT> the packet passes <H1, H2 ..., Hn, Dst>,

Type-P-One-way-Packet-Lost-Vector metric is defined as the sequence of values <B1, B2, ..., Bn> such that for each Hi of the path, a value of Bi of 0 means that dTi is a finite value, and a value of 1 means that dTi is undefined.

4.3.5. Discussion

Following are specific issues wich may occur:

o the result includes the sequence 1,0. This case means that the packet was seen by a host but not by it successor on the path;

o

The location of the meter in the device influences the result:

o Even if the packet is received by a device, it may be not observed by a meter located after a buffer;

4.3.6. Reporting

Section in progress.

4.4. A Definition for Spatial One-way Jitter Vector

This section uses parameters from the definition of Type-P-One-way-ipdv. When a parameter from section 2 of [RFC3393] is first used in this section, it will be tagged with a trailing asterisk.

Sections 3.5 to 3.7 of [RFC3393] 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 them, especially those related to methodology, clock, uncertainities and reporting.

Following we adapt some of them and introduce points specific to

spatial measurement.

4.4.1. Metric Name

Type-P-Spatial-One-way-Jitter-Vector

4.4.2. 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, exchange points of the path digest.

+ T1*, the time the first packet was sent.

+ T2*, the time the second packet was sent.

+ P, the specification of the packet type.

+ P1, the first packet sent at time T1.

+ P2, the second packet sent at time T2.

+ <Src, H1, H2,..., Hn, Dst>, a 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.

4.4.3. Metric Units

A sequence of times.

4.4.4. Definition

Given the Type-P packet having the size L and sent by the sender Src at wire-time (first bit) T1 to the receiver Dst in the path <H1, H2,..., Hn>.

Given the Type-P packet having the size L and sent by the sender Src at wire-time (first bit) T2 to the receiver Dst in the same path.

Given the Type-P-Spatial-One-way-Delay-Vector <T1,dT1.1, dT1.2,..., dT1,n,dT1> of the packet P1.

Given the Type-P-Spatial-One-way-Delay-Vector <T2,dT2.1, dT2.2,..., dT2,n,dT2> of the packet P2.

Type-P-Spatial-One-way-Jitter-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 passes 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*.

4.4.5. Sections in progress

See sections 3.5 to 3.7 of [RFC3393].

4.5. Pure Passive Metrics

Spatial metrics may be measured without injecting test traffic as described in [I-D.boschi-ipfix-reducing-redundancy] .

4.5.1. Discussion on Passive measurement

One might says that most of the operational issues occur in the last mile and that consequently such measure are less useful than active measuremeent. Nevertheless they are usable for network TE and interdomain QoS monitoring, and composition of metric.

Such a technique have some limitations that are discussed below.

4.5.1.1. Passive One way delay

As the packet is not a test packet, it does not include the time it was sent.

Consequently a point of interest Hi ignores the time the packet was

send. So It is not possible to measure the delay between Src and Hi in the same manner it is not possible to measure the delay betwwen Hi and Dst.

4.5.1.2. Passive Packet loss

The packet is not a test packet, so it does not include a sequence number.

Packet lost measurement doe not require time synchronization and require only one point of observation. Nevertheless it requires the point of interest Hi to be expecting the packet. Practically Hi may not detect a lost of packet that occurs between Src and Hi.

A point of interest Hi ignores the time the packet is send because the packet does not carry the time it was injected in the network. So a probe Hi can not compute dTi.

An alternative to these issues consist in considering sample spatial One-way delay that T is the time when H1 (the first passive probe of the path) observed the packet.

4.5.2. Reporting and composition

To avoid misunderstanding and to address specific reporting constraint a proposal consists in defining distinct metrics for pure passive measurement based on the definition above.

It is crucial to know the methodologie used because of the difference of method of detection (expecting Seq++); because of the difference of source of time (H1 vs Src) and because of the difference of behavior of the source (Poisson/unknown).

4.5.3. naming and registry

Having distinct metrics identifiers for spatial metrics and passive spatial metrics in the [RFC4148] will avoid interoperabily issues especially during composition of metrics.

4.5.4. Passive One way delay metrics

4.5.5. Passive One way PacketLoss metrics

4.5.6. Passive One way jitter metrics

4.6. Discussion on spatial statistics

Do we define min, max, avg of spatial metrics ?

having the maximum loss metric value could be interesting. Say, the segment between router A and B always contributes loss metric value of "1" means it could be the potential problem segment.

Uploading dTi of each Hi consume a lot of bandwidth. Computing statistics (min, max and avg) of dTi locally in each Hi reduce the bandwidth consumption.

5. One-to-group metrics definitions

5.1. A Definition for one-to-group One-way Delay

5.1.1. Metric Name

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

5.1.2. Metric Parameters

- o Src, the IP address of a host acting as the source.
- o Recv1,..., RecvN, the IP addresses of the N hosts acting as receivers.
- o T, a time.
- o dT1,...,dTn a list of time.
- o P, the specification of the packet type.
- o Gr, the multicast group address (optional). The parameter Gr is the multicast group address if the measured packets are transmitted by multicast. This parameter is to identify the measured traffic from other unicast and multicast traffic. It is set to be 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 receivers.

5.1.3. Metric Units

The value of a Type-P-one-to-group-One-way-Delay-Vector is a set of singletons metrics Type-P-One-way-Delay [RFC2679].

5.1.4. 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 }.

5.2. A Definition for one-to-group One-way Packet Loss

5.2.1. Metric Name

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

5.2.2. Metric Parameters

- o Src, the IP address of a host acting as the source.
- o Recv1,..., RecvN, the IP addresses of the N hosts acting as receivers.
- o T, a time.
- o T1,...,Tn a list of time.
- o P, the specification of the packet type.
- o Gr, the multicast group address (optional).

5.2.3. Metric Units

The value of a Type-P-one-to-group-One-way-Packet-Loss-Vector is a set of singletons metrics Type-P-One-way-Packet-Loss [RFC2680].

5.2.4. 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>}.

5.3. A Definition for one-to-group One-way Jitter

5.3.1. Metric Name

Type-P-one-to-group-One-way-Jitter-Vector

5.3.2. 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 multicast group address (optional)

5.3.3. Metric Units

The value of a Type-P-one-to-group-One-way-Jitter-Vector is a set of singletons metrics Type-P-One-way-ipdv [RFC3393].

5.3.4. Definition

Given a Type P packet stream, Type-P-one-to-group-One-way-Jitter-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 Scr 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-Jitter-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}.

5.4. Discussion on one-to-group statistics

The defined one-to-group metrics above can all be directly achieved from the relevant unicast one-way metrics. They managed to collect all unicast measurement results of one-way metrics together in one profile and sort them by receivers and packets in a multicast group. They can 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 can not be directly used to conveniently present the performance in terms of a group and neither to identify the relative performance situation.

One may say that no matter how many people join the communication, the connections can still be treated as a set of one-to-one connection. However, we might not describe a multiparty communication by a set of one-way measurement metrics because of the difficulty for understanding and the lack of convenience. For instance, an engineer might not describe the connections of a multiparty online conference in terms of one-to-group one-way delay for user A and B, B and C, and C and A because people might be confused. If there are more users in the same communication, the description might be very long. And he might use the one-way metrics with worst and the best value to give users an idea of the performance range of the service they are providing. But it is not clear enough and might not be accurate in a large multiparty communication scenario.

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 worse delay will result in failure in the game. We have to use the new 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., need a rule to judge the relative performance requirement. Therefore, we can see the importance of new statistic metrics to feed this need.

We might 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 FRCs. They provide the foundation of definition for performance statistics. For instance, there are definitions for minimum and maximum One-way delay in [RFC2679] and One-way delay mean in [I-D.ietf-ippm-spatial-composition]. 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 dimension and space dimention. This space dimension is introduced by the Matrix concept. For a Matrix M shown in the Fig. 2, each row is a set of One-way singletons spreading over the space dimension and each colume is another set of One-way singletons spreading over the time dimension.

```
(preamble)
/                    \
| dT11, dT12,..., dT1N |
| dT21, dT22,..., dT2N |
|                :      |
|                :      |
| dTm1, dTm2,..., dTmN |
\                    /
```

Fig. 2 Matrix M (m*N)

In Matrix M, each element is a One-way delay singleton. Each row is a delay vector contains the One-way delays of the same packet observed at N points of interest. It implies the geographical factor of the performance within a group. Each colume 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 columes 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 farely by calculating the statistics over the space dimension. This memo does not intent 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 stantistics 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 dimention first and then have the 2-level delay mean. Both two results will be exactly the same. Therefore, when define a 2-level statistic, it is no need to specify in which procedure the calculation should follow.

There are many statistics can be defined for the proposed one-to-group metrics over either the space dimension or the time dimension or both. In this memo, we define one-to-group mean and one-to-group variation over the space dimension. These statistics are offered mostly to be illustrative of what could be done.

One-to-group mean are trying to measure the overall performance for a multicast group associated to one source. It is a reflection of the absolute performance of a multiparty communication service when we treat all receivers as one customer. It can also present the trend of the absolute performance of all receivers, i.e., it shows that most of the receivers in the multiparty communication service trend to receive an absolute performance close to the mean.

One-to-group variation streams are trying to measure how the performance varies among all of the users in a multicast group associated to one source. The word "variation" in this memo is the population standard deviation. It reflects the relative

performancesituation in a multiparty communication service, i.e., the level of the difference between the absolute performanceof each receivers.

Using the one-to-group mean and one-to-group variation concepts, we can have a much clear understand on the performanceof a multiparty communication service in terms of its trend and range. There can be mean and variation stream definitions for each of the three one-to-group metrics defined above. We only present the definition of Type-P-one-to-group-One-way-Delay-Space-Mean and Type-P-one-to-group- One-way-Delay-Space-Variation as examples in this memo.

5.4.1. Type-P-one-to-group-One-way-Delay-Space-Mean

Given a Type-P-one-to-group-One-way-Delay-Vector, the mean { dT1, dT2,...,dTN } for the packet from Src at time T to { Recv1,...,RecvN }.

For example, suppose we take a delay vector and the results is:

```
Delay_Vector = {dT1,...,dTN}
```

Then the mean over space dimension would be:

```
Delay_Space_Mean = DsM = sum{dT1,...,dTN}/N
```

5.4.2. Type-P-one-to-group-One-way-Delay-Variation-Stream

Given a Type-P-one-to-group-One-way-Delay-Vector, the variation { dT1, dT2,...,dTN } for the packet from Src at time T to { Recv1,...,RecvN }.

We still take the above Delay_Vector as an sample and the variation would be:

```
Delay_Variation_Stream = {SUM[(dT1-DsM)^2,...,(dTN-
DsM)^2)}/N)^(1/2)
```

6. Extension from one-to-one to one-to-many measurement

The above one-to-group metrics were defined to compose measurement results of a group of users who receive the same data from one source. Moreover, this is one of efforts to introducing the one-to-many concern to the IPPM working group with respect to the fact that all existing documents in the group are unicast oriented, which talk about only one-to-one single "path" in measurements. This concept can be extended from the "path" to "path tree" to cover both one-to-

one and one-to-many communications. Actually, the one-to-one communications can be viewed as a special case of one-to-many from the routing point of view. The one-to-many communications build up a routing tree in the networks and one-to-one can be viewed as a special simplified tree without branches but only the "trunk".

Therefore, the one-to-group metrics described in this memo can even be viewed as general metrics to measure the delay, jitter and packet loss in IP networks. When it applies to one-to-one communications, the metrics will have N receivers while N equal to 1. And the statistic metrics for one-to-one communications are exactly the one-to-group metrics themselves when calculated using the methods given.

7. Open issues

8. Security Considerations

Active measumrement: see security section in owd pl, jitter rfcs (editor notes: add references).

passive measurement:

> The generation of packets which match systematically the hash function may lead to a DoS attack toward the collector.
>
> The generation of packets with spoofing adresses may corrupt the results without any possibility to detect the spoofing.

one-to-group metrics require collection of singletons which may overload the network the measurement controller is attach to.

9. Acknowledgments

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

10. IANA Considerations

Metrics defined in this memo will be registered in the IANA IPPM METRICS REGISTRY as described in initial version of the registry [RFC4148].

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