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Abstract:

This document presents the project activities related to the needs of conformance of 6QM with IPPM (IETF).

Keywords:

IETF, IPPM, Metrics, Standardization.

Revision History

The following table describes the main changes done in the document since its creation.

Revision	Date	Description	Author (Organization)
v0.0	05/12/2002	Document creation	Emile Stephan (FT)
v0.1	31/01/2003	Update	Alex Dubus (FT)
v1.0	28/02/2003	Document ready for delivery	Emile Stephan (FT)
v1.1	28/02/2003	Document review	Emile Stephan (FT)
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v1.3	20/03/2003	Document review	Emile Stephan (FT)
v1.4	30/03/2003	Document review	Emile Stephan (FT)
v1.5	18/05/2003	Final Review	Jordi Palet (Consulintel)

Executive Summary

The objective of this document is to give a brief overview of the ongoing standardization work at the IETF in the IPPM (IP Performance Measurement) working group. The working group general information is outlined, including the goals and milestones, as well as the current Internet drafts and RFC documents.

The IPPM framework is defined, beginning with general measurement concepts, and then explicit definitions for all the metrics that have currently been defined. This set of metrics includes:

- Metrics for Measuring Connectivity. Metrics that determine whether pairs of hosts (IP addresses) can reach each other form the basis of a measurement suite for connectivity.
- Metrics for Measuring One-way Delay. The measurement of one-way delay from one host to another can be useful for a variety of reasons, some of which include:
    - Certain applications do not perform well if end-to-end delay between hosts is large relative to some threshold value.
    - Erratic variation in delay makes it difficult to support many real-time applications
    - The larger the value of the delay, the more difficult it is for transport-layer protocols to sustain high bandwidths.
- Metrics for Measuring One-Way Packet Loss. Understanding one-way packet loss from a source to a destination host can be beneficial for many of the same reasons as listed above for one-way delay.
- Metrics for Measuring Round Trip Delay. Round-trip delay of a Type-P packet from a source host to a destination host.
- Metrics for Measuring IP Packet Delay Variation. The definition of the IP Packet Delay Variation (ipdv) can be given for packets inside a stream of packets. The ipdv of a pair of packets within a stream of packets is defined for a selected pair of packets in the stream going from measurement point MP1 to measurement point MP2. The ipdv is the difference between the one-way-delay of the selected packets.

Certain works are still in progress, including the definition of a one-way active measurement protocol, and an IPPM REGISTRY (list of all object identifiers for known RFC metrics), and an IPPM REPORTING MIB.

The IPPM Working Group is the most appropriate place to submit standardization contributions related to IPv6 QOS measurement. This document identifies 2 contributions related to the 6QM project.

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1. INTRODUCTION

The IPPM WG will develop a set of standard metrics that can be applied to the quality, performance, and reliability of Internet data delivery services. These metrics will be designed such that network operators, end users, or independent testing groups can measure them. It is important that the metrics not represent a value judgment (i.e. define "good" and "bad"), but rather provide unbiased quantitative measures of performance.

Functions peripheral to Internet data delivery services, such as NOC/NIC services, are beyond the scope of this working group.

The IPPM WG will produce documents that define specific metrics and procedures for accurately measuring and documenting these metrics. The metrics are:

- Connectivity
- One-way delay and loss
- Round-trip delay and loss
- Delay variation
- Loss patterns
- Packet reordering
- Bulk transport capacity
- Link bandwidth capacity

This is the cumulative set, including the metrics already completed and published.

The working group will closely review and then be guided by an IESG document on how metrics advance along the standards track within the IETF. This document will also be relevant to the work of the benchmarking working group (BMWG). The first draft of this document was discussed at IETF 51. Additionally, the WG will produce Proposed Standard AS documents, comparable to applicability statements in RFC 2026, that will focus on procedures for measuring the individual metrics and how these metrics characterize features that are important to different service classes, such as bulk transport, periodic streams, or multimedia streams. It is specifically out of scope for this working group to actually characterize traffic, for example to characterize a voice-over-IP stream. Each AS document will discuss the performance characteristics that are pertinent to a specified service class; clearly identify the set of metrics that aid in the description of those characteristics; specify the methodologies required to collect said metrics; and lastly, present the requirements for the common, unambiguous reporting of testing results. The Area Directors as charter additions must approve specific topics of these AS documents.

The WG will produce a protocol to enable communication among test equipment that implements the one-way metrics. The intent is to create a protocol that provides a base level of functionality that will allow different manufacturer's equipment that implements the metrics according to a standard to interoperate. A protocol requirements document will guide the protocol design.

The WG will also produce a MIB to retrieve the results of IPPM metrics, such as one-way delay and loss, to facilitate the communication of metrics to existing network management systems. Thus, the group will create a MIB that contains predominantly read only variables. If, after the protocol requirements document is finished, the group decides that it is appropriate to add variables that control the underlying measurements that the metrics report, such a control structure may be added as a separate document, subject to review by the IESG.

The intent of the WG is to cooperate with other appropriate standards bodies and fora (such as T1A1.3, ITU-T SG 12 and SG 13) to promote consistent approaches and metrics. Within the IETF process, IPPM metrics definitions will be subject to as rigorous a scrutiny for usefulness, clarity, and accuracy as other protocol standards. The IPPM WG will interact with other areas of IETF activity whose scopes intersect with the requirement of these specific metrics. These include working groups such as BMWG, RMONMIB, and TEWG.

2. IPPM WG

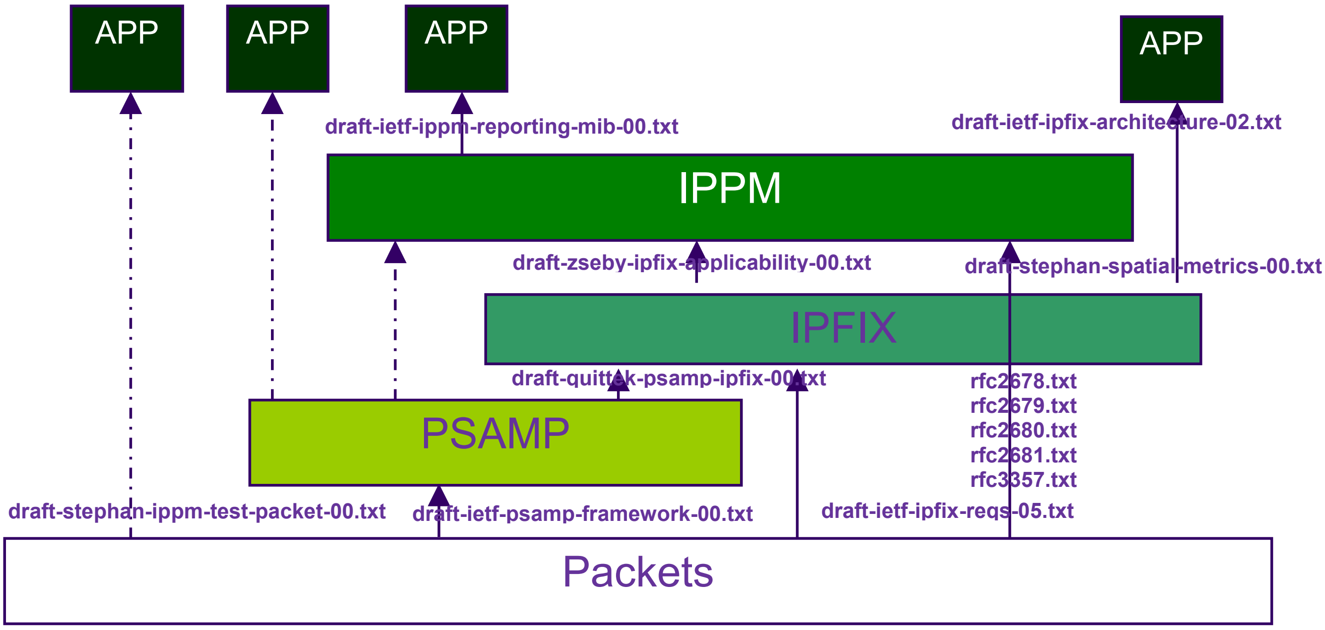

Figure 2-1: IPPM WG Interrelation

The IPPM WG is part of the Transport area. The chairs are Merike Kaeo and Matthew Zekauskas. Andy Bierman is the technical advisor for the MIB aspects.

The IPPM WG is in charge of defining both standard metrics that can be applied to the quality, performance, and reliability of Internet data delivery services and procedures for accurately measuring these metrics.

The metrics are:

- Connectivity.
- One-way delay and loss.
- Round-trip delay and loss.
- Delay variation.
- Loss patterns.
- Packet reordering.
- Bulk transport capacity.
- Link bandwidth capacity.

The WG is defining a protocol to enable communication among test equipment that implements the one-way metrics. The protocol requirements document should guide the protocol design.

The WG is defining a MIB to retrieve the results of IPPM metrics.

The effort to define the Applicability Statements documents is not started yet. It consists in defining procedures for measuring the individual metrics, defining the scope of use of the metrics specifying the methodologies required to collect the results.

The intent of the WG is to cooperate with other appropriate standards bodies.

2.1 Internet-Drafts

Document	ref	Domain	WP
A One-way Active Measurement Protocol	Owap	Metric	D2.3
A One-way Active Measurement Protocol Requirements	OwapReq	Metric	D2.3
IPPM metrics registry	IppmReg	Interoperability	D2.3
IPPM reporting MIB	IppmRep	Data reporting	D2.2, D2.3
Packet Reordering Metric for IPPM	PktReor	Metric	D2.1, D2.4
One-Way Metric Applicability Statement	OwdAS	Measure	D2.3

2.2 Request For Comments:

Document	ref	Domain	WP
Framework for IP Performance Metrics	RFC2330	Metric	D2.1
IPPM Metrics for Measuring Connectivity (RFC 2678)	RFC2678	Metric	D2.1
A One-way Delay Metric for IPPM (RFC 2679)	RFC2679	Metric	D2.1
A One-way Packet Loss Metric for IPPM (RFC 2680)	RFC2679	Metric	D2.1
A Round-trip Delay Metric for IPPM (RFC 2681)	RFC2681	Metric	D2.1
A Framework for Defining Empirical Bulk Transfer Capacity Metrics (RFC 3148)	RFC3148	Metric	D2.1
One-way Loss Pattern Sample Metrics (RFC 3357)	RFC3357	Metric	D2.1
IP Packet Delay Variation Metric for IPPM (RFC 3393)	RFC3393	Metric	D2.1
Network performance measurement for periodic streams (RFC 3432)	RFC3432	Metric	D2.1

3. IPPM CHARTER

Considering the charter of IETF IPPM working group described above, it is believed that the IPPM Working Group is the most appropriate place to submit the initial standardization contributions related to the IST-2001-37611 6QM project. Such contributions could then be submitted to other standardization committees if needed.

IPPM is responsible to choose the required fundamental parameters and metrics necessary and sufficient to accurately define network Quality of Services.

Some of the relevant documents are:

- [RFC2330] specifies the general framework for QoS measurement within IP networks. The specification defines the general framework for the definition of IP performance metrics (IPPM), highlights the main measurement issues including the composition of metrics, time stamping issues, sampling methodologies as well as other measurement methodologies. Finally it defines the terminology to be used in the rest of IPPM related specifications. An important part of the terminology refers to the various types of metrics. In particular:
    - A *singleton* metric is defined as an atomic metric resulting from measures made on one or several non sampled datagrams.
    - A *sample* metric is defined as a metric derived from a set of singleton metrics by selecting a number of instances of these metrics.
    - A *statistical* metric is defined as a metric derived from a sample metric by computing some statistics on the singleton metrics located in the sample.

Figure 3-1 illustrates the relations between these three types of metric.

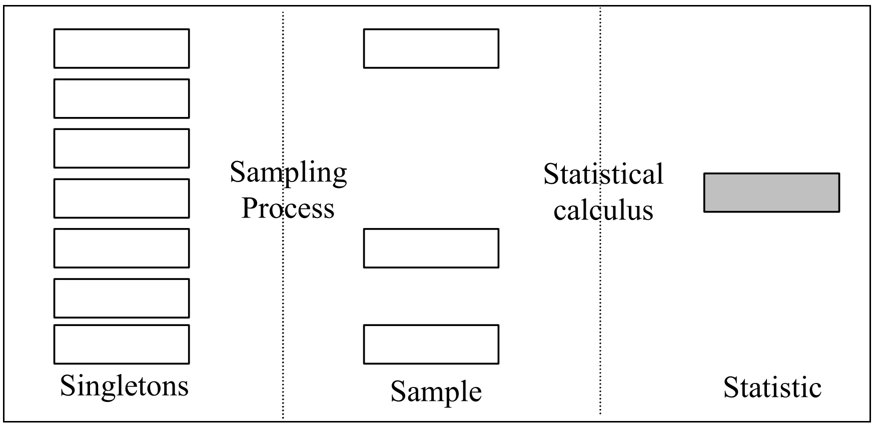

Figure 3-1: Metrics Computation Process

- [RFC3148] extends the original framework for the measurement of Bulk Transfer Capacity (BTC). The main difficulty for the definition of a single BTC metric lies in the diversity of TCP implementations. In particular attention should be paid to the different types of congestion control methods implemented in existing implementations. As a result the framework suggest on this point to define BTC metrics per type of TCP implementation in order to perform unbiased measurements.

The IPPM Framework consists in 4 major components:

- A general framework for defining performance metrics, described in the Framework for IP Performance Metrics, RFC 2330
- A set of standardized metrics, which conform to this framework
    - The IPPM Metrics for Measuring Connectivity, RFC 2678.
    - The One-way Delay Metric for IPPM, RFC 2679.
    - The One-way Packet Loss Metric for IPPM, RFC 2680.
    - The Round-trip Delay Metric for IPPM, RFC 2681;
- Emerging metrics which are being specified in respect of this framework;
- A Reporting MIB to exchange the results of the measures. It is an interface between a system of measure and the administrative entities interested in these results. This proxy controls the access to the results. These entities use the results to compute statistics and aggregated metrics.

IPPM is the necessary elementary brick defining the metrics to be developed for Quality of services measurements. This will feed the work realized in other relevant working groups like the IPFIX in charge of standardizing the way to export flow information in a standard way to external systems such as mediation systems, accounting/billing systems, and network management systems to facilitate services such as Internet research, measurement, accounting, and billing.

It is also the source of information for another working Group like PSAMP focusing on (i) specify a set of selection operations by which packets are sampled (ii) specify the information that is to be made available for reporting on sampled packets; (iii) describe protocols by which information on sampled packets is reported to applications; (iv) describe protocols by which packet selection and reporting configured.

Overall IPPM will define every metrics that an SLA needs to take account for Quality of Service‘s measurements. Such an SLA should have an external view of the Quality of service independently of how this Quality of Service is implemented (IP/ATM, IP/MPLS or over-dimensioned IP).

4. RFC2330 IPPM FRAMEWORK

The overarching goal of the IP Performance Metrics effort is to achieve a common understanding in which users and providers of Internet transport service have accurate knowledge of the performance and reliability of the Internet component 'clouds' that they use/provide. To this extent, the IPPM WG has defined performance and reliability metrics for paths through the Internet

The IPPM Framework [RFC2330] defines a metric as, “A quantity related to the performance and reliability of the Internet …of which we would like to know the value”. This WG has defined a number of separate metrics, for which each is specified as an RFC. Each metric is defined in terms of standard units of measurement, based upon the international metric system.

The following specific characteristics of all metrics have been specified:

- The metrics must be concrete and well-defined,
- A methodology for a metric should have the property that it is repeatable: if the methodology is used multiple times under identical conditions, the same measurements should result in the same measurements.
- The metrics must exhibit no bias for IP clouds implemented with identical technology.
- The metrics must exhibit understood and fair bias for IP clouds implemented with non-identical technology.
- The metrics must be useful to users and providers in understanding the performance they experience or provide.
- The metrics must avoid inducing artificial performance goals.

4.1 Measurement Methodologies

For a given set of well-defined metrics, a number of distinct measurement methodologies may exist. A partial list includes:

- Direct measurement of a performance metric using injected test traffic. For example, the measurement of the round-trip delay of an IP packet.
- Projection of a metric from lower-level measurements. Example: Given accurate measurements of propagation delay and bandwidth for each step along a path, projection of the complete delay for the path for an IP packet of a given size.
- Estimation of a constituent metric from a set of aggregated measurements.
- Estimation of a given metric at one time from a set of related metrics at other times.

A methodology for a given metric should always be repeatable, which is to say that if used multiple times under identical conditions, it should result in consistent measurements.

4.2 Definitions

4.2.1 A-Frame Concepts

As the Internet has evolved from the early packet-switching studies of the 1960s, the Internet engineering community has evolved a common analytical framework of concepts known as “A-Frame” concepts.

4.2.2 Packet of typeP

A fundamental property of many Internet metrics is that the value of the metric depends on the type of IP packet(s) used to make the measurement. Thus, we introduce the generic notion of a "packet of type P", where in some contexts P will be explicitly defined (i.e., exactly what type of packet we mean), partially defined (e.g., "with a payload of B octets"), or left generic. Thus, one may talk about generic IP-type-P-connectivity or more specific IP-port-HTTP-connectivity.

4.2.3 Spatial Metrics

By spatial composition, we mean a characteristic of some path metrics, in which the metric as applied to a (complete) path can also be defined for various sub-paths, and in which the appropriate A-frame concepts for the metric suggest useful relationships between the metric applied to these various sub-paths (including the complete path, the various cloud sub-paths of a given path digest, and even single routers along the path).

4.2.4 Temporal Composition

When we speak of temporal composition, we mean a characteristics of some path metric, in which the metric as applied to a path at a given time T is also defined for various times t0<t1<…tn<T., and in which the appropriate A-frame concepts for the metric suggests useful relationships between the metric applied at times t0,….,tn.

4.2.5 Singleton Metric

A “singleton” metric is one that is “atomic” in nature. For example, a single instance of “bulk throughput capacity” from one host to another could be defined as a “singleton” metric, even though the instance involves measuring the timing of a number of internet packets.

4.2.6 Sample Metric

Metrics that are derived from a given singleton metric by taking a number of distinct instances together are referred to as “sample” metrics.

4.2.7 Statistical Metric

We refer to “statistical” metrics as metrics that are derived from a given sample metric by computing some statistic of the values defined by the singleton metric on the sample. For example, the average of all the one-way-delay values taken during a sampling period.

4.2.8 Synchronization

Measures the extent to which two clocks agree on what time it is.

4.2.9 Accuracy

Measures the extent to which a given clock agrees with the Universal Time Clock (UTC).

4.2.10 Resolution

Measures the precision of a given clock. For example, the clock of an old Unix host might tick only once every 10 msec, and thus have a resolution of 10 msec.

4.2.11 Skew

Measures the change of accuracy, or of synchronization, with time. For example, the clock on a given host might gain 1.3 msec per hour and thus be 27.1 msec behind UTC at one time and only 25.8 msec an hour later.

5. RFC2678 IPPM METRICS FOR MEASURING CONNECTIVITY

Metrics that determine whether pairs of hosts (IP addresses) can reach each other form the basis of a measurement suite for connectivity.

5.1 Type-P-Instantaneous-Unidirectional-Connectivity

This analytic metric defines one-way-connectivity at one moment in time. The metric parameters consist of:

- Src, the IP address of the host
- Dst, the IP address of the host
- T, a time

Src is considered to have *Type-P-Instantaneous-Unidirectional-Connectivity* to Dst at time T if a type-P packet transmitted from Src to Dst at time T will arrive at Dst.

For most applications (e.g., any TCP connection) bi-directional connectivity is considerably more germane than unidirectional connectivity, although unidirectional connectivity can be of interest for some security applications (e.g., testing whether a firewall correctly filters out a "ping of death").

5.2 Type-P-Instantaneous-Bidirectional-Connectivity

This metric is introduced to define two-way connectivity at a given moment in time. Its' parameters are comprised of:

- A1, the IP address of a host
- A2, the IP address of a host
- T, a time

Addresses A1 and A2 are considered to have "Type-P-Instantaneous-Bidirectional-Connectivity" at time T if address A1 has Type-P-Instantaneous-Unidirectional-Connectivity to address A2 and address A2 has Type-P-Instantaneous-Unidirectional-Connectivity to address A1.

5.3 Type-P-Interval-Unidirectional-Connectivity

This metric refers to one-way connectivity between two hosts over a given period of time. The metric parameters include:

- Src, the IP address of a host
- Dst, the IP address of a host
- T, a time
- dT, a duration [Note: the closed interval {T, T+dT} denotes a time interval]

Address Src has "Type-P-Interval-Unidirectional-Connectivity" to address Dst during the interval [T, T+dt] if for some T' within [T, T+dT] it has Type-P-Instantaneous-Connectivity to Dst.

5.4 Type-P-Interval-Bidirectional-Connectivity

This metric refers to bi-directional connectivity between two hosts over a given period of time. The metric parameters include:

- A1, the IP address of a host
- A2, the IP address of a host
- T, a time
- dT, a duration [Note: the closed interval {T, T+dT} denotes a time interval]

Addresses A1 and A2 have "Type-P-Interval-Bidirectional-Connectivity" between them during the interval [T, T+dt] if address A1 has Type-P-Interval-Unidirectional-Connectivity to address A2 during the interval, and address A2 has Type-P-Interval-Unidirectional-Connectivity to A1 during the same interval.

5.5 Type-P1-P2-Interval-Temporal-Connectivity

This metric defines the notion of two-way connectivity between two hosts over an interval of time. The metric parameters include:

- Src, the IP address of a host
- Dst, the IP address of a host
- T, a time
- dT, a duration [Note: the closed interval {T, T+dT} denotes a time interval]

Address Src has *Type-P1-P2-Interval-Temporal-Connectivity* to address Dst during the interval [T, T+dT] if there exist times T1 and T2, and time intervals dT1 and dT2, such that:

- T1, T1+dT1, T2, T2+dT2 are all in [T, T+dT].
- T1+dT1 <= T2.
- At time T1, Src has Type-P1 instantanous connectivity to Dst.
- At time T2, Dst has Type-P2 instantanous connectivity to Src.
- dT1 is the time taken for a Type-P1 packet sent by Src at time T1 to arrive at Dst.
- dT2 is the time taken for a Type-P2 packet sent by Dst at time T2 to arrive at Src.

6. RFC2679 "A ONE-WAY DELAY METRIC FOR IPPM"

The measurement of one-way delay from one host to another can be useful for a variety of reasons, some of which include:

- Certain applications do not perform well if end-to-end delay between hosts is large relative to some threshold value.
- Erratic variation in delay makes it difficult to support many real-time applications
- The larger the value of the delay, the more difficult it is for transport-layer protocols to sustain high bandwidths.

6.1 Type-P-One-Way-Delay

This metric is used to measure a single observation of one-way delay between two hosts. The metric parameters include:

- Src, the IP address of a host
- Dst, the IP address of a host
- T, a time
- dT, a duration

For a real number dT, the *Type-P-One-way-Delay* from Src to Dst at T is dT implies that Src sent the first bit of a Type-P packet to Dst at wire-time* T and that Dst received the last bit of that packet at wire-time T+dT.

6.2 Type-P-One-Way-Delay-Poisson-Stream

Given the singleton metric Type-P-One-way-Delay, we now define one particular sample of such singletons. The idea of the sample is to select a particular binding of the parameters Src, Dst, and Type-P, and then define a sample of values of parameter T. The means for defining the values of T is to select a beginning time T0, a final time Tf, and an average rate lambda, then define a pseudo-random Poisson process of rate lambda, whose values fall between T0 and Tf. The time interval between successive values of T will then average 1/lambda.

The metric parameters include:

- Src, the IP address of a host
- Dst, the IP address of a host
- T0, a time
- Tf, a time
- lambda, a rate in reciprocal seconds

Given T0, Tf, and lambda, we compute a pseudo-random Poisson process beginning at or before T0, with average arrival rate lambda, and ending at or after Tf. Those time values greater than or equal to T0 and less than or equal to Tf are then selected. At each of the times in this process, we obtain the value of Type-P-One-way-Delay at this time. The value of the sample is the sequence made up of the resulting <time, delay> pairs. If there are no such pairs, the sequence is of length zero and the sample is said to be empty.

6.3 Type-P-One-Way-Delay-Percentile

Given a Type-P-One-way-Delay-Poisson-Stream and a percent X between 0% and 100%, the Xth percentile of all the dT values in the Stream. In computing this percentile, undefined values are treated as infinitely large. Note that this means that the percentile could thus be undefined (informally, infinite). In addition, the Type-P-One-way-Delay-Percentile is undefined if the sample is empty.

6.4 Type-P-One-Way-Delay-Median

Given a Type-P-One-way-Delay-Poisson-Stream, the Type-P-One-Way-Delay median is defined as the median of all the dT values in the Stream. In computing the median, undefined values are treated as infinitely large. As with Type-P-One-way-Delay-Percentile, Type-P-One-way-Delay-Median is undefined if the sample is empty.

6.5 Type-P-One-Way-Delay-Minimum

Given a Type-P-One-way-Delay-Poisson-Stream, the minimum of all the dT values in the Stream. In computing this, undefined values are treated as infinitely large. Note that this means that the minimum could thus be undefined (informally, infinite) if all the dT values are undefined. In addition, the Type-P-One-way-Delay-Minimum is undefined if the sample is empty.

6.6 Type-P-One-Way-Delay-Inverse-Percentile

Given a Type-P-One-way-Delay-Poisson-Stream and a time duration threshold, the fraction of all the dT values in the Stream less than or equal to the threshold. The result could be as low as 0% (if all the dT values exceed threshold) or as high as 100%. Type-P-One-way-Delay-Inverse-Percentile is undefined if the sample is empty.

7. RFC2680 "A One-Way Packet Loss Metric for IPPM"

Understanding one-way packet loss from a source to a destination host can be beneficial for many reasons, including:

- Certain applications do not perform well if end-to-end packet loss between hosts is large relative to some threshold value.
- Excessive packet loss may make it difficult to support certain real-time applications
- The larger the value of the loss, the more difficult it is for transport-layer protocols to sustain high bandwidths.

7.1 Type-P-One-Way-Packet-Loss

This metric is used to measure a single observation of one-way packet loss between two hosts. The metric parameters include:

- Src, the IP address of a host
- Dst, the IP address of a host
- T, a time

"The *Type-P-One-way-Packet-Loss* from Src to Dst at T is 0" means that Src sent the first bit of a Type-P packet to Dst at wire-time* T and that Dst received that packet.
"The *Type-P-One-way-Packet-Loss* from Src to Dst at T is 1" means that Src sent the first bit of a type-P packet to Dst at wire-time T and that Dst did not receive that packet.

7.2 Type-P-One-Way-Packet-Loss-Poisson-Stream

Given the singleton metric Type-P-One-way-Packet-Loss, we now define one particular sample of such singletons. The idea of the sample is to select a particular binding of the parameters Src, Dst, and Type-P, and then define a sample of values of parameter T. The means for defining the values of T is to select a beginning time T0, a final time Tf, and an average rate lambda, then define a pseudo-random Poisson process of rate lambda, whose values fall between T0 and Tf. The time intervals between successive values of T will then average/lambda.

The metric parameters include:

- Src, the IP address of a host
- Dst, the IP address of a host
- T0, a time
- Tf, a time
- Lambda, a rate in reciprocal seconds

Given T0, Tf, and lambda, we compute a pseudo-random Poisson process beginning at or before T0, with average arrival rate lambda, and ending at or after Tf. Those time values greater than or equal to T0 and less than or equal to Tf are then selected. At each of the times in this process, we obtain the value of Type-P-One-way-Packet-Loss at this time. The value of the sample is the sequence made up of the resulting <time, loss> pairs. If there are no such pairs, the sequence is of length zero and the sample is said to be empty.

7.3 Type-P-One-Way-Packet-Loss-Average

Given a Type-P-One-way-Packet-Loss-Poisson-Stream, the Type-P-One-Way-Packet-Loss Average is defined as the average of all the L values in the Stream, where L is either a 0 or a 1. The Type-P-One-Way-Packet-Loss-Average is undefined if the sample is empty.

8. RFC2681 "A Round-trip Delay Metric for IPPM"

Round-trip delay of a Type-P packet from a source host to a destination host is useful for several reasons, including:

- Certain applications do not perform well if end-to-end delay between hosts is large relative to some threshold value.
- Erratic variations in delay make it difficult to support certain real-time applications
- The larger the value of the delay, the more difficult it is for transport-layer protocols to sustain high bandwidths.

However, the measurement of round-trip delay instead of one-way delay has some weaknesses as summarized below:

- The Internet path from a source to a destination may differ from the path from the destination to the source, such that different sequences of routers are used for the forward and reverse paths. The paths may not be symmetric.
- Even when two paths are symmetric, they may have radically different performance characteristics due to queuing.
- Performance of an application may depend mostly on the performance in one direction only.
- In QoS enabled networks, provisioning in one direction may be different from in the other direction, and thus the QoS guarantees will differ.

8.1 Type-P-Round-Trip-Delay

This metric is used to measure a single observation of a round-trip delay between two hosts. The metric parameters include:

- Src, the IP address of a host
- Dst, the IP address of a host
- T, a time
- DT, a duration

For a real number dT, “the *Type-P-Round-trip-Delay* from Src to Dst at T is dT” means that Src sent the first bit of a Type-P packet to Dst at wire-time* T, that Dst received that packet, then immediately sent a Type-P packet back to Src, and that Src received the last bit of that packet at wire-time T+dT.

“The *Type-P-Round-trip-Delay* from Src to Dst at T is undefined (informally, infinite)” means that Src sent the first bit of a Type-P packet to Dst at wire-time T and that (either Dst did not receive the packet, Dst did not send a Type-P packet in response, or) Src did not receive that response packet.

“The *Type-P-Round-trip-Delay between Src and Dst at T” implies either the *Type-P-Round-trip-Delay from Src to Dst at T or the *Type-P-Round-trip-Delay from Dst to Src at T. When this notion is used, it is understood to be specifically ambiguous which host acts as Src and which as Dst.

8.2 Type-P-Round-Trip-Delay-Poisson-Stream

Given the singleton metric Type-P-Round-trip-Delay, we now define one particular sample of such singletons. The idea of the sample is to select a particular binding of the parameters Src, Dst, and Type-P, then define a sample of values of parameter T. The means for defining the values of T is to select a beginning time T0, a final time Tf, and an average rate lambda, then define a pseudo-random Poisson process of rate lambda, whose values fall between T0 and Tf. The time interval between successive values of T will then average 1/lambda.

The metric parameters include:

- Src, the IP address of a host
- Dst, the IP address of a host
- T0, a time
- Tf, a time
- Lambda, a rate in reciprocal seconds

Given T0, Tf, and lambda, we compute a pseudo-random Poisson process beginning at or before T0, with average arrival rate lambda, and ending at or after Tf. Those time values greater than or equal to T0 and less than or equal to Tf are then selected. At each of the times in this process, we obtain the value of Type-P-Round-trip-Delay at this time. The value of the sample is the sequence made up of the resulting <time, delay> pairs. If there are no such pairs, the sequence is of length zero and the sample is said to be empty.

8.3 Type-P-Round-Trip-Delay-Percentile

Given a Type-P-Round-trip-Delay-Poisson-Stream and a percent X between 0% and 100%, the Xth percentile of all the dT values in the Stream. In computing this percentile, undefined values are treated as infinitely large. In addition, the Type-P-Round-trip-Delay-Percentile is undefined if the sample is empty.

8.4 Type-P-Round-Trip-Delay-Median

Given a Type-P-Round-Trip-Delay-Poisson-Stream, the Type-P-Round-Trip-Delay median is defined as the median of all the dT values in the Stream. In computing the median, undefined values are treated as infinitely large.

8.5 Type-P-Round-Trip-Delay-Minimum

Given a Type-P-Round-Trip-Delay-Poisson-Stream, the minimum of all the dT values in the Stream. In computing this, undefined values are treated as infinitely large. In addition, the Type-P-Round-Trip-Delay-Minimum is undefined if the sample is empty.

8.6 Type-P-Round-Trip-Delay-Inverse-Percentile

Given a Type-P-Round-Trip-Delay-Poisson-Stream and a time duration threshold, the fraction of all the dT values in the Stream less than or equal to the threshold. The result could be as low as

0% (if all the dT values exceed threshold) or as high as 100%. Type-P-Round-Trip-Delay-Inverse-Percentile is undefined if the sample is empty.

9. RFC3357: "ONE-WAY LOSS PATTERN SAMPLE METRICS"

9.1 Terminology

Sequence number: Consecutive packets in a time series sample are given sequence numbers that are consecutive integers. This document does not specify exactly how to associate sequence numbers with packets. The sequence numbers could be contained within test packets themselves, or they could be derived through post-processing of the sample.

- Bursty loss: The loss involving consecutive packets of a stream.
- Loss Distance: The difference in sequence numbers of two successively lost packets that may or may not be separated by successfully received packets.
- Loss period: Let P_i be the i'th packet. Define f(P_i) = 1 if P_i is lost, 0 otherwise. Then, a loss period begins if f(P_i) = 1 and f(P_(i-1)) = 0

9.2 Metrics

This memo defines 6 metrics:

- Type-P-One-Way-Loss-Distance-Stream metric;
- Type-P-One-Way-Loss-Period-Stream metric;
- Type-P-One-Way-Loss-Noticeable-Rate metric;
- Type-P-One-Way-Loss-Period-Total metric;
- Type-P-One-Way-Loss-Period-Lengths metric;
- Type-P-One-Way-Inter-Loss-Period-Lengths metric.

10. RFC3393: "IP Packet Delay Variation Metric for IP Performance"

The variation in packet delay is sometimes called "jitter". This term, however, causes confusion because it is used in different ways by different groups of people. In order to avoid confusion, the term “ip packet delay variation” is used.

A definition of the IP Packet Delay Variation (ipdv) can be given for packets inside a stream of packets. The ipdv of a pair of packets within a stream of packets is defined for a selected pair of packets in the stream going from measurement point MP1 to measurement point MP2. The ipdv is the difference between the one-way-delay of the selected packets.

This memo defines 6 metrics:

- Type-P-One-way-ipdv metric
- Type-P-One-way-ipdv-Poisson-stream metric
- Type-P-One-way-ipdv-percentile metric
- Type-P-One-way-ipdv-inverse-percentile metric;
- Type-P-One-way-ipdv-jitter metric;
- Type-P-One-way-peak-to-peak-ipdv metric.

11. RFC3432: "Network performance measurement with periodic streams"

This memo describes a sampling method and performance metrics relevant to certain applications of IP networks and defines the metric named Type-P-One-way-Delay-Periodic-Stream.

This metric is similar to Type-P-One-way-Delay-Poisson-Stream presented in [RFC 2679].

12. WORK IN PROGRESS

12.1 One-way Active Measurement Protocol Requirements

To measure IP performance metrics with high precision in an interoperable manner, a common protocol for such measurements is required. This document specifies the requirements to measure one-way delay, as well as other unidirectional characteristics, such as one-way loss.

Since measurement session setup and the actual measurement session (i) are different tasks; (ii) require different levels of functionality, flexibility, and implementation effort; (iii) may need to run over different transport protocols, there should exist two protocols: one for conducting the actual measurement session and another for session setup/teardown/confirmation/retrieval. These protocols are further referred to as OWAMP-Test and OWAMP-Control, respectively.

It should be possible to use devices that only support OWAMP-Test but not OWAMP-Control to conduct measurement sessions (such devices will necessarily need to support one form of session setup protocol or the other, but it doesn't have to be known to external parties). OWAMP-Control would thus become a common protocol for different administrative domains, which may or may not use it for session setup internally.

12.2 A One-way Active Measurement Protocol

There is not currently a standard that would permit initiation of test streams or exchange of packets to collect singleton metrics in an interoperable manner. OWAMP actually consists of two inter-related protocols: OWAMP-Control and OWAMP-Test. OWAMP-Control is used to initiate, start and stop test sessions and fetch their results, while OWAMP-Test is used to exchange test packets between two measurement nodes.

The authors have deliberately chosen to include both protocols in the same draft to encourage the implementation and deployment of OWAMP-Control as a common denominator control protocol for one-way active measurements. They neither anticipate nor recommend that OWAMP-Control form the foundation of a general-purpose extensible measurement and monitoring control protocol.

12.3 IPPM REPORTING MIB

The IPPM-REPORTING-MIB defines a portion of the Management Information Base (MIB) designed for use with network management protocols in TCP/IP-based Internets. In particular, this MIB specifies the objects used for managing the results of the IPPM metrics measures, for pushing alarms, and for reporting the measures results.

It introduces a framework where each application identifies its measures in an owner namespace. Using the namespace framework, an application may grant other owners access to its measurement results for aggregated metrics computation, reporting, or alarming.

Different architectures may be used to perform metric measurements, using a control protocol and a test protocol. Different control frameworks are suitable for performing measurements. The memo lists them, while also looking for a way to integrate them with the IPPM-REPORTING-

MIB. This section is for informational purposes only, and is intended to help to specify the relationship among the test protocol, the control protocol and IPPM-REPORTING-MIB.

This document should be stable for the end of 2003.

12.4 IPPM REGISTRY

This draft defines a registry of the IPPM working group metrics. It provides an OBJECT IDENTIFIER to each metric currently standardized by the IPPM WG. It defines the rules for the identification of the metrics standardized in the future.

The version 2 identifies 33 IPPM metrics.

13. SECURITY REVIEW

It should be recognized that conducting Internet measurements can raise both security and privacy concerns. Active techniques, in which traffic is injected into the network, can be abused for denial-of-service attacks disguised as legitimate measurement activity. Passive techniques, in which existing traffic is recorded and analyzed, can expose the contents of Internet traffic to unintended recipients. Consequently, Each step of the development of a measurement system that make use of metrics and of the methodology described above must include security considerations.

14. SUMMARY AND CONCLUSIONS

This document presents the relevance of IPPM IETF activities related to submission of input standardization contributions regarding this project.

Despite Spatial composition as explained in the framework, there has not been any effort in the IPPM WG to standardize such metrics, even if an individual draft on this topic was presented during the 55th IETF.

OWAP scope is deliberately limited. It does respect the requirement on the independency of the Test protocol and of the Control protocol. The test protocol is limited to UDP. Therefore, it does not permit the measurement of the performance of any type of applications. Especially it does not permit the measurement of the QoS of TCP based applications.

ITU is standardizing a general-purpose test packet for IPv4 and IPv6 and sent a liaison statement to the IETF. It asks for cooperation and feedback with IETF WGs such as the IPPM WG.

15. REFERENCES

Name	Title	Version	Date
RFC2330	Framework for IP Performance Metrics		1998
RFC2678	IPPM Metrics for Measuring Connectivity		1999
RFC2679	A One-Way Delay Metric for IPPM		1999
RFC2680	A One-Way Packet Loss Metric for IPPM		1999
RFC3357	One-way Loss Pattern Sample Metrics		2003
RFC3393	IP Packet Delay Variation Metric for IP Performance Metrics (IPPM)		2003
RFC3432	Network performance measurement with periodic streams		2003

Figure 15-1: References