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Spatial Composition of Metrics

Status of this Memo

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Abstract

This memo utilizes IPPM metrics that are applicable to both complete paths and sub-paths, and defines relationships to compose a complete path metric from the sub-path metrics with some accuracy w.r.t. the actual metrics. This is called Spatial Composition in RFC 2330. The current version of the memo gives some background and proposes wording for a Scope and Application section to define this new work.

The description of several example metrics and statistics follow.

Contents

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1. Conventions used in this document

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 [RFC2119]. Although RFC 2119 was written with protocols in mind, the key words are used in this document for similar reasons. They are used to ensure the results of measurements from two different implementations are comparable, and to note instances when an implementation could perturb the network.

In this memo, the characters "<=" should be read as "less than or equal to" and ">=" as "greater than or equal to".

2. Introduction

The IPPM framework RFC 2330 [RFC2330] describes two forms of metric composition, spatial and temporal. Spatial composition encompasses the definitions of performance metrics that are applicable to the complete path, and to various sub-paths. Also, the text suggests

that the concepts of the analytical framework (or A-frame) would help to define useful relationships between the complete path metrics and the sub-path metrics. The effectiveness of such metrics is dependent on their usefulness in analysis and applicability with practical measurement methods.

The relationships may involve conjecture, and [RFC2330] lists four points that the metric definitions should include:

+ the specific conjecture applied to the metric,
+ a justification of the practical utility of the composition in terms of making accurate measurements of the metric on the path,
+ a justification of the usefulness of the composition in terms of making analysis of the path using A-frame concepts more effective, and
+ an analysis of how the conjecture could be incorrect.

RFC 2330 also gives an example where a conjecture that the delay of a path is very nearly the sum of the delays of the exchanges and clouds of the corresponding path digest. This example is particularly relevant to those who wish to assess the performance of an Inter-domain path without direct measurement, and the performance estimate of the complete path is related to the measured results for various sub-paths instead.

Approximate relationships between the sub-path and complete path metrics are useful, with knowledge of the circumstances where the relationships are/are not applicable. For example, we would not expect that delay singletons from each sub-path would sum to produce an accurate estimate of a delay singleton for the complete path (unless all the delays were essentially constant - very unlikely). However, other delay statistics (based on a reasonable sample size) may have a sufficiently large set of circumstances where they are applicable.

2.1 Motivation

One-way metrics defined in other IPPM RFCs all assume that the measurement can be practically carried out between the source and the destination of the interest. Sometimes there are reasons that the measurement can not be executed from the source to the destination. For instance, the measurement path may cross several independent domains that have conflicting policies, measurement tools and methods, and measurement timeslot assignment. and the simple One-way measurement can not be carried out. The solution then may be the composition of several sub-path measurements. That means each domain performs the One-way measurement on a sub path between two nodes that are involved in the complete path following it own policy, using its own measurement tools and methods, and within its own measurement timeslot. One can combine all the sub-path One-way mmetric results to estimate the complete path One-way measurement metric with some accuracy.

>>>>>>>>>>>>Open issue:
What is the relationship between the decomposition and composition metrics? Should we put both kinds in one draft to make up a framework? The motivation of decomposition is as follows:

The One-way measurement can provide result to show what the network performance between two end hosts is and whether it meets operator expectations or not. It cannot provide further information to engineers where and how to improve the performance between the source and the destination. For instance, if the network performance is not acceptable in terms of the One-way measurement, in which part of the network the engineers should put their efforts. This question can to be answered by decompose the One-way measurement to sub-path measurement to investigate the performance of different part of the network.

Editor s Questions for clarification:
What additional information would be provided to the decomposition process, beyond the measurement of the complete path?

Is the decomposition described above intended to estimate a metric for some/all disjoint sub-paths involved in the complete path?

>>>>>>>>>>>>>>>>>>>

3. Proposed Scope and Application

3.1 Scope of Work

For the primary IPPM metrics (currently Loss, Delay, and Delay Variation), this memo gives a set of complete path metrics that can be composed from the same or similar sub-path metrics. This means that the complete path metric may be composed from:

+ the same metric for each sub-path;

+ multiple metrics for each sub-path (possibly one that is the same as the complete path metric);

+ a single sub-path metrics that is different from the complete path metric;

+ different measurement techniques like active and passive (recognizing that PSAMP WG will define capabilities to sample packets to support measurement).

Each metric will clearly state:

- the definition (and statistic, where appropriate);

- the composition relationship;

- the specific conjecture on which the relationship is based;

- a justification of practical utility or usefulness for analysis using the A-frame concepts;

- one or more examples of how the conjecture could be incorrect and lead to inaccuracy;

- the information to be reported;

3.2 Application

For each metric, the applicable circumstances are defined, in terms of whether the composition:

Requires the same test packets to traverse all sub-paths, or may use similar packets sent and collected separately in each sub-path.

Requires homogeneity of measurement methodologies, or can allow a degree of flexibility (e.g., active or passive methods produce the "same" metric). Also, the applicable sending streams will be specified, such as Poisson, Periodic, or both.

Needs information or access that will only be available within an operator's domain, or is applicable to Inter-domain composition.

Requires synchronized measurement time intervals in all sub-paths, or largely overlapping, or no timing requirements.

Requires assumption of sub-path independence w.r.t. the metric being defined/composed, or other assumptions.

Has known sources of inaccuracy/error, and identifies the sources.

3.3 Terminology

This section will define the terminology applicable to both complete path and sub-path metrics.

Measurement Points:

<there must be a suitable definition for this in IPPM s literature>

Equivalent measure:

The equivalent measure is the end-to-end metric that a composite metric is estimating.

Equivalent path:

The Equivalent path is the list of sub path that is equivalent to the path of the end-to-end measure the composition measure is estimating.

4. One-way Delay Composition Metrics and Statistics

4.1 Name: Type-P-Finite-One-way-Delay-Poisson/Periodic-Stream

4.1.1 Metric Parameters:

+ Src, the IP address of a host

+ Dst, the IP address of a host

+ T, a time (start of test interval)

+ Tf, a time (end of test interval)

+ 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+dT] to start generating packets and taking measurements (for Periodic Streams)

+ TstampSrc, the wire time of the packet as measured at MP(Src)

+ TstampDst, the wire time of the packet as measured at MP(Dst), assigned to packets that arrive within a "reasonable" time.

4.1.2 Definition:

Using the parameters above, we obtain the value of Type-P-One-way-Delay singleton as per RFC 2679 [RFC2679]. For each packet [i] that has a finite One-way Delay (in other words, excluding packets which have undefined, or infinite one-way delay):

```
Type-P-Finite-One-way-Delay-Poisson/Periodic-Stream[i] =
               FiniteDelay[i] = TstampDst - TstampSrc
```

4.1.3 Discussion and other details...

4.1.4 Mean Statistic

+ L, the total number of packets received at Dst (sent between T0

and Tf)

The

```
Type-P-Finite-One-way-Delay-Mean =

           MeanDelay = (1/L)Sum(from i=1 to L, FiniteDelay[i])
```

where all packets i= 1 through L have finite singleton delays.

4.1.5 Composition Relationship: Sum of Mean Delays

The Type-P-Finite Composite-One-way-Delay-Mean, or MeanDelay for the complete Source to Destination path can be calculated from sum of the Mean Delays of all its S constituent sub-paths.

+ S, the number of sub-paths involved in the complete Src-Dst path

Then the

Type-P-Finite-Composite-One-way-Delay-Mean =

CompMeanDelay = (1/S)Sum(from i=1 to S, MeanDelay[i])

4.1.6 Statement of Conjecture

The mean of a sufficiently large stream of packets measured on each sub-path during the interval [T, Tf] will be representative of the true mean of the delay distribution (and the distributions themselves are sufficiently independent), such that the means may be added to produce an estimate of the complete path mean delay.

4.1.7 Justification for the composite relationship

It is sometimes impractical to conduct active measurements between every Src-Dst pair. For example, it may not be possible to collect the desired sample size in each test interval when access link speed is limited, because of the potential for measurement traffic to degrade the user traffic performance. The conditions on a low-speed access link may be understood well-enough to permit use of a small sample size/rate, while a larger sample size/rate may be used on other sub-paths.

Also, since measurement operations have a real monetary cost, there is value in re-using measurements where they are applicable, rather than launching new measurements for every possible source-destination pair.

4.1.8 Sources of Error

The measurement packets, each having source and destination addresses intended for collection at edges of the sub-path, may take a different specific path through the network equipment and parallel exchanges than packets with the source and destination addresses of the complete path. Therefore, the sub-path measurements may differ from the performance experienced by packets on the complete path. Multiple measurements employing sufficient sub-path address pairs might produce bounds on the extent of this error.

others...

4.1.9 Specific cases where the conjecture might fail

If any of the sub-path distributions are bimodal, then the measured means may not be stable, and in this case the mean will not be a particularly useful statistic when describing the delay distribution of the complete path.

The mean may not be sufficiently robust statistic to produce a reliable estimate, or to be useful even if it can be measured.

others...

4.1.10 Application of Measurement Methodology

The methodology:

SHOULD use similar packets sent and collected separately in each sub-path.

Allows a degree of flexibility (e.g., active or passive methods can produce the "same" metric, but timing and correlation of passive measurements is much more challenging).

Poisson and/or Periodic streams are RECOMMENDED.

Applicable to both Inter-domain and Intra-domain composition.

SHOULD have synchronized measurement time intervals in all sub-paths, but largely overlapping intervals MAY suffice.

REQUIRES assumption of sub-path independence w.r.t. the metric being defined/composed.

5. Loss Metrics/Statistics

>>>>>>>>>>>>>>>>>
Editor s note: there is considerable redundancy between the material in sections 5.1 and 4.1, need to determine how best to reduce it.

5.1 Name: Type-P-One-way-Packet-Loss-Poisson/Periodic-Stream

5.1.1 Metric Parameters:

+ Src, the IP address of a host

+ Dst, the IP address of a host

+ T, a time (start of test interval)

+ Tf, a time (end of test interval)

+ 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+dT] to start generating packets and taking measurements (for Periodic Streams)

+ TstampSrc, the wire time of the packet as measured at MP(Src)

+ TstampDst, the wire time of the packet as measured at MP(Dst), assigned to packets that arrive within a "reasonable" time.

+ Tmax, a maximum waiting time for packets at the destination

5.1.2 Metric Units:

Using the parameters above, we obtain the value of Type-P-One-way-Packet-Loss singleton and stream as per RFC 2680 [RFC2680]. We obtain a sequence of pairs with elements as follows:

+ TstampSrc, as above

+ L, either zero or one, where L=1 indicates loss and L=0 indicates arrival at the destination within TstampSrc + Tmax.

5.1.3 Discussion and other details...

5.1.4 Statistic: Type-P-One-way-Packet-Loss-Empirical-Probability

Given the following stream parameter

+ N, the total number of packets sent between T0 and Tf

We can define the Empirical Probability of Loss Statistic (Ep), consistent with Average Loss in [RFC2680], as follows:

Type-P-One-way-Packet-Loss-Empirical-Probability =

Ep = (1/N)Sum(from i=1 to N, L[i])

where all packets i= 1 through N have a value for L.

5.1.5 Composition Relationship: Combination of Empirical Probabilities

The Type Type-P-One-way-Composite-Packet-Loss-Empirical-Probability, or CompEp for the complete Source to Destination path can be calculated by combining Ep of all its constituent sub-paths (Ep1, Ep2, Ep3, ... Epn) as

Type-P-One-way-Composite-Packet-Loss-Empirical-Probability =
CompEp = 1   {(1 - Ep1) x (1   Ep2) x (1   Ep3) x ... x (1   Epn)}

5.1.6 Statement of Conjecture

The empirical probability of loss calculated on a sufficiently large stream of packets measured on each sub-path during the interval [T, Tf] will be representative of the true loss probability (and the probabilities themselves are sufficiently independent), such that the sub-path probabilities may be combined to produce an estimate of the complete path loss probability.

5.1.7 Justification for the composite relationship

It is sometimes impractical to conduct active measurements between every Src-Dst pair. For example, it may not be possible to collect the desired sample size in each test interval when access link speed is limited, because of the potential for measurement traffic to degrade the user traffic performance. The conditions on a low-speed access link may be understood well-enough to permit use of a small sample size/rate, while a larger sample size/rate may be used on other sub-paths.

Also, since measurement operations have a real monetary cost, there is value in re-using measurements where they are applicable, rather than launching new measurements for every possible source-destination pair.

5.1.8 Sources of Error

The measurement packets, each having source and destination addresses intended for collection at edges of the sub-path, may take a different specific path through the network equipment and parallel exchanges than packets with the source and destination addresses of the complete path. Therefore, the sub-path measurements may differ from the performance experienced by packets on the complete path. Multiple measurements employing sufficient sub-path address pairs might produce bounds on the extent of this error.

others...

5.1.9 Specific cases where the conjecture might fail

A concern for loss measurements combined in this way is that root causes may be correlated to some degree.

For example, if the links of different networks follow the same physical route, then a single event like a tunnel fire could cause an outage or congestion on remaining paths in multiple networks. Here it is important to ensure that measurements before the event and after the event are not combined to estimate the composite performance.

Or, when traffic volumes rise due to the rapid spread of an email-born worm, loss due to queue overflow in one network may help another network to carry its traffic without loss.

others...

5.1.10 Application of Measurement Methodology

The methodology:

SHOULD use similar packets sent and collected separately in each sub-path.

Allows a degree of flexibility (e.g., active or passive methods can produce the "same" metric, but timing and correlation of passive measurements is much more challenging).

Poisson and/or Periodic streams are RECOMMENDED.

Applicable to both Inter-domain and Intra-domain composition.

SHOULD have synchronized measurement time intervals in all sub-paths, but largely overlapping intervals MAY suffice.

REQUIRES assumption of sub-path independence w.r.t. the metric being defined/composed.

6. Delay Variation Metrics/Statistics

>>>>>>>>>>>>>
Editor s note: We have studied various approaches and have at least one proposal for this section. We plan to add the text in the next version.
>>>>>>>>>>>>>

7. Other Metrics/Statistics: One-way combined Metric

This definition may be the common part for the definition of "Loss Metrics/Statistics" and for the definition of "One-way Delay Composition Metrics and Statistics".

7.1 Metric Name

Type-P-One-way-Combo-mean

7.1.1 Metric Parameters:

Editorial notes (ES): parameters list to be completed

<P1,T1,dt1>...<Pn,Tn,dtn>:

It is a stream of One-way delay corresponding either to an end to end measure of a sub-path, or to the spatial measure of the sub-path:

- Type-P-One-way-Delay-Poisson-Stream as per [RFC2679];
- Type-P-One-way-Delay-Periodic-Stream a per [RFC3432];
- Type-P-One-way-Composition-Stream as defined below;
- Type-P-subpath-One-way-Delay-Stream as per [I-D.stephan-ippm-multimetrics].

7.1.2 Definition:

Using the value <P1,T1,dt1>...<Pn,Tn,dtn> of one of the One-way delay Stream listed above, we define Type-P-One-way-Combo as the couple (D,L) where D is the mean of the delay of the packets that have a finite One-way, and where L is the average of lost of packets (which have undefined, or infinite one-way delay).

D corresponds to the Type-P-Finite-One-way-Delay-Mean defined above.

L corresponds to the Type-P-One-way-Packet-Loss-Empirical-Probability defined above.

7.1.3 Discussion and other details...

7.1.4 Type-P-One-way-Combo-subpathes-stream

Parameters:

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

+ <Src, H1, H2,..., Hn, Dst>, the equivalent path.

Definition:

Using Type-P-One-way-Combo-mean of each sub-path in the equivalent path we define a Type-P-One-way-subpathes-stream as the list of couples (D,L) of the sub-path list;

Results: {<D0,L0>, <D1,L1>, <D2,L2>,   <Dn,Ln>}

7.1.5 Type-P-One-way-composition

The composition over a path gives D and L which give an estimation of the end-to-end delay and end-to-end packet lost over this path.

Parameters:

+ <Src, H1, H2,..., Hn, Dst>, the equivalent path.

+ {<D0,L0>, <D1,L1>, <D2,L2>,   <Dn,Ln>}, the composition stream of the sub-pathes of a path.

Definition:

Using Type-P-One-way-subpathes-stream we define Type-P-One-way-composition as the couple <D,L> where D is the mean of the delays Di and where L is the average of lost of Li.

Results: <D,L>, where D is a delay and L is the lost

7.1.6 Type-P-One-way-composition-stream

The sample of Type-P-One-way-composition is defined to permit the usage of the results of Type-P-One-way-composition measure in computation of Type-P-One-way-Combo-mean composition.

Parameters:

+ T1,..., Tn, a list of time;

+ <D,L>, the delay and the lost computed by composition.

Definition:

Using Type-P-One-way-composition we define Type-P-One-way-composition-stream as the stream of couples <D,L> over time.

Results: <T1,D1,L1>...<Tn,Dn,Ln>

7.1.7 Statement of Conjecture

7.1.8 Justification for the composite relationship

Combo metric is very easy to measure and to compose.

It gives the delay and the lost, so most of the need.

Combo metric may be performed on com metric too.

7.1.9 Sources of Error

Packets may cross different sub path than the equivalent end-to-end measure because Type-P differ.

Packets may experiment different behavior than the equivalent end-to-end measure because of access classification based on packet addresses.

7.1.10 Specific cases where the conjecture might fail

When

+ Sum of subpath differ from the equivalent path.

+ Type-P differ.

+ Size differ.

7.1.11 Application of Measurement Methodology

The methodology:

Is applicable to Intra and interdomain;

SHOULD report the context of the measure;

8. Security Considerations

8.1 Denial of Service Attacks

This metric requires a stream of packets sent from one host (source) to another host (destination) through intervening networks. This method could be abused for denial of service attacks directed at

destination and/or the intervening network(s).

Administrators of source, destination, and the intervening network(s) should establish bilateral or multi-lateral agreements regarding the timing, size, and frequency of collection of sample metrics. Use of this method in excess of the terms agreed between the participants may be cause for immediate rejection or discard of packets or other escalation procedures defined between the affected parties.

8.2 User data confidentiality

Active use of this method generates packets for a sample, rather than taking samples based on user data, and does not threaten user data confidentiality. Passive measurement must restrict attention to the headers of interest. Since user payloads may be temporarily stored for length analysis, suitable precautions MUST be taken to keep this information safe and confidential. In most cases, a hashing function will produce a value suitable for payload comparisons.

8.3 Interference with the metric

It may be possible to identify that a certain packet or stream of packets is part of a sample. With that knowledge at the destination and/or the intervening networks, it is possible to change the processing of the packets (e.g. increasing or decreasing delay) that may distort the measured performance. It may also be possible to generate additional packets that appear to be part of the sample metric. These additional packets are likely to perturb the results of the sample measurement.

To discourage the kind of interference mentioned above, packet interference checks, such as cryptographic hash, may be used.

9. 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].

10. Normative References

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12. Open issues

Point1:

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